The Problem of Chemical and Biological Warfare

Volume I

The Rise of CB Weapons

SIPRI

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Contents of the Study

Volume I. The Rise of CB Weapons

A description of the main lines of development in the technology underlying CBW and in the constraints affecting use of CB weapons. The period covered is approximately 1914–1945, although more recent developments in CW technology are also described. In addition, the volume includes an account of all instances known to SIPRI when CB weapons have been used in war, or when their use has been alleged; in this case the time-span is 1914–1970.

Volume II. CB Weapons Today

A description based on the open literature of the present state of CBW technology and of national CBW programmes and policies. It also includes a discussion of the attractions and liabilities of CB weapons, and of the consequences, intentional or unintentional, that might follow their use.

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Volume VI. Technical Aspects of Early Warning and Verification

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PREFACE

The birth of this study of chemical and biological warfare can be traced back to 1964, when a group of microbiologists who were concerned about the problems of biological warfare started meeting under the auspices of Pugwash. After some meetings it became evident that there was need for more intense study than could be achieved through occasional gatherings of people who were busy with other work. In 1966–67 SIPRI, which was then starting up, decided to take on the task of making a major review of biological warfare. The study was soon extended to cover chemical warfare as well. It was found impossible to discuss one without the other. The two have traditionally been grouped together in law, in military organization, in political debate and in the public mind.

The aim of the study is to provide a comprehensive survey of all aspects of chemical and biological warfare and of the problems of outlawing it more effectively. It is hoped that the study will be of value to politicians, their advisors, disarmament negotiators, scientists and to laymen who are interested in the problem. Those parts of the study which are technical or highly specialized are preceded by a summary for the general reader.

The authors of the report have come from a number of disciplines-microbiology, chemistry, economics, international law, medicine, physics and sociology and soldiery-and from many countries. It would be too much to claim that all the authors had come to share one precisely defined set of values in their approach to the problem. Some came to the problem because they were specially concerned that the advance of science in their field should not be twisted to military uses; others because they had taken a scholarly interest in the law or history of CBW; others because they had particular experience of military or technical aspects of it. What is true is that, after working together for a period of years, they have all come to share a sober concern about the potential dangers of CBW.

In reviewing the issues for policy (in Volume V) the aim has been not to produce a set of recommendations or a plan for action but to analyse the main factors influencing national policies and international negotiations over CBW, to indicate alternative courses of action as they emerge from the analysis, and to present as clearly as possible the perspective on the problem at which an international team of people working for a period of years on neutral soil has arrived.

At an early stage it was necessary to face the question whether, if we assembled a lot of information on CBW and published all that we thought was relevant, we would risk contributing dangerously to the proliferation of these weapons. This proposition was rejected on the grounds that the service we could do by improving the level of public discussion was greater than any disservice we might do by transmitting dangerous knowledge, Secrecy in a field like this serves mostly to keep the public in ignorance. Governments find things out for themselves.

While the study has been in progress there has been an increase in public discussion of the subject. A group of experts appointed by the Secretary-General of the United Nations has produced a report on *Chemical and Bacteriological (Biological) Weapons and the Effects of Their Possible Use.* In the United States a rising tide of concern about CBW has given rise to Congressional hearings; a policy review, commissioned by the President, has led to the unilateral renunciation by the United States Government of biological weapons and to the decision to renounce first use of chemical weapons and to seek ratification of the Geneva Protocol. At the United Nations and at the Disarmament Committee in Geneva, CBW has received a lot of attention. In response to an invitation from the UN Secretary-General, early drafts of parts of this study were circulated to this group of experts in February 1969. Provisional editions of parts of this study were issued in February 1970.

The authors are conscious of the problem of avoiding biases. A disproportionate part of the information we have used comes from the United States. This is partly because the United States has been very active in the field of chemical and biological warfare in the post-war period. It is also because the United States is much more open with information than most other countries.

Since this is a team work and since, like most studies of this size, it grew and changed shape and changed hands in some degree as it went along, it is not easy to attribute responsibility for its preparation. The authorship of each part is indicated at the start of it, but these attributions do not convey the whole story. The team of people who produced the study met together often, shared material, exchanged ideas, reviewed each others' drafts in greater or lesser degree, and so on. So it is a corporate product, and those who wrote the final drafts sometimes had the benefit of working papers, earlier drafts, ideas or material provided by others.

At first, Rolf Björnerstedt was briefly in charge of the study. After an interval, Professor Carl-Göran Hedén took over. When he had to return to the Karolinska Institute-from which he has continued to give us his advice and help-1 assumed responsibility for the project. The other main members of the team have been Anders Boserup, who from the earliest stages has found time to come frequently from Copenhagen to help on the project, Jozef

Goldblat, Milton Leitenberg, Theodor Nemec, Julian Perry Robinson, and Hans von Schreeb. Åke Ljunggren was a member of the team in Stockholm in the early stages of the project. Sven Hirdman joined in at the later stages.

The work on rapid detection of the use of biological warfare agents (Volume VI) was undertaken separately from the main study by Konstantin Sinyak, who came from the Soviet Union to work at the Karolinska Institute in Stockholm, and Åke Ljunggren, who went from Sweden to work at the Microbiological Institute in Prague. Both worked in close contact with Carl-Göran Hedén who contributed a study on automation. We are indebted to the two host institutes for the facilities and help they generously provided.

It is usually wrong to single out one person from a team but in this case there is no doubt that one person has contributed more than anyone else to the study. He is Julian Perry Robinson who has written more of the study than anyone else and has had a great influence on the whole shape and quality of it.

Rosemary Proctor undertook the formidable task of acting as editorial assistant for the whole study and preparing an index for it.

A great debt is also owed to many people outside the institute—too many to name—for the help they have given us. This includes those who attended the early Pugwash meetings on biological warfare, those who attended meetings at SIPRI on biological and chemical warfare, those who wrote working papers for us, those who gave their time to the biological inspection experiment and many people who have visited us or helped us with advice and material at different times. It includes people from many countries, East and West, and many disciplines. It includes people with many different kinds of expertise. The amount of help they gave us—and it was far greater than we had expected at the start—was clearly an expression of their concern about the problem. We are very grateful to them all. The responsibility for what is said is, of course, ours.

12 February 1971

Robert Neild
Director

ATTRIBUTION

The author of Volume I is Julian Perry Robinson. Appendix 2 and material on allegations of biological warfare were written by Milton Leitenberg.

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Introduction

This volume comprises the first of our five-volume study of the problem of chemical and biological warfare (CBW). It is intended to provide a general picture of the growth of CBW technology over the past sixty years, its exploitation and its changing implications. The main features of each chapter of the volume are these.

Chapter 1 is concerned with the development of chemical and biological weapons and of the defences against them. It describes the chief technical innovations in chemical weapons between 1914 and the late 1950s. The emphasis here is on the competing advances of the weapons and the defences against them. It describes their rapid progress towards stalemate during World War I and the increasing ascendency of the defences during the next two decades. The latter period was also one of attempts by weapons designers to adapt chemical warfare to mobile battlefield conditions; but, with the exception of the development of chemical weapons for aircraft delivery, no significant advance was made here until the development of the nerve gases in Germany shortly before and during World War II. Although CW was not employed during World War II, the nerve gases led to a revival of military interest in it during the post-war period, particularly with the discovery of still more potent nerve gases during the mid-1950s. Developments in CW defences have, however, kept pace with improvements in chemical weapons. Biological weapons are discussed more briefly, primarily because the history of intensive endeavours to develop them is much shorter than for chemical weapons. It was not until shortly before World War II that any serious attempt was made to advance their possible military role beyond clandestine use by individual saboteurs. The discussion of biological weapons is therefore confined to a description of some of the main national research programmes that were mounted to achieve this objective or to assess its feasibility. While World War II work showed that the notion of large-scale biological warfare could no longer be regarded as science fiction, it was not until some time later that serviceable arsenals of the weapons began to accumulate. This latter process is not discussed in this volume, but will be treated in some detail in Volume II.

While Chapter 1 chiefly comprises a set of technical descriptions, a number of wider themes that have present-day relevance are implicit in it.

These will be discussed further in later parts of this study. One such theme is the nature of the whole development process for chemical and biological weapons. Different stimuli have operated at different times. In the case of chemical weapons they came initially from chemists anxious to put their own particular expertise at the service of national war efforts. Later on, as the development process became institutionalized in different countries, the stimuli became more varied: they included known weaknesses in enemy protective equipments, for example, or the availability of new weapons delivery systems, or the requirements of changing patterns of warfare, not to mention the inevitable tendency towards self-preservation and propagation displayed by any kind of institution. It seems clear that the enthusiasm of the scientists and technologists involved has frequently outstripped that of the armed services, particularly in the case of biological weapons. Nonetheless, the destructive potential of the weapons has compelled military people to pay attention to them, however much they might dislike the whole notion of CBW. Even today, when military establishments have long since come to terms with technological progress, there are many serving officers who regard CB weapons as the unsolicited offering of misguided scientists.

Chapter 2 has two purposes. The first is to provide a catalogue of instances when the use of chemical or biological weapons has been alleged. The second is to describe the military rationale underlying their use in those cases where the fact of their employment is beyond reasonable doubt.

As regards the catalogue of allegations, many of these seem improbable, and some may be thought patently absurd. Yet in no case is there enough published evidence to exclude them from a list of instances in which CB weapons might have been employed. Although this may mean the inclusion of irresponsible and unfounded reports, or indeed deliberate propaganda fabrications, we nonetheless consider the catalogue to be useful. In the first place it is likely that allegations, whether substantiated or not, have an important influence on the continued "unconventionality" of CB weapons, and therefore on the inhibitions governing their future employment. In the second place the allegations illustrate the complexities that must be resolved if a reliable machinery for investigating future allegations is to be created. With the latter consideration in mind, we have chosen to describe three sets of allegations rather extensively: the reports of biological warfare in China in 1942 and in Korea in 1952, and the reports of chemical warfare in the Yemen in the mid-1960s. We treat the Korea and Yemen allegations more fully in Volume V of this study, where there is a discussion of the lessons which may be learned from them as regards possible verification machinery.

No report of biological warfare has yet been fully substantiated, and for this reason the discussion contained in Chapter 2 of past military uses of CB weapons is confined to chemical warfare. There have been four adequately substantiated instances of this on a large scale over the past sixty years: during World War I, during the Italian invasion of Ethiopia, during the Japanese invasion of China, and during the present war in Indo-China. Many people also believe that large numbers of chemical weapons were used during the recent Yemeni Civil War, but as yet the documentary evidence on this is not conclusive one way or the other. A study of past combat applications of chemical weapons is thought to be useful for the guidance it may give to present-day appreciations of the value of chemical weapons, a subject that is of obvious relevance to disarmament and arms-control negotiations. The accounts given in Chapter 2 will be drawn on frequently in the discussion contained in Volume II of the possible military importance of CB weapons today.

There are two points emerging from Chapter 2 to which it is worth drawing brief attention here. First, it is clear that in those rare cases since World War I when chemical weapons have been used on a substantial scale, it has always been against an enemy known to be deficient in anti-gas protective equipment or retaliatory capability. Second, in all substantiated cases of chemical warfare during this century the employment of chemical irritants, such as tear gas, has always preceded resort to more lethal agents. This is true for World War I, for the Italian invasion of Ethiopia and for the Japanese invasion of China. Even as regards an unsubstantiated instance of chemical warfare, that alleged to have occurred during the Yemeni Civil War, the earliest reports concerned tear gas. In the present Indo-China War, where irritants have been used on a scale approaching that of World War I, the reported uses of more lethal chemicals by both sides remain unsubstantiated. Because the sample is so small, it would be dangerous to draw firm conclusions from these points, but they seem to suggest (*a*) that chemical weapons are likely to be militarily attractive only in strongly asymmetric conflicts, and (*b*) that use of chemical irritants in war carries a risk of inducing more drastic forms of chemical warfare.

The remaining three chapters in this volume are intended to provide historical insight into the various factors that may inhibit wider use or acceptance of CB weapons. This was thought to be useful because any new treaty constraints on CBW that may be negotiated seem likely to be stronger if they supplement existing *de facto* constraints. Conversely, there is also a possibility that the conclusion of an unduly narrow agreement on CBW might weaken rather than strengthen existing constraints by appearing to condone CBW activities that fall outside its scope; this risk is discussed in Volume V of this study.

Chapter 3 is concerned with popular attitudes towards CBW during the period between the two world wars. It describes the manner in which public opinion in this field was aroused, particularly in the USA and the UK, how it was exploited, and what some of its effects were or might have been. One such effect was to stimulate the negotiation of the 1925 Geneva Protocol, the most important piece of conventional international law prohibiting the use of CB weapons. Another effect may well have been to retard the development of the weapons within the military establishments, and thus to have diminished the likelihood of their future employment.

Chapter 4 describes national policies and programmes relating to CBW during the inter-war period. The intention here is both to illustrate the impact of public opinion on national policy making, and to provide historical depth for the discussion of present-day CBW postures that appears in Volume II. The chapter is primarily concerned with those countries that became the principal belligerents during World War II, namely the UK, the USA, Germany, the USSR, Japan, France and Italy. As between these countries, the treatment is regrettably uneven; this reflects the dearth or inaccessibility of published information in this area.

Chapter 5 deals with a subject that provides a rather fitting conclusion for this volume, namely the non-use of CB weapons during World War II. For biological weapons this abstention is not especially remarkable, for microbiology was not then a science that had yet found much application outside the laboratories. In contrast, the abstention from chemical warfare seems much more surprising, for by the end of the war the total stockage of chemical weapons by the belligerents far exceeded the total consumption during World War I. The chapter first explores the incentives there might have been for the different belligerents to use the weapons at different stages of the war, and then contrasts these with the constraints that might have been operating. The impressions that emerge are these: the incentives to use chemical weapons seem to have been strongest in those cases when a belligerent's homeland was directly threatened and it was to his advantage to reduce enemy mobility—against *Blitzkrieg* advances on land, or against amphibious landings from the sea. But in these and all other cases the temptation was rejected. The reasons for this restraint varied from belligerent to belligerent: fear of retaliation-in-kind against other fronts and against civilian populations; the weight given to the adverse affect on neutral opinion, especially in the early phases of the war; personal opposition to chemical warfare on the part of political leaders; and, in certain of the combat zones, an absence of trained troops and the large supplies believed necessary to sustain a CW campaign. To these must be added what was perhaps the most important constraint of all, namely the marked lack of interest in CW amongst the opposing military staffs. In Chapter 1 the point is made that it was not until after World War II that chemical weapons became at all amenable to fast-moving campaigns. Quite apart from this, or perhaps because of it, military authorities on neither the Axis side nor the Allied side (but here it is possible to speak only of the Western Allies, for very little has been published about the contemporary Soviet appraisals of chemical warfare) had formed any clear idea of the relative merits of poison gas as an offensive weapon compared with the range of other weapons available. A consequence of all this might well have been that although the various other constraints may have been substantial, notably the fear of retaliation-in-kind, there may in fact have been little serious incentive for them to constrain.

The relevance of these considerations to the present day is clear enough: since CB weapons were not used during World War II, is there any good reason to suppose that they might be used today? Is there any real need to worry about them? These questions are discussed in the light of post-war developments in the next volume of this study.

UNITS OF MEASUREMENT

The metric system has normally been used in the text for quantitative values, so that units of length are expressed in metres or kilometres rather than feet or miles, and so on. The "tons" used are therefore metric tons (tonnes) rather than the short or long tons more commonly used in, say, the UK or the USA. In cases where published material is being quoted directly, or where for other reasons it would be inappropriate to shift units, units other than those of the metric system occasionally appear. Thus, poundage figures have been retained for British and US bomb-ratings because they refer more to the size or shape of the bomb and indicate only its approximate weight.

For readers unfamiliar with the units we have employed, the following conversion factors may be helpful:

Units of length

1 micron = 0.001 millimetre = 10 000 Ångströms
1 millimetre (mm) = 0.039 inch
1 inch = 25.4 mm
1 metre (m) = 1.1 yard (yd) = 3.28 feet (ft)
1 yard = 3 ft = 36 inches = 0.91 m
1 kilometre (km) = 0.62 statute mile (mi) = 1 094 yd
1 statute mile = 1.61 km = 1 760 yd

Units of mass

1 ton = 1 000 kg = 2 205 pounds, avoirdupois (lb) = 0.98 long ton = 1.1 short ton
1 short ton = 2 000 lb = 0.91 ton = 0.89 long ton
1 long ton = 2 240 lb = 1.1 ton = 1.12 short ton
1 kilogram = 2.2 lb
1 pound = 0.45 kg

Units of area

1 hectare (ha) = 2.47 acres
1 acre = 0.4 ha
1 square kilometre (km^2) = 100 ha = 0.39 square mile
1 square mile = 2.59 km^2

Units of volume

1 litre (l) = 0.264 US liquid gallon

1 US liquid gallon = 3.785 l

1 cubic metre (m^3) = 1 000 litre = 35.3 cubic feet

1 cubic foot = 0.028 m^3

Miscellaneous conversion factors and units

Fahrenheit to Centigrade: degF = 9/5 degC + 32

Parts per million (ppm) to milligrams per cubic metre (mg/m^3):

An airborne concentration of 1 ppm of a substance of molecular weight M corresponds to a concentration of 0.0416M mg/m^3 at 20 degC and 760 mm/Hg pressure. Likewise, under the same conditions, 1 mg/m^3 = 24.05/M ppm.

Volatility:

This is the mass of a substance contained in a unit volume of its saturated vapour, under specified conditions of temperature and pressure. As used in the present text, it is expressed in units of mg/m^3 at 760 mm/Hg and, generally, 20 degC.

Volatility is related to vapour pressure, thus:

Volatility = 16 000 Mp/T mg/m^3 where M = gram-molecular weight and p = vapour pressure in mm/Hg at a temperature of T degrees absolute.

Density:

100 US liquid gallons of water weigh about 380 kg = ca. 840 lb

100 gallons of mustard gas or agent *Orange* = ca. 480 kg

100 gallons of nerve gas (e.g. tabun, sarin or VX) = ca. 410 kg

100 gallons of hydrogen cyanide = ca. 260 kg

Chapter 1. The developing technology of CBW

Chemical warfare means the wartime use against an enemy of agents having a direct toxic effect on man, animals or plants. The use of chemical warfare agents against man, rather than against animals or plants, is sometimes referred to as *gas warfare,* even though the substances involved may be solid, liquid or gaseous. The toxic effects produced in gas warfare may be transient or permanent, ranging, for example, from a temporary irritation of the eyes to serious injury or death.

Biological warfare means the wartime use against an enemy of agents causing disease or death in man, animals or plants following multiplication within the target organism. Biological warfare agents thus include pathogenic micro-organisms and infective materials derived from such micro-organisms.

In this study, we use the abbreviation *CW* for chemical warfare and *BW* for biological warfare. The term *CBW* embraces both CW and BW.

In that weapons based on toxic or infective substances have been used since ancient times, CBW has a long history; but the form in which it is known today, a potential instrument of mass destruction, has a much shorter history. Modern chemical weapons were conceived during World War I, when they were used widely by most of the belligerents. They have become enormously more potent since then, but have never been used on so substantial a scale. Biological weapons began to be developed for purposes other than sabotage during the early years of World War II, but have never been used in such a form. They remain unproven weapons of potentially enormous destructive power.

In this chapter we describe the growth of CBW technology over the last six decades. We deal first with CW, then with BW. For CW, the underlying theme is the competition between the development of the weapons and the development of the defences against them. The groundwork for this is laid in a discussion of CW technology during World War I, from which certain aspects are taken up and their development over the subsequent fifty years described: on the one hand, the search for new CW agents, the requirements made of chemical weapons by changing patterns of warfare and the development of new weapons delivery systems; on the other hand, the refinement of anti-gas equipment for the individual soldier. Developing

BW technology is described in terms of past efforts at upgrading pathogens from their ancient role as sabotage weapons to one more suited to large-scale warfare. The starting-off point for this is a description of the Japanese BW programme during 1934–45 and of the beginnings of similar programmes in other countries.

The greater emphasis in this chapter on CW compared with BW reflects both the earlier development of the former as a modern method of fighting, and the greater accessibility of information about it.

I. *Chemical weapons*

CW technology during World War I

The beginning of the development of chemical weapons during World War I was somewhat haphazard. The impetus came from chemists who had become aware of the noxious effects of certain chemicals in their laboratories, and who felt that these effects could be exploited to assist national war efforts. From about 1914 onwards, attempts were being made in several academic laboratories throughout Europe to convert laboratory chemicals into weapons of war. It took some time for these initial efforts (in which a number of scientists succeeded in killing or severely injuring themselves) to produce significant results on the battlefield. When they eventually did so, military establishments started to invest in research stations of their own, bringing together the academic chemists and their own specialized technologists. In some countries, notably Germany, a well-developed chemical industry served both to act as go-between and to stimulate the chemists. In other countries, where the chemical industry was less advanced, the arrangements were on a more *ad hoc* basis, and took longer to settle down into an efficient machinery.

By around 1916, the technology of chemical warfare had established itself as a thriving subject for military research, and its subsequent progress was determined less by the practicalities of forcing chemicals into existing weapons systems—the basic problems had been understood and working rules evolved—than by the immediate requirements of the war. The underlying stimulus had advanced from a simple desire to exploit the harmful effects of noxious chemicals; it now came from the day-to-day requirements of the battlefield itself. Encouraged by early successes, the protagonists of CW considered gas to be a versatile weapon, despite its dependence on weather conditions and on the level of enemy anti-gas defence. They saw chemical weapons as being adaptable to almost any tactical situation, superior to explosives, bullets or fragmentation weapons in some situations, if inferior in others. Their problems were to develop chemical weapons in such a way as to overcome existing or anticipated defences, and to maximize their efficacy in those tactical situations where they might be the weapons of choice. The attempts to meet these design requirements are described here. The first section describes the various methods used to convert toxic chemicals into weapons; the second describes the competing developments of chemical weapons and anti-chemical defences.

The conversion of chemicals into weapons

Despite the great physiological activity of the more obvious candidate CW agents, the weapons designers of 1914 soon realized that it was no easy matter to design a weapon that could deliver effective dosages of the agents to an enemy deployed over a distant target area. The only practicable way of delivering an agent was to contaminate the enemy's surroundings, particularly the air he breathed, in the hope that some of the agent would eventually penetrate his body. The performance of the weapon was thus crucially dependent on the state of the atmosphere, and while in some circumstances this could be an asset, in others it could be a severe liability. On the one hand, a great load of poison might be carried by the wind and permeate the entire target area; on the other hand, the whole load might uselessly be blown away by an unexpected air current, or become so diluted by it as to be harmless. The greater the dependence of a weapon system on the prevailing weather conditions, the fewer would be the occasions on which it could be used.

EARLY IRRITANT-AGENT WEAPONS

In the early days, the sponsors of CW were obliged to show that it could be waged with existing weapon delivery systems, and the first chemical munitions were simply normal artillery shell, trench mortar bombs or grenades with part of the explosive or shrapnel charge replaced by a CW agent. The first such device to be prepared for battlefield use was proposed by Professor Nernst. This was the Germans' 105 mm *Ni-Schrapnell,* used for the first and last time at Neuve-Chapelle in October 1914 [1]. It consisted of the high explosive (HE) shell for the light field howitzer redesigned as a shrapnel in which lead balls embedded in a powder of *o-dianisidine chlorosulphonate* were scattered by a propellant charge [2]. The dianisidine *Niespulver* was a moderately powerful irritant of the mucous membranes and upper respiratory tract [3]. The weapon was not particularly successful and was abandoned in favour of other irritant-agent artillery shells.

The second German chemical weapon was based on a liquid lachrymatory composition proposed by Dr Tappen, the brother of a general on the staff of Field Marshal von Mackensen [3]. The composition, known as *T-Stoff* after its sponsor, was a mixture of brominated aromatic hydrocarbons; filled into a lead canister, it was substituted for two-thirds of the HE filling of a 150 mm heavy field howitzer shell. The remainder of the HE charge was intended to burst open the canister and shell, scattering the contents; thereafter, the volatility of the agent was thought to be sufficient to create a powerfully irritant vapour concentration. When the weapon was first used, in January 1915 on the Russian front, the weather was too cold to permit the necessary evaporation of the agent, and its results were disappointing. In warmer weather, however, it proved a useful weapon [2–5].

The T-Stoff shell was first used on the Western front in March 1915, at about the same time as the French introduced their first artillery chemical weapon. This had been improvised with some difficulty from the shrapnel shell for the 75 mm field gun. *Ethyl bromoacetate,* another irritant agent, was used in this shell following the practice of the police-issue tear-gas rifle cartridges and hand grenades that had been introduced earlier on the initiative of a conscripted French policeman; but this agent was replaced first by *chloroacetone* and then by more potent irritants as French bromine supplies dwindled [2, 5, 6].

CYLINDERS OF COMPRESSED TOXIC GAS AS WEAPONS

By the end of 1914 pressure was building up to use chemicals that produced a more decisive physiological effect than a transient irritation. This escalation from irritant agents to more lethal agents is described in more detail in Chapter 2. Although later in the war lethal chemical weapons were provided simply by replacing irritant-agent fillings with lethal-agent fillings, it was realized, when the introduction of lethal agents was first being considered, that the payloads of existing chemical weapons were too slight for anything other than small-area attacks. For this reason Professor Haber proposed the *chlorine cylinder* as a weapon. Rejecting the intermediary of special munitions, he relied entirely on the atmosphere to carry the agent from the German lines across to the enemy. Provided the wind was right, very much higher dosages could be created with this method than with existing artillery capabilities. Chlorine was an agent well suited to such a technique; gaseous except at low temperatures, it could be liquefied comparatively easily, at any rate by the German chemical industry of the time, and would evaporate almost instantly into a low-hanging vapour when released from its cylinder. Toxicologically, it was a powerful lung irritant producing death by asphyxiation.

The background to the first occasion when Professor Haber's proposal was put into practice is described in Chapter 2. Details of the attack itself, and of its counterpart in the following month on the Eastern front, are given here.

The gas-cylinder attacks at Ypres, April 1915. The German Supreme Command had requisitioned 6 000 cylinders of compressed chlorine, about half the available commercial supplies, and placed orders for a further 24 000 [7]. By mid-February, enough cylinders had been dug in along the Ypres sector of the Western front for an adequate trial, but a delay occurred because of bad weather, during which time additional cylinders were emplaced as they became available. On 25 March, orders were given for another battery to be set up further along the front where the wind seemed more likely to be favourable; this second front was ready by 11 April, but still the weather was unsuitable, and remained so for another ten days. Gas cylinders were thus present in the German front line around Ypres for over two months, and in fact provided several warnings to Allied forces: prisoners and deserters gave information; impregnated gauze/cotton-waste respirators were captured; and emplaced cylinders were ruptured by shell fire. [8] In addition, German radio broadcasts and official communiqués had begun making a number of unsubstantiated allegations that the French, the British and the Russians were firing asphyxiating-gas shell [9–11]. Minimal attention was paid to these warnings. The French regarded their intelligence on the imminent gas attack as a German plant: they suspected a German ruse to prevent French troops being withdrawn from Ypres to assist in the Arras offensive. [8] The British drew up contingency plans of a sort [8], but since no one knew what sort of gas might be used or what it would do, these were rather sketchy, and the matter tended to be regarded as an absurdity. A London newspaper, reporting it all on 9 April, treated the rumours of German plans to asphyxiate enemy troops with cylinders of gas as something of a joke [12]. The joke was short-lived.

Orders for the gas attack to begin were given on 9 April, but they could not be carried out until the late afternoon of 22 April when the requisite northerly wind appeared, and then only the second emplacement of cylinders could be discharged. Accordingly, at 5 p.m. on 22 April, 180 000 kg of chlorine were released from 5 730 cylinders along a 6 km front extending between Steenstraat on the Yser Canal, through Bixschoote and Langemark, and eastwards towards Poelcappelle. The cylinders to the southeast of Poelcappelle remained sealed. [8]

The Allied line west of the Yser Canal was held by the Belgians, and east of the Poelcappelle road by the Canadians. The intermediate sector, against which the gas was directed, was held by the French. As it happened, the experienced French XX Corps had just been relieved, and in their place were seventeen companies of Territorials and two battalions of the 45th (Algerian) Division. When the huge yellowish-green gas cloud reached them they broke quickly, the Africans first, then the Territorials. The unopposed German infantry advanced for a few hundred yards with considerable trepidation behind the cloud; then, in accordance with current doctrine, as dusk was falling, they dug themselves in. [8]

It took several hours for the Allied Command to grasp precisely what had happened. By the middle of the night, it became clear that the Germans had made an 8 or 9 kilometre gap in the line and could, if they had chosen, have broken through it altogether. Canadians were rushed in to provide a stop-gap while the French reorganized themselves. [8]

In their official communiqués to the press next day, German Headquarters reported their advance and the capture of 1 600 Allied prisoners, but made no mention of gas [13]; the British spoke of the German use of "a large number of appliances for the production of asphyxiating gases" but did not report the Allied setback [14]. The German propaganda machinery was still preoccupied with matching accusations with its British counterpart over the gas-shell allegations, and on the day after the first gas-cloud attack, German radio was stating that German troops had not fired any shell "the sole purpose of which is the spreading of asphyxiating or poisonous gases" [15], a verbatim quotation from the very Hague rule which was intended to prevent chemical warfare. If the Germans had started these particular allegations with the intention of providing a future justification for their chlorine attack, the broadcast would have been a fine example of the right hand not knowing what the left was doing, but probably there was no such intent: the first allegation appears to have been made on 13 April [10], several days after the orders for the attack had been given and nearly four months after the original decision to try lethal chemicals had been made.

On 23 April the Allied forces tried to regain their lost ground and the Second Battle of Ypres got under way. On the following day the wind moved a few points to the east, and the remainder of the gas cylinders could be discharged [8]. The majority of these were used that day against the Canadians, who by then had some idea of what to expect even though they lacked all but the crudest forms of protection. The discharge was accompanied by a more concerted infantry follow-up together with a bombardment with T-Stoff shell [16] to thicken the cloud and to increase its psychological effect.

Just what the effects of the chlorine attacks at Ypres were in terms of gas casualties is uncertain. A British author, writing two years after the war ended, stated that there were at least 5 000 dead, with many times that number wounded [17]. A few years later a German writer gave figures of

15 000 casualties including 5 000 dead [18], but in 1934 he withdrew these figures, saying that for propaganda reasons the Allies had quintupled their casualty figures [19].

The French, who suffered most from gas at Ypres, do not appear to have published their casualty figures: probably the necessary records could not be made. In the absence of these, the most reliable indications are the statistics contained in the official British medical history of the war, based on the war diaries of the medical units in the Ypres area. About 7 000 gas casualties passed through the field ambulances and casualty clearing stations; 350 of these subsequently died [16]. It is not clear whether these refer to French or British Empire troops, or both. They do not include gas casualties taken prisoner by the Germans or those not admitted to medical aid posts, whether because they died or recovered before reaching them. As to the prisoners, a German source quotes a figure of 200 Allied gas casualties admitted to German hospitals: twelve subsequently died [19]. It is impossible to say how many failed to reach medical aid stations. A British authority estimates that the figure of 7 000 should be expanded by a further 3 000, mostly dead [20]. Part of the dead would have fallen on ground soon to be occupied by the Germans, and although one German writer states that an army doctor visiting captured French trenches on 23 April could not discover a single gassed corpse [19], his is a rather partisan account; it seems unlikely that the French retired quite as quickly as this would imply.

The gas-cylinder attack at Bolimow, May 1915. At the time of the Ypres experiment, the Germans were preparing additional gas-cylinder attacks on the Eastern front. News of the success of the Ypres attack had made commanders of the German armies in the East enthusiastic about the new weapon. Ludendorff says in his memoirs: "We had received a supply of gas and anticipated great tactical results from its use, as the Russians were not yet fully protected against gas." [21] Drawing from the experience of their western allies, the Russian High Command had in fact issued directives on anti-gas defensive measures, but the protection recommended amounted only to cloth face-pads impregnated with a solution of thiosulphate. The production of this mask did not proceed at all fast, and when the Germans launched their attack the Russian troops were almost completely unprotected.

On 31 May[1] the 9th German Army employed gas in support of its advance on Warsaw. The attack took place along the Bolimow sector of the front near Skierniewice, some 50 km southwest of Warsaw. Twelve thousand cylinders containing a total of 264 tons of chlorine were discharged along

[1] Two Western writers, including Ludendorff, record an earlier date, 2 May [2, 21]. However, the details of the attacks which they give agree with those contained in the official Soviet sources used here.

a 12 km front against troops from two infantry divisions of the 2nd Russian Army. The discharge went according to plan, but the infantry assault which was supposed to follow it up did not succeed. The German troops had been led to believe that the cloud would completely neutralize any resistance, and when the Russian guns continued to fire after the discharge they assumed that the gas had been ineffective [21]. In fact 8 934 gas casualties were recorded, of which 1 101 died [22].[2]

After the success of these first two experiments, gas-cylinder attacks continued to be launched throughout the war: nearly two hundred such operations took place. The largest was carried out by the Germans against the French at Rheims in October 1915, when 550 tons of chlorine were discharged from 25 000 cylinders. In terms of casualties per ton of agent, the most effective attack, with the possible exception of the initial one at Ypres, seems to have been that conducted by the Austro-Hungarians against the Italians on the Plateau of Doberdo in June 1916; 100 tons of a chlorine/phosgene mixture caused 6 000 casualties, 5 000 of them fatal [2]. The British made the most use of the weapon—the prevailing winds were more often in their favour. At the time of the German spring offensive of 1918, the British were planning a gigantic attack designed to engulf not merely a wide sector of the German front line but also the artillery positions well to the rear. About 5 800 tons of gas were to have been discharged from 200 000 cylinders mounted in railway trucks [20].

These operations, however, were not popular with line commanders who were nervous of having lethal chemicals in their trenches and deplored the uncertainties which the weather-dependence of the weapon introduced into their schedules. In addition, mounting these operations demanded a huge quantity of manpower: thousands of heavy cylinders had to be brought up to the front and dug in, at night so as to avoid alerting the enemy. For these reasons, weapons designers felt there was more to be gained by trying to reduce the weather-dependence of chemical weapons than to exploit it. While efforts to improve the efficacy of cylinder operations continued, mainstream research reverted to chemical projectiles. There were two basic approaches to the problem of improving their performance: either their chemical payloads could be increased by developing special projectiles and delivery systems, or the potency of the payload could be increased by using more toxic agents or more efficient disseminating mechanisms. Both approaches were followed.

[2] The figures are taken from official Soviet sources [22]. Other commentators record gas fatalities as high as 6 000 among a total 9 000 gas casualties [2, 23].

SPECIAL GAS WEAPONS

The Germans had continued their work on chemical projectiles while the cylinder-gas experiments were in progress; they still concentrated mainly on irritant agents. Tear-gas projectiles in the form of trench mortar bombs of various calibres were introduced for infantry use. These weapons could carry a much larger payload than artillery shell because they did not need to be as solidly constructed. The early models were nothing more than sheet metal or wooden cylinders containing bottles of agent embedded in explosive powder.

By September 1915 the British had struck upon a combination of calibre and rate of fire that was particularly well suited to CW. These early trench mortars were the forerunners of the most widely deployed infantry gas weapon of World War II. The weapon was the *4 inch Stokes mortar,* first used at the Battle of Loos, and thereafter throughout the war. Each mortar bomb held 3 to 4 kg of agent and could be fired at up to 20 rounds per minute at ranges of up to 1 000 metres [2]. The Stokes mortar was the first weapon designed specifically to deliver a chemical projectile.

The next advance in infantry gas weapons was also made by the British. This was the gas projector, developed by Captain Livens in the winter of 1916–17 as a way of setting up sudden, very high, gas concentrations at ranges of 1 to 2 km. In many ways the new weapon, called the *Livens Projector,* was the obvious advance over cylinder emplacements, if the object was to decrease weather-dependence. Instead of the gas being discharged from cylinders towards the enemy line, the entire battery of cylinders was thrown at the enemy and burst over him. Accordingly, rather than emplacing hundreds of cylinders, the chemical troops dug in a great number of large-calibre mortars, crude affairs improvized from oil drums or lengths of pipe. Bags of propellent were then inserted, followed by the gas cylinders fitted up with percussion fuses and small bursting charges, and when the time came the whole battery was discharged simultaneously. This was an extraordinarily effective technique, first used on a large scale at the Battle of Arras in April 1917, and thereafter throughout the war. The weapon was improved upon as time went by: a standard Livens Projector drum, holding about 15 kg of agent, was produced and further developed. Incendiaries and HE were also fired from it. The projector was extremely simple in construction so that it could be manufactured swiftly in vast numbers; by the end of 1917 operations involving batteries of several thousand projectors were being conducted [20]. For some time the Germans did not have anything comparable: their 250 mm heavy trench mortar, although firing larger bombs (holding up to 24 kg of agent), was too cumbersome to be used in large batteries [2]. In due course they copied the weapon, using it for the first time on the Italian front in October 1917 [1], and two months later against the British at Cambrai. Towards the end of the war they introduced a smaller and more complicated version which had a rifled bore and hence a longer range, of up to 3 km [17].

The main drawback of the Livens Projector was the time and effort needed to dig in a battery, and because of this it was only suited to trench-warfare conditions. Nonetheless, the design principle it established—the value of a weapon that could deliver, simultaneously, suddenly and reasonably accurately, a large number of chemical projectiles onto a broad target area—is of great importance today. The heirs of the Livens Projector are the multiple rocket launchers and the aircraft cluster bombs.

The Germans had pioneered artillery-delivered chemical weapons in their early irritant-agent projectiles. By the summer of 1915 their 150 mm T-Stoff shell had been supplemented by smaller calibre munitions for the 105 mm light howitzer and the 77 mm light field gun. The same design principles were used: a lead canister of agent in the body of the shell burst open by detonation of a large HE charge in the ogive. Two types of lachrymatory irritant were standardized, a less volatile one for persistent effect (T-Stoff), and a more volatile one for nonpersistent effect (*K-Stoff,* a mixture of *chloromethyl* and *dichloromethyl chloroformates*).

The K-Stoff shell was in fact the first German step towards lethal chemical shells, for, as the agent was rather volatile and well over twice as poisonous as chlorine, lethal dosages were much more likely to be experienced from its field concentrations than from the earlier irritant agents. As a lethal agent, K-Stoff was an unsatisfactory filling: goggles might not adequately protect friendly troops who became exposed to it, and its lethal properties were not sufficiently great to warrant a radical change in gas-shelling techniques. It was therefore replaced by two agents: *B-Stoff* (*bromoacetone*), another irritant as volatile but much less poisonous than K-Stoff; and *K2-Stoff* (*trichloromethyl chloroformate* or "diphosgene"), less irritant but more poisonous than K-Stoff.

K2-Stoff shells, the first of the so-called *Green Cross* weapons,[3] were first used in May 1916; they were available in 77 mm, 105 mm and 150 mm calibres for field guns and howitzers. [2] Their basic design was the same as the earlier gas shells, but while a heavy burster charge was an asset

[3] One element of the marking system used on German chemical weapons was a coloured cross, which indicated the nature of the chemical filling. A green cross meant a volatile filling capable of causing severe damage to the respiratory tract. A yellow cross meant an involatile filling, especially one capable of damaging the skin. A white cross meant a tear-gas filling. In later years a red cross was sometimes used to denote the so-called "nettle gases".

with irritant agents it proved to be a defect with agents that required higher dosages for effect. The French already knew that heavy burster charges were in fact unnecessary. They had been firing lethal artillery gas shell charged with phosgene since February 1916 [2]. Their principal weapon was the *Special Shell 5,* a projectile for the 75 mm field gun, a fieldpiece which made up for its lack of weight by an unusually high rate of fire, supplemented by 105 mm and 155 mm gun and howitzer projectiles. The absence of a heavy HE charge in these munitions, besides permitting a larger gas payload, also reduced the areas over which the chemical was scattered: a small volume of air was contaminated to give a high gas concentration, rather than a large volume to give a comparatively harmless one.

The success of the French Special Shell 5 during the defence of Verdun was a crucial point in the development of the gas war. All belligerents began to pay serious attention to lethal-effect CW, for here was a CW technique that was highly effective without demanding the laborious preparations of a gas-cylinder operation. The British made haste to acquire their own lethal-gas shell: in May 1916 Sir Douglas Haig, commanding the British Expeditionary Force, asked for gas shell supplies of 10 000 rounds per week, increasing this to 30 000 in July. Production lagged however; it not only had to wait upon the necessary R & D work, but it also had to compete with demands for production of HE shell, of which there was a serious shortage during 1916. By the end of 1916 only 160 000 shells had been filled with lethal or partly lethal CW agents, and it was not until May 1917 that British gas shelling became at all significant. [24]

The Germans also learned from the French designers, and by the end of 1916 they were using Green Cross shell in which the bursting charge was provided solely by the gaine of the fuse [2]. The shell casings were still those used for HE, but by 1917 a special casing for CW fillings had been introduced; it was longer than the normal one and had thinner walls. The version for the 77 mm field gun held 1 kg of diphosgene, as compared with the 0.5 kg carried by the earlier short-type shell [2]. By August 1917 Green Cross shell were available for the entire range of German field artillery, from the small field gun up to the 210 mm heavy howitzer.

Thus, by 1917 artillery had become the principal means of delivering CW agents, and all belligerents were firing gas shell on a considerable scale. This trend is shown in table 1.1.

The emphasis placed on artillery CW by the end of the war is an indication both of the rapidity with which the chemical arm developed and of its failure to reach anything like its full potential. The tactical requirements of the war demanded that a radically new class of weapon be forced into a weapons delivery system which at the time was not well suited to it. For-

Table 1.1. The increasing reliance placed on artillery as a delivery system for CW agents during World War I

	Estimated expenditure of artillery ammunition (*millions of rounds*)		*Gas shell as percentage of total artillery ammunition fired in WWI*	Tonnage of CW agents delivered by artillery (*hundreds of tons*)					*CW agents delivered by artillery as a percentage of total CW agents delivered*				
	Gas shell 1915–18	Other shell 1914–18		1915–18	1915	1916	1917	1918	1915–18	1915	1916	1917	1918
Germany	33	485	*6.4*	482	14	59	136	273	*92*	*48*	*84*	*92*	*98*
France	16	334	*4.6*	236	3.2	27	64	142	*90*	*100*	*79*	*85*	*95*
British Empire	4	178	*2.2*	91	0	4.5	30	56	*64*	*0*	*29*	*62*	*73*
Austro-Hungary	5	170	*2.9*	72	0	5.9	24	42	*91*	*0*	*74*	*39*	*95*
Italy	4	146	*2.7*	58	0	3.2	23	32	*91*	*0*	*78*	*89*	*95*
Russia	3	69	*4.2*	34	1.8	14	18	..	*71*	*100*	*75*	*67*	..
USA	1	7	*12*	9	..	..	0	9	*91*	..	..	*0*	*91*
Total	**66**	**1 389**	***4.6***	**982**	**19**	**114**	**295**	**554**	***87***	***53***	***76***	***84***	***94***

Source: Prentiss, A. M., *Chemicals in War* (New York, 1937).

midable design problems had to be solved. Given the stresses imposed on a shell of a given calibre if it was to be projected a useful distance, how could a sufficiently robust shell casing be constructed which would hold an adequate volume of CW agent and at the same time incorporate an efficient agent-dissemination mechanism? How were they to be sealed? What was to be done to prevent corrosion by the agent and to minimize the effects of agent decomposition during storage? How did the ballistics of liquid-filled shell differ from other types of shell? If one type of agent was no longer available, could the shell be used to disseminate a substitute?

The achievements in at least partially overcoming these problems could not compensate for the inadequacies of contemporary ordnance or fundamental shell design. If effective field concentrations of CW agents were to be set up over large areas, accurate shelling at high rates of fire was essential. The contemporary ballistic theory was not sufficiently refined to permit the design of projectiles of the required accuracy, and the larger field-pieces could not be fired at rates of much more than a round a minute. In addition, the shell fuses then available were in most cases inappropriate to a chemical payload. The great majority of gas shell had to carry normal HE percussion fuses and these were rather slow, with the result that a substantial portion of the charge was driven into the ground, often collecting in a pool at the bottom of the shell crater. It was not until well after the war that super-quick fuses became available. For many CW agents, especially the comparatively involatile ones, the most satisfactory fusing would have allowed the shell to burst a few feet above the ground, the height of burst being adjusted according to the prevailing wind conditions. The Germans were, in fact, experimenting with projectiles time-fused for air-burst by the end of the war, but the fuses were not reliable [2].

IMPROVED DISSEMINATING MECHANISMS

Alongside the development of special gas weapons, the second broad approach to improving the performance of chemical projectiles was to increase the potency of the agent fillings. This could be done in two ways; more toxic agents could be employed, or existing agents could be disseminated more efficiently. This section describes the latter approach.

All projectiles used during the war relied upon an explosive charge to disseminate the chemical filling over the target area. The problem was to select the size and shape of charge best suited to the agent payload: if too much explosive were used, the agent would be spread over too wide an area and so become too dilute; if too little were used, much of the agent would collect in a harmless puddle in the shell crater. The more volatile the agent, the smaller could be the charge, and with substances like phosgene or hydrogen cyanide it needed to do little more than rupture the projectile casing. With involatile agents there was an additional problem because for greatest effect these substances have to be broken up into smaller droplets than agents that rapidly vapourize. Mustard gas (see page 46) was a case in point. A high proportion of the German weapons for disseminating this agent—the *Yellow Cross* projectiles—were simply Green Cross designs filled with mustard gas, and exactly the same applied to all French and British mustard-gas shell [2]. The Germans did not appreciate that still greater effects could be obtained from their new weapon (by increasing the bursting charge so as to shatter the filling into finer droplets) until several months after introducing it, and their enemies never did appreciate this. The later designs of German mustard-gas weapons—the *Double Yellow Cross* shell—contained a massive amatol charge in the ogive (and thus reverted to the principle set by the early T-Stoff shell). On detonation this charge shattered the mustard gas into a fine spray, forcing it in an upwards direction away from the ground. The final version of the 150 mm Double Yellow Cross shell used 1.2 kg amatol to disseminate rather less than 2.9 kg mustard gas [2, 25]. In comparison, the Green Cross shell of the same calibre used about 0.1 kg HE, held in a central burster tube, to spread about 5 kg diphosgene, while the old 15 cm 12 T shell of 1915 used 1.5 kg HE for about 3.1 kg T-Stoff [2].

The HE burst principle was applied to solid CW agents as well as liquid, but here it was not successful. When the Germans introduced their *Blue Cross* agents, they embedded small bottles of the substances inside the explosive charge of normal HE shell. It was hoped that the shock of explosion would break up the solid into an airborne cloud of small particles, but this did not happen, or happened only to a very small extent. The British found a satisfactory way of using solid agents of this type but did not apply it to projectiles. They evolved the *thermogenerator* principle, which consisted of distilling the agent into the atmosphere as a vapour whereupon it would immediately condense into the desired aerosol cloud. This principle, however, was never put into practice on the battlefield: at the time of the Armistice, the British were secretly building up stocks of thermogenerator "candles" for a massive surprise attack. The weapon, known as the *M device,* was to have been used in the same manner as a gas cylinder: tens of thousands of the candles would have been emplaced a short way behind the British line and simultaneously ignited when a favourable wind appeared. [20] The Germans also are said to have developed a Blue Cross candle using the thermogenerator principle, and to have done so before the British [3], but there are no reports of its having been used.

IMPROVED CW AGENTS

The search for new and better CW agents accounted for a major proportion of the chemical weapons research effort during the war, and the number of candidate agents examined ran into tens of thousands. In Britain, for instance, much of the search comprised a compound-by-compound scanning of the myriad substances listed in *Beilstein's Handbook* for any suggestion of offensive properties, followed by laboratory experiment and field-testing, the latter often being conducted on the battlefield itself. That the searches were comprehensive is suggested by the fact that the agents being manufactured at the outbreak of World War II were no different from those that had come to the fore twenty years earlier.

While the main incentive in the search for new CW agents was to find substances that were effective at lower and lower dosages, there were other factors at work as well. For instance, if the manufacture of a candidate agent was beyond the capabilities of the chemical industry of the country concerned, then it clearly could not be used. In this respect, Germany had a considerable advantage over its enemies, for its chemical industry was the most advanced in the world. German dyestuffs factories, for example, were speedily converted to turn out great quantities of mustard gas, whereas it took the French nine months and the British fourteen months to develop the necessary new plant. Again, the raw materials requirements of the war effort, or the inaccessibility of external sources of supply, might curtail stocks of an essential raw material or intermediate for a CW agent, and substitute agents had to be found. The tactical requirements of the battlefield raised another set of considerations: there might be a need, for example, for an agent which could provide prolonged ground-contamination. This meant that a substance had to be found which was toxic and involatile enough to persist in an effective form for long periods. Again, the enemy might have introduced a new piece of anti-gas protective equipment which had to be circumvented in some way: a new type of agent, perhaps one which was not retained by the filter used or which attacked an unprotected area of the body, could be a solution.

The effects of existing or anticipated enemy anti-gas equipment on CW agent selection are discussed in the next section. The present section deals primarily with the search for more toxic and more amenable chemicals to act as payloads for chemical projectiles.

The chemicals that were eventually developed may be grouped into two broad categories, *harassing agents* and *casualty agents.* A harassing agent may be defined as a CW agent whose normal field concentrations are capable of rapidly causing a temporary disablement that lasts for a period not greatly exceeding that of exposure. A casualty agent may be defined as a CW agent whose normal field concentrations are capable of causing severe injury or death in anyone exposed to them. The main function of harassing agents was to force the enemy to put on respirators or to disconcert his combat activities; in this role, their direct casualty effect was of minor importance. Casualty agents, on the other hand, were intended to produce casualties, as their designation implies, a *casualty* being defined as someone rendered incapable of performing military duties for a prolonged period of time, whether through death or injury. The category of casualty agents may be subdivided into *respiratory* agents, intended to cause casualties after inhalation, and *percutaneous* agents, intended to cause casualties after absorption through the skin.

Harassing agents. Barring Germany's 105 mm Ni-Schrapnell, the first harassing-agent projectiles were based on irritants whose predominant effect was to produce *lachrymation,* a flow of tears. Although such "tear-gas" weapons were used throughout the war, the main concern in the selection of new agents was less with improved irritant properties than with improved physical or chemical ones. The length of time for which field concentrations would remain effective after dissemination was possibly the most important consideration in tear-gas shelling operations, and a range of lachrymators of widely differing persistency was available so that the choice could be made in accordance with the prevailing CW doctrine. If necessary, the persistency of the agent could be modified by admixture with suitable solvents or other lachrymators. As for chemical properties, the prime restrictions on the choice of agent were the reactivity of the chemical with the material of the projectile casing, and its stability on storage.

The most extensively used lachrymator was *bromoacetone,* of which 1 000 tons were used in artillery shell alone [2]. Its use was restricted, however, by shortages of raw materials, bromine in the case of France and Britain, and acetone (needed for powder and dope production) for all belligerents. The Germans, who introduced it, could use only small quantities; they were forced to adopt other brominated ketones in its place, inferior agents of inconvenient persistency and reduced irritancy, requiring lead or enamel shell linings to prevent corrosion. The British also used very little and, despite the high price of iodine, opted for *ethyl iodoacetate,* increasing its volatility with alcohol. When US forces came into the war, they chose bromoacetone as their standard lachrymator; the French also used it whenever they could, making do with *iodoacetone, benzyl iodide* or *acrolein* when stocks ran low.

The other widely used lachrymator was the Germans' T-Stoff which has been described. Despite the need for lead linings for the shell casings, it had a useful persistency, and some 500 tons were fired. [2]

Towards the end of the war, the French came upon a lachrymator of such startlingly high irritancy that they adopted it in place of bromoacetone; the US forces did likewise, despite the agent's corrosive and rather unstable properties. This was *α-bromobenzyl cyanide (CA).* Its preeminence among lachrymators was to be short-lived, however, for the Americans were developing *α-chloroacetophenone (CN)*[4] as the war was ending.

In 1917 the Germans introduced a new class of irritant agents. These were the Blue Cross agents, solid arsenical *sternutators* (causing sneezing) whose irritancy exceeded even that of CA and CN. They could not be disseminated in the same way as the lachrymators of the time and, as noted in the previous section, were never efficiently used during the war. The principal Blue Cross agents were *diphenylchloroarsine* (*DA*) and *diphenylcyanoarsine* (*DC*). The British sternutator of choice, selected because it was

[4] The toxic effects of CN, described here, illustrate the general effects of lachrymators. Exposure to a CN aerosol concentration exceeding about 0.5 mg/m^3 induces a copious flow of tears in less than a minute. At higher concentrations, or with prolonged exposure, intense irritation is experienced in the nose and upper respiratory tract, soon followed by an itching and burning of moist areas of exposed skin, which may even lead to blistering. On cessation of exposure, recovery is swift; but at high dosages serious lung damage may occur. A number of deaths following CN exposure have been reported in the literature, due mainly to pulmonary oedema [16, 26–28].

easier to manufacture than DA,[5] was *10-chloro-5,10-dihydrophenarsazine* (*DM* or *adamsite*[6]), and was to have been used in the M device. The Italians are said to have used DM towards the end of the war [2]; the Germans, in whose laboratories it had been discovered in 1913 [29], did not use it.

Table 1.2 lists the principal harassing-agent compositions used by the belligerents during the war; further details of the agents used in these compositions are given in table 1.6.

Respiratory casualty agents. In the selection of respiratory casualty agents during the war, toxicity was of much greater concern than with the harassing agents just described, and each newly introduced casualty agent generally was more poisonous than its predecessor. From a toxicological point of view, two principal categories of agent were used, both of which killed by interfering with oxygen uptake. *Lung irritants* blocked respiration by damaging the breathing mechanism, and *blood gases,* on entering the blood stream through the lungs, interfered with the transport of oxygen around the body.

The first lung irritant used was *chlorine,* employed solely in cylinder operations. The next was *phosgene,*[7] at first used for cylinder attacks (when

[5] The toxic effects of DA, described here, illustrate the general effects of sternutators.

"When used in minimum concentrations, this compound [DA] causes great irritation to the upper respiratory tract, the sensitive peripheral nerves, and the eyes; it also irritates the outer skin, but not to so great an extent; when present in stronger concentrations or when inhaled in weaker concentrations for a long time, it attacks the deeper respiratory passages. The irritation begins in the nose, as a tickling sensation, followed by sneezing, with a flow of viscous mucus, similar to that which accompanies a bad cold. The irritation then spreads down into the throat and coughing and choking set in until finally the air passages and the lungs are also affected. Headache, especially in the forehead, increases in intensity until it becomes almost unbearable, and there is a feeling of pressure in the ears and pains in the jaws and teeth. These symptoms are accompanied by an oppressive pain in the chest, shortness of breath, and nausea which soon causes retching and vomiting. The victim has unsteady gait, a feeling of vertigo, weakness in the legs, and trembling all over the body." [2]

These symptoms set in two or three minutes after exposure begins; after it ends, recovery is usually complete in one or two hours. Deaths were caused by Blue Cross agents during the war, even though they were inefficiently disseminated. [2]

[6] Adamsite was the name used for the agent in the USA, where it was discovered at the beginning of 1918 by a team working under Major Roger Adams at the University of Illinois [30]. A British team came upon it independently at about the same time [31]. Neither of these teams was aware of the German work on the agent, published in Germany in a patent specification in 1914 [29]: copies of the specification were not available in England until 1920 or so [31].

[7] The toxic effects of phosgene, described here, are typical of those of lung irritants. Having inhaled a lethal dosage of phosgene, the victim at first feels nothing more than a rather mild irritation of the eyes and throat. This generally passes quickly and for a period between two hours and three days he may have almost no other complaints, and may even feel mildly euphoric. During this latent period, however, a

Table 1.2*a*. Harassing agents used in World War I: some details of the agents

Chemical name	Date of first use I	Employing countries II	Harassing concen-tration (*mg/m³*) III	Volatility at 20°C, *mg/m³* IV	Approx. lethal dosage *mg–min/m³* V	Code name
Ethyl bromoacetate	8/1914	F	40	21 000	23 000	..
o-Dianisidine chlorosulphonate	10/1914	G	..	..	..	G: Niespulver F: Tonite
Chloroacetone	11/1914	F, G, R	100	61 000	23 000	G: A-Stoff
Xylyl bromide[a]	1/1915	G, A–H	15	600	56 000	
Xylylene bromide	1/1915	G	..	..	..	..
Benzyl bromide[a]	3/1915	G, F	60	2 400	45 000	F: Cyclite
Methyl chlorosulphonate	6/1915	G, F	40	60 000	20 000	F: Villantite
Ethyl chlorosulphonate	6/1915	F	50	18 000	10 000	F: Sulvinite
Chloromethyl chloroformate	6/1915	G, F	50	40 000	10 000	F: Palite
Dichloromethyl chloroformate	6/1915	G	75	45 000	..	..
Bromoacetone[a]	7/1915	G, F, A-H	10	75 000	32 000	F: Martonite G: B-Stoff B: BA A-H: Be-Stoff
Bromomethylethyl ketone	7/1915	G, F, A-H	50	34 000	20 000	G: Bn-Stoff F: Homo-martonite
Iodoacetone	8/1915	F	100	3 000	19 000	F: Bretonite
Dimethyl sulphate	8/1915[d]	G, F	50	3 300	5 000	G: D-Stoff F: Rationite
Ethyl iodoacetate[a]	9/1915	B	15	3 100	15 000	B: SK
Benzyl iodide	11/1915	F, I	30	1 200	30 000	F: Fraissite
o-Nitrobenzyl chloride	end/1915	F	15	..	..	..
Benzyl chloride	end/1915	F	85	..	..	..
Acrolein	1/1916	F	50	20 000	3 500	F: Papite
Diphenylchloroarsine	7/1917	G	1	7	15 000	G: Clark I B: DA
Phenyldichloroarsine[c]	9/1917	G	16	400	2 600	G: Pfiffikus B: DJ F: Sternite
Thiophosgene	3/1918	F	..	..	..	F: Lacrymite
Diphenylcyanoarsine[c]	5/1918	G	0.25	3	10 000	G: Clark II B: DC
N-ethylcarbazole	7/1918	G	..	..	..	..
α-Bromobenzyl cyanide	7/1918	F	5	130	10 000	F: Camite B: BBC
10-Chloro-5,10-dihydro-phenarsazine[c]	9/1918	F[b]	0.4	<1	15 000	B: DM
Phenyldibromoarsine	9/1918	G	..	..	2 000	..

it was mixed with chlorine to get the necessary volatility), but later used in projectiles. Phosgene, some six times as poisonous as chlorine, became the principal offensive casualty agent of the Allies: it made up more than half of the tonnage of CW agents used by the French, for example, as compared with less than a fifth of that used by the Germans. [2, 32] Phosgene had two drawbacks: its main toxic effects did not appear until some hours after exposure, and it was a difficult material to load safely into projectiles. For the latter reason, the Germans preferred trichloromethyl chloroformate (diphosgene) for their Green Cross shell, having tried and rejected a number of other agents, such as *methylsulphuryl chloride.* They used some 12 000 tons of it [32]; it was a less volatile substance than phosgene, but its toxicity and physiological action were almost identical. The third important lung irritant was *chloropicrin,* first used by the Russians in August

(*Note 7 continued*)
catastrophic oedema of the lungs is building up, which is accelerated by any form of physical exertion. Quite suddenly, the situation is reached when an adequate supply of oxygen is prevented from reaching the lungs, and thereafter the victim quickly goes into a state of collapse, his breathing hurried, shallow and spasmodic, his chest constricted, his lungs spewing up a yellowish expectorate, in a state of extreme weakness and fearfulness until unconsciousness and death supervene. [3, 33]

· · = unknown.
[a] Important during World War I.
[b] According to Matoušek and Tomaček [278], but disagreeing with most other commentators, who state that DM was not used during World War I.
[c] For further details, see table 1.6.
[d] According to Hanslian [18], but denied by Müller-Kiel [279] who maintains that Germany deliberately refrained from using dimethyl sulphate.

Notes and Sources

Col. I. Month and year of first use of the agent.

Col. II. Belligerents who both manufactured and used the agent, with first user listed first. F = France, G = Germany, B = Britain, R = Russia, I = Italy, A–H = Austro-Hungary.

Col. III. Approximate harassing concentration of the agent, *mg/m³*.

Col. IV. Volatility of the agent (concentration of its saturated vapour) at *20°C, mg/m³*.

Col. V. Estimated lethal dosage by inhalation, *mg–min/m³*.

1. Several of the substances listed above are also casualty agents, and may actually have been introduced as such, notably ethyl and methyl chlorosulphonate and dimethyl sulphate. They are included here as harassing agents because of their comparatively high irritancy and low volatility (compared with the more widely used casualty agents)—the latter suggesting that casualty dosages would have been difficult to set up. It may also be noted that bromoacetone—undoubtedly introduced as a harassing agent—was classified by the French as a "*lacrymogène et suffocant*"; its high volatility must certainly have led to casualties.

2. Dimethyl sulphate and phenyldichloroarsine both have a powerful effect on the skin, and although neither was apparently used in compositions intended for skin attack, they presumably could have been.

3. Although the USA used harassing agents during the war, they were all procured either from France or from Britain. None of the output of harassing-agent weapons from US manufacturing plants reached Europe in time to be used there. The US Chemical Warfare Service symbols for some of the agents were:

bromoacetone	BA
α-bromobenzyl cyanide	CA
10-chloro-5,10-dihydrophenarsazine	DM (also referred to in the USA as Adamsite)
diphenylchloroarsine	DA
diphenylcyanoarsine	CDA (later, DC)

4. The information in tables 1.2, 1.3, and 1.4 is drawn from several authoritative texts—German [1, 18, 280], British [16, 20], Czechoslovak [278], French [281–82], Italian [35], and US [2, 39]—but on certain points it reflects disagreement among these authorities.

Table 1.2*b*. German, French and British harassing-agent fillings for artillery shell

Shell designation	Filling designation	Composition of shell-filling	*Percentage composition of shell filling*
German weapons			
Ni-Schrapnell	Niespulver	*o*-Dianisidine chlorosulphonate	
T-Granate	T-Stoff	Xylyl and xylylene bromide isomers, and/or benzyl bromide	
T-Granate, grün		T-Stoff	*50*
		Bromoacetone	*50*
		or	
		Xylyl bromide	*90*
		Bromomethylethyl ketone	*10*
K-Granate	K-Stoff	Chloromethyl chloroformate	*90*
		Dichloromethyl chloroformate	*10*
Blaukreuz		Diphenylchloroarsine	*50–100*
		N-ethylcarbazole	*0–50*
		With or without phenyldichloroarsine as solvent	
Blaukreuz 1		Diphenylcyanoarsine, with or without phenyldichloroarsine as solvent	
French weapons			
No. 6	Palite	Chloromethyl chloroformate	*75*
		Stannic chloride	*25*
No. 8	Papite	Acrolein	*75*
		Stannic or titanic chloride	*25*
No. 9	Martonite	Bromoacetone	*60*
		Chloroacetone	*20*
		Stannic chloride	*20*
No. 9 B	Homomartonite	Bromomethylethyl ketone	*60*
		Chloromethylethyl ketone	*20*
		Stannic chloride	*20*
No. 10	Bretonite	Iodoacetone	*75*
		Stannic chloride	*25*
No. 11	Cederite	Benzyl bromide	*75*
		Stannic chloride	*25*
No. 12	Fraissite	Benzyl iodide	*60*
		Benzyl chloride	*20*
		Stannic chloride	*20*
No. 13	Sulvinite	Ethyl chlorosulphonate	*75*
		Stannic chloride	*25*
No. 14	Cyclite	Benzyl bromide	*80*
		Titanic chloride	*20*
No. 15	Lacrymite	Thiophosgene	*75*
		Stannic chloride	*25*
No. 16	Rationite	Dimethyl sulphate	*75*
		Chlorosulphonic acid *or* methyl chlorosulphonate	*25*
No. 21	Camite	α-bromobenzyl cyanide	*100*

Table 1.2 *b*. Continued.

Shell designation	Filling designation	Composition of shell filling	*Percentage composition of shell filling*
British weapons			
	SK	Ethyl iodoacetate	*100*
	KSK	Ethyl iodoacetate	*70*
		Ethanol and ethyl acetate	*30*

Notes and sources

1. These and other fillings were used in other irritant-agent projectiles—trench mortar bombs, hand grenades, etc. In the case of certain German trench mortar bombs, fillings that were identical with artillery shell fillings were given different code names. Thus the chloromethyl/dichloromethyl chloroformate composition, called K-Stoff in artillery shell, was known as C-Stoff in mortar bombs.

2. Almost all French artillery shell fillings included up to 25 per cent of smoke agent for shell-spotting purposes. (The principal exception was the Camite filling in Special Shell no. 21.) Although the active components of the different shell fillings are sometimes referred to by the code name for the filling as a whole, in most cases it was the filling not the agent for which the code name was originally intended.

3. For information about the sources, see table 1.2a, note 4.

1916 and thereafter by all belligerents. Its chief attraction was its ability to penetrate contemporary gas masks; it was also a powerful lachrymator.

The first blood gas to be used was *hydrogen cyanide.* On paper, this seemed a most promising agent—high toxicity, high volatility, much faster acting than phosgene, easy to manufacture, and so on—and by the end of 1915 the French were filling large numbers of artillery shell with it. Its use was not authorized, however, until July 1916, because until then the French authorities still felt bound in some measure by the Hague rule against gas projectiles [18]. Thereafter it was employed on a large scale, some 4 000 tons being manufactured for war use [32]. But the munition with which it was delivered, the *Special Shell 4* for the 75 mm field gun, was unsuited to it, and the agent was not a success. Because the payload delivered was small, about 0.5 kg [30], and because the agent was so volatile and its vapour so light, it was almost impossible to establish lethal dosages, especially as the agent was used mixed with some 50 per cent stabilizers, dilutents and smoke-markers. No other belligerent adopted it, although the British, who had acquired stocks of it in various formulations from the French before it had been fully tested, used up their stocks on the battlefield, without replenishing them. [20]

Subsequently employed blood gases, none of them particularly important, included *hydrogen sulphide,* used by the British in cylinder-gas compositions [20], *cyanogen bromide,* introduced by the Austro-Hungarians and subsequently abandoned in favour of diphosgene [34], *cyanogen chlo-*

ride, tried out by the French as a possible substitute for hydrogen cyanide[8] [2], and mixtures of *methyl* and *ethyl cyanoformates* (*Cyclon*),[9] used at intervals by the Germans as extenders for other casualty agents when stocks ran low [3].

Table 1.3 lists the principal respiratory casualty-agent compositions used by the belligerents during the war; further details of the agents used in these compositions are given in table 1.6.

Percutaneous casualty agents. Casualty agents whose principal function was to attack the skin were introduced in July 1917 as a means of poisoning a masked enemy. The effects of the skin attack were rarely fatal, although the agents, if inhaled in large enough dosages, had effects similar to those of the lung irritants. As lung irritants they were generally extremely potent from a dose-level point of view, but the weapons with which they were used were not capable of setting up the necessary airborne concentrations. During 1918, when these substances were the most widely used German CW agents, British gas casualties, which had been 7.2 per cent of the total British battlefield casualties in 1917, rose to 15 per cent of the total; however only 2.4 per cent of those gassed died, as compared with 3.4 per cent in 1917 [36]. It was not until World War II that munitions were designed that could exploit the lethal effects of percutaneous casualty agents at all fully.

The first percutaneous agent used was the *vesicant* (blistering agent) *bis-(2-chloroethyl) sulphide* (mustard gas). This was by far the most important CW agent of the war, not only from a battlefield point of view, but also, as will be seen, for the long-term development of CW. Within three weeks of introducing Yellow Cross shell, the Germans had caused as many gas casualties as had resulted from the entire gas shelling of the preceding year [16].

The Germans did not begin using mustard gas until they could do so on a massive scale, firing more than a million shell (2 500 tons of mustard gas) in the ten days following its introduction [1]. They had begun developing

[8] The symptoms of hydrogen cyanide poisoning, described here, exemplify those of blood gases. Low dosages of hydrogen cyanide have almost no effect on the body, which detoxifies the agent rapidly; but above a certain threshold dosage, symptoms set in very rapidly indeed, and the victim becomes confused, befuddled and dizzy in a few seconds. Great weakness and muscular incoordination come on simultaneously, and within ten to twenty seconds the victim is unconscious and beginning to be seized with convulsions. Respiration stops in less than a minute, except for an occasional gasp, but the heart continues to beat for several minutes. The chances of survival after respiration ceases, whatever aids are applied, are extremely small. [33]

[9] Cyclon was used in occupied Poland and Russia towards the end of the war to destroy the lice that were spreading typhus among civilians and troops [3]. It is related to the fumigant developed in post-World War I Germany known as *Zyklon A*, a mixture of methyl cyanoformate and methyl chloroformate and containing 90 per cent of the former [35].

Table 1.3*a*. Respiratory casualty agents used in World War I: some details of the agents

Chemical name	Date of first use I	Employing countries II	Harassing concentrations *mg/m*³ III	Volatility at 20°C, *mg/m*³ IV	Approx. lethal dosage *mg–min/m*³ V	Code name
Chlorine[a, b]	4/1915	G, all	100	3 000 000	19 000	F: Bertholite
Bromine	5/1915	G	..	..	..	..
Perchloromethyl mercaptan	9/1915	F, R	70	18 000	30 000	F: Clairsite
Phosgene[a, b]	12/1915	G, all	..	4 100 000	3 200	F: Collongite G: Zusatz B: CG
Trichloromethyl chloroformate[a]	5/1916	G	..	54 000	3 200	F: Surpalite G: Perstoff B: Diphosgene
Hydrogen cyanide[b]	7/1916	F, B, R	n.a.	891 000	4 000	F: Forestite
Hydrogen sulphide	7/1916	B	..	1 400 000	..	..
Chloropicrin[a]	8/1916	R, G, F, B	50	170 000	20 000	F: Aquinite G: Klop B: PS
Cyanogen bromide	9/1916	A-H, B	..	200 000	11 000	A-H: Ce-Stoff B: CB
Cyanogen chloride[b]	10/1916	F	85	2 600 000	11 000	F: Mauguinite B: CC
Phenylcarbylamine chloride	5/1917	G	30	2 100	5 000	..
Bis (chloromethyl) ether	1/1918	G	40	180 000	4 700	F: Cici
Bis (bromomethyl) ether	1/1918	G	50	21 100	4 000	F: Bibi
Cyanoformate esters	1918	G	..	..	..	G: Cyclon

n.a. = not applicable; .. = unknown.
[a] Important in World War I.
[b] For further details, see table 1.6.

Notes and sources

Col. I. Month and year of first use of agent.

Col. II. Belligerents who both manufactured and used the agent, with first user listed first. F = France, G = Germany, B = Britain, R = Russia, I = Italy, A–H = Austro–Hungary, all = F, G, B, R, I, and A–H.

Col. III. Approximate harassing concentration of the agent, *mg/m*³.

Col. IV. Volatility of the agent (concentration of its saturated vapour) at *20°C, mg/m*³.

Col. V. Estimated lethal dosage by inhalation, *mg–min/m*³.

1. Chloropicrin was widely used both as a casualty agent and as a harassing agent. Phenylcarbylamine chloride was a German attempt at finding a persistent lung irritant, but as persistency could be achieved only at the expense of volatility, it was not easy to establish casualty-producing dosages with it.

2. Some of the substances originally introduced as percutaneous agents came to be used for respiratory effect. They are noted in table 1.4.

3. The USA did not use any casualty-agent weapons of its own manufacture. US Chemical Warfare Service symbols for some of the agents listed above were:

chlorine	Cl
phosgene	CG
chloropicrin	PS
trichloromethyl chloroformate	DP (also called Superpalite)
cyanogen chloride	CC (later, CK)
hydrogen cyanide	AC

4. For information about the sources, see table 1.2a, note 4.

Table 1.3*b*. German, French and British respiratory casualty-agent fillings for artillery shell

Shell designation	Filling designation	Composition of shell filling	*Percentage composition of shell filling*
German weapons			
Grünkreuz		Trichloromethyl chloroformate, with or without a lesser proportion of chloropicrin or bromomethylethyl ketone	
Grünkreuz 1		Phenylcarbylamine chloride and halogenated ketones	
Grünkreuz 2		Phosgene	*60*
		Trichloromethyl chloroformate	*30*
		Diphenylchloroarsine	*10*
Grünkreuz 3 = Gelbkreuz 1[a]			
French weapons			
	Manganite	Hydrogen cyanide	*50*
		Arsenic trichloride	*50*
No. 4	Vincennite	Hydrogen cyanide	*50*
		Stannic chloride	*15*
		Arsenic trichloride	*30*
		Chloroform	*5*
No. 4B	Vitrite	Cyanogen chloride	
		Arsenic trichloride	
No. 5	Collongite	Phosgene	*75*
		Stannic chloride	*25*
No. 7	Aquinite	Chloropicrin	*75*
		Stannic chloride	*25*
British weapons			
	CG	Phosgene	
	CBR	Phosgene	*50*
		Arsenic trichloride	*50*
	PS	Chloropicrin	
	PG	Phosgene	*50*
		Chloropicrin	*50*
	NC	Chloropicrin	*80*
		Stannic chloride	*20*
	JL	Hydrogen cyanide	*50*
		Chloroform	*50*
	VN	(See French "Vincennite" above.)	
	JBR	Hydrogen cyanide	*50*
		Arsenic trichloride	*25*
		Chloroform	*25*
	CB	Cyanogen bromide	

[a] See table 1.4 b.

Sources: For information about the sources, see table 1.2a, note 4.

Table 1.3c. British[a] casualty-agent fillings for gas-cylinder operations

Cylinder designation	Composition of cylinder filling	*Percentage composition of cylinder filling*
Red Star	Chlorine	*100*
Blue Star	Chlorine	*80*
	Sulphur chloride	*20*
White Star	Chlorine	*50*
	Phosgene	*50*
Yellow Star	Chlorine	*70*
	Chloropicrin	*30*
Green Star	Hydrogen sulphide	*35*
	Chloropicrin	*65*
2 Red Star	Hydrogen sulphide	*90*
	Carbon disulphide	*10*

[a] Only British gas-cylinder compositions are noted in table 1.3c because they were the most varied of those used by the different belligerents. Chlorine and chlorine/phosgene compositions, however, were the most widely employed by all the belligerents.

Sources: For information about the sources, see table 1.2a, note 4.

the agent for war use in September 1916, selecting it in preference to *dimethyl sulphate,* another vesicant, not only because it was a superior if less easily made agent, but also because they knew their enemies were more likely to be able to make the latter if given a lead to do so [3]. (The French did in fact use it in artillery shell and hand grenades at the end of the war [2].) By the spring of 1917 shell filling had begun [3].

The Allies did not possess chemical plants which could be converted to manufacture mustard gas, so they had to build them. Several months elapsed before a satisfactory process could be developed. The French did not have any battlefield supplies until June 1918, and the British did not have theirs until September 1918. Not only was the necessary plant difficult to construct, it was also extremely hazardous to operate. At the main British factory, there were 1 400 casualties among the plant workers [37], the accidentally burned and blistered exceeding 100 per cent of the staff every three months [5]. Conditions at the principal French plant, which supplied three-quarters of all Allied-fired mustard gas, were equally unpleasant:

> The personnel ... is 90 per cent voiceless. About 50 per cent cough continuously. ... [B]y long exposure to the small amounts of vapour constantly present in the air of the work rooms, the initial resistance of the skin is finally broken down. ... The chief result is that the itch makes sleep nearly impossible and the labourers become very much run down. [38]

The British in fact tested mustard gas as a CW agent in the summer of 1916 [39], but its developers were unable to convince the military authorities that its field behaviour was likely to be of any use [20].

The symptoms produced by mustard gas do not appear for some hours after exposure.[10] In addition, the agent is rather involatile and persists in an effective form in the field for long periods. For these reasons, it was chiefly suited only to defensive operations, and a search was accordingly made for an offensive vesicant to supplement it, one which would have an immediate effect on the enemy's skin, and which would dissipate reasonably quickly after dissemination.The Germans started the search shortly after they began work on mustard gas and soon decided to develop an arsenical, *ethyldichloroarsine*. In doing so, they rejected among other compounds, *2-chlorovinyldichloroarsine* [3], better known in later years as *lewisite*,[11] the Americans' much vaunted, but untried, secret weapon which became available as the war ended. Ethyldichloroarsine was ready for use in time for the spring offensive of March 1918. The Germans expected much from it, but it turned out that the incapacitation produced by its vesicancy had been overestimated, and as a percutaneous agent it was a comparative failure. The markings on the projectiles in which it was used were changed from a yellow cross, signifying primarily vesicant effects, to a green cross, signifying lethal respiratory effects, and it continued in use as an additive in diphosgene shell. *Methyldichloroarsine*, had it been chosen, might possibly have been more successful [2], but this is doubtful [42].

The final development in percutaneous agents came during the last weeks

[10] The chief symptoms produced by the percutaneous casualty agents of World War I are illustrated by the following descriptions of the effects of mustard gas and lewisite. Immediate contact with mustard gas, whether in liquid or vapour form, causes no eye or skin pain nor any other instantaneous symptoms. As its smell, in any case slight, is easily masked, this makes for considerable insidiousness of effect. After the initial latent period, symptoms develop as follows. Within about twelve hours, the eyes water and feel gritty, becoming progressively sore and bloodshot; the eyelids redden and swell. Temporary blindness is likely. Within thirty-six hours of exposure, the skin begins to redden and itch. Blisters then appear, accompanied by stiffness, throbbing pain and swelling, the burns most severe in moist areas of the body. A few hours after inhalation, throat irritation sets in, with hoarseness and coughing. If a large dosage is inhaled, the lining of the respiratory tract swells and interferes with breathing. This may lead to a fatal pulmonary oedema, or promote a bacterial infection culminating in suppurative bronchitis or bronchopneumonia. Extensive exposure, either through inhalation or massive skin contamination, may lead to systemic effects, characterized by a state of shock accompanied by nausea and vomiting. [40, 41]

In contrast to the insidious action of mustard gas, the arsenical vesicants, such as ethyldichloroarsine or lewisite, cause immediate excruciating pain upon striking the eye, a stinging pain in the skin, and sneezing, coughing, pain and tightness in the chest on inhalation, often accompanied by nausea and vomiting. Actual skin burns appear rather more quickly than those from mustard gas, but they are less severe and quicker-healing. The pattern of lung attack is similar to mustard gas, but the systemic effects, typical of arsenical poisoning, are more severe, and may in themselves be fatal. [33, 40]

[11] Lewisite was discovered in the spring of 1918 by a team working under Captain Winford Lee Lewis at a Chemical Warfare Service research station housed at Catholic University, Washington, D.C. [43–45].

Table 1.4*a*. Percutaneous casualty agents used in World War I: some details of the agents[a]

Chemical name	Date of first use I	Employing countries II	Harassing concen- trations *mg/m³* III	Volatility at 20°C, *mg/m³* IV	Approx. lethal dosage *mg-min/m³* V	Code name
Bis (2-chloroethyl) sulphide[b, c]	7/1917	G, F, B	n.a.	610	1 500	G: Lost F: Yperite B: Mustard gas or HS
Ethyldichloroarsine	3/1918	G	10	20 000	4 000	G: Dick
Methyldichloroarsine	3/1918[d]	G	25	75 000	5 000	G: Methyl- dick or Medikus
Ethyldibromoarsine	9/1918	G	. .	. . .	. .	. .

n.a. = not applicable; · · = unknown.
[a] For an explanation of the column headings, see table 1.3a.
[b] Important during World War I.
[c] For further details, see table 1.6.
[d] According to Matoušek and Tomaček [278], but compare Prentiss [2].

Notes and sources

1. Dimethyl sulphate and phenyldichloroarsine, listed in table 1.2a, can also produce casualties by skin attack, but were not apparently used primarily for such a purpose during the war.

2. The US troops used mustard gas during the war, like the Italians procuring French Special Shell no. 20 for the purpose. Output from their own manufacturing plant for the agent did not reach Europe in time to be used; their output (150 tons) of 2-chlorovinyldichloroarsine, another vesicant, was en route to Europe at the time of the Armistice. Some US Chemical Warfare Service symbols for percutaneous agents were:

phenyldichloroarsine	PD
bis (2-chloroethyl) sulphide (following the British, who used it as an abbreviation of "Hun Stuff")	HS
methyldichloroarsine	MD
ethyldichloroarsine	ED
2-chlorovinyldichloroarsine (later called L, for Lewisite, another name for the agent)	M-1

3. For information about the sources, see table 1.2a, note 4.

of the war when the Germans began looking for a more persistent agent than mustard gas, one which could be used for denying terrain for still longer periods. The only candidate agent which at that time showed any promise was *bis-(2-bromoethyl) sulphide,* but it was rather quickly destroyed by moisture. It was not used. [2]

Table 1.4 lists the principal percutaneous casualty-agent compositions used by the belligerents during the war; further details of the agents used in these compositions are given in table 1.6.

The competing development of chemical weapons and anti-chemical defences

At the Second Battle of Ypres it was shown that chemical weapons possessed what amounted to a strategic capability, for by their almost unsupplemented use the Allied line was broken over an extended front, and had the

Table 1.4*b*. German, French and British percutaneous casualty-agent fillings for artillery shell

Shell designation	Filling designation	Composition of shell filling	*Percentage composition of shell filling*
German weapons			
Gelbkreuz		*Bis* (2-chloroethyl) sulphide and chlorobenzene, nitrobenzene, carbon tetrachloride and/or	*70–90*
		Bis (chloromethyl) ether	*30–10*
Gelbkreuz 1		Ethyldichloroarsine	*5–50*
		Bis (chloromethyl) ether, or	*95–50*
		Ethyldichloroarsine	*40*
		Ethyldibromoarsine	*40*
		Bis (chloromethyl) ether	*20*
French weapons			
No. 20	Yperite	*Bis* (2-chloroethyl) sulphide	*80*
		Chlorobenzene or carbon tetrachloride	*20*
British weapons			
	BB	*Bis* (2-chloroethyl) sulphide	

Notes and sources

1. The Germans' Gelbkreuz 1 shell proved a disappointment as far as the production of casualties by skin attack was concerned. It was therefore redesignated "Grünkreuz 3" and used for respiratory effect.

2. For information about the sources, see table 1.2a, note 4.

Germans exploited their success, the Channel ports might again have been severely threatened. But this strategic potential was to last for no longer than it took the Allied armies to equip themselves with gas masks. Thereafter gas was useful only in comparatively restricted situations. If one side introduced a new chemical weapon or technique to overcome the opposing defences, it could expect at most a limited tactical success, given the existing state of CW technology, and could certainly not base a major offensive operation on such a weapon. It was not until the 1950s that military commanders were again in a position to be able seriously to contemplate the use of gas for anything other than limited battlefield objectives.

IMPROVING RESPIRATOR DESIGN

As has been described above, the atmosphere is an essential component in a chemical-weapon system. In 1915, all that was needed to protect troops from gas was to provide them with respirators containing filters which would remove airborne contaminants from the atmosphere before they reached the lungs. This was clearly a more dependable method of defence than any that could be deployed against other weapons systems. For the next two years the race between gas and gas mask consisted of the exploitation of deficiencies in constantly improving filter designs.

The respirators used on the Western front in the days immediately succeeding the chlorine attack of 22 April 1915 were necessarily crude. On 23 April the British Medical Service arranged for buckets of sodium bicarbonate solution to be kept in the trenches for troops to soak handkerchiefs or pieces of cloth in; they could then tie these over the nose and mouth when the gas alarm was given. Failing bicarbonate, other sorbents were used, ranging from urine to earth folded into the cloth or tamped into broken bottles. By 28 April arrangements had been made in the UK for copies of a captured German respirator to be manufactured. In their homes thousands of women assisted in this, but their products were too often defective, and orders eventually had to be issued to prevent front-line troops from relying on them. By 15 May the official model was in issue. This became known as the *Black Veil Respirator;* it consisted of a long piece of veiling folded to form a pocket which held a pack of cotton waste soaked in a water solution of sodium thiosulphate, sodium carbonate and glycerol, the latter to keep the pad moist. This was seen to be nothing more than an interim measure, for there was considerable risk that a high proportion of the inhaled air would not pass through the impregnated pad Throughout June 1915, 2.5 million copies [17] of a new design were issued. This was the *Hypo Helmet,* a bag of flannel soaked in the impregnating solution, which was put over the head and tucked into the collar. It was fitted with transparent cellulose acetate eyepieces. [16]

The Hypo Helmet proved adequate against chlorine, in the way it was then being used, and could be expected to work against any other strongly acidic gas. By this time there was a lull in the gas war, for the Germans were taking stock of their results so far, and the Allies were preparing their countermoves. The latter were thus given time to improve their defences and to speculate on what was to come, relatively unhampered by the demands of the moment (although the increased use of tear-gas shell by the Germans had to be met by an issue of tight-fitting goggles). It was clearly only a matter of time before the Germans introduced an agent which would not react chemically with either thiosulphate or bicarbonate. The British were themselves thinking of using phosgene in their retaliatory operation, and this was just such a compound. With phosgene in mind, and hydrogen cyanide also, the British began issuing a modification of the Hypo Helmet: it incorporated caustic soda and phenol in the impregnant, replaced the flannel by an alkali-resistant fabric, and included a rubber exhaust tube fitted with a one-way valve for exhaled air. This was the *P Helmet,* of which

9 million [17] were issued just in time to meet the first phosgene cylinder attack in December 1915. [16]

The P Helmet gave protection against phosgene concentrations up to about 1 200 mg/m³ for rather short periods of time [46]. This was only barely adequate, particularly against cylinder attacks in which the front lines were close together. Accordingly, at the suggestion of the Russians, the British added a further anti-phosgene impregnant, hexamethylenetetramine, in issue in the *PH Helmet* from mid-January 1916 up to February 1918; by then it was useful only as a reserve line of defence. [16]

Helmet-type respirators had many drawbacks: not only were they exceedingly unpleasant to wear, but they could only incorporate a limited amount of gas sorbent, namely the quantity that could be held by the material of the helmet. The final version of the PH Helmet could cope with phosgene concentrations of up to about 4 000 mg/m³ for reasonable periods of time [46], but by early 1916 the Germans had refined their cylinder attacks to such a point that long-lasting field concentrations greatly in excess of this could be set up over wide areas. Accordingly, in the winter of 1915/16 the issue of small quantities of a radically new type of mask began. This was the *Large Box Respirator:* in it the gas sorbents were contained in a canister held in a satchel slung over the back; air was drawn into this at one end, passing out at the other into a flexible hose leading to a mouthpiece fitted to a PH Helmet. Using a separate container for the sorbents made a much higher sorptive capacity possible and, furthermore, it would be a relatively simple matter to incorporate improved sorbent materials should they be needed. Three different sorbents were used: soda lime granules soaked in sodium permanganate solution and pumice particles soaked in sodium thiosulphate, to react chemically with acidic or oxidizable CW agents (such as chlorine, phosgene, diphosgene and hydrogen cyanide), and animal charcoal. The latter was a particularly important innovation for it removed substances from the air by a process of physical adsorption and so did not depend on the chemical properties of the air contamination. [16]

The canister principle came to be widely used. Towards the end of 1915 the Germans introduced a mask embodying it, probably delaying employment of phosgene until it was in production [17]. The principle was used in a rather ambitious way, however. Instead of slinging the canister on the back or chest of the individual soldier, they built it into a drum screwed into the front of the facepiece. The advantage of this method was that the soldier was not cluttered up with lengths of hose. But the strength of the facepiece material and the way in which the airtightness of the material was maintained around the face imposed a weight limit on the drum. As the war progressed, this proved a severe drawback, for the upper limit thus imposed on the sorptive capacity of the respirator was too low. The sorbent was rather too quickly saturated by the massive phosgene concentrations the British were able to set up in their cylinder attacks. But once the Germans had committed their manufacturers to the design, the exigencies of the war apparently prevented them from radically altering it and no other type of respirator was issued. [16, 17]

IMPROVING OFFENSIVE TECHNIQUES

These limitations in German respirator design clearly indicated to the Allies the sorts of offensive CW technique which they should develop. The limited filtering capacity of the German masks was to be exploited as much as possible, and this could best be done by using weapons which created high field concentrations: hence the British emphasis on cylinder and Livens Projector operations.

The techniques which the Germans should adopt were not so well defined, for it was not until the end of 1916 that their enemies were at all widely equipped with canister-type masks. Until then, German chemical-weapons designers could choose between a search, on the one hand, for new agents which would penetrate the chemical absorbents of helmet-type respirators and, on the other hand, for new munitions capable of setting up high dosages. Possibly because the former approach seemed more attractive, German artillery CW developed very quickly. The massive use of Green Cross shell at Verdun in the summer of 1916 is said to have been motivated by the inability of the French *XTX Respirator,* which did not contain a charcoal adsorbent, to keep out diphosgene [7].

As soon as the Allies were equipped with high-capacity canister-type respirators, the options open to German chemical-weapons designers were much more limited. Broadly speaking, two types of offensive operation remained open to the Allies, but only one to the Germans. Both sides could to some extent overcome the opposing defences with sudden massive attacks to surprise the enemy with his mask off. In addition to these high *surprise dosage shoots,* the Allies could also rely on high *total dosage shoots,* in which the object was not so much to create a very high initial concentration as to maintain a rather lower field concentration for prolonged periods of time. The munitions expenditure for an effective total dosage shoot against the Germans would be considerably lower than one against the British, simply because the latter's respirators would hold out longer. In this type of operation the 4 inch Stokes Mortar was particularly useful.

The final British design of respirator, of which 16 million copies [17] were made from June 1916 onwards, was a simplified and improved version of the Large Box Respirator. The impregnated flannelette helmet was replaced by an impermeable rubberized facepiece, copied from the Germans, held tightly around the face. This was the first line of defence against inhalation of unfiltered air; an improved mouthpiece was introduced which provided the second line of defence: it was airtight, but at the same time permitted the wearer to talk audibly. (The German standard respirator lacked this airtight mouthpiece, and relied solely on a close-fitting facepiece to keep out unfiltered air.) The canister sorbents were improved. This was necessary because the Germans had begun firing chloropicrin, a chemically rather inert substance for which it was difficult to find a chemical absorbent. For this reason the proportion of charcoal was increased by replacing the layer of thiosulphate-impregnated pumice with a second layer of charcoal. [16] Issue of this *Small Box Respirator* was complete by January 1917.

The Germans now faced a defence that was difficult to overcome. Their chemical weapons would produce British casualties only if the troops were inadequately trained in anti-gas discipline or if their masks were defective. Surprise dosage attacks were only rarely possible: cylinder operations were too often ruled out by the direction of the wind, and the weapons designers had not yet come up with anything to match the Livens Projector. Artillery was the only delivery system which could be used to carry out the gas attack, and in this its performance was indifferent, even with the new larger-capacity, long-type gas shell.

The Germans eventually broke the deadlock by introducing the Yellow Cross vesicant, mustard gas, which attacked the enemy's anatomy at a point not protected by the respirator. It was introduced alongside another new class of agent, the Blue Cross sternutators. The latter were intended to overcome the defences by penetrating the respirator filters; their irritant action would cause the wearer to tear off his mask and expose himself to the casualty agents fired simultaneously. Mask penetration was thought possible because the agents were to be used in the form of a particulate aerosol smoke, and neither the absorbents nor the adsorbents were capable of retaining airborne particulates. However, even if the Blue Cross munitions had been capable of disseminating the requisite aerosol concentrations, it is doubtful whether the techniques would have been particularly effective. Shortly before the agents were first used the British had in fact incorporated a layer of cellulose wadding which acted as a particulate filter in the canister of their Small Box Respirator. The reason for this apparently surprisingly perceptive action was that the British were beginning to use an agent in particulate form. This was *stannic chloride,* a component of the chloropicrin-containing mixture known as *NC* used in artillery shell. Stannic chloride was a smoke agent, used chiefly to mask the presence of toxics. The smoke it created was an opaque cloud of solid hydrolysis products which had a markedly irritant effect if inhaled.

While the Blue Cross shell were a failure, the Yellow Cross ones were an instant success. They were first used on 12 July 1917 during the artillery bombardment of the British line preceding the Third Battle of Ypres. At the receiving end the bombardment did not seem a particularly violent one and was soon over without anyone suspecting that a CW agent had been disseminated. The troops duly emerged from their dugouts and carried on as before. "But within an hour or two strange symptoms began to appear among the men occupying the recently bombarded area. They developed violent conjunctivitis—so severe that their eyes closed up. Great areas of skin under their arms and between their legs turned fiery red and blistered. Many of them began to cough, and enough laryngitis to cause hoarseness was almost universal." [38] By the end of the day, several hundred men had to withdraw or be led away to medical aid posts. That night the town of Ypres was shelled with the new gas, causing a further 2 000 casualties.

Thus, in July 1917 the Germans had again introduced a chemical weapon against which there was no defence. This time the weapon was essentially a defensive one, in the sense that a target-area which had been bombarded with it could not be occupied by friendly troops until at least a day after the attack.

PROTECTION AGAINST PERCUTANEOUS AGENTS

Satisfactory protection against skin-effect agents did not appear during the war (respirators protected only the eyes and lungs), and whenever mustard gas was employed it could be relied upon to put substantial numbers of enemy troops out of action for some weeks. Three methods of defence were tried out, however. The principal defence was to use clothing made of impermeable oilcloth, but this was cumbersome and uncomfortable and was issued only to special troops, for example gun crews, whom it was essential to keep in action. The second approach was to use barrier creams, which were rubbed onto the skin, thus forming an impermeable layer. But mustard gas was a surprisingly penetrative substance and the troops could not use the cream continuously. It, too, was useful only in special circumstances, for example before an assault. The third, and least successful, approach was to treat contaminated skin with reactive chemicals that would react with and destroy the contaminant. To this end, the Germans supplied each soldier with boxes of bleaching powder or permanganate after the French had begun firing mustard-gas shell. The method was unsatisfactory as a first line of defence because the skin contamination was often not noticed in time, and the boxes were a further burden to individual soldiers. [17]

Conclusions

The war thus ended with offensive CW techniques having an advantage over the available defences. No doubt if percutaneous agents had possessed a lethal percutaneous toxicity at the dosages that could be created by existing weapons—as they do nowadays—CW would have played a more significant role in the fighting; its status in the coming years would certainly have been more assured. As it was, the military establishments in most of the belligerent countries were not convinced of the future value of chemical weapons to their own forces, but realized that at least part of the CW R & D effort would have to be continued in an attempt to improve the defences. As for the CW technologists, many of them felt that chemical weapons were still at an early stage of development and that, with more research, greatly improved weapons would be found. There were several leads to follow up. Work on respirators during the war had shown that the adequate filtration of small particle aerosols was difficult to accomplish: there therefore seemed to be a future for weapons disseminating such aerosols. Improved shell-fuse designs could reduce crater-loss of agent, thereby increasing the performance of chemical projectiles. A more fundamental understanding of meteorology could increase the ability to exploit the weather-dependence of chemical weapons. The search for new CW agents would surely produce quick-acting vesicants, or substances with a higher percutaneous toxicity, or substances that could persist for long periods in the field while being sufficiently toxic and volatile to generate lethal vapours. In addition to all this, there was an untried weapons delivery system, the aircraft, that was undoubtedly potentially much better suited to CW than artillery.

The remainder of this chapter describes how these various research incentives have been followed up. Three topics are pursued separately: developments in CW agents, developments in CW defences, and the response to changing military requirements.

Developments in CW agents since World War I

In the course of World War I virtually every known chemical had been screened for possible offensive use, and a great many new compounds had been prepared for the first time as candidate CW agents. During the post-war years, CW agent research consisted of:

1. a re-checking of compounds that had been inadequately examined during the war;
2. a search for the active components of the many highly toxic naturally-occuring substances that were known;

3. a surveillance of new compounds emerging from academic and industrial laboratories; and

4. further programmes of synthesis of candidate CW agents guided by existing leads or by new theories of molecular toxicology.

The results of each of these four approaches will be reviewed in turn.

During the first fifteen years or so after the war this research work was performed within an environment of opinion that in many countries was hostile towards offensive CW preparations. Quite apart from popular hostility towards such efforts, the attitude within military establishments was often decidedly lukewarm. This is described in more detail in Chapter 4. The result was that for the most part the research efforts were badly endowed and were in most cases only tolerated where they had some direct and obvious bearing on national anti-gas preparedness. Consequently, while several promising candidate CW agents came up for consideration, it was not until shortly before the outbreak of World War II that full examinations of them could be begun from an offensive CW point of view and development programmes initiated.

Re-examination of candidate CW agents

Since CW research during World War I had been geared to producing weapons for immediate use, many candidate CW agents had been rejected for further development because they did not obviously fulfill the requirements of the moment. In addition, there were a number of substances that could not be effectively exploited with the dissemination mechanisms and delivery systems then available, but which might become useful as this hardware improved. Three agents in particular come within these categories, *chloroacetophenone, cyanogen chloride* and *hydrogen cyanide.*

CHLOROACETOPHENONE (CN)

As a CW agent, CN was a US innovation. It had in fact been known to German chemists since 1871 [47], but German interest in solid irritants during the war had centred mainly on the arsenical sternutators. Its US sponsor proposed it for investigation in May 1917, but its somewhat desultory examination did not begin until January 1918, with field trials delayed until October 1918 [48], so its development into a CW agent came too late for the war. However, in the immediate post-war years there was a renewed interest in the use of lachrymators in riot-control and law-enforcement apparatus. In the 1920s the US Army Chemical Warfare Service (CWS) conducted more research on CN than on any other agent: in 1921 the CWS offered a CN device for experimental trial to the Philadelphia police [49], and built a manufacturing plant for the agent at Edgewood Arsenal in the following year [30].

Following the US initiative, other countries also developed CN, and during World War II it was the principal lachrymatory harassing agent in the chemical-weapons stockpiles. For those of the belligerents for whom CW agent manufacturing output figures are available, a total output of more than 8 000 tons is recorded: 172 tons for Japan [50], 500–1 000 tons for the USA (the figures given are conflicting) [30], and more than 7 000 tons for Germany, of which about 2 000 tons were on hand at the outbreak of the war [51, 52]. The Japanese output was charged into grenades, self-propelled candles and artillery shell [30, 50]; the US output went into grenades, pots, 4.2 inch mortar projectiles, and 75 mm, 105 mm and 155 mm artillery shell [30]; and the German output went into 250 kg and 500 kg aircraft bombs, 77 mm, 105 mm and 150 mm artillery shell, and 7.92 mm armour-piercing bullets [30, 53, 125]. The British also manufactured CN during World War II and in the years before it;[12] the USSR is also said to have done so [54].

After World War II, CN continued as a standard military harassing agent; for this purpose, and for police employment, it was eventually replaced in many countries by 2-chlorobenzalmalononitrile (CS).

HYDROGEN CYANIDE (AC)

AC had been used on quite a large scale in artillery shell by the French during World War I, but, as noted above, these weapons were not a success. The principal reason was that the relative vapour density of the agent was so low that field concentrations did not persist at ground level long enough to build up into lethal dosages except in the immediate vicinity of the weapon. If means could be found to increase this persistency, the agent might be more useful. The incentives for such a search were high, for AC was one of the few rapidly acting casualty agents then available.

One approach was described in a patent specification filed by Dr Stoltzenberg[13] in 1925. Compounds in which AC was loosely held by coordinate bonds were proposed; these were said to evolve AC vapour slowly on contact with moisture [55]. A far more promising approach emerged from Japanese and US proving grounds during the 1930s: this suggested the use of larger agent payloads. If a sufficient bulk of the agent were vapourized, the resultant cooling would increase the relative vapour density of the agent

[12] The principal British harassing agent manufactured during World War II was not CN, but CA, which was charged into base-ejection artillery shell of various calibres.
[13] Some of Dr Stoltzenberg's activities in the field of CW are described on pages 257 and 293.

and cause it to remain at ground level until it warmed up again. The Japanese used 50 kg bombs; the Americans found during World War II that bombs ten times this size were the optimum. [30, 56]

The agent still had its drawbacks. When used in cold weather it needed an anti-freeze additive [56]; it was rather unstable in storage, although stabilizers were found to counter this [30, 56]; but above all, it had a strong tendency to inflame when the weapon into which it was charged was detonated. The latter problem was never fully solved by the Americans, even though they adopted the agent as a substitute standard filling for 1 000 lb bombs during World War II [30]. To the western Allies at least, the attractions of AC were still substantial; in addition to its quick-kill effect, it had potential as a mask-breaker, for the small molecule of the agent was not easily adsorbed on charcoal, making it much easier to saturate respirator-filters with this agent than with any other.

During World War II, AC was manufactured at least by the USA (514 tons [30]), the USSR, Japan (255 tons [50]) and Germany. In fact the Germans made very little of it—they already had tabun—but maintained a manufacturing potential of 20 tons per month from March 1944 onwards [50]. The USA charged its output into small frangible grenades and 500 lb and 1 000 lb bombs [30]; a Soviet AC weapon was an aircraft spray tank [57]; the Japanese charged AC into frangible grenades, 90 mm and other calibre mortar bombs, 150 mm artillery shell, and 50 kg bombs [30, 53]; and the Germans considered charging AC into small rockets [58].

With the discovery of the nerve gases, AC rapidly faded into obscurity.

CYANOGEN CHLORIDE (CK)

CK had been tried by the French on a small scale as a replacement for AC, but never attracted much attention. The US Army CWS re-examined the agent in 1933, but rejected it as inferior to phosgene [30]. Further investigation by the CWS during World War II showed that it had potential as a mask-breaker under humid weather conditions, particularly against Japanese masks in the tropics. In addition it had many of the attractions of AC—being a quick-kill agent, albeit somewhat less toxic—coupled with additional attractions as a lung irritant so that, unlike AC, it could inflict casualties even at sublethal dosages. Accordingly, the USA developed stabilizers to inhibit its polymerization on storage, and put it into large-scale production, manufacturing over 11 000 tons during the war [30]. With the possible exception of the USSR [54], the only other belligerent reported to have had an interest in the agent during the war was Germany, who maintained a 20 ton per month stand-by production capacity [52]. The USA charged its output into 500 lb and 1 000 lb bombs, and would also have used it in 4.2 inch mortar bombs had there been a need [30].

As in the case of AC, the nerve gases rendered CK obsolete.

2-CHLOROVINYLDICHLOROARSINE (LEWISITE)

In comparison with CN, AC and CK, agents which received the re-examination that they probably deserved, lewisite was an agent that undoubtedly had far greater importance attached to it than was warranted, but whose re-examination was long-delayed.

Lewisite was a vesicant that had been developed for war use by the USA during the final months of World War I. There was great pressure on the US Army CWS at that time to provide US-manufactured CW agents, and the additional merit of doing so with a novel agent seems to have led the CWS into unduly hasty action. Lewisite went into large-scale production on the basis of relatively meagre laboratory data and without field testing; a shipload was on its way to Europe in November 1918 [42]. When the war ended, the activities of the CWS were severely curtailed by staff shortages and budgetary restrictions, so much so that further investigation of the agent had to make way for higher priority projects. Nonetheless, throughout the 1920s the existence of lewisite was bandied about by publicists, including those for the CWS, with alarming estimates of its potency; this apparently convinced the CWS itself that lewisite was a peculiarly valuable CW agent, even though a full investigation of its properties had still to be made. When World War II began, the CWS speedily erected lewisite manufacturing plants; after some 20 000 tons had been made, the long-delayed assessment of the agent showed that its properties did not warrant such a scale of effort. [30]

Lewisite was found to have few advantages over mustard gas and a number of important disadvantages. Mustard-gas vapour was more effective in producing skin and eye damage than lewisite vapour, and although liquid lewisite was more vesicating than liquid mustard gas, the resultant skin burns were less severe. In addition, mustard gas penetrated clothing more efficiently than lewisite and was more resistant to decomposition by moisture [42].

Lewisite was manufactured by the USA, and at least by the USSR [30], France [59] and Japan (1 381 tons [50]) as well. The USSR and Japan used it as an anti-freeze additive for mustard gas [30]. The UK also manufactured a few tons, but did not charge it into weapons.

IMPROVED MANUFACTURING PROCESSES FOR MUSTARD GAS

Every country that had any sort of interest in acquiring offensive CW capabilities gave a great deal of attention to developing new methods for making mustard gas, and a variety of competing methods emerged from this work. Broadly speaking, there were three main groups of processes: those starting from sulphur monochloride, as in the Levinstein process; those going by way of thiodiglycol, as in the original German process; and those starting from sulphur dichloride. The Levinstein process required the least complicated installations of these three and was the one most widely used during World War II, for example by the USSR [60] and the USA. The product, however, contained corrosive impurities and suspended solids that were difficult to remove. The latter tended to settle out into a sludge during storage, thereby altering the ballistics of projectiles into which the agent was charged. Many methods were proposed for removing the impurities—for example the South African DESA process involving ethanol [61]—but the only adequate solution was to adopt other manufacturing processes. The Levinstein process thus became increasingly obsolescent during World War II, giving way to the sulphur dichloride processes developed in the UK [62], or those involving vacuum distillation of the final product [61].

During World War II and the years immediately preceding it, mustard gas was manufactured at least by the USA (83 345 tons [30]), the UK, France, Canada (about 1 500 tons of mustard gas and phosgene during World War II [63]), Poland, the USSR, Hungary, Italy, Japan (3 610 tons [50]), and Germany (25 000 tons [52], 37 700 tons [64]). [30, 59, 65] The output was charged into every type of chemical weapon.

NEW MUSTARD-GAS WEAPONS

The weapons-development work in CW R & D programmes up to the end of World War II was in large part concerned with providing better ways of disseminating mustard gas. World War I had demonstrated a need for a quick-acting vesicant of reduced persistency on the ground. Although no such substance was subsequently found, improved dissemination mechanisms for mustard gas itself looked at one point as if they would fulfill the requirement. The approach was to look for ways of increasing the concentration of the airborne agent: the higher the vapour or aerosol dosage received by the victim, the quicker would be the onset of cutaneous symptoms or eye damage, while the higher the proportion of mustard gas payload put up as vapour or aerosol, the less would be the ground contamination.

One technique examined in the USA during World War II was to include a few per cent of a pyrogen, such as white phosphorus, in mustard gas chargings [61]. Another approach was in the use of the thermogenerator principle. Experimental pots proved capable of disseminating most of their mustard-gas charging as a high-concentration cloud of vapour and aerosol.

This technique was being developed for aircraft bombs by the USA as the war ended [66], and continued to be developed after the war [67].

The study of natural poisons

Naturally-occurring poisons were of interest to CW establishments for two reasons. If they could be isolated in sufficient quantities and sufficiently cheaply, they might themselves be candidate CW agents, and if their toxic principles could be elucidated, they might guide research programmes towards new CW agents.

Although many hundreds of naturally-occurring poisons have undoubtedly passed through CW laboratories over the past fifty years, six will be singled out for special treatment here: they are capsaicin, aconitine, eserine, ricin, botulinal toxin and saxitoxin.

CAPSAICIN

Capsaicin is the pungent principle of cayenne pepper and paprika, and was first isolated in 1876. About 10 grammes can be extracted from 2 kilos of cayenne pepper [68]. It was proposed for war use as a harassing agent during World War I [20]. Soon after the war, its structure was established as a long-chain acyl derivative of vanillylamide [68], and this led to the synthesis within CW laboratories of a variety of vanillylamides, some of which were found to be extremely powerful sternutators [69–71]. Some were proposed for use in domestic riot-control apparatus [72], but were never apparently developed for such use.

During World War II, when the Allies were faced with a possible shortage of arsenic for their standard sternutators, vanillylamides again came up for investigation—vanillin was readily available as a by-product of the paper industry—but the neeed to produce such substitutes never arose [73]. In the mid-1950s the British considered them during their search for a CN replacement in riot-control weapons, and one of them was included in the short list from which CS was eventually selected [74].

Capsaicin in the form of "oleoresin of capsicum" is employed nowadays in several commercially available irritant-agent weapons, for example certain "personal protectors" manufactured by Penguin Associates, Inc., in the USA. This firm also produces irritant-agent weapons based on α-chloroacetophenone (CN) and 2-chlorobenzalmalononitrile (CS). [301]

ACONITINE AND ESERINE

Aconitine and *eserine* are examples of toxic alkaloids, of which a great many have been studied in CW laboratories. Aconitine itself has a long history as a CW agent; it was used, apparently, by the Moors in Europe during the fifteenth century, and in India and China during earlier centuries.

In the 1930s the Japanese considered aconitine for use in weapons firing poisoned darts [56], following the precedent, no doubt, of Indian elephant hunters. Aconitine was apparently also considered in Germany during World War II for use in poisoned bullets: small-arms ammunition containing aconitine nitrate is said to have been tested in Buchenwald concentration camp [75]. In the USA work on aconitine was included in a far-ranging World War II programme on involatile toxic agents; one team succeeded in isolating half a kilo of the pure alkaloid from 2 tons of aconite tubers [76]. In this particular programme, work on aconitine was hampered by ignorance of its complete chemical structure, but related work on eserine (*physostigmine*) was much more productive, leading to the preparation of several hundred new pharmacologically-active aromatic carbamates [77]. This latter programme was also stimulated by the results of pre-war work by certain drug houses on eserine analogues [78].

These carbamates were comparatively easily made and some of them, for example *2-diethylaminophenyl N-methylcarbamate methiodide,* were strong candidate casualty agents. The British and the Canadians had in fact been studying them as CW agents since 1940 [77] and, in that the compounds were powerful cholinesterase inhibitors, some of this work anticipated subsequent work on nerve gas. The agents were the forerunners of the carbamate pesticides that were developed commercially after the war.

Post-World War II work on aromatic carbamates has revealed a number of substances exceeding the nerve gases in toxicity. These are described in Volume II of this study.

RICIN

Ricin is the toxic principle of castor beans, a well-known hazard in the manufacture of castor oil and other castor-bean products since the nineteenth century. During World War I the US Army CWS investigated it as a candidate CW agent [79], and during World War II it engaged a good deal of attention in the UK, Canada, the USA and France [79–84]. Based on the 1941–44 industrial consumption of castor beans in the USA, a US industrial concern estimated that, with existing techniques for isolating ricin, the USA could produce more than 1 000 tons of ricin per annum at a cost of about $28 per kilo. During the war US pilot plants in fact produced about 1 700 kg; the scale of operations in the British pilot plant is not known. [79]

The attractions of ricin as a CW agent were its high toxicity and its insidious action. It was judged against the standard respiratory-effect casualty agent of the time, phosgene. By the time the war ended, the western Allies had developed experimental ricin weapons which, in terms of aircraft stowage space needed to produce a given effect on the ground, were seven times as potent as existing phosgene weapons; an effective-dosage comparison of the agents themselves suggested that ricin was at least forty times as potent as phosgene. Both agents had a delayed effect, but with ricin there was no warning smell and detection in the field would have proved a far more difficult task. [79]

Work on ricin served another significant function during World War II. As a solid material requiring dissemination in particulate aerosol form, combined with its sensitivity to degradation by heat and shock, it provided a model and a guide for concurrent work on the dissemination of living BW agents. [79]

THE BOTULINAL TOXINS (BTX)

The toxins of *Clostridium botulinum* are among the most poisonous substances known to man and as such have, since the 1920s, frequently been held up as candidate CW agents of amazing potency [85]. Information on their assessments by CW laboratories, however, is extremely scanty in the open literature, and although it is apparent from the scientific literature of the past two decades that many nations are taking precautions to protect themselves against BTX attack,[14] it is not clear whether any CW establishments in fact see BTX as a basis for potentially useful weapons.

Work on BTX seems to have been included in the initial programmes of the British BW research unit when it was set up in 1940; part of this work comprised an investigation of the toxicity of BTX aerosols by the respiratory route [87]. Shortly afterwards Canada and the USA started large programmes on BTX, from which a range of toxoids were standardized and mass-produced [30, 88]. In connection with this work a wartime director of the US BW effort stated in 1946 that one of the more important accomplishments of the BW effort had been the "development and production of an effective toxoid [against BTX] in sufficient quantities to protect large-scale operations should this be necessary" [88]. This is an ambiguous statement, but one construction is that the "large-scale operations" that needed to be protected were operations involving Allied use of BTX. It is published information, for example, that the Canadians carried out a good deal of work during the war on improving the yields of Type A and Type B toxins from *Cl. botulinum* cultures [89], and although such work was as important for

[14] One remarkable study which no doubt emerged from such work is a Polish investigation published in 1968 of the combined effects on mice of BTX and the nerve gas sarin [86].

toxoid production as for CW agent production, the concurrent work on spray-drying and freeze-drying techniques for the toxin have less obvious defensive implications, particularly as work was also done on grinding and milling the dried toxin into a fine powder. It was, however, stated that the dry powdered form was much easier to dissolve than the unpowdered lyophilized material. [90]

A further discussion of BTX appears in Volume II of this study.

SAXITOXIN

Paralytic shellfish poisoning has been recognized as a clinical entity since the mid-nineteenth century; eating poisonous shellfish of various kinds has frequently caused mass-poisoning. The toxic principle involved was not isolated until World War II, when a programme for that purpose was initiated[15] within the US BW effort [30, 95].

Initial attempts to isolate the toxic principle were extremely laborious, involving the collection of huge numbers of mussels and clams that had become poisonous. In one case, it was necessary to process 8 tons of clams to obtain a single gramme of the pure poison [94]. In view of this, the poison remained of theoretical interest only to CBW establishments. This interest was considerable, however, for the poison was among the most toxic substances known to man, and, furthermore, its active principle was found to be a low molecular-weight compound that therefore held out promise of laboratory synthesis, once its structure had been determined. Programmes therefore continued after World War II, at least in Canadian and US CBW establishments.

While the structure of the active principle, called *saxitoxin* by some, has still not been definitely established—it has the empirical formula $C_{10}H_{17}N_7O_4 2HCl$, and seems to contain a novel pyrrole [1,2*c*]pyrimidine ring system [96]—another possibility for its production on a large scale has appeared. Researchers had long felt that the original source of the poison was in certain plankton on which the shellfish fed before becoming poisonous; in 1966 a paper published by the US BW research laboratories finally established what had long been assumed, namely that saxitoxin was identical with a toxin produced by the dinoflagellate *Gonyaulax catanella,* from which it could easily be isolated [97]. With the recent rapid development of axenic culture techniques for protista,[16] it seems likely that cheap microbiological

[15] The programme in fact took over the work that had been going on since 1927 following a number of outbreaks of paralytic shellfish poisoning around San Francisco at that time [94].

[16] Axenic culture techniques provide a means for growing multicellular organisms in liquid media in much the same way as bacteria and other single-cell organisms can be grown.

methods for the mass-production of the toxin will have been elaborated before chemical methods of doing so appear.

In this connection, it may be noted that interest in saxitoxin as a CW agent has accelerated markedly in some countries over the past few years. Quite apart from the obvious attractions of the agent in weapons for clandestine use, regular battlefield weapons have been designed to disseminate it and have been tested on proving grounds. This and the properties of saxitoxin are discussed further in Volume II of this study.

Serendipitous discoveries

As national chemical industries began to expand after World War I, more and larger industrial chemical laboratories were established. In the course of their search for new chemical commodities, a great range of novel compounds were synthesized. Some of these turned out to be highly toxic and found their way into governmental CW research laboratories; formal and informal arrangements were instituted in some countries to facilitate this process. To this flow of new compounds were added those from academic laboratories. In some instances the toxic substances which came to light in this manner became candidate CW agents; in other instances, the substances contained structural characteristics that suggested to CW laboratories potentially fruitful areas for future programmes of synthesis.

The following sections discuss seven of the many groups of compounds discovered in industrial and academic laboratories that had relevance to chemical weapons.

LEAD TETRAETHYL AND RELATED COMPOUNDS

Lead tetraethyl was developed during the early 1920s as an anti-knock agent for petrol engines and has been manufactured on a large scale in many countries ever since. Its high toxicity, which has been responsible for the deaths of many industrial workers [98], inevitably led to its examination in CW laboratories, particularly during World War II. In the inter-war years the compound was frequently held up as one of the many new super poisons that were being secretly developed. Its high liposolubility was stated to confer skin-penetrating properties [99].

During World War II, lead tetraethyl was not in fact seriously thought of as a CW agent, largely because of its instability. In some countries, however, particularly the USA and the UK, its properties sparked off searches for other toxic plumbanes with more amenable physical and chemical properties [76, 100]. These searches were expanded to include work on a number of other organometallic compounds, notably those of cadmium, selenium and tellurium [76]; some of the results of this work are described in the next section.

One interesting off-shoot of the plumbane programme in the UK was the discovery of a number of intensely sternutatory trialkyl lead salts. This was of some importance for, as noted above, the Allies were looking for irritants not based on arsenic. These new lead-based irritants were therefore investigated further, and a search was also begun for possible irritants based on other metals, notably tin, bismuth, thallium and mercury. From this work, *tri-n-propyl lead methanesulphonamide* and a range of *diphenylbismuth* salts emerged as potentially at least as powerful irritants as the diphenylarsines [100].

In connection with the anti-knock properties of tetraethyl lead, it is interesting that World War II work in Germany included a search for pro-knock agents. These substances were apparently intended for use in anti-aircraft shell as a means for damaging aero-engines. Neither this work, nor the related search for compounds that would destroy aero-engine lubricants —*chemisches Sandkorn*—appear to have been successful. [101] The notion of such substances as weapons lives on, however, in the specific prohibition of their possession by Germany in Annex II of Protocol no. III on the control of armaments, a text forming part of the conventions within the Paris Agreements of 23 October 1954 which led to the formation of the Western European Union and by which Germany and Italy acceded to the Treaty of Brussels.

THE BENZALMALONONITRILES

During an investigation of the chemical properties of malononitrile in 1928, two US academic chemists came across a series of benzylidene derivatives having an intense sternutatory effect. The CW potential of these substances was suggested by a Dutch writer in 1934 [102], and in the same year their properties were looked at in the British CW establishment [74]. When World War II started they were further investigated; a US team did part of this at the request of the British who were concerned about possible arsenic shortages for their standard sternutators [103]. However, a concerted effort to develop the compounds for use in irritant weapons was not made until the mid-1950s. This occurred during the British search for CN substitutes noted above.

The British found that *2-nitrobenzalmalononitrile* offered the greatest aggressive potential of the series, closely followed by the 2-chloro analogue, and then by the 2-cyano, 2-bromo, and 2-hydroxy analogues. Of these, *2-chlorobenzalmalononitrile* (later coded *CS* after the names of its US discoverers, R. B. Corson and R. W. Stoughton) was selected to replace CN: it had a better thermal stability than the 2-nitro analogue, and 2-chlorobenzaldehyde was a more widely available intermediate than 2-nitrobenzaldehyde. [74]

In use, CS rapidly established its superiority to existing irritant agents, and has been massively used in Indo-China as a military harassing agent. The properties of the agent are further discussed in Volume II of this study.

METHYL FLUOROACETATE (MFA) AND RELATED COMPOUNDS

A patent filed by a branch of *IG Farbenindustrie* in Germany in 1930 claimed the use of MFA as an insect repellent [104].

In 1934 the research laboratories at the Wuppertal-Elberfeld branch (Bayer) of IG Farben began to seek new types of insecticide. Dr Gerhard Schrader was put in charge of this programme, and as he had previously been working with fluorine compounds he continued to do so in the search for new insecticides. Progressing through series of acyl fluorides and, with more success, fluorosulphonates, he moved on to derivatives of *2-fluoroethanol,* the manufacturing processes for which had recently been developed by Dr Ufer, of the Ludwigshafen branch of IG Farben, and subsequently patented. IG Farben's Industrial Hygiene Laboratories at Elberfeld established that 2-fluoroethanol was toxic to warm-blooded animals; this further evidence that fluorine atoms tended to confer toxicity to molecules containing them was an additional encouragement to Schrader's continued search for insecticides among fluorine compounds. He went on to prepare a series of 2-fluoroethyl esters and, in due course, fluoroacetic acid. Development of these compounds into commercial pesticides was impeded by the inadequacies of the preparative processes then available. [105] It is not known whether the compounds were further examined within German military laboratories, but after the war a German chemist who had earlier been working on the compounds in Würzburg found employment in the US Army CW laboratories [106].

While this work was in progress a research team in Warsaw, apparently connected with the Polish CW effort, was examining aliphatic fluorine compounds, and on discovering the great toxicity of 2-fluoroethanol began to investigate the compound and its derivatives further [107, 108]. With the German invasion of Poland a member of this team fled to the UK where he joined a group of chemists who were beginning work on aliphatic fluorine compounds. A great range of highly toxic substances emerged from this work and, among them, the volatility and stability of MFA suggested that it was a promising CW agent. Pilot plant studies of its manufacture were accordingly begun in the UK and USA. [109, 110] However, by 1944 it had been established, by a formidable piece of self-experimentation by a British worker [111], that man was remarkably resistant to fluoroacetate poisoning: had man been as susceptible as most laboratory animals, the fluoroacetates would be as potent as nerve gases. Thereafter, they were only important as water-contaminants, for their toxicity was retained even after long periods in water, from which they were difficult to remove. [111]

DISULPHUR DECAFLUORIDE (Z)

Z had been discovered in a British university laboratory in 1934 during a study of the interaction of sulphur and fluorine. At the beginning of World War II, its high toxicity in laboratory animals, its stability, and its complete lack of smell or irritancy drew attention to its strong candidacy as a CW agent. It was accordingly investigated as such in British and US CW laboratories.

Its principal drawback lay in its preparation which demanded elemental fluorine, at that time extremely difficult to make. In the USA only 3 kg of Z could be prepared, and this required the work of four men for about a year [112]. Accordingly, full toxicological studies were not made, and none has apparently since been published.

Some evidence suggested that man might not be as vulnerable to Z as the laboratory animal tests at first indicated for, in the rhesus monkey, Z was later found to be only one-tenth as toxic as phosgene [113].

TABUN AND THE G-AGENT NERVE GASES

Dr Schrader's progression through organofluorine compounds in his search for new insecticides led him on, in 1935, to fluorophosphorus compounds, and in the first of these, *NN*-dimethylamidophosphoryl fluoride, he found insecticidal properties. The compound was duly patented in Germany, the UK, Switzerland and the USA [105]; the British patent was published in 1938 [114]. Using this compound as a starting point, Schrader prepared an enormous range of new organophosphorus compounds over the next few years [115]. The first group of these to show really good promise as insecticides, more specifically as systemic insecticides against plant-sucking insects, was a series of P-acyl derivatives of alkyl esters of *NN*-dimethylamidophosphoric acid, on which a number of patent applications were filed [116–118]. One sub-group of these compounds, in which the acyl substituent was a cyanide radical, was found to be exceedingly toxic to mammals. This group included *tabun (ethyl NN-dimethylphosphoramidocyanidate),* first prepared on 23 December 1936 [119].

In accordance with an official decree of 1935 which required that inventions of possible military significance be reported to the Ministry of

War [98], a sample of tabun was sent to the CW section of the Army Weapons Office (*Wa Prüf 9*) in May 1937 [119]. The value of tabun as a CW agent was immediately realized, and the patent applications covering it were made secret [105]. An extensive development programme was initiated within certain academic laboratories, but principally within the Army's CW establishments [98]. In 1939 a pilot plant was set up for its manufacture at Munster-Lager (Heidkrug) [119] to provide supplies for field testing at the Army proving grounds at Raubkammer [98], and plans were made to build a full-scale production plant at Dyhernfurth near Breslau (Wroclaw) in Silesia [119]. The Dyhernfurth plant was duly built with an output of 1 000 tons per month on full run [52]; it was operated between April 1942 [120] and the beginning of 1945, by which time some 12 000 tons had been made[17] [52]. It was occupied by Soviet forces, and production is said to have been resumed in September 1946 [54].

By 1939 Schrader's work had taken him on to fluorine-containing organophosphorus compounds embodying a carbon-phosphorus bond. Among such compounds was *isopropyl methylphosphonofluoridate* (*sarin*), an even more toxic substance to mammals than tabun. A sample of this new compound was sent to the Wa Prüf 9 laboratories at Berlin-Spandau for examination [123]. The Waffenamt rapidly started development work but encountered great difficulties in the manufacture of the agent. A variety of preparative routes were tried, but all of them required a final fluoridation step involving hydrofluoric acid. This raised acute corrosion problems and in the various pilot plants at Spandau and Munster-Lager quartz and silver components had to be used [120, 123]. In due course, however, a potentially satisfactory process was worked out, and the erection of a large-scale production plant at Falkenhagen (near Fürstenberg, on the Oder, southeast of Berlin) was begun in September 1943. By the time of the Soviet advance to the Oder the plant was still not finished. (There had been controversy between IG Farben, the Army and the SS as to who should control the plant, which was in any case given a lower priority than the adjacent *N-stoff*[18] plant.) In January and February 1945 much of it was dismantled and evacuated. [121]

[17] A French authority states that 13 500 tons of tabun were found in occupied Germany; this excludes any that might have been captured by Soviet forces [64]. A British authority states that 12 000–15 000 tons of tabun were filled into weapons [121]. A Soviet appraisal of German CW capabilities estimated a total CW agent production of 250 000 tons — an estimate some four to five times larger than is generally made by Western writers; this authority states that 20 000–30 000 tons of tabun were in reserve at the outbreak of the war [122].

[18] N-Stoff was the name given to *chlorine trifluoride*. In addition to being somewhat toxic, this remarkable substance can also cause inflammation of organic materials such as asphalt, fabric and hair, either in liquid form or in very high vapour concentration [60]. The German Army became interested in it as a possible shell filling,

In all, the Germans made no more than 500 kg or so of sarin,[19] although substantial quantities of its intermediates were on hand (300 tons of dimethyl phosphite, 5 to 10 tons of dimethyl methylphosphonate, etc.) [120]. The production capacity of the Falkenhagen plant was intended to have been 500 tons per month [52].

In 1944 during the course of work for the Army on the pharmacology of tabun and sarin, Dr Richard Kuhn, the Nobel laureate, prepared the pinacolyl analogue of sarin [123]. This substance, *1,2,2-trimethylpropyl methylphosphonofluoridate* (*soman*) was found to exceed sarin in toxicity. By this stage in the war, however, it was too late to complete the necessary development work on the new agent, and in any case the pinacol needed for its manufacture was in short supply.

The Germans succeeded in concealing their work on organophosphorus compounds from the Allies throughout the war, and although in British and US laboratories a variety of such substances were synthesized and examined —notably Dr B. C. Saunders' dialkyl phosphorofluoridates,[20] such as DFP, and alkyl *NN*-dialkylamidophosphorofluoridates—the nerve gases themselves were not found. [120] The nerve gases, called *G-agents* after the marking on the weapons containing tabun,[21] were the only really significant advance in CW agent work since the development of mustard gas during World War I. All nations that had any interest in maintaining CW preparedness after the war made haste to examine them.

Post-war development of the G-agents is discussed in Volume II of this study. Despite the examination of a great many congeners, sarin and soman continue to be regarded as among the most militarily attractive of these agents. Sarin went into large-scale production in the USA in the early 1950s, something on the order of tens of thousands of tons being made. In the view of US intelligence, the Soviet CW stockpile, considered several times larger than the US stockpile, contains large quantities of soman [126].

either for incendiary purposes or to provide a means for burning through the charcoal filters used in respirators and collective anti-gas shelters. By the autumn of 1944, however, it had been rejected for use not only by the Army, but also by the Navy and the Air Force. For some reason, Hitler then seems to have instructed the SS organization to re-evaluate the substance. The SS not only did this, but also recommended that a manufacturing programme for it should be instituted without delay. The plant was duly erected, under SS control, with a 50 ton per month capacity: some 22 tons were made before it had to be evacuated. It is not known how the SS intended to use the substance or why it was given priority over sarin. [121]

[19] However, some authorities state that as much as 10 tons were made [124].

[20] The dialkyl phosphorofluoridates were in fact first reported in Germany in 1932, but Dr Saunders was the first to develop an efficient preparative process for them.

[21] In addition to the colour/number coding which indicated the broad characteristics of the filling of German chemical weapons, a code letter was included for more precise identification. "G" indicated a pure tabun filling. "GA" indicated a tabun filling diluted with 20 per cent chlorobenzene. [125] "GA" has since become the standard US code for tabun.

No information is available on this point from published Soviet sources, but the Soviet scientists whom the present authors consulted emphasize that this intelligence appraisal, which they regard as fraudulent, was given in the course of appropriations hearings [996].

V-AGENT NERVE GASES

After World War II, insecticide manufacturers were just as interested in developing Dr Schrader's compounds as were the CW establishments, and in industrial research laboratories throughout Europe and the USA work on organophosphorus compounds went ahead at a great rate. During 1952 and 1953 at least three chemical firms came upon a group of organophosphate esters of various substituted 2-aminoethanethiols that possessed remarkably potent insecticidal activity, particularly against mites. Around 1954, after acrimonious patent litigation, some of these began to appear on the market [127–29]. One such compound was ICI's *Amiton—diethyl S-2-diethylaminoethyl phosphorothiolate*—first described by R. Ghosh and J. F. Newman in 1955 [130], available as its quaternary hydrogen-oxalate salt as *Tetram* (R6199).

These amiton-type compounds attracted considerable attention outside the industrial laboratories, for the increased toxicity produced by introducing a basic nitrogen atom into the organophosphate molecule was of considerable interest in the theories of cholinesterase inhibition then being developed. Such an increase in anti-cholinesterase activity had already been predicted by a number of workers, for example a team at the I. M. Sechenov Institute in Leningrad which had begun looking at amiton-type compounds around 1955. [131]

It was a logical step to move from the dialkyl phosphorothiolate type of structure, as embodied in the amitons, to their alkyl alkylphosphonothiolate analogues when developing the potential of the basic-nitrogen side chain, for sarin-type compounds had demonstrated the increase in activity to be expected from having an alkylated phosphorus atom in the molecule. A number of academic, CW and industrial research workers quickly took this step at about the same time. Thus, at *Farbenfabriken Bayer AG,* Dr Schrader's team prepared *isopropyl S-2-diethylaminoethyl methylphosphonothiolate* [132], while at the Swedish CW laboratories Dr Tammelin prepared the *NN*-dimethyl and the *O*-ethyl analogues [133]. A year or two before this, however, Dr Ghosh at *ICI Ltd.* had prepared *ethyl S-2-diethylaminoethyl ethylphosphonothiolate,* on which a patent application was in due course filed [134]; this later interfered with a patent application made by Dr Schrader [135]. As with Amiton, Dr Ghosh's new compound had a powerful miticidal action, but it was even more poisonous to warm-blooded animals. By the time the patent was granted on the new compound and its congeners, Amiton had been withdrawn from the market because of its dangerous toxicity to man, especially through the skin; in view of this toxicity the new compounds clearly had no commercial future.

In 1954, however, shortly after Dr Ghosh had discovered the new compounds, their existence was reported to the British governmental CW establishment at Porton, which then began to investigate them as candidate CW agents, notifying the US CW establishment at the same time [136, 137]. The Americans called the new compounds *V-agents,* and by 1958 had selected one, code-named VX, for large-scale manufacture. In 1959 construction work for the necessary factory was begun, and in April 1961 full-scale production of VX commenced. This apparently continued until 1968 when the plant was laid down. [126] It is reported that US manufacture of sarin, which continued at full rate until 1956, cost the US Army about $3 per kilo, while VX cost them about $5 per kilo [126]. It may thus be estimated from the US Army's lethal chemical procurement figures [138] that the US CW stockpile contains some tens of thousands of tons of VX.

The precise chemical structure of VX is a military secret. Why VX was selected in preference to the several hundred other possible V-agents is unknown. Table 1.5 lists sixteen compounds that have been described in the open literature and which correspond to the general formula for the V-agents published by the British CW establishment, namely $R(RO)P(O)SC_2H_4NR_2$ [136].

The V-agents appear to be potentially the most effective casualty agents yet produced. They are further described in Volume II of this study.

THE PSYCHOCHEMICALS

The term "psychochemical" is used to describe those CW agents having a psychotropic action that is intended to produce casualties without causing permanent harm. The notion of incapacitating agents of this and related types is and old one [139, 140] but the chemicals that are apparently attractive in this role have only become available since World War II. Besides psychotropic drugs, these materials include anaesthetics, emetics, temporary vision blockers, temporary paralysants, etc.; they are discussed in more detail in Volume II of this study.

The US Army's interest in psychochemicals was probably stimulated by the rapid development of psychotropic drugs by a number of chemical manufacturers after World War II. With the increasing use and availability of tranquillizers, stimulants and even hard drugs for the general public, it was perhaps inevitable that the possible military uses of the new substances should be investigated. By 1952 Chemical Corps contracts on psychochemi-

Table 1.5. V-agents that have been described in the open literature

General formula for the V-agents: $R-P(O)\begin{smallmatrix}OR' \\ SCH_2CH_2NR''_2\end{smallmatrix}$

Substituents −R	−R′	=R″₂	Code name	Source
1. cyclohexyl	ethyl	diethyl		Farbenfabriken Bayer AG [132]
2. n-hexyl	ethyl	diethyl		I.C.I. Ltd. [134]
3. n-butyl	ethyl	diethyl		I.C.I. Ltd. [134]
4. n-propyl	ethyl	diethyl		I.C.I. Ltd. [134]
5. isopropyl	ethyl	diethyl		I.C.I. Ltd. [134]
6. ethyl	ethyl	piperidyl		I.C.I. Ltd. [134]
7. ethyl	ethyl	diethyl		I.C.I. Ltd. [134]
ethyl	ethyl	diethyl		British CW laboratories [283]
8. ethyl	ethyl	dimethyl		I.C.I. Ltd. [134]
9. methyl	ethyl	N-methyl-N-phenyl	GT 23[a]	I. M. Sechenov Inst., Leningrad [284]
10. methyl	ethyl	diethyl		I.C.I. Ltd. [134]
methyl	ethyl	diethyl		British CW laboratories [283]
methyl	ethyl	diethyl	edemo	Belgian CW laboratories [285]
methyl	ethyl	diethyl	edemo-3	Inst. of Toxicology, Belgrade Univ. [286]
methyl	ethyl	diethyl	"a typical F-gas"	Swedish CW laboratories [287]
11. methyl	ethyl	dimethyl	33 SN	Swedish CW laboratories [133, 288]
methyl	ethyl	dimethyl		French CW laboratories [289]
methyl	ethyl	dimethyl	medemo	Inst. of Toxicology, Belgrade Univ. [924]
methyl	ethyl	dimethyl		Institute of Toxicology, Rome Univ. [302]
methyl	ethyl	dimethyl	V_x	Romania [290]
12. methyl	hydrogen	diethyl	S 27	Dutch CW laboratories [291]
13. methyl	methyl	diethyl		Inst. of Toxicology, Belgrade Univ. [292]
14. methyl	isopropyl	diethyl		Farbenfabriken Bayer AG [132]
methyl	isopropyl	diethyl		Dutch CW laboratories [293]
15. methyl	isopropyl	dimethyl	37 SN	Swedish CW laboratories [133]
methyl	isopropyl	dimethyl	S 36	Dutch CW laboratories [291, 293–94]
16. methyl	cyclopentyl	dimethyl		Dutch CW laboratories [291]

[a] Other Soviet writers use the coding GT 23 to describe the amiton-type compound OO-diethyl S-2-(N-methyl-N-phenylamino) ethyl phosphorothiolate [295].

cals had been let (for example a contract for "the preparation of tetrahydrocannabinol analogs for investigation of their effects on the mind"[22]), and by 1958 the Corps claimed that it had found an agent that was apparently twice as potent in mice as LSD [142]. LSD was naturally the compound from which people in the psychochemical field drew hope, even though it was not a strong candidate CW agent itself. Its psychotomimetic effects had been discovered in 1943 following a laboratory accident during a pharmaceutical company's search for new analeptic agents [143]. Although

[22] Chemical Corps Procurement Agency contract number CML-4564 let in 1952 to Shell Development Company [141].

the structure of LSD was rather complex, it could be made on a large scale, albeit at very high cost, by a combination of microbiological and chemical techniques. It had an extremely potent effect and dosages smaller than were likely to be lethal apparently could produce militarily significant incapacitation.

The possible military uses of psychochemicals are discussed in Volume 2 of this study. For the present, it may be noted that during the late 1950s, the US Chemical Corps succeeded in arousing a good deal of interest in the possible military applications of incapacitating agents, notably by skillful deployment of a film demonstrating the effect of LSD on the behaviour of a cat towards a mouse [144]. In the process, the potentialities of the incapacitating-agent programme and its likelihood of success were undoubtedly greatly exaggerated. For the most part, the programme consisted—and apparently still does—of a routine scanning of new compounds produced by the US chemical industry, which is no doubt attracted to the programme by the facilities of the CW establishments and the possibility of having toxicological screening done cheaply. Some 10 000 such compounds were passing through Edgewood Arsenal each year. In 1958 the Chemical Corps estimated that it would take five to ten years to produce a useful incapacitating-agent weapon [145]; in 1964 they are reported to have made the same estimate [146].

In 1962, however, the US Army was in fact in the process of erecting a manufacturing plant for incapacitating-agent weapons [147]. The agent involved was code-named *BZ*; although its precise structure is a military secret, it appears to be a benzilate or some other substituted glycollate ester of an amino-alcohol, such as 3-quinuclidinol, having the properties of an anticholinergic psychotomimetic. It was apparently discovered during an investigation of compounds related to the commercially produced drug *Ditran.* Since then the Army seems to have become discontented with BZ, and although it has only 10 tons of the bulk agent in storage,[23] it is not seeking to procure more. [126] The unpredictable nature of the effects of the agent, its cost ($44 per kilo [126]), and the marginal military utility of psychochemicals in general presumably contribute to this. It seems that the Chemical Corps went into production of the agent before fully evaluating it; whether any substance will take, or indeed has taken, its place is a matter for conjecture.

Informed searches for new CW agents

This section considers the fourth and last of the methods whereby new CW agents are discovered, namely by instituting, within CW laboratories, pro-

[23] How much BZ has been filled into weapons is, however, not known.

grammes of candidate agent synthesis, the programmes being guided by existing indications that certain lines of research may be fruitful. The indications may be derived from new theories of molecular pharmacology, for example, or from the potential of known toxic molecules for productive structural modification.

While the discussion which follows may give the impression that searches of this kind have not been particularly successful in the past, it is well to note the caveat that CW research establishments are notoriously secretive places, and that we are here talking about in-house research efforts.

DEVELOPMENTS AROUND EXISTING CW AGENTS

After World War I a considerable amount of work was done in synthesizing hitherto unknown compounds structurally related to existing CW agents, particularly the arsenicals and mustard gas; after World War II, the discovery of the G-agents provoked the same sort of activity. While it appears that few CW agents of any great attraction came forward from these programmes until the nerve-gas work, it is interesting to note briefly some of the directions they took.

Mustard-gas homologues and related vesicants. During World War I there had been requirements for percutaneous agents that were either more volatile or less volatile than mustard gas. Accordingly after the war, more especially during World War II, a huge range of compounds containing the 2-chloroethyl group were synthesized and examined. While no substances were found that exceeded mustard gas in general utility, three groups of them proved to be of some interest: a series of *2-chloroethylamines* (the *nitrogen mustards*), a series of substituted nitrosamines, and some of the higher homologues of mustard gas itself.

The nitrogen mustards held out some promise of providing more volatile vesicants [148]. At one point during World War II, the British were thinking of manufacturing one of them on a large scale; this was *methyl-bis-(2-chloroethyl)amine* (code-named *S* in the UK and *HN2* in the USA), but after some had exploded in storage they changed their minds [148]. The Americans were more attracted by its ethyl homologue (*HN1*), but decided against manufacturing it until they learned that the Germans were producing a nitrogen mustard. Then, in 1943, they put up a small HN1 manufacturing plant, mainly, so it was said, to mislead German intelligence. Quite what the object of this was is not clear. The plant produced about 100 tons of the agent [30]. The Germans were in fact manufacturing a third nitrogen mustard, *tris(2-chloroethyl)amine* (code-named *T9* in Germany and *HN3* in the USA), producing about 2 000 tons [52], which they charged into 15 cm rockets and 105 mm and 150 mm artillery shell [125]. As for the other principal belligerents in World War II, the Germans apparently believed that the Soviet Union was producing a nitrogen mustard [56] as indeed it is reported to have done, selecting HN3 [54]; the Japanese had investigated the compounds but decided against making them [56].

The 2-chloroethyl substituted nitrosamines were apparently first developed by the Allies at the beginning of 1942. The lead had been provided by nitrosomethylurethane, one of the most disagreeable and toxic commercially available compounds that remained to be examined by CW laboratories. Insufficiently toxic itself to be a candidate CW agent, it was quickly found to have a number of more toxic congeners. Of these, *methyl N-(2-chloroethyl)-N-nitrosocarbamate* (*KB-16*) and its ethyl homologue (*KB-10*) were the most widely studied. KB-16 was attractive because it had a more damaging effect on the eye than mustard gas and, with its lesser smell and still more delayed action, it was also more insidious in its effect. [149] Because of these properties, KB-16 was considered slightly more useful than mustard gas in circumstances where delayed and long-continued disorganization of the enemy was required, rather than a sudden shock effect [150]. However, the agent had a very poor storage stability[24] and was not manufactured.

The first of the higher sulphur mustards to be isolated was *1,2-bis-(2-chloroethylthio)ethane* (known as *sesqui-mustard* or *Q*), first reported in the literature in 1922 by a university team engaged on US Army CWS work [151]. Curiously, the preliminary toxicological studies carried out at Edgewood Arsenal were reported to have shown that Q produced less severe skin burns than mustard gas. In 1931 a British CW laboratory reported its vesicant power to be five times that of mustard gas [152], and even this may have been an underestimate [153]. However, being a solid, the substance was difficult to use as a CW agent at that time; and although liquid mixtures of it with mustard gas were considered for production during World War II, apparently none were actually produced [61]. This was not the case, however, with another higher mustard, *bis(2-chloroethylthioethyl) ether (T)*, first reported from British CW laboratories in 1931 [154]. Less potent than Q, T was a liquid with about three times the vesicancy of mustard gas, possibly more. It was developed as a standard weapons filling by

[24] One proposal made for countering the storage instability of KB-16 is of interest in connection with the new US "binary" nerve gas weapons (described in Volume 2 of this study). It was proposed that instead of charging weapons with KB-16 itself, the filling should comprise the more stable KB-16 intermediate, methyl *N*-(2-chloroethyl)carbamate, and a nitrosating agent capable of swiftly converting this to KB-16, the two being kept apart by a frangible partition until the weapon was used. [149]

the UK and the USA during World War II,[25] and was intended for use mixed with 60 per cent mustard gas as a highly persistent ground contaminant and percutaneous agent. Code-named *HT*, this mixture apparently still exists on the US CW operational inventory. [156]

Arsenicals. As was the case with the nerve gases after World War II, the arsenicals consumed a large proportion of the energies of CW agent research teams after World War I, particularly after the US publicity about lewisite. Not only had arsenic compounds been comparative late-comers to the battlefield during the war, but in the field they had demonstrated that arsenicals could provide not only harassing effects but also respiratory and percutaneous casualty effects. Literature citations in the CW textbooks of the inter-war period, for example that by Dr Mario Sartori of the Italian chemical warfare service [35], indicate that concerted work on arsenicals was being conducted in most European countries—Germany, Poland, the USSR, UK, Italy, Romania, France, etc. As it turned out, however, no really attractive candidate CW agents were found, despite an examination of many hundreds of new arsenicals. Among the monoalkyl and monoaryl arsines, lewisite, ethyldichloroarsine and phenyldichloroarsine remained the best arsenical vesicants, while DA, DC and DM continued to dominate the many new dialkyl and diaryl arsines. *Arsine* itself attracted some attention during World War II as a possible replacement for phosgene, but its inferior toxicity and difficult liquefaction ruled it out [42]. Nonetheless, in 1939 the UK was sufficiently fearful of apparent German interest in arsine to produce an emergency respirator-canister attachment that provided increased protection against the agent [157]. The Germans apparently considered producing solid arsenides that would liberate arsine on contact with moisture,[26] and there was a scare at one point that the French had actually used such substances near the Siegfried Line [155]. The arsenicals manufactured during and shortly before World War II were thus the same as in World War I, and were produced at least by the following belligerents:

Diphenylchloroarsine (DA) and diphenylcyanoarsine (DC): UK (less than a ton of DC), Japan (1 957 tons of DC [50]), Germany (1 000–3 000 tons [52, 158]) and the USSR [54]. The Japanese output was charged into pots and self-propelling candles, mortar bombs of various sizes, 75 mm, 105 mm

[25] During World War II the Germans were reported to be working on a material known as *Doppellost* (*Lost* was the German name for mustard gas), but it is not known whether this was a higher mustard derivative. [155]

[26] Plans to produce a substance of this type, code-named *T300*, called for a production capacity of 100 tons per month. They never went ahead, though, because of the very slight importance of the agent and the lack of raw materials. [52]

and 150 mm artillery shell, and 15 kg and 60 kg aircraft bombs [50, 53]. The German output went into artillery shell and 15 cm rockets [125].

Adamsite (DM): the USA (293 tons [30]), France [53, 59], the USSR [54] and Germany (3 000 tons [52]). The US output went into candles and hand grenades [30]; the French into their DM aerosol generator *Engin-Z*; and the German into candles, 105 mm and 150 mm artillery shell and 50 kg aircraft bombs [125].

Phenyldichloroarsine (PD): Hungary [65] and Germany (3 000–8 000 tons [52, 158]). This agent was used as an anti-freeze additive for mustard gas and as such the Germans charged it into 105 mm and 150 mm artillery shell, 100 mm mortar projectiles, 15 cm rockets, 10 litre chemical mines and 250 kg bombs [127]. Czechoslovakia is also reported to have manufactured arsenicals [53].

Developments around phosgene, diphosgene and chloropicrin. Although a number of compounds related to phosgene, diphosgene and chloropicrin were synthesized after World War I, none were superior to these agents. The more promising of the new compounds included *carbonyl chlorofluoride* [159], *hexachlorodimethyl oxalate* [56], and a variety of *chlorinated nitroethanes* [35].

Although respirator design had improved sufficiently during the inter-war years to deprive chloropicrin of most of its attractions as a CW agent, it was nonetheless produced at least by the USA (500–600 tons [30]), the USSR [54], and Japan (ca. 1 000 tons [50]) shortly before and during World War II. The Americans used theirs in a liquid irritant-agent formulation of CN as a charging for mortar bombs and artillery shell [30]; the Japanese mixed theirs with a smoke agent and put it into 75 mm artillery shell [53].

Phosgene remained the standard nonpersistent casualty agent for most of the belligerents during World War II, and was manufactured at least by the USA (18 000 tons [30]), the UK, France, the USSR, Italy, Japan (1 080 tons [50]), Germany (5 000 tons [52], 10 500 tons [64]) and Canada [63]. The USA charged its phosgene into 4.2 inch mortar bombs, 7.5 inch rockets, and 500 lb and 1 000 lb bombs [30]. The British used some of their output in Livens Projector drums, 5 inch rockets, 4.2 inch mortar bombs and 250 lb and 500 lb aircraft bombs [160, 161]. The Germans put theirs into 250 kg and 500 kg bombs [125]; the Japanese into artillery shell of various calibres and into 50 kg bombs [30, 53]. Soviet phosgene weapons included various sizes of aircraft bomb [57], while the Italian and French ones included various sizes of artillery shell [162, 163].

Only Japan [56] and the Soviet Union [54] are reported to have produced diphosgene during World War II [56].

TOXIC METAL COMPOUNDS

In addition to arsenic compounds, there were a number of derivatives of other metals that were known to be highly toxic, and which therefore were studied within CW laboratories during the inter-war and World War II years. For example, antimony, closely related to arsenic, was found to yield a variety of toxic antimonials; some of these, for example the sternutator *bis-(2-aminophenyl)hydroxystibine,* were in fact comparable in potency with the corresponding arsenicals [74, 164]. Three other groups of compounds, in addition to the lead, tin and bismuth sternutators referred to earlier, also warrant mention here.

Radioactive metal derivatives have also attracted some attention as possible toxic agents—"radiological warfare agents"—since World War II. They are discussed in Volume II of this study.

Throughout the 1920s and 1930s selenium compounds had been finding increasing industrial applications, during the course of which their toxic effects became more widely known. From the point of view of CW laboratories, the properties of *selenium dioxide* were especially interesting, for it was both extremely toxic and easy to generate as an aerosol by including selenium metal or its derivatives in incendiary or explosive compositions. While selenium weapons do not appear to have been produced during World War II, the US CW establishment developed a variety of projectiles for artillery and naval ordnance to disseminate selenium dioxide smokes [165].

Compared with selenium, cadmium derivatives found even greater use in industry after World War I, and a number of accidents showed that inhalation of the finely divided metal, its oxide or its salts, could produce a severe lung oedema, comparable with that produced by phosgene. A range of cadmium compounds were examined as potential CW agents in the USA during World War II and, as with selenium, the oxide proved to be particularly attractive, and was proposed for use in incendiary bomb formulations. By the end of 1942 cadmium metal had been tested as an ingredient in the thermite filling of the 4 lb AN-M54 incendiary bomb, and soon afterwards as a component of the magnesium alloy in the AN-M50A1 bomb. [165] Such weapons were thought to be potentially useful because the toxic *cadmium oxide* smoke given off by the burning incendiary would impede firefighting activities. The weapons were patented by the US Army [166], and standardized for possible procurement. It is not known if any were actually mass-produced.

Metallic carbonyls interested CW laboratories during the 1920s and 1930s for two reasons. First, they offered a means for exploiting the toxic effects of carbon monoxide, a substance whose physical properties were not amenable to CW; most carbonyls decompose rapidly on contact with respirator-charcoal to yield carbon monoxide, which is not thereafter retained by the charcoal. Secondly, some of them were strong poisons in their own right and had a marked ability to penetrate the skin [98]. However, when they were examined in the USA during World War II, it appeared that in either of these two roles the carbonyls would have had to be used in impracticably large quantities if they were to have any effect. It was concluded that one of their few possible applications might be as additives for flame-thrower fuels: the high concentration of carbon monoxide gas and metallic aerosol produced by combustion of the fuel in a confined space might increase the overall effectiveness of the weapon against fortifications [165].

INVOLATILE AGENTS IN GENERAL

By the time of World War II there was an accumulation of knowledge about substances that were highly toxic but whose involatility had hitherto ruled them out as CW agents. Some of these have been mentioned above. Only those toxic solids that were sufficiently stable to withstand distillation from thermogenerator devices or pyrotechnic compositions—such as the arsenical sternutators or the metal oxide smokes—were regarded as candidate CW agents. However, spurred by the ready availability of substances such as ricin and the vesicant agent Q, a number of CW laboratories began to search for ways and means of exploiting involatile agents. Their problem was essentially an engineering one: how to develop a particulate aerosol generator that would not impose thermal stresses on the agent. In the case of the more delicate agents, it was important to minimize mechanical stresses as well.

Anticipating a solution to the problem, searches were also begun for new involatile toxic agents; some of the results of these have been noted above.

The problem also faced groups of researchers outside CW laboratories. There was an urgent military requirement, for example, to find ways of combatting mosquitos and other insect disease vectors in combat theatres; in remote jungle areas the most promising way of doing this seemed to be by dropping bombs through the jungle canopy that would disseminate DDT aerosols over the insect breeding grounds.

A range of aerosol-generating devices was proposed, and some of them went most of the way towards providing an adequate solution. In the case of DDT, for example, one device had the insecticide suspended or dissolved in a volatile liquid; in operation the liquid was forced out of its container through a fine nozzle by a propellant gas. This device formed the basis for the aerosol spray cans that are so familiar in many households today. Other devices made use of particular types of explosive to scatter the agent in powder or liquid suspension form, the explosive and the agent container being shaped to minimize thermal and mechanical stresses. Field tests of this type of device charged with toxic protein agents, and with bacterial pathogens, were reasonably successful. [167]

As a result of this work, it had become apparent by the end of World War II that the involatility of toxic substances was no longer an adequate reason for dismissing them as candidate CW agents. Although weapons for exploiting them would clearly be more complicated, and therefore more expensive and less reliable, than those for more volatile agents, reasonably adequate prototypes had been developed ready for further improvement should the need arise.

While this work opened up a whole new field of aerosol studies which would have a multitude of peaceful applications, it also greatly increased the potentialities of CB weapons. In the first place, means for disseminating pathogens were no longer confined to the aircraft spray tank. In the second place, it caused chemical-weapons designers to focus their attention on the physical and toxicological properties of aerosols, rather than of vapours and liquids as hitherto. Major improvements even in the performance of weapons based on comparatively volatile agents resulted from this. Once it had been found out that deepest lung penetration, for example, occurred with particles in the 1 to 5 micron diameter size range, or that particles smaller than about 70 microns did not impact at all readily on the skin, a new theoretical foundation was provided for the design of chemical weapons. In combination with the discovery of the nerve gases, this made chemical warfare an altogether different proposition after World War II than it had been previously.

The importance of the nerve gases

It is as well to conclude this section on post-World War I CW agents with some further comments on the nerve gases, for the discovery of these materials is largely responsible for the gravity of existing and future threats of CW.

The G-agent nerve gases were attractive for several reasons, but two of their properties were especially important. The first was their great toxicity and ease of dissemination: because such small doses of G-agents could be lethal, the efficiency of the smaller types of chemical weapon, such as artillery shell, was greatly increased. The second was the rapidity of their effect once inhaled: a lethal respiratory dose of tabun, sarin or soman is believed to cause death in one to ten minutes. In contrast to this, a lethal dose of the most toxic respiratory-effect CW agent previously available, phosgene, took four to twenty-four hours to kill.

These two properties enormously increased the potential utility of chemical weapons to ground forces. Quick-acting casualty agents existed before World War II—the blood gases AC and CK—but were effective only if delivered in huge bombs. Mustard gas was the only available agent at all well suited to artillery shell, mortar bombs and the other normal weapons of ground forces, but it was a delayed-effect agent. The nerve gases thus combined the efficiency of mustard gas with the rapidity of action of the blood gases, and made CW techniques far less unsuitable for fast-moving land-warfare operations.

The G-agents had other attractions as well. First, the less volatile ones could produce casualty effects through the skin, although they might take upwards of an hour or more to produce their maximum effect. The G-agents could therefore take over some of the functions of mustard gas as a percutaneous agent. Secondly, the G-agents could produce casualties at sublethal dosages (unlike AC), and the field concentrations needed to do so were so small as to be comparable with effective field concentrations of irritant agents. The G-agents could therefore also serve as harassing agents in some roles, such as forcing the enemy to mask. Finally, the range of G-agents available was so large that they could be selected as much for their chemical and physical properties as for their toxicological ones: the volatilities of the agents, for example, and hence the persistency of their ground contamination, ranged from above that of water to about that of fuel oil.

With the discovery of the V-agents, many of these properties were accentuated. The best of the new nerve gases was five or ten times as poisonous as the best of the old. Through the lungs, the V-agents were as rapid-acting as the G-agents, but through the skin—and this was especially significant—they were faster and effective in smaller dosages. Their stability was high enough to permit their dissemination as high-concentration, nonpersistent aerosols, if necessary, while as persistent ground contaminants they greatly exceeded mustard gas in efficacy. While the G-agents had shown that chemical weapons could be adapted to mobile ground fighting, the V-agents suggested that in some land-warfare situations chemical weapons might conceivably be the most effective weapons available. This is discussed further in Volume II of this study.

Table 1.6 collects together some relevant information on CW agents that have either been used in war, or that have been stockpiled in quantity against such use.

Table 1.6. Some properties of CW agents of past or present importance

Chemical name	Freezing point °C I	Volatility *20°C, mg/m³* II	Casualty dosage among unmasked personnel, *mg–min/m³* III
Casualty agents: lung irritants			
Chlorine	−102	3 000 000	1 800
Carbonyl chloride (phosgene)	−128	4 100 000	1 600
Trichloronitromethane (chloropicrin)	−69	170 000	..
Trichloromethyl chloroformate (diphosgene)	−57	54 300	1 600
Casualty agents: blood gases			
Hydrogen cyanide	−14	891 000	2–5 000[c]
Cyanogen chloride	−7	2 600 000	7 000
Casualty agents: vesicants			
Bis (2-chloroethyl) sulphide (mustard gas)	14	610	200
2-Chlorovinyl dichloroarsine (lewisite)	−18	2 300	300
Ethyl-*bis* (2-chloroethyl)amine	−34	1 500	200
Methyl-*bis* (2-chloroethyl)amine	−65	2 000	100
Tris (2-chloroethyl)amine	−4	100	200
1,2-*bis* (2-chloroethylthio)ethane (sesquimustard)	56	<1	40
Bis (2-chloroethylthioethyl) ether	10	2	50
Casualty agents: nerve gases			
Ethyl NN-dimethylphosphoramidocyanidate (tabun)	−50	400	300
Isopropyl methylphosphonofluoridate (sarin)	−56	12 100	75
1,2,2-Trimethylpropyl methylphosphonofluoridate (soman)	−80	2 000	35
VX[a]	..	10	5
Other casualty agents			
Ricin	n.a.	n.a.	..
Botulinal toxin	n.a.	n.a.	..
Incapacitating and harassing agents: irritants			
Diphenylchloroarsine	44	7	15
Diphenylcyanoarsine	30	3	25
10-Chloro-5,10-dihydrophenarsazine (adamsite)	195	<1	10
α-Chloroacetophenone	55	105	80
2-Chlorobenzalmalononitrile	95	..	20
Other incapacitating agents			
BZ[b]	190	..	110
Staphylococcal enterotoxin B	n.a.	n.a.	<1

[a] The structure of VX has not been published in the open literature; it is one of the O-alkyl S-2-dialkylaminoethyl alkylphosphonothiolates, such as O-ethyl S-2-diisopropylaminoethyl methylphosphonothiolate.

[b] The structure of BZ has not been published in the open literature; it is an anticholinergic benzilate or glycollate ester with psychotomimetic properties, such as 3-quinuclidinyl benzilate or a 3-quinuclidinyl thenilate.

[c] Hydrogen cyanide produces few symptoms at sublethal dosages; the size of the lethal dosage is likely to vary widely according to exposure time.

Notes

Col. I. The freezing point of the agent, °*C*,

Col. II. The volatility of the agent at *20°C, mg/m³*.

Col. III. Approximate dosage of the airborne agent likely to produce casualties among about half the people exposed to it, if they lack any kind of protection: *mg–min/m³*.

Casualty dosage among masked personnel, *mg–min/m³* IV	Harassing concentration, unmasked personnel *mg/m³* V	Approx. lethal dosage, unprotected personnel *mg–min/m³* VI	Percutaneous lethal dosage, *mg* VII	References to literature consulted	Record of use or status VIII
n.a.	100	19 000	n.a.	[3, 180]	A
n.a.	..	3 200	n.a.	[180]	A, B?, C, D, F, G
n.a.	50	20 000	n.a.	[2, 35, 39]	A, C, D
n.a.	..	3 200	n.a.	[2, 180]	A, C, D
n.a.	n.a.	2–5 000[c]	..	[35, 180]	A, C, D
n.a.	85	11 000	..	[35, 180]	A, D
2 000	n.a.	1 500	4 500	[35, 180]	A, B, C, D, F, G
1 500	..	1 300	..	[2, 180]	C, D
9 000	n.a.	1 500	..	[35, 180]	D
4 000	n.a.	3 000	..	[35, 180]	D
2 500	n.a.	1 500	..	[35, 180]	D
400	n.a.	200	..	[61]	D?
500	n.a.	..	..	[61]	D, G
..	n.a.	400	1 000	[120, 180]	D, G?
8 000	n.a.	100	1 700	[180, 296]	G
..	n.a.	50	100	[122, 287, 296]	G
..	n.a.	10	6	[287, 297]	G
n.a.	n.a.	30	n.a.	[79]	
n.a.	n.a.	0.02	n.a.	[298]	G
n.a.	1	15 000	n.a.	[35, 180]	A, C, D
n.a.	<1	10 000	n.a.	[35, 180]	A, C, D
n.a.	<1	15 000	n.a.	[35, 180]	A?, D, E
n.a.	5	11 000	n.a.	[35, 180]	C, D, E, G
n.a.	2	25 000	n.a.	[180]	E, G
n.a.	n.a.	..	n.a.	[299]	G
n.a.	n.a.	..	n.a.	[300]	G?

Col. IV. Approximate dosage of the airborne agent likely to produce casualties among about half the people exposed to it, if they have only their eyes and lungs protected: *mg–min/m³*.

Col. V. Approximate effective field concentration for harassing unmasked personnel: *mg/m³*.

Col. VI. Approximate dosage of airborne agent likely to kill about half the people exposed to it if they are unprotected: *mg–min/m³*.

Col. VII. Approximate dosage of liquid agent likely to have a 50 per cent chance of killing a man when applied to his skin: *mg*.

Col. VIII. Record of past or present use or status:

A. used during World War I
B. used during the Italian invasion of Ethiopia
C. used during the Japanese invasion of China
D. stockpiled during World War II
E. used in the Viet-Nam War
F. allegedly used in the Yemeni Civil War
G. stockpiled today

Developments in CW defences since World War I

At the close of World War I offensive CW techniques had the advantage over defensive ones in that no adequate protection existed against the skin effects of mustard gas. By the time of World War II this situation had to some extent been rectified by the development of air-permeable anti-vesicant impregnated clothing, but this was by no means a full solution. Today percutaneous agents continue to provide a more formidable threat than respiratory-effect agents, but the divergence between defensive and offensive CW capabilities is not nearly as marked as it was in 1918.

This section briefly reviews the main developments in the five principal fields of anti-gas R & D since World War I: respirators, protective clothing, alarm systems, medical countermeasures, and decontaminants.

Improvements in respirator design

After World War I it was realized that the future could be expected to bring an increasing use of particulate agents disseminated as smokes. While German Blue Cross weapons had been a failure, the development of thermo-generator devices undoubtedly meant that particulate aerosols, at least of irritant agents, might be encountered on future battlefields. One of the first steps in improving respirator design, then, was to increase the performance of existing particulate filters. Once the physical properties of particulate aerosols had been examined in detail, this task was soon accomplished and better filter materials developed. An important advance came in the mid-1930s with the development of resin-wool filters: mats of this material had a very high filtration efficiency, even for micron-sized particles. This was due to electrostatic attraction between the particles and the fibres of the mat, for during carding of the resin-wool mixture the resin acquired a substantial negative charge. Resin-wool particulate filters were used in several World War II respirator designs, and remain in use in some armies today [168]. Their principal deficiency was a tendency to lose some of their retentiveness when dampened, either by water getting into the mask or through prolonged exposure to aerosols containing a high proportion of large liquid droplets [169]. Approaches towards overcoming these defects included the use of asbestos fibres and hydrophobic surfactants in the preparation of the particulate filter [169] and, more recently, the use of micron-diameter glass and plastics fibres [168, 170]. Adequate filtration of aerosols is no longer a serious problem.

Military specifications for respirators nowadays require that at least 99.999 per cent of all possible contaminants be removed from inhaled air during passage through the respirator [168]. From a CBW point of view, the contaminants may either be at a molecular level of dispersion, as in the case of gases or vapours, or in aerosol form of particle size ranging from less than 0.1 micron to around 200 micron in diameter. Even at the lowest level of this latter range, the particulate filters just described are capable of meeting the specification as regards aerosols. For gases and vapours, active charcoal is easily capable of meeting the specification also; but here there is the additional problem that much heavier challenges are possible with vapours than with aerosols because a vapour cloud may have a very much higher agent concentration than any possible aerosol cloud. There is thus the danger that charcoal filters may become saturated, a problem that is especially pressing with low molecular weight substances like hydrogen cyanide (AC) or cyanogen chloride (CK), or chemically inert substances such as chloropicrin.[27] This danger had been appreciated during World War I (and was indeed one of the principal reasons for the selection of chloropicrin as a CW agent). A good deal of post-World War I work on respirators was therefore concerned with improving the retentiveness of charcoal filters against low molecular weight and inert CW agents. One line of research was to look for more active charcoals; another was to seek charcoal impregnants that would increase the sorptive capacity of existing charcoals. The general tendency was thus away from the use of soda-lime and granules of other chemical absorbents, and towards the use of impregnated and better adsorptive charcoals. During the 1920s and 1930s the most active charcoal available was derived from coconut, and it was realized that in times of war the supply of this might be jeopardized. Most countries therefore attempted to prepare charcoals of comparable or better activity from domestic sources, and satisfactory results were in due course obtained, both with wood and with coal or lignite charcoals [60, 168]. As for suitable charcoal impregnants, the search was for substances that could catalyse the decomposition of the incoming chemical vapour to yield oxidation or other breakdown products that were either non-toxic or else were more easily adsorbed by the charcoal than the agent itself. By the end of World War II, the charcoal in British, Canadian, German and US respirators, at least, contained various combinations of copper, silver, chromium and pyridine or picoline impregnants. These materials effectively adsorbed and destroyed agents such as AC and CK. The Japanese masks, however, which lacked such a range of impregnants, were markedly vulnerable to high

[27] For an easily-adsorbed CW agent vapour, like that of phosgene, respirator saturation was not a problem. Thus the British general service respirator that was standard between the two world wars could keep out phosgene concentrations as high as 40 000 mg/m^3 for half an hour or more. The corresponding period for the British civilian respirator, in issue from the end of 1938, was more than ten minutes. [171]

concentrations of these agents [172]. The best of the World War II designs all proved to be adequate against the G-agents, and presumably therefore against the V-agents also.

In addition to the development of better filter elements, an important part of respirator-development work has been concerned with reducing the fatigue resulting from long periods of masking, and minimizing the reduction in combat efficiency of masked troops. These points are discussed in Volume II of this study.

Development of anti-gas protective clothing

The first attempt at providing anti-vesicant clothing was the World War I use of oil cloth. This material was heavy and uncomfortable and although it was impermeable to mustard gas it was also impermeable to air and water vapour, with the result that its wearer quickly became overheated and exhausted. Furthermore, the stiff material could act as a bellows when the wearer moved about, sucking in mustard-gas vapour through the various apertures of the clothing. In hot weather this kind of protection was clearly impossible to use for long periods; in cold weather it was impractical.

During the inter-war years the search began for substances that could be used to impregnate ordinary combat clothing and which would retain any vesicant penetrating the clothing but without interfering with its air and water-vapour permeability. The difficulty was to find a material that was sufficiently active, stable on storage, and non-irritating to the skin. One of the earliest successes was the US development during the late 1920s and early 1930s of a clothing-impregnating process based on a chloracetamide that chemically decomposed mustard gas [173–75]. The impregnant, *sym-bis-(chloro-2,4,6-trichlorophenyl) urea* (code-named *CC-2),* was one of a large group of active-chlorine compounds that were being investigated, not only as clothing impregnants [176–77], but also as decontaminants and as ingredients for anti-mustard skin ointments. The US CC-2 process was used throughout World War II and, in a modified form, is still used [156]. The impregnant is in micronized powder form containing 10 per cent zinc oxide stabilizer; the formulation is code-named *XXCC-3*.

The chief drawback of the CC-2 process is that the impregnant rapidly loses its active chlorine content in warm weather so that the clothing has to be reimpregnated at frequent intervals. In an alternative approach, which was being developed by the British before World War II, active carbon was used as the impregnant to adsorb the invading vesicant rather than to decompose it. A variety of ways of getting the carbon into the cloth were examined, but apparently large-scale techniques were not developed either before or during the war. [178] The British, like the Americans, relied instead on chloramide-impregnated protective clothing [60]. In post-war years however, the British have continued to develop carbon-impregnated clothing, and have recently announced the successful development of a promising new material [179].

It is not known how well CC-2 clothing stands up to nerve gases, which require a very much higher level of protection than is needed against mustard gas. Even against mustard gas, its performance is strictly limited. [180] The British apparently feel that their carbon cloth is adequate, at any rate against single, surprise nerve-gas attacks. It seems doubtful, however, whether any form of air-permeable impregnated clothing could adequately keep out nerve gas for prolonged periods of time: even if as much as 99.5 per cent of the incoming nerve gas were adsorbed, the remaining 0.5 per cent, combined with the amount that would inevitably be desorbed, would surely eventually build up into a casualty-producing dosage (which may be as low as a milligram or two with the more potent nerve gases). If the attack disseminates large drops of liquid nerve gas, local overloading of the fabric impregnant may produce casualties in a much shorter space of time.

But this does not mean that impregnated clothing is useless against nerve-gas attack. An attack with volatile nerve gases is most unlikely to be sustained long enough for nerve-gas vapour or aerosol to saturate the impregnants. Under attack with involatile ones, field commanders are unlikely to keep their troops in contaminated areas for long. The clothing is thus unlikely to be exposed to nerve gas for more than a few minutes at a time, after which it can be discarded and replaced or reimpregnated. During the interim period other protective means, such as personal decontaminants or therapeutic measures, are available to cope with any nerve gas that has penetrated the clothing. The clothing may not stop nerve-gas casualties altogether, but it can reduce their level from an intolerable level to a tolerable one. Expressed another way, the clothing may increase the necessary intensity of attack from a level advantageous to the attacker to one which is excessively expensive for him.

Another approach towards providing skin protection has been to develop special overgarments that can be worn on top of normal battle dress whenever there is risk of chemical attack. Protective clothing of this type is available in many armies today; it is generally made from impermeable materials of various sorts. Typical items of equipment are long overboots and gloves made of rubber, and capes made of lightweight plastics materials or coated paper, all of which are intended to be discarded after use in a contaminated area. [181] Some of them can serve other functions as well: anti-gas capes can double as rain capes, for example.

Permeable overgarments have also been developed; a joint US/UK/Canadian/Australian research effort has recently produced clothing of this type made from a charcoal-impregnated porous polyurethane material. These overgarments are intended to complement impregnated undergarments worn underneath normal battledress. [182]

If prolonged exposure to nerve gas is unavoidable, then the only form of reliable skin protection is impermeable clothing. But while there have been great improvements in this since the oil-cloth days—notably by the use of light-weight plastics material—the basic problem of interference with the temperature-regulating mechanisms of the body remains, the attendant risk of heat-stroke being more acute the hotter the weather. Thus, the standard US impermeable clothing is issued with the recommendation that at temperatures above about 35°C the clothing should not be worn for more than fifteen minutes [156]. A full solution to this problem can probably only be found by developing lightweight cooling units for impermeable suits, or, conceivably, one-piece air-permeable clothing that fastens closely about the neck and limbs, with some sort of pressurizing unit incorporated in the garment.

Development of CW agent alarms

Until the discovery of the nerve gases, standard CW casualty agents were almost always detectable by the senses long before they had accumulated into casualty-producing dosages. Attempts were sometimes made to find ways of concealing their existence in CW attacks by masking them with smoke or irritant agents, but such attempts were never regarded as a particularly severe threat by anti-gas defence workers. Agent vapour detectors and related equipment were available, but their function was seen to be more a means for telling people when to take their respirators off than when to put them on. The nerve gases, however, were in an altogether different category: a concentration that could easily be lethal had almost no smell. It was thus possible that entire combat units might be put out of action before they had a chance to protect themselves. The attack might easily be delivered with an off-set aerosol cloud technique, in which the delivery vehicle for the weapons employed was too far away from the target to give adequate warning of their use.

The approaches followed to provide nerve-gas warning systems are described in Volume II of this study. The devices that have been developed all appear to work quite well, but they are complicated and expensive. Even if they are developed further, it will of course still be necessary to have stocks of respirators and protective clothing available in forward areas, ready for immediate issue and use whenever there are indications that a nerve-gas attack is likely.

Medical countermeasures

As with alarm systems, medical countermeasures did not become a significant part of the first line of defence against chemical attack until after the discovery of the nerve gases. In the first place, only supportive treatments were available for the intoxications produced by the principal pre-tabun casualty agents.[28] In the second place, respirators, good anti-gas discipline and decontaminants provided an adequate first line of defence. With the nerve gases, however, it was likely that a far greater number of troops than before would be unable to put on their masks or protect their skin in time, given the poor warning that they were likely to receive.

Despite the extremely rapid action of the nerve gases, medical countermeasures have been developed that hold out promise of substantially reducing the number of casualties likely to be suffered by a combat unit exposed to nerve gas. These are described in Volume II of this study. Essentially, they consist of auto-injectors carried by each soldier with which he can give himself a nerve-gas antidote as soon as he begins to feel the symptoms of nerve-gas poisoning. These devices are reckoned to be capable of saving the life of anyone receiving a median lethal or somewhat greater dose of nerve gas. Larger doses require additional medical aid of a type that the victim cannot administer to himself.

With this type of medical countermeasure, fatalities (but not casualties) from some (but not all) types of nerve gas might be cut down by perhaps one-third or so. [183] Viewed in these terms, auto-injectors are not nearly as important as the provision of efficient respirators or protective clothing in maintaining the combat effectiveness of troops in a nerve-gas environment. It is important to note, though, that when protective devices are worn and casualties do nonetheless occur, existing medical countermeasures can reduce both fatalities and casualties to a greater extent than if protective devices are not worn. The possibility that nerve-gas prophylactics will eventually become available is discussed in Volume II of this study.

Improvements in decontaminants

Continued military operations within areas heavily contaminated by the less volatile CW casualty agents require the use of substances that destroy the

[28] The only agents for which adequate therapies have been developed apart from the nerve gases are lewisite and, to a lesser extent, hydrogen cyanide. As noted earlier, neither of these have ever been really important CW agents.

contaminants. The first of such decontaminants to be employed were used against mustard gas during World War I. They were *bleaching powder* and, to a much lesser extent, *potassium permanganate.* Both compounds destroyed the mustard gas by oxidizing it to its sulphoxide and sulphone. After the war a variety of other decontaminants were studied, chiefly materials other than bleaching powder that contained active chlorine.

In principle, decontamination of a man's skin or of matériel is a simple process, provided sufficient time is available. But in battle, time is generally short. Contaminated individuals in a fighting unit may become casualties in a few minutes. Vehicles and weapons that have been used in contaminated terrain must be decontaminated as soon as possible to reduce contact hazards and to prevent the contaminants being carried to other areas. The longer the decontamination period forced on a defender by chemical attack, the more successful the attack has been, and the more likely is the attacker to gain his objectives. Accordingly, the main focus in decontaminant research work after World War I, and especially after the discovery of the nerve gases, was to find faster and simpler methods for coping with contaminants on the immediate battlefield. The refinement of techniques for dealing with contaminants where the time factor was not so critical was of lesser importance.

By World War II, *superchlorinated bleaching powder* was the most common general-purpose decontaminant. It was effective against all the standard involatile CW agents and was available cheaply. It could be used as a personal decontaminant, in powder or ointment formulations, or as a matériel or terrain decontaminant. In dust dispensers it remains standard antigas equipment for individual soldiers in most of today's armies. For the second function it is also standard equipment for many armies, but here it has two important drawbacks. First, since it is a solid, it is not completely amenable to application by spraying: although it can be made into a slurry, it tends to clog spray nozzles, and in cold weather slurries may freeze. Secondly, its active chlorine content is both rather low and rather unstable. Alternative agents that pre-World War II work had turned up were *trichlorocyanuric acid, NN-dichloromethanesulphonamide* and *1,3-dichloro-5,5-dimethylhydantoin.* The first two, designated *Entgiftungsstoff 40* and *Waffenentgiftungsmittel* (*WEM*), were adopted by the German Army as special purpose decontaminants alongside bleach [52, 184–85]. The third was adopted by the US Army, also for special purposes alongside bleach, in the form of a 6.25 per cent solution in acetylene tetrachloride, known as *DANC solution.* It had disadvantages, notably the alarming toxicity of the solvent, and it is now gradually being phased out of the US inventory. [186] When the G-agents were discovered, bleach could cope with them adequately, but DANC was ineffective (although it was subsequently found to be effective against the V-agents). The search for better liquid decontaminants was therefore accelerated. Another consideration in this search was that as the weather became colder, bleach became increasingly less effective: around freezing point, it was virtually inactive.

The search therefore moved away from active-chlorine decontaminants and explored other types of CW agent decomposition reaction, such as catalysed hydrolyses and oxidations of various types [187]. In the USA an alkaline hydrolytic composition known as *DS-2 solution* was developed. This contains 70 per cent of *diethylenetriamine* as active agent, with 2 per cent of caustic soda as catalyst [186, 188]. DS-2 is effective against all standard CW agents down to temperatures as low as −25°C. It is too expensive a material for wide use by most countries, though, and until its price comes down—and there are indications that it will—cold weather decontamination will remain a problem for many CW establishments.

Summary

The chief weakness in anti-chemical defences remains the problem of protection against percutaneous agents. The only point, however, at which this might have been critical was during the 1950s. Between the late 1920s and the development of the nerve gases, the inability to provide complete protection against percutaneous agents would not have left an up-to-date combat unit open to devastating attack; the protective clothing and decontaminants that had been developed by then would have prevented any repetition of the World War I successes with mustard gas. With the arrival of the G-agents, however, particularly soman with its high toxicity and rather low volatility, the skin protection that had been just about adequate against mustard gas was no longer sufficient. Although completely safe protective clothing had probably still not been developed by the time the V-agents with their even greater percutaneous toxicity appeared on the scene, it seems that such protective clothing as existed had been improved and been given back-up support by the development of better decontaminants and new medical countermeasures for use by forward area troops.

The offensive potential of the nerve gases was thus considerably blunted against modern combat troops carrying up-to-date anti-gas equipment. If an attacker was to achieve any great success with chemical weapons, this could only be by exploiting the time it took for a defending unit to put on its respirators and protective clothing after it had received whatever warning was available to it. The ways in which he might do this are described in the next section.

Developments in chemical weapons since World War I

Chemical warfare during World War I had been fought for the most part with artillery gas shell. Other techniques had been developed, notably cylinder and Livens Projector operations, but they were cumbersome and uncertain. Although with sufficient planning and preparation they might produce a far more devastating effect than artillery gas bombardments, they could not be adapted nearly as readily as artillery to the mobile warfare conditions that gradually developed at the end of the war. Further attempts to mobilize infantry gas weapons could therefore be expected in post-war years. Alongside this work, the development of gas weapons for hitherto unused weapons delivery systems could also be expected, principally the aircraft, but also naval ordnance and, in later years, guided and ballistic missiles.

The following section describes how chemical weapons have developed since 1918 under the influences of changing patterns of warfare, the discovery of new CW agents, and the availability of new weapons delivery systems.

New weapons delivery systems

NAVAL ORDNANCE

Naval staffs were never seriously attracted by chemical weapons during World War I;[29] it has been said that they felt CW to be too dishonourable a method of fighting to be countenanced. Nonetheless, respirators were issued to the crews of most fighting ships against the possibility of surprise attack. German crews are said to have used them against the nitrous fumes produced by detonating explosives. A British ship moored at Zeebrugge in April 1918, HMS *Vindictive,* is said to have been exposed to CW agents, but it is not clear where they originated. [46]

It was appreciated from the early days of CW that gas could be an effective weapon against ships at sea. The confined spaces of a ship would favour the persistence of gas clouds. Decontamination on board ship would be far more of a problem than on land, for ground forces can by-pass a contaminated area while ships have to carry it with them. Meteorological

[29] An exception might be made in the case of the British Admiralty. The Admiralty, specifically its First Lord, Winston Churchill, showed interest in Lord Dundonald's proposal for CW in 1914, eventually developing the notion of naval smoke screens from it [189]. Churchill was also responsible for the first British trials of aircraft-delivered chemical weapons, shortly after the Ypres chlorine attacks. The weapons tested included experimental hydrogen cyanide bombs [20]. But Admiralty interest was short-lived.

conditions over large bodies of water are often much more suitable to drifting cloud attacks than over land. The first two of these points can be illustrated by actual examples.

In December 1943 a US ship berthed in Bari Harbour, the SS *John Harvey,* was blown up during a German air raid. The ship was carrying 100 tons of 100 lb mustard-gas bombs, and most of the bomb-filling found its way into the sea where it dissolved in oil and floated on the surface.[30] In the course of the air raid great numbers of people had jumped or been thrown into the sea and thus became heavily contaminated with mustard gas. (There were 617 known mustard-gas casualties, of whom 81 subsequently died.) Thirty such victims were picked up by an Allied ship, the *Bisteria,* which then put out to sea, heading for Taranto. At the time of the air raid, no one apparently realized that mustard gas was around, certainly not the crew of the *Bisteria*; and with the delayed effects of mustard gas, the thirty survivors on the ship did not at first give any signs of mustard-gas poisoning. Within five hours or so after the *Bisteria* left Bari, however, the mustard gas evaporating from the clothes of the survivors had begun to take effect, and almost the entire crew of the ship began to lose their sight. In due course they were almost all blind (temporarily), and the ship had great difficulty in docking at Taranto. Here, then, was a case of an entire ship losing most of its combat readiness under the effects of at most a kilogram of mustard gas. [191]

The second example occurred three years later. In July 1946 a Liberty ship, the SS *Francis L. Lee,* arrived at a US port to unload 5 000 tons of captured German chemical weapons. During the unloading an accident with these weapons led to the discharge of a considerable amount of mustard gas within the ship. Decontamination measures therefore had to be taken. These proved to be extremely difficult: apart from the liquid mustard gas, mustard-gas vapour had permeated most of the ship, and the below-deck forced-air ventilation system had aided this. Eventually, after 51 000 man-hours of work and the consumption of 26 000 pounds of bleaching powder, 1 500 pounds of caustic soda and 2 200 gallons of DANC solution, the ship was reported clear. [192] According to one report, however, the ship was never properly cleared and had to be sunk [193].

The lesson to be drawn from these incidents was clear. Gas could be an extremely powerful weapon in naval engagements; but if both sides used it efficiently both could suffer enormously, however good their defences.

It is not clear whether any nation actually stocked naval gas weapons during World War II. Development programmes for them certainly existed,

[30] A mustard gas/oil mixture had been developed by Edgewood Arsenal around 1924 as a means of contaminating sea surfaces against amphibious landings [190].

for example US Navy work on armour-piercing selenium dioxide weapons and projectiles containing cacodyl derivatives [165, 194]. But in addition to the powerful disincentives against using gas in naval actions, there was also the hazard of even having chemical weapons on board ship, with the risk of leakage. While a number of proposals have been made in post-World War II years for reducing storage hazards—notably the use of built-in decontaminants [195] and the recent US work on "binary" nerve-gas weapons[31]—fear on this score must inevitably further reduce the attractions of CW at sea.

Naval gas operations are thus likely to be attractive only in a ship-to-shore context, and it appears that existing US Navy chemical weapons are all intended for use by off-shore fire-support ships.

AIRCRAFT

It is said that during World War I the air forces of all the belligerents refused to participate in the gas war, although the Chiefs of Staffs recognized the utility of air-delivered chemical weapons. A certain amount of development work on such weapons was carried out, however, but of a very rudimentary kind. In early 1915 the British were experimenting with aerial bombs charged with AC in both British and French proving grounds; and, as noted earlier, the Commander of the British Expeditionary Force called for chemical bombs as part of his retaliatory CW matériel. [20] The US Army CWS claimed it had designed a practical chemical bomb by 1918 [196].

The Allied and Central Powers accused each other of using aerial gas bombs during the war, but all the reports of such incidents were either unconfirmed or stated to be false [20]. A German communiqué in October 1916 reported twelve civilian gas casualties from bombs dropped on Metz and Lorraine villages [197]. In March 1918, US positions near Toul were said to have been bombed with mustard gas on at least three occasions [198–99]. In July and August 1917 and again in July 1918, line commanders on certain sections of the British front reported being bombed with munitions containing Blue Cross agents [17].

Civil defence authorities in Paris and London had made preparations to meet chemical attack. In June 1915 there had been plans to issue service respirators to police forces in Paris against possible Zeppelin gas raids. [200] A British War Cabinet committee set up to study the air defences of the United Kingdom after the heavy German attacks on London of July

[31] These are described in Volume II of this study.

1917 thought that gas bombs would probably be used in subsequent raids [201]. This fear proved unfounded.[32]

Some evidence suggests that the strategic gas bombing of cities was nonetheless being contemplated during the war. Professor Haber, lecturing in Berlin in 1926, spoke of suggestions made by Count Zeppelin for the gas bombing of Verdun; these were apparently turned down by the Chief of the German Imperial General Staff because the techniques of Zeppelin bombing were too inaccurate at the time [204]. Another authority refers to plans made by the British Independent Bombing Force during the closing stages of the war to include gas in the bombloads with which it was proposed to attack Berlin (both from English bases and from those that had recently become available in Prague) [205]. However, there is no indication that a decision was ever made to initiate strategic gas bombing [51].

Quite apart from the dislike of CW shown by the contemporary air forces, a powerful explanation for the absence of aerial gas warfare during World War I is simply that the available weapons were not good enough. For the small bombloads then possible, mustard gas was the only CW agent that was remotely suitable, and for the Allies' part there was barely time enough before the Armistice to develop manufacturing processes for the agent, let alone specialized munitions. [17]

Alongside the post-World War I exploration of aircraft-delivered chemical weapons, the air arm as a whole was developing rapidly. Aircraft payloads increased, so that if chemical weapons were to be used from the air they could probably be employed against large targets. The "aerochemical" arm thus attracted the attention of popular writers, both sober and scaremongering. The advent of the strategic bomber was seen as the forerunner of total warfare in which civilians and military alike would be targets of attack; with bombloads of rumoured new-found CW agents, the mass destruction of populations of whole continents was predicted [206, 207]. Official attitudes seemed to confirm this nightmare and in the USA Congressional testimony from the armed services in the early 1920s contained horrendous figures: 200 tons of phosgene dropped in bombs from a comparatively small fleet of aircraft would be enough to kill every occupant of an area 100 miles square (US Army Air Corps) [208]; one aeroplane carrying 2 tons of a newly discovered percutaneous agent—lewisite, presumably—could spray an area 100 feet wide and 7 miles long with enough agent to kill practically every man in it through his skin (US Army Chemical Warfare Service) [208–209].

The apparent official recognition of the tremendous dangers of aero-

[32] The discovery of a Zeppelin gas bomb was recently reported from the west of England [202], but the device in fact dated from the time of World War II and had nothing to do with Zeppelins or the Germans [203].

chemical warfare held out by its publicists probably had motivations other than a respect for the truth: as we shall see, official attitudes to the effectiveness of counter-city gas bombing were in fact decidedly dismissive. But there is no doubt that it reflected—and encouraged—a widespread attention to the new weapons.

Two types of chemical weapon were being developed for aircraft use—the bomb and the spray tank. The latter could be used from both light and heavy aircraft; the former would probably be militarily useful only if delivered in massive bombloads. At the time of World War II, gas bombs were the dominant weapon in CW stockpiles. The USA regarded its 50 kg mustard-gas bombs as its principal retaliatory CW weapon [210]: when the USA entered the war it had some 24 000 of them available [51] and by the end of the war well over a million [30]. In contrast, US spray-tank stockage was about 1 500 in 1942 [51] and 113 000 in 1945 [30]. Well over half of the German CW agent output was filled into chemical bombs [51, 52], principally of 250 kg rating, at first charged with phosgene or mustard gas but later with tabun; at the end of the war half a million such bombs were found in the British and US zones of occupied Germany [211].

For large-scale CW attacks, the heavy bomber would undoubtedly be the most economical delivery system. However, although in 1945 the US Army CWS reckoned that it could reduce Japan to surrender within three months by concentrated B-29 gas-bombing operations, no nation seems ever seriously to have contemplated using gas for strategic attack. With the present decline of the heavy bomber, whatever attractions there might have been in strategic gas warfare are presumably diminishing still further. One should note, though, that the bombload of a World War II heavy bomber can now be carried by a single modern fighter-bomber, and that nerve-gas bombs greatly exceed those containing mustard gas in efficacy.

MISSILES

When Germany was preparing to launch its missile attacks during World War II, there was considerable fear in London that these might include CBW warheads. In fact this was not so, although the possibility appears to have been considered by German CW people. They felt that the payloads of the rockets, about 1 ton, were too small, so that with the low rates of fire then possible it would not be feasible to establish effective CW agent dosages over areas of any great size. Furthermore, under the circumstances, HE payloads, causing material damage as well as loss of life, would be more profitable. Had payloads of several tons been possible, CW warheads might have been designed: their role would have been to set up great clouds of vapour that would drift with the wind over populated areas. [212] The question was essentially one of cost versus effect, and the costs of ballistic-missile operations are great.

With the development of the post-tabun nerve gases, however, such cost-effect calculations became less unfavourable, and apparently during the late 1940s or early 1950s work on CW missile warheads began. If reports of US intelligence assessments are to be believed, the USSR was the early leader in this field, developing nerve-gas missiles in an attempt to field something comparably effective against the small US nuclear weapons. [213] In due course, so it is said, the USSR deployed medium-range nerve-gas missiles in bases within the USSR [997] and, more recently, produced similar warheads for rockets in what NATO calls the *Frog* and *Scud* series [998].

The first US chemical warheads appear to have been developed for *Corporal* and *Honest John* missiles in the late 1950s. At the present time the US inventory contains nerve-gas warheads at least for *Honest John, Little John, Sergeant* and *Lance* missiles. These are referred to again in Volume II of this study.

Changing military requirements

This section deals with the adaptability of gas to changing patterns of warfare. Following the remarks in the preceding section about heavy bomber and missile delivery, it begins with a short commentary on the notion of gas as a weapon of mass destruction. It then describes the development of gas as a modern battlefield weapon and as a weapon of what the USA calls "lower-case" or "counter-insurgency" warfare. It closes with a short discussion of the use of CW agents in irregular weapons, such as those intended for assassination and clandestine use. In all cases the treatment is intended principally to provide an historical introduction to more detailed discussion in Volume II of this study.

GAS AS A WEAPON OF MASS DESTRUCTION

During the 1920s and 1930s many people felt that the rise of aerochemical warfare had provided the means for destroying life on an unprecedented scale. Some of the predictions made at the time credited chemical weapons with mass-destruction capabilities comparable to those made nowadays about nuclear weapons.[33] Such fears are discussed in Chapter 3. Typical predictions included estimates that a dozen lewisite bombs might elimi-

[33] For example, during a debate in the British Parliament in 1927 one speaker made the following remarks [214]: "Our cities will be not merely decimated but rendered utterly uninhabitable by chemical bombs. Bombs are now being manufactured... which would render utterly impossible for days...any kind of life, human, animal or vegetable. These things make us realise that it is not war in the ordinary sense that we are talking about. ... We are faced with the wiping out of our civilisation."

nate the entire population of Berlin [215], or that a single bomb dropped on Picadilly Circus, in the middle of London, would kill everyone from Regents Park to the Thames [216]. These popular assessments did not coincide with those made by the military establishments, who generally rated the casualty-producing ability of the CW agents of the time as being about the same as that of conventional weapons, bombload for bombload. The military establishments thus had little incentive to develop gas as a weapon for large-scale attack on civilian targets. If they were forced to mount such attacks as retaliatory measures, these would be made more as a gesture than in the expectation of securing substantial strategic advantage. There was little to be gained by killing civilians; it would be far more advantageous to destroy their homes, their factories or their transportation.

Although popular fear that great numbers of civilians were in imminent danger of being gassed had been aroused primarily by the threat of counter-city gas attacks, there was also the possibility that large numbers might also be killed by clouds of gas drifting downwind from battlefields. This was a far more real danger, but again the capabilities of the chemical weapons of the 1930s were probably not sufficient to create a massive hazard by this means. In the first place, the huge drifting cloud attacks practised in World War I—which had indeed killed civilians some distance behind the lines—had been rendered obsolete by increasing battlefield mobility. In the second place, the projectile-delivered agents of the time were not toxic enough and were unlikely to be used in sufficiently large quantities to establish dangerous dosages more than a few hundred metres downwind. There would undoubtedly have been large numbers of noncombatant gas casualties if CW had been used during World War II, but it is not obvious that these casualties would have greatly exceeded those due to conventional weapons.

With the arrival of the nerve gases, however, the possibility of huge civilian gas casualties, both intended and unintended, has greatly increased. Even if the likelihood of deliberate nerve-gas attacks on civilian targets can be discounted for strategic reasons in the event of a future major war, the use of nerve gas against combatants would inevitably kill great numbers of noncombatants living around the battle zones. In the case of a chemical war in Europe, the figure might well be in tens of millions. [213] Figures given in US Army CBW manuals, for example, imply that the burst of a single Honest John sarin warhead could create dangerous dosages up to 100 km downwind, if the weather permitted.

Nerve-gas weapons must therefore be regarded as potential weapons of mass destruction even if their users or designers have no intention of employing them against anything other than battlefield targets.

DEVELOPMENTS IN BATTLEFIELD CHEMICAL WEAPONS

Battlefield chemical weapons have been in a state of fairly continuous development since World War I. Two broad trends will be described: (*a*) the development of World War I infantry gas weapons into weapons better suited to a mobile battlefield, and (*b*) the development of weapons that can create surprise airborne casualty dosages over ever wider areas.

The mobilization of infantry gas weapons. The principal infantry gas weapons of World War I had been the cylinder, the mortar and the Livens Projector.

The large World War I cylinder, whose handling required two men, was clearly an obsolete weapon. Even lightweight cylinders, weighing 25 kg or so, such as the British were experimenting with in 1917 [20], had little future in combat, for they were essentially trench-warfare weapons; whatever their size, they were ill-suited to a shifting front. The farther away the enemy, the weaker would be the gas cloud reaching him; and on most occasions the chance of his being sufficiently close and of the weather being right was clearly going to be small. During World War II one of the few situations where cylinders might have been useful was during the US attempts to reduce Japanese cave defences [30], for here the situation was comparable to the old trench-warfare conditions. On a mobile battlefield, phosgene-chlorine cylinders were not often going to be worth their weight—which still had to be fairly large if they were to produce any effect. One alternative which was considered, and indeed used by the Japanese, was the toxic smoke pot, developed from the British M device of 1918. Such weapons generated a toxic aerosol from combustion of a pyrotechnic mixture containing the agent, and although they were just as weather-dependent as the cylinders, they could be much smaller and lighter, for the sternutatory agent generally used in them was effective at far lower field concentrations than phosgene. There was therefore a much better case for carrying around smoke pots against the possibility of suitable target and weather conditions. Nonetheless, it was not a widely deployed weapon during World War II, and there seems to be little interest in it now.

The chemical mortar was a far more attractive weapon, even in the heavy calibres required for effect with chemical projectiles. It could be carried about fairly easily or mounted on a small wheeled chassis, and was not greatly dependent on the weather. It could set up high vapour concentrations with volatile agents or dense ground contamination with involatile ones. Apart from anything else, it could as well fire HE or smoke projectiles as gas. Thus during World War II the chemical mortar of around 100 mm calibre was the principal infantry gas weapon. The World War I

Stokes mortar provided the basic design: its range was increased, its construction made more robust and its rate of fire improved. It remains one of the basic chemical weapons.

The Livens Projector, like the cylinder, demanded a great deal of manpower and preparative time before it could be used on any scale, but it was not nearly as weather-dependent as the cylinder. Furthermore, it had the great advantage that if used in large enough batteries it could create sudden massive field concentrations of agent over large target areas. If the object was to gas large numbers of the enemy before they could put on respirators, projectors were the best means available for doing so. Neither mortar nor artillery units could produce this effect without an elaborate concert of effort. Livens Projectors were thus still in the operational chemical-weapons inventories of a number of the belligerents during World War II (as were phosgene-chlorine cylinders). In October 1940 the British, for instance, had 25 000 Livens Projector projectiles on hand, filled with mustard gas or phosgene.

The search for a mobile equivalent of the Livens Projector culminated shortly before and during World War II with the development of multiple rocket launchers. Rockets did not have to withstand explosive propellants as did mortar projectiles and the bombs for the Livens Projector itself; this compensated for the weight disadvantage imposed by the rocket motor. If ways could be found of launching small rockets accurately and over a useful distance, then it should be no great problem to develop mobile launch units capable of dispensing a multitude of rockets at a time. Ways were duly found. Only the Soviet Union and Germany in fact used such weapons —but not with gas payloads—on any scale on World War II battlefields. The Soviet Union had a range of *Katyushas* and *Vanyushas,* some mounted on vehicles, others on wheeled trailers. Germany had *Wurfgeräte, Raketenwerfer* and multiple-tubed *Nebelwerfer* which could take rockets from 15 cm up to 32 cm calibre [125]. For chemical payloads, the USA experimented with 24-, 48-, and 56-tube launchers for 7.2 inch rockets and with a small bazooka rocket [217, 218]. The British had multiple launchers for 5 inch chemical rockets; when CW did not break out these were adapted for use as anti-aircraft HE barrage weapons [217, 219].

Modern multiple rocket launchers have improved considerably since World War II and have a range comparable with that of equivalent calibre tube-artillery. They give ground forces the area-attack capability of ground-support aircraft. A pair of typical launchers can set up a lethal dosage of sarin over a square kilometre or more in less than half a minute.

The improvement of surprise dosage weapons. Besides the Livens Projector, artillery had been the weapon used during World War I for surprise dosage gas shoots. The huge concentrations of artillery that were possible under trench-warfare conditions permitted such surprise shoots with the gas weapons of the time. But with increasing battlefield mobility and, later, because of the dispersion demanded by the tactics of nuclear warfare, large batteries of heavy guns would become rarer, and thus the ability of artillery to set up surprise dosages of CW agents over large areas decreased. This was not compensated for by the greater accuracy of post-1918 artillery, resulting from improved ballistics, nor by the greater efficiency with which artillery gas shell could disseminate their fillings, resulting from better fusing (time fuses, super-quick point-detonating fuses and, later on, proximity or VT fuses). By World War II, many of the belligerents had abandoned artillery shell as a means for disseminating respiratory casualty agents; they concentrated mainly on mustard-gas shell for ground contamination and irritant-agent shell for harassment. (Small-calibre, irritant-agent, armour-piercing shell were available that were potentially useful anti-tank weapons [125, 220].)

With the development of the nerve gases, however, the much greater toxicity of shell payloads compensated for their rather low volume and artillery shell for surprise dosage shoots with respiratory casualty agents again became popular. Those that have been developed by the USA [221] follow the principle of the old German Double Yellow Cross shell of 1918, as later elaborated by the Germans during World War II, in which a massive HE charge is used to shatter the payload [148]. This gives an increased aerosolization of the agent and hence a higher airborne field concentration. A typical modern HE-burst nerve-gas shell contains almost half as much HE as, say, VX and is proximity- or time-fused for airburst to avoid crater losses and to increase area coverage.

Even with these improved projectiles, artillery cannot match the surprise-dosage, area-coverage performance of multiple rocket launchers. To achieve a casualty-producing surprise dosage of sarin over a square kilometre target area would require the concerted fire of at least six 6-weapon batteries of 155 mm howitzers, under the most favourable weather conditions. [222]

Use of the multiple rocket launcher is severely limited by the virtual impossibility of concealing its location once in use. The enormous flash and smoke cloud produced by the discharge of a rocket barrage can be expected to attract swift enemy counterfire. To some extent this limitation can be reduced by increasing the mobility of the launcher, so that it can be moved rapidly away after each discharge, but this is an unsatisfactory procedure at the best of times. Ground support aircraft are therefore the preferred weapon for setting up surprise dosages of casualty agents over large areas.

Generally speaking, the aircraft spray tank is accurate only when used from low altitudes, in which case its efficient employment is easily perturbed by ground fire. The contamination pattern that it produces can to some extent be mimicked by in-line bomblet dispensers of the type pioneered by the USSR in such weapons as the *AK-2* mustard/lewisite dispenser.[34] Because the bomblets are not nearly as sensitive to meteorological conditions, dispensers can be used at much higher altitudes than spray tanks. However, unless the bomblets are fitted up for airburst above the ground the effective area coverage is inferior to that of a spray tank, even if it is more accurate.

Other compromise approaches that have been tried include the use of large agent containers dropped from the aircraft, spraying agent out as they fall [224]. During World War II the British had one such device, which they supplied to the Americans while the latter were building up their CW capability; it was known as a *Flying Cow* [210]. Work on this type of weapon still continues [225].

The aircraft bomb is a more versatile weapon than the spray tank, even though it lacks the latter's potential for area coverage. At the time of World War II a typical chemical bomb comprised a large streamlined container filled with liquid CW agent and equipped with a central HE burster tube. For agents such as AC, the larger the bomb was the longer the agent-vapour cloud persisted at ground level, but for less volatile agents, or those with a higher vapour density, the bomb size was chiefly governed by the configuration of existing bomb racks. A number of refinements were developed for mustard gas. One was the use of very heavy burster charges to increase area coverage and aerosolization, a technique used principally by the Germans for tabun as well as mustard gas [125, 226]. In another, base-ejection designs were used: the bomb was supposed to embed itself in the ground, whereupon a propellant charge in the nose ejected mustard-gas canisters through the tail and up into the air where they exploded [220, 227–29]; the British used a similar technique in some of their phosgene bombs [160]. A third refinement, the use of cluster bombs, was the most important, however, for it anticipated later needs for efficient ways of spreading highly toxic agents.

Cluster-bomb designs emerged from World War II work on both mustard gas and incendiaries. For mustard gas, a massive bomb invariably pro-

[34] Descriptions of this weapon derive from examples captured by the Germans in 1942. It was a 16-tube downward-discharge bomblet dispenser, with fifteen bomblets per tube. Four such units could be carried in the bomb bays of typical World War II Soviet bombers. Each bomblet consisted of a frangible metal sphere containing about a kilogram of CW agent. The entire payload of bomblets could be dispensed in less than two seconds, so that about a ton of agent could be dropped along 200 metres or so of flight path by individual aircraft. [223]

duced gross over-contamination of the ground in the immediate vicinity of the bomb burst and was therefore uneconomical. For incendiaries, it was found that the initiation of many small fires over a wide area was more productive than an intense conflagration in the middle of the area. Weapons were therefore designed in which large numbers of small mustard-gas or incendiary bombs could be dropped as a single unit from an aircraft; the cluster would break open during its fall to scatter the bombs over a wide area. In the USA, at least, the early cluster-bomb designs were the same whether charged with incendiary or with mustard gas [220].

With the arrival of highly toxic respiratory agents—not only the nerve gases but also solid agents such as ricin and other toxins—the problem of gross over-dosing around the point of burst was intensified. Towards the end of the war and after it, cluster bombs were therefore being developed for respiratory agents as well as for mustard gas [79, 167]. The first such US weapon, the *M-34* cluster for sarin, was based directly on a mustard-gas design that had been standardized at the end of World War II.[35]

Even though the World War II cluster-bomb designs were a great improvement over massive bombs for air-dropped nerve gas and toxin weapons, the high toxicity of the agents was clearly still not being exploited to the full. Further ways had to be found of reducing local over-dosage. The most significant improvement came with the development of Magnus-effect bomblets, in which the old cylindrical bomblet was replaced by a spherical one provided with small carefully-shaped vanes that would impart horizontal motion to the bomblet after ejection from the cluster unit. By such means, the lateral dispersion of the bomblets over the target area was greatly increased. By using several hundred such bomblets per cluster, each containing only a few hundred grammes of agent, a much greater effective area coverage was achieved than with the old designs [231–33].

The self-dispersing bomblet principle has been adapted to other types of area-effect weapons, not merely CBW ones, but also fragmentation, smoke and incendiary weapons. It is applicable as much to cluster-bomb units as to in-line bomblet dispensers [233–34]. It is also applicable to missile warheads and is used for sarin and VX in US Lance, Sergeant, Little John and Honest John warheads [222].

Refinements of the self-dispersing bomblet principle, used to increase area coverage still further, are the incorporation of rocket motors in the cluster unit to spin out bomblets like a pin-wheel [235], and the use of

[35] The cluster was for the M-74 series of 10 lb tail-ejection bombs, originally standardized both for mustard-gas and incendiary fillings. The M-74 bomb remains on the US operational inventory, but only with an incendiary filling. [230]

cluster units of cluster units. The latter are described later in the context of biological weapons.

GAS AS A COUNTER-GUERILLA WEAPON

In Viet-Nam, the USA demonstrated the uses to which chemical weapons may be put against (*inter alia*) guerillas. This is described in Chapter 2. From the point of view of weapon technology, there are two aspects of particular interest: first, the development of an extraordinarily wide range of chemical weapons for the infantryman; second, the manner in which weapons were designed around a single irritant agent—CS—to serve the functions not only of harassment but also of casualty production and area denial.

When US infantrymen first began to use chemical agents in Viet-Nam, the only individual weapons they had were irritant-agent hand and rifle grenades. These could produce harassment over a maximum area of perhaps 150 m^2, at ranges of up to 145 metres. Within a space of less than three years, the infantryman was equipped with a whole battery of weapons that trebled his range and increased his area coverage capability by a factor of thirty. The weapons are listed in Chapter 2; some are further described in Volume 2 of this study.

On the second point, US chemical-weapons designers were obliged to restrict themselves to irritant agents. They had little guiding experience with past usage of such agents in the type of warfare being waged in Viet-Nam. Apparently what they did was to develop CS weapons for every delivery system in use in Viet-Nam, sending out batches for operational evaluation and then deciding which to develop further. The current US Army training circular guiding irritant-agent employment in Southeast Asia lists CS weapons for grenade-launchers, mortars, cannon, howitzers, multiple rocket launchers, low-performance and high-performance fixed-wing aircraft, and helicopters. The manual states that many of these are experimental weapons for which "users are urged to submit after-action reports". Precisely which of these weapons, and the others sent to Viet-Nam after the manual was compiled, found especially attractive applications is not known.

Irritant-agent procurement figures suggest that the use of CS for area-denial operations became increasingly popular, so much so that by 1969 over half the CS procured was apparently being used for this purpose. Previously, use of percutaneous casualty agents was seen as the principal chemical means of area denial. In Viet-Nam, however, where respirators were initially available only to US and ARVN forces, it proved possible to use CS for this purpose also. The powdered agent was dusted onto the ground so that anyone passing across it stirred it up into an intolerably irritant cloud. The agent was made available in a modified form (*CS-2*) that had an increased persistency on the ground. The powder particles were coated with a silicone water-repellent to resist weathering and to remain effective even on damp or swampy ground. On open terrain, under normal weather conditions, untreated CS powder (*CS-1*) is effective for about a fortnight; for mustard gas, the period would be less than a day; for VX, perhaps three or four days (in a tropical climate).

By 1968 four principal types of filling for CS weapons were being used. They were as follows:

1. Technical grade CS. This is crystalline CS of about 96 per cent purity. It is used in thermogenerator weapons such as the *M7A3* and *XM54* grenades. The CS is contained in gelatine capsules embedded in a pyrotechnic composition. [236]
2. CS/pyrotechnic mix. This is used in burning-type weapons based on a modification of the thermogenerator principle. Powdered CS is mixed into a pyrotechnic composition, making up 40 to 50 per cent of its weight. [236]
3. CS-1. This is micronized CS powder mixed with 5 per cent of silica aerogel [180] (*Cab-o-Sil 5* [237]). It is used in HE burst weapons, such as the *M25A2* grenade, and in bulk-agent dispersers.
4. CS-2. This is CS-1 treated with *hexamethyldisilazane* [237].

The aerosol produced by thermogenerator CS weapons is made up of particles of around 2 microns diameter [238]. As supplied by the manufacturer, CS-1 and CS-2 are powders of about a micron diameter (mass median); CS-1 or CS-2 aerosols generated in the field may or may not have as fine a particle size, depending on weather and operational conditions.

WEAPONS FOR CLANDESTINE USE

Certain CBW agents have properties which suggest that they are well suited to clandestine use. One such property is their ability to kill or disable after a latent period during which their presence is not sensorily perceptible. An attacker exploiting this insidiousness may have a greater chance of avoiding detection or capture after delivering his attack than if he used a more conventional weapon. In addition, the area effectiveness, and hence the kill capability, of a weapon disseminating a CB aerosol may far exceed that of an equivalent weight of some other weapon. The same would hold for an operation in which CBW agents were used to contaminate food supplies or drinking water.

There is an appreciable literature on the past use of CBW agents for these purposes, and on present-day activities to do with the design, procurement and deployment of such weapons. While the provenance and context of this literature is generally far too disreputable to warrant serious attention, the realities of the world and the obvious suitability of the weapons to the functions described for them confer a measure of credibility. The absence of adequate substantiation in the various reports may be as much due to the fact that they concern activities that are normally and necessarily kept well away from the public eye, as to the possibility that they are fabrications.

Published references to the clandestine use of CW agents during World War II mainly relate to the operations of Soviet and Polish partisans against German forces of occupation [30] and to operations mounted by the US Office of Strategic Services [92] and the British Special Operations Executive. One such operation mounted by the latter organization achieved the assassination of Reinhardt Heydrich, the German *Reichsprotektor* of Bohemia and Moravia, who died in 1942 some hours after receiving a flesh wound from a bullet containing botulinal toxin. Incidents allegedly involving the clandestine use of BW agents are referred to in Chapter 2.

As regards more recent times, there have been published references either to the use or to the possession of clandestine CB weapons by such organizations as the Special Forces of the US Army, the Komitet Gosudarstvennoi Bezopasnosti of the USSR, and the Unutrašnja Državna Bezbednost of Yugoslavia [93, 928–31]. In addition, certain unofficial paramilitary organizations are reported to have equipped themselves with the weapons [932–33]. These and other publications include purported descriptions of weapons designed either to assassinate individuals or to kill or disable groups of people. The assassination weapons include ones intended both for close-up use and for use at a distance. The former are distinguished from more conventional instruments of murder in that they are designed to conceal their function from the victim and to attract the minimum of attention when used. One such weapon employs a spring-loaded mechanism to discharge a spray of hydrogen cyanide into the face of the victim, who is then likely to die within seconds. The long-range weapons are based on high-velocity projectiles. Some are designed to ensure that the victim dies even if the projectile fails to hit a vital organ; others dispense projectiles so small and apparently harmless that the victim is scarcely aware of having been struck by them. For these weapons the poison need not be as quick-acting as hydrogen cyanide, but it must be more toxic; it is often a toxin. The literature contains references to rifle bullets and small rifle-projected darts or flechettes treated with such agents as aconitine, botulinal toxin and saxitoxin. It is reported that a leg wound with an aconitine-containing bullet kills in about two hours; a saxitoxin-coated flechette may kill in less than fifteen minutes.

The weapons intended for clandestine use against groups of people work by setting up aerosol or vapour clouds of the agent. Such a weapon may be designed either to overcome its victims before they can take counter-measures, or to be so inconspicuous or disguised in operation and delayed in effect that they do not notice it. The occupants of a building or a vehicle might be typical targets. Other types of clandestine mass-effect CB weapon include those intended for water- or food-contamination. Several weapons of these different types have been described: the concealable canister of hydrogen cyanide that is shattered by an explosive charge detonated by a radio-controlled fuse; the "aerosol" spraycan of nerve gas; the small powder-disseminator that blows out an inconspicuous aerosol of botulinal toxin, *Bacillus anthracis* spores or staphylococcal enterotoxin; the gelatin-encapsulated culture of intestinal pathogens intended for drinking water; and the rifle-fired explosive shell containing botulinal toxin or anthrax spores.

II. *Biological weapons*

Introduction

The history of past usage of biological weapons, described in Chapter 2, is primarily that of pathogens employed for sabotage. The form of biological warfare which is most to be feared today is its use as a method of mass destruction. While examples can be put forward to suggest that covert use of pathogens may lead to disease and death on a gigantic scale—the sabotage of the rabbit population in the Eure et Loire department of France in 1952 with myxomatosis virus might be one such example—the use of pathogens on a scale too large for the individual saboteur is the main threat of the present time. This chapter provides a brief account of how this new threat arose.

Biological warfare is so particularly odious that most governments are reluctant to say much about their preparations, even in defence against it. For this and other reasons the literature on the subject is much more fragmentary than for CW, and in the account which follows only the broadest statements are generally possible.

After World War I popular writers apparently began to pay attention to the possibilities of large-scale germ warfare some time before official[36] or military interest in it arose [206, 215, 239–49]. By World War II, at least

[36] It is reported, however, that in 1917 Dr Haber, in charge of Germany's wartime CW effort, founded a technical division attached to the Prussian War Ministry to develop defensive measures against animal and vegetable parasites [250].

four countries were taking official or semi-official notice of BW. These were Germany [251], the UK, France,[37] Japan and, less certainly the USSR[38] [252–53]. Of these—and no doubt there were others—it appears that the Japanese programme was the first to become at all extensive, and for this reason a description of its main features and results will be used as a starting point for the subsequent discussion. The discussion is primarily concerned with showing how biological weapons other than sabotage weapons began to be developed; for this reason it is weighted heavily towards the offensive side of BW. The development of protective measures against BW attack is described more fully in Volume 2 of this study.

The Japanese biological weapons programme, 1934–1945

The main body of information on the Japanese BW programme comes from two sources: first, reports of the interrogation of personnel involved in the programme by their US captors [254–55]; second, reports of the trial of twelve other such personnel by a Soviet military tribunal at Khabarovsk [91]. These are not the most desirable types of source material, and the usefulness of the following account is limited by their obvious flaws. Thus, the Americans did not occupy the principal Japanese BW facility in Manchuria and therefore had little opportunity to check the statements of their captives; and the latter were no doubt influenced in giving their evidence by the imminence of the Tokyo War Crimes Tribunal. The Khabarovsk trial—whose lengthy proceedings were swiftly translated into English and widely circulated—took place in December 1949, more than four years after the war had ended.

The summary and conclusion of one of the US reports was as follows [255]:

1. Responsible officers of both the [Japanese] Army and Navy have freely admitted to an interest in defensive BW.
2. Naval officers maintained that offensive BW had not been investigated.
3. Information has been obtained that from 1936 to 1945 the Japanese Army fostered offensive BW, probably on a large scale. This was apparently done

[37] French BW activities are said to have begun around 1936. The CW R & D establishment at the Poudrerie Nationale du Bouchet contained a bacteriological laboratory at the time of its capture by the Germans [59].
[38] A 1928 publication stated that the Soviet Union had set up a military proving ground to the north of the Caspian Sea to examine bacterial bombs [253]. It is not known whether this statement was true or false. German intelligence documents captured by the Western allies at the end of World War II are said to make reference to extensive Soviet BW R & D activities that had been under way at least by 1934. From the open literature, however, nothing is known of these documents beyond the fact of their existence. Reports that Soviet saboteurs employed BW agents in Japanese-occupied Manchuria are referred to later.

without the knowledge (and possibly contrary to the wishes) of the Emperor. If this was the case, reluctance to give information relative to offensive BW is partially explained.
4. BW seems to have been largely a military activity, with civilian talent excluded in all but minor roles.
5. The initial stimulus for Japanese participation in BW seems to have been twofold: (*a*) The influence of Lt Gen Shiro Ishii. (*b*) The conviction that the Russians had practised BW in Manchuria in 1935, and that they might use it again. (The Chinese were similarly accused.)
6. The principal BW center was situated in Pingfan, near Harbin, in Manchuria. This was a large, self-sufficient installation with a garrison of 3,000 in 1939–1940. (Reduced to 1,500 in 1945.)
7. Intensive efforts were expended to develop BW into a practical weapon, at least eight types of special bombs being tested for large-scale dissemination of bacteria.
8. The most thoroughly investigated munition was the Uji type 50 bomb. More than 2,000 of these bombs were used in field trials.
9. Employing static explosion techniques and drop tests from planes, approximately 4,000 bombs were used in field trials at Pingfan.
10. By 1939, definite progress had been made, but the Japanese at no time were in a position to use BW as a weapon. However, their advance in certain bomb types was such as to warrant the closest scrutiny of the Japanese work.
11. Japanese offensive BW was characterized by a curious mixture of foresight, energy, ingenuity, and at the same time, lack of imagination with surprisingly amateurish approaches to some aspects of the work.
12. Organisms which were considered as possible candidates for BW, and which were tested in the laboratory or in the field included: All types of gastrointestinal bacterial pathogens, P. pestis (plague), B. anthracis (anthrax), and M. malleomyces (glanders).
13. Japanese defensive BW stressed: (*a*) Organization of fixed and mobile preventive medicine units (with emphasis on water purification). (*b*) An accelerated vaccine production program. (*c*) A system of BW education of medical officers in all echelons (BW Defensive Intelligence Institute).
14. The principal reasons for the Japanese failure were: (*a*) Limited or improper selection of BW agents. (*b*) Denial (even prohibition) of co-operated scientific effort. (*c*) Lack of co-operation of the various elements of the Army (e. g. Ordnance). (*d*) Exclusion of civilian scientists, thus denying the project the best technical talent in the empire. (*e*) A policy of retrenchment at a crucial point in the development of the project.
Conclusion. It is the opinion of the investigating officers that: (*a*) If a policy had been followed in 1939 which would have permitted the reasonably generous budget to be strengthened by an organization with some power in the Japanese military system, and which would have stressed integration of services and cooperation among the workers, the Japanese BW project might well have produced a practicable weapon. . . .

From the US assessment of the Japanese BW effort, it appears that one of the first approaches towards finding ways of waging BW on a large scale was to design aircraft bombs containing bacterical agent slurries. The Japanese had produced eight basic bomb designs, including an experimental cluster unit, but concentrated on three of them only. Two were intended to disseminate airborne clouds or aerosols of BW agent, while the third was for percutaneous infection and ground contamination. The main features of these three bombs are described at the end of this section.

Besides the aircraft bomb, other possible BW weapons that were studied at Pingfan[39] included artillery shell, speedily rejected as impractical, and the aircraft spray tank, on which a lot of work was done. Here the aim was to generate a large bacterial cloud several hundred feet above the ground which would sink, expanding further in size, to produce an infective aerosol over a very broad area at ground level. Field trials were carried out with spray tanks charged with slurries of simulant BW agent. General Ishii[39] was reported to have appreciated that spray tanks charged with finely-divided powders of dried agent were potentially far more effective, but dry-agent spray trials were not performed. In the first place, the freeze-drying facilities at Harbin were too limited in capacity to produce an adequate quantity of dried material; in the second place, the process of milling or grinding dried pathogens was felt to be too hazardous.

US interrogators felt that a substantial amount of work was done at Harbin on developing BW sabotage weapons, in view of the apparent large-scale production of intestinal pathogens, principally the causative agents of typhoid fever, dysentery and cholera. The available reports of their interrogations, however, show that little information on this could be obtained from their subjects. At the Khabarovsk trial, on the other hand, all the defendants described work on sabotage techniques, and the overall picture emerging from the trial is that a large range of sabotage techniques of proven efficacy were developed.

Evidence was also presented at Khabarovsk of Japanese development of a third technique for waging biological warfare, namely the use of infected

[39] The history of this establishment, as it emerges from the US reports, is as follows. In 1934 or 1935 work on offensive BW began in laboratories attached to the military hospital at Harbin. Two stimuli for this are stated. The first was Major Ishii's influence and personal interest in BW, which was said to have been aroused during a European tour in the course of which he heard BW discussed at the League of Nations. The second stimulus was the capture of a number of Soviet saboteurs carrying vials of anthrax and cholera bacteria. In 1937 the Japanese War Ministry was sufficiently convinced of the value of Ishii's work to authorize its expansion, and construction work at Pingfan, near Harbin, was begun. By 1939–40, 3 000 workers were garrisoned at Pingfan, and the BW programme was at its height. Thereafter the scale of effort declined. With the Soviet advance into Manchuria, the establishment and its store of biological weapons were destroyed and all records burned in August 1945.

insect vectors to spread disease. The principal BW agent described in this connection was the plague-infected flea. One of the defendants spoke of field trials in 1941 of porcelain aircraft bombs that discharged large numbers of such fleas on impact with the ground; another spoke of the discharge of fleas at high altitudes from aircraft spray tanks. It was said that the latter was the most effective biological weapon that the Japanese had developed: inside the fleas, the pathogens were protected from the atmospheric degradation which had imposed a severe limitation on the performance of the agent-slurry bombs. Successful field trials of flea-spraying were said to have been conducted in 1944. The flea-breeding facilities at Harbin were reported capable of turning out around 45 kg of fleas per three to four month cycle. (It was stated that there were about 3 million fleas to the kilogram.) The US reports make no mention of vector delivery techniques for BW agents.

It is difficult to compare the figures that emerge from the US reports with those from the Khabarovsk trial for the BW agent manufacturing capacity at Harbin. At the Khabarovsk trial the figures for this were presented in terms of the weight of agent paste skimmed from the surface of the cultivators. Depending on which agent was being produced, the theoretical maximum output of the available apparatus was estimated to be 300–1 000 kg per month, the lower figure for *Pasteurella pestis,* the higher for cholera vibrio. The US estimate was that the BW agent manufacturing capacity was "on an equal scale" with that of vaccine production, namely about "21 million doses per annum".

According to the US reports, the annual budget of the Pingfan establishment was about $2.5 million (6 million yen) in 1944, with a similar allocation for 1945. These figures were understood to be smaller than in earlier years. At the Khabarovsk trial, the 1940 budget was reported to have been about $4.1 million, and that this too was smaller than in earlier years.

The details of the three bomb designs referred to above are as follows:

The Uji bomb. It was intended to create airborne bacterial clouds. It was made of frangible porcelain to minimize the explosive bursting charge needed, and thus to reduce thermal and mechanical stresses on the agent payload. The casing was shattered by a length of detonating cord cemented into its surface, and the agent was scattered by a small powder charge in the nose of the weapon. A time-fuse was used, set to burst the bomb just above the ground. (Proximity fuses were not available.) Several sizes were produced with payloads ranging from 10 litres of agent slurry up to 100 litres, but the most widely studied version had a 10 litre payload and a total weight of about 35 kg. The principal agent chargings tested were

Pasteurella pestis and *Bacillus anthracis*,[40] some 2 000 of the bombs were field tested. Study of the characteristics of the cloud produced by the weapon was somewhat perfunctory: it was stated that under typical weather conditions a static-burst bomb produced a fairly uniform cloud over a distance of 500 metres. Field dosages are not recorded. The disseminated particles were reported to have a "mean diameter" of 0.5 mm. There was said to be little destruction of the agent on dissemination.

The Ha bomb. This was a fragmentation and anti-animal ground contamination weapon. Its casing was of steel and it had a central explosive burster tube. It was charged with 5 kg of shrapnel and half a litre of fluid-suspended *Bacillus anthracis* spores, weighing 41 kg [*sic*] in all. The bomb detonated on impact, and was intended to kill its victims (men or animals) through anthrax contamination of shrapnel wounds. Ground contamination with anthrax spores was a secondary consideration. The weapon was tested experimentally on large numbers of sheep and horses.[41]

The Ro bomb. This was less studied than the Uji and Ha bombs and was never field tested. It weighed about 22 kg and contained 2 litres of BW agent fluid. It was of steel construction and functioned on a base-ejection, air-burst principle.

The World War II BW programmes in Germany, the UK and Canada

Germany

Rumours that Germany was conducting a BW research effort became widespread soon after the rise of Hitler. In 1933 a German scientist was reported as having said that biological warfare

> is undoubtedly the given weapon for a nation that has been disarmed and is defenceless. ... It cannot be taken ill of such a nation if one day it defends itself by this means against brutal violation and destroys its oppressors by purely scientific means. ... [W]hen the existence of a state and nation is at stake every method is permissible to stave off the superior enemy and to vanquish him. [248]

In 1934 the English journalist Wickham Steed published what purported to be reports of a series of Reichswehrministerium experiments conducted during 1932 in the field of BW [257–58]. It seems clear, however, that if BW work was carried out during the pre-war years, it was on a small and

[40] Two deaths from plague occurred during 1944 field trials. Two deaths from glanders in 1937 among laboratory workers led to the stoppage of glanders field trials: no glanders therapy was available.

[41] In the Khabarovsk proceedings, it was reported that Soviet and Chinese prisoners were used in these trials, during which other wound-contaminants besides anthrax spores were studied.

haphazard scale, and at the initiative of people having only subordinate positions within the German military hierarchy. Hitler is supposed to have suppressed what initiatives there were to develop biological weapons until 1943, when, after the German reverses in the USSR, a BW research station was established at Posen under the auspices of the SS. As the Soviet forces began to advance towards Germany, work at Posen accelerated, but the station was finally evacuated in the face of the Red Army in March 1945 without having accomplished anything very startling. Development work on biological weapons had concentrated primarily on the aircraft spray-tank dissemination of bacterial suspensions. The diseases studied were apparently all human ones, including plague, cholera, typhus and yellow fever, but experiments were also conducted on the feasibility of using insects to attack enemy animals and crops, for example the use of Colorado beetles against potato crops. [259–60]

It is said that BW work was also conducted during the war under the Vichy Government in Southern France. Such studies are rumoured to have included work on pulmonary anthrax, including studies of the increased susceptibility of organisms to the disease following exposure to lung-irritant chemicals.

The United Kingdom

Official consideration of BW in the UK does not appear to have begun until the mid-1930s, and is said to have followed reports that Germany was interested in BW. In 1934 the government consulted the Medical Research Council about the possible implications of BW and received advice that led it to begin taking precautionary measures against clandestine biological attack [261]. In 1936 the Committee of Imperial Defence set up a BW advisory group. The Committee, in concert with the Medical Research Council, took steps to procure stocks of toxoids and antisera for those human and animal diseases considered to be the most likely to be introduced by enemy saboteurs. Stocks of insecticides and fungicides were also built up against the contingency of anti-crop attacks with such insects as the Colorado beetle. An emergency Public Health Laboratory Service was organized, responsible for dealing with cases of infection and pronouncing upon suspected cases of BW sabotage. In 1939 the BW advisory group assessed BW as less effective than orthodox methods of warfare, but felt that its sabotage applications might have a severe effect on national food supplies. Further evaluation was thought to be necessary, and exploratory laboratory work and field assessments began at about the time of the fall of France. [262]

In 1940 a small BW research unit was set up within the CW research establishment at Porton Down. Very little information has been published about the wartime activities of this unit. At no time was it at all large: in the summer of 1944 it numbered 45 people, comprising 15 officers and civilians, four of whom were on secondment from the US BW laboratories, 20 enlisted technicians and 10 female helpers [30]. Much of its wartime work reportedly comprised practical experiments designed to answer specific questions concerning feasibility [263]. One such experiment, conducted in 1941–42, involved the dissemination of anthrax spores from small aircraft bombs and cannon shell at Gruinard Island off the northwest coast of Scotland.

By 1942 it was felt that greater resources were needed than could be mustered within the UK, and in May arrangements were made to collaborate with the recently initiated Canadian BW effort. Later in the year representatives were sent to the United States to make a full disclosure of results to date and to seek assistance there. Thereafter BW studies proceeded in close concert in the UK, Canada and the USA, each country contributing according to its resources. The British War Cabinet had maintained that only by a full examination of methods of BW attack could the UK develop effective means of defence; BW policy was stated in the following terms: "That our principal aim in these studies and experiments was defensive and protective, and that we should under no circumstances initiate these forms of frightfulness" [264].

Canada [42]

Canadian R & D activities in the field of BW began in 1941; they were stimulated by an awareness that the North American continent was vulnerable to clandestine biological attack by enemy saboteurs. This fear was related at least as much to attacks on livestock as on human beings. There is no published explanation of why this fear did not come to a head until 1941. In collaboration with US scientists a commission was set up to study the problem, and in due course laboratory research and field experimentation began.

The R & D activities were placed under the control of the Canadian Army, more specifically its Directorate of Chemical Warfare. Most of the work was conducted in three establishments, beginning early in 1942. The Kingston Laboratory at Queen's University was assigned work on anti-personnel BW problems, and was operated as an adjunct to the Army's Chemical Warfare Laboratories in Ottawa. Anti-animal BW problems were studied at a special establishment known as the War Disease Control Station set up on

[42] This section relies almost entirely on *A History of the Defence Research Board of Canada* by Captain D. J. Goodspeed (Ottawa: The Queen's Printer, 1958).

Grosse Ile, a small island in the lower St Lawrence River, near Quebec City. The Grosse Ile establishment was initially staffed jointly by nine US and Canadian scientists and technicians, but was administered by the Canadian Army.[43] Field testing of BW matériel was performed at the Suffield Experimental Station, a Canadian Army-administered joint British-Canadian proving ground for CW matériel near Ralston, Alberta, that had been operating since the summer of 1941.

Little information has been published about the scale of the Canadian wartime BW effort, and it is not known how many people were involved or how much money was spent on it. Some information is available about some of the lines of research that were pursued, and these are summarized here.

Among the several major projects at Kingston Laboratory was the development of a method for the large-scale production of botulinal toxins. From this work emerged a bivalent toxoid that gave a high measure of protection against poisoning by botulinal toxin types A and B. Several million doses of this were in due course produced and shipped to the UK. Alongside the toxin/toxoid work were successful studies on methods of preserving pathogens during storage. Other studies concerned the behaviour and properties of bacterial aerosols.

At the Grosse Ile establishment, the principal task was to provide a vaccine that would protect against rinderpest virus, for it was feared that Canadian and US cattle were extremely vulnerable to this exotic disease. The project was successful and was felt to have eliminated rinderpest as an effective BW agent. Any outbreak of rinderpest which might have occurred could have been surrounded with a ring of immunized animals that would prevent the disease from spreading.

Almost nothing has been published about the BW activities at Suffield. Experimental weapons that could disseminate the toxic protein ricin or bacterial agents were tested. A weapon of this type is referred to again later.

The US biological weapons programme during World War II

The only other national BW programme about which much detail has been published is the US programme which began around 1941. Although information about it is scanty, it seems clear that it surpassed most, if not all, others in ambition and size. Thus the tone of the US reports on the Japanese

[43] Since the late 1950s the Canadian Department of Agriculture has administered the Grosse Ile station. It is now used largely for quarantine and teaching purposes; in addition to serving as an isolation centre for cattle and other animals being imported to Canada, it also provides courses to students and veterinarians on exotic animal diseases. [265]

BW programme, which was extensive, as we have seen, suggests that the US BW effort had been the more productive; and in 1949 the Chief of the US Army Chemical Corps (responsible for US Army BW work) claimed that "at the end of World War II we were ahead of any of our enemies". [266]

The programme reached its zenith in August 1945, by which time it was occupying nearly 4 000 military and civilian workers.[44] By then, "it was the largest single research element in the CWS and vied with the Manhattan Project—at times successfully—in securing certain types of scientist". In April 1943 the US Army CWS had begun constructing a BW research station at Camp Detrick, Maryland, which was in operation seven months later. By January 1944 an 8 km^2 field-test station on Horn Island in Mississippi Sound was in operation, with much larger field-testing facilities under construction adjacent to the Dugway Proving Ground in Utah. This Granite Peak Installation in Utah was activated in June 1944, and was thereafter used for all major field studies of living pathogenic agents. In May 1944 an ordnance plant at Terre Haute, Indiana—the Vigo plant—was being converted to produce BW and simultant agents. By the end of the war, there were around 1 400 workers at the Vigo plant [267] which con-

[44] The US Army CWS had maintained a passing interest in BW since the 1920s, but did not apparently initiate any research work until August 1941 when an element known variously as the Medical Research Division or the Special Assignments Branch was created at Edgewood Arsenal. In November 1941 the US War Department formed a BW committee from, *inter alia*, the National Academy of Sciences, the Office of Scientific Research and Development (OSRD), the Department of Agriculture, the Public Health Service, the Office of the Surgeon-General, the Navy Bureau of Medicine and Surgery, the Ordnance Corps and Army intelligence (G-2). In February 1942 this committee—the WBC Committee—reported to the Secretary of War that BW was a potential threat to national security. In May 1942 a civilian agency within the Federal Security Agency was set up by the President to formulate BW defensive and retaliatory measures. This War Research Service (WRS) was directed by George W. Merck, and included personnel from the dissolved WBC Committee—which had in the meantime, with the CWS, been establishing communications with the BW teams in Canada and the UK. [30]

The WRS functioned until the beginning of 1944 and, guided by its own technical advisory group, the ABC Committee, acted as an advisory group and general go-between among universities, industry and government agencies, initiating a variety of BW R & D programmes, both offensive and defensive, and creating BW intelligence-gathering machinery. In January 1944 assessments of enemy BW activities led to a great expansion of the US BW effort, and the whole programme was transferred to the CWS, which was authorized by the War Department "to begin preparation for possible retaliation in BW". The CWS formed a Special Projects Division to cope with BW work, which grew rapidly. It was advised by the DEF Committee, and later functioned under the overall supervision of the US Biological Warfare Committee (BWC), formed in October 1944 with Mr Merck as chairman, to make BW policy recommendations to the Secretary of War and Chief of Staff, and to liaise with its British counterpart, the Inter-Service Sub-Committee on Biological Warfare. The BWC remained in existence until October 1945 when its function was transferred to the New Developments Division of the War Department. [30]

tinued in operation after the war [268]. Funds for construction of additional refrigerated storage capacity were authorized to Edgewood Arsenal in June 1945. In all, US expenditure on construction of BW installations was around $45–50 million during World War II. [30]

No detailed survey of what precisely was done in these BW facilities during the war has yet been published in the open literature. One day, possibly, the 500-page monograph written in 1947 by Rexmond C. Cochrane, *Biological Warfare Research in the United States: History of the Chemical Warfare Service in World War II* [30] will have its security classification removed. Until then one can only piece together the multitude of miscellaneous small items of information. There are two main groups of such material: first, the brief summaries of US World War II BW activities written by George Merck and published in 1946 [88, 269], and by a US Navy BW group in 1952[45] [270]; secondly, the great flood of papers from Camp Detrick that appeared in scientific journals during the late 1940s, describing specific World War II research projects.[46]

As far as the future offensive potential of BW was concerned, perhaps one of the most important elements in the US programme was the cloud chamber project, begun in October 1943 and in full operation by January 1945 at Camp Detrick. Its object was to obtain reproducible data on the infection of small laboratory animals by the inhalation route. [273] At this time in history, it was not yet widely accepted that the airborne transmission of pathogens was an important factor in the spread of natural disease. This cloud chamber project, in addition to the less elaborate experimentation along similar lines in the UK and Canada, provided a mass of data establishing some of the mechanisms of airborne infection. Once these mechanisms had been elucidated, it became possible to assess the feasibility of creating unnatural forms of airborne infection, namely the feasibility of effective dissemination of BW agents in aerosol form.

[45] A Naval group was included in the Camp Detrick establishment, but in 1943 Naval Laboratory Research Unit no. 1—established some time before the USA entered the war to work on the medical problems of mass mobilization—was given a BW mission. It was housed in a University of California building. Renamed Naval Medical Research Unit no. 1 (NAMRU 1), BW research became its main activity. It was a much smaller organization than the Army's Camp Detrick, totalling only seventy-five workers at the end of the war. In January 1946 it formed the nucleus of a group, largely comprising University of California workers, that was assigned to the US Navy's BW programme (ONR Task V). In 1950 the group had moved out to the Naval Supply Center at Oakland, and its laboratories became known as the Naval Biological Laboratory, Oakland. [270] It remains today as the chief US Navy BW research establishment [271].

[46] One hundred and fifty-six such papers were published between October 1945 and January 1947. See the two books by Dr Theodor Rosebury—who worked in the cloud chamber project at Camp Detrick during the war—for a partial bibliography of them. [272–73]

Pathogens studied at Camp Detrick[47] included the bacteria of anthrax, glanders, brucellosis, tularemia, melioidosis, and plague; the virus of psittacosis; the fungus of coccidioidomycosis; a variety of plant pathogens—such as *Piricularia oryzae* (rice blast), *Helminthosporium oryzae* (rice brown-spot disease), *Phytophthora infestans* (late blight of potato), and *Puccinia graminis* (stem rust of cereals); animal and fowl pathogens such as rinderpest virus, Newcastle disease virus and fowl plague virus. To this list, which is presumably not exhaustive, may be added the virus of meningopneumonitis, studied chiefly as a model viral agent [273], much as *B. globigii* and *S. marescans* were studied as model bacterial agents.

In 1949 Rosebury[46] noted that the pathogens of brucellosis, tularemia, plague, melioidosis, dengue and Rift Valley fever were strong candidate BW agents, mentioning also typhus, psittacosis, glanders, yellow fever and the equine encephalitides [272]. In this connection, the following remark by the US interrogators of Japanese BW workers may be noted [255]:

> General Ishii and his assistants also exhibited a curiously limited imagination insofar as the virus/rickettsial agents were concerned. Why this group of pathogens was not even considered in the selection of agents is not clear. This is especially puzzling since rickettsiae in mass production were available at the typhus vaccine plant. It is, of course, quite possible that fear of retroactivity was the important brake in the policy of agent selection.

It is also worth noting that in June 1969 a US Department of Defense witness told a Congressional committee that the potential BW agents that had been studied in the USA for offensive and defensive purposes included:

Incapacitating agents:[48]	Lethal agents:
Rickettsia causing Q-fever	Yellow fever virus
Rift Valley fever virus	Rabbit fever virus
Chikungunya disease virus	Anthrax bacteria
Venezuelan equine encephalitis virus	Psittacosis agent
	Rickettsia of Rocky Mountain spotted fever
	Plague

No explanation was given for the inclusion of "Rabbit fever virus" under the heading of lethal agents. [126] Rabbit fever is another name for tulare-

[47] World War II accidents at Camp Detrick have been reported involving anthrax, brucellosis, tularemia, glanders and psittacosis. None were fatal. [272]

[48] Incapacitating BW agents are those which can cause diseases having a low mortality rate, lower than 1 or 2 per cent or so. Lethal agents are those having a very high mortality rate. Pathogens of intermediate lethality are not considered as militarily attractive as either of these classes. This is discussed further in Volume 2 of this study.

mia, a bacterial disease which in its natural form generally has a mortality rate in man of 5–8 per cent, although unusual forms are known in which the mortality rate may be as high as 40 per cent.

More recently it has been reported that the US Army has stockpiled the pathogens of Q fever, Venezuelan equine encephalitis, tularemia and anthrax as anti-personnel BW agents [274], together with rice blast fungus and possibly also the fungi of stem rust and stripe rust of cereals [458] as anti-crop BW agents.

Almost nothing is known about the development of hardware for biological weapons in the USA during World War II. The only device on which there is any information is a BW cluster-bomb unit based on a 4 lb HE burst bomblet containing a few millilitres of BW agent fluid. Field trials of this weapon were said to have shown that 10 per cent of the agent payload was disseminated as an infective aerosol, and that the dosage created would be sufficient to cause 50 per cent casualties over a square mile of target area if 4 tons of the weapons were dropped on it. [275] There is good reason for supposing that this weapon was of the same design as one of those developed for ricin. Certainly 4 lb ricin bombs intended for 500 lb cluster units were tested on Canadian and US proving grounds during the war, and in at least one such test the ricin payload was replaced by a slurry of "bacteriological agent U".[49] [276]

Dry BW agents, as well as those in the form of liquid suspensions, were studied. The results of Camp Detrick work on the large-scale freeze-drying of pathogens were a significant input to the general technology of lyophilization that was being developed by US industry at this time [277].

The manner in which the mass of experimental data collected in US BW facilities during the war was assimilated, expanded and exploited in post-war years is described in Volume II of this study.

BW technology after World War II

By the close of World War II it had been demonstrated in several research establishments around the world that it was feasible to use pathogens in other than sabotage operations. The developing science of aerobiology indicated that widespread disease could be initiated among men, animals and crops through the intermediary of unnatural pathogenic aerosols. The me-

[49] It was calculated that 1.2 such 500 lb ricin bomb clusters would be needed to set up a dosage exceeding the LCt_{50} over 80 per cent of a 100 by 100 yard target area under a particular set of weather conditions [79]. The weapons requirement for a square mile target area would therefore have been about 90 tons. For 500 lb phosgene bombs under the same conditions, the requirement would have been more than 600 tons.

dium for BW attack was thus no longer restricted to the food or drink that an enemy might consume, but now included the air he breathed as well. It had been shown that pathogens could be exploited in much the same manner as the toxic agents used in chemical weapons, so that in a sense BW had now become an extension of CW. In principle at least, pathogens could enormously increase the casualty-producing ability of CW troops, for in that the new weapons could disseminate self-replicating agents they might be enormously more potent than those based on inanimate poisons. It seemed that there was now nothing inherently impossible in developing CB weapons that would threaten whole countries with disablement or death.

Although the full potentialities of BW were now becoming apparent, the technologies capable of exploiting them did not yet exist. They remained a threat or a challenge to post-war CBW technologists. The indications are that even the USA, which seems to have had the largest and best-endowed BW programme, had not produced a biological weapon by the end of the war that had any marked superiority over existing conventional or chemical weapons. But several countries now possessed a body of experimental data and basic theory from which such weapons might be developed during the years to come. In Volume II of this study we will decribe the extent to which the potentialities of BW have now been harnessed.

Chapter 2. Instances and allegations of CBW, 1914–1970

In this chapter we review the published literature on past instances or alleged instances of CBW. Although the truth of many of these reports can reasonably be questioned, we have not attempted to separate those that seem plausible from those that do not. To do this would be to make assessments which the published evidence could in most cases not support. All reports are included, whether verified or unverified. They are listed chronologically, first CW then BW.

In those instances of CW that have been verified, we attempt to describe the reasons why chemical weapons were used. This is done in order to provide an historical background for the discussion of the military attractions of modern CB weapons that appears in Volume II of this study. It is not possible to do the same for biological weapons, for there are no indisputably verified instances of their having been used.

The review covers the literature available to us up to January 1971.

I. *Chemical warfare*

1914–1918: World War I

Although chemical weapons had been used many times before 1914,[1] it was not until World War I that that confluence of chemical science and mili-

[1] See, for example, the texts of Lewin [303] and Partington [304]. Toxic smokes used as siege weapons and for overcoming fortifications, and made from a variety of poisons and supposed poisons, were characterized as "German poison gas" by Leonardo da Vinci at the end of the fifteenth century [305], and by the Polish artilleryman Siemienowitz (*Ars magnae artilleriae*, Amsterdam, 1650) in the seventeenth century [304]. The smoke could be delivered as a drifting cloud from large fires burning upwind of the enemy, from artillery projectiles, or from hand grenades, following the prescriptions of Brechtel (*Büchsenmeisteri*, Nürnberg, 1591) and others, many of whose recipes are collected together by Fleming (*Der volkomme teutsche Soldat*, 1726). The meteorological problems of toxic smoke warfare were appreciated. Appier and Thybourel (*Recueil de plusieurs machines militaires*, Pont-à-Mousson, 1620) warned that the toxic incendiary projectiles they described should only be used with a "good wind". Siemienowitz warns "one must take care lest one suffers oneself from the means intended to injure others", and goes on to remark that toxic projectiles "do not give the effect expected of them since the poisonous cloud goes straight up into the air, and is dissipated by the wind". He perceived that foggy

tary technology had occurred which could make their use at all significant. As the war progressed, the belligerents came to appreciate that they could use toxic substances to attain a variety of different battlefield objectives, some of which were unattainable with other types of weapons.

Chemical weapons came to be used extensively on the Western and Eastern fronts, less so on the Austro-Italian front. In the Balkans, the Romanians and the Bulgarians are said to have suffered large numbers of gas

or rainy weather favoured chemical warfare. [303] A drifting cloud attack with an arsenical smoke was used by Hunyadi in his defence of Belgrade against the Turks in 1456; it is described by the Austrian writer, von Senfftenberg (*Von allerlei Kriegsgewehr und Geschütz*, mid-sixteenth century), with the comment: "It was a sad business. Christians must never use so murderous a weapon against other Christians. Still, it is quite in place against Turks and similar miscreants." [304] Valckenier (*Das verwirte Europa*, 1677) describes the use of arsenical projectiles as a siege weapon against Groningen in 1672 by the Bishop of Münster's soldiers [303].

A German *Feuerwerkbuch* of the early fifteenth century recommends the use of irritant and poisonous smokes against enemy sappers [304], following a much earlier precedent set by Marcus Fulvius against Ambracian sappers in the second century B.C. described by Polybius [306]. Leonardo copies Polybius' description almost word for word [305a]. The use of irritants as harassing agents in combat was known to the Byzantines, and is described in the Emperor Leo's *Tactica* [304]. Plutarch describes an action by a Roman general in Spain in which an irritant-agent cloud was used to drive the enemy out of concealment in caves [307].

The military use of hypnotics is frequently recorded [303]; Buchanan, the seventeenth century Scottish historian, holds their use responsible for Duncan I's rout of a Danish invasion in the early eleventh century [303]; Frontinus records their use by a Carthaginian general in North Africa during the third century B.C. [308]. The uses of what would nowadays be called "psychochemicals" and other types of CW agent were apparently known to the authors of the nineteenth century B.C. Indian epic *Ramayana* and of the later epic *Mahabharat,* or at any rate to the subsequent interpolators of the epic [309]. The use of another type of "incapacitating agent" —one which provoked incessant diarrhoea—during a seventh century B.C. siege of Cirrha, near Delphi in Greece, is recorded by Polyaenus, Fronto and Pausanias [310].

Poisonous smoke compositions based on alkaloids and toxins are described in Indian, Chinese and European military treatises. The Indian *Arthaśastra of Kautilya* from the fourth century B.C. contains a number of formidable recipes; one of these [311] includes seeds of Indian liquorice—*Abrus precatorius*—from which modern chemistry has isolated a toxin known as abrin, and which the US Army has described in a recent addendum to a manual on CW agents. The Chinese Sung dynasty text *Wu Ching Tsung Yao* ("Essentials of the Military Classics" ca. 1040 A.D.) describes a toxic-smoke projectile containing powdered aconite tubers [304]. The Moors are said to have used aconite extracts as arrow poisons against the Spaniards in 1483 [312].

As chemistry advanced during the nineteenth century, many new proposals for chemical weapons were made, for example organoarsenical bombs and shell at the time of the Crimean War and chlorine shell and other devices during the American Civil War [313]. Napoleon III is said to have put hydrogen cyanide to military use in 1865 [314]. The CW proposals of a British admiral, the 10th Earl of Dundonald, were considered on several occasions between 1811 and 1914. The admiral had prefaced his plans thus: "To the Imperial mind, one sentence will suffice. All fortifications, especially marine fortifications, can under cover of dense smoke be irresistably subdued by fumes of sulphur kindled in masses to windward of their ramparts." [189, 313, 315–17] He had in fact been partly anticipated by a good two millenia: Thucydides describes how the Peloponnesians had attempted to reduce the town of Plataea with sulphur fumes in the fifth century B.C. [318].

casualties, but there is little documentation available on this. [2] There was no significant use of gas during the fighting in the Middle East.[2] The following tables illustrate the general scale of employment of gas during the war.

Table 2.1 shows the tonnages of CW agents employed during the war, broken down by year and by belligerent. Table 2.2 shows the relative emphasis given to each of the four main classes of CW agent during each of the belligerents' manufacturing programmes. Table 2.3 compares overall casualty figures due to gas, high explosives and small-arms ammunition. Table 2.4 compares the casualty figures due to the different classes of CW agent. Table 2.5 gives approximate gas casualty figures for each of the belligerents. Table 2.6 gives gas casualty figures for one of the belligerent nations—Britain[3]—for each year of the war.

The decision to use chemical weapons

By the autumn of 1914 interest in the combat possibilities of toxic chemicals had quickened. In the UK the Admiralty was reconsidering the proposal of Admiral Sir Thomas Cochrane[4] for the offensive use of sulphur dioxide clouds—for the second time since the Napoleonic Wars [189]. In the USA a patent application was being prepared that related to artillery shell charged with hydrogen cyanide [325]. In France, army officers were considering the tactical possibilities of the tear-gas weapons that a Paris police force had been using for the past three years [317]. In Germany, so it was later alleged, a team of scientists under Professor Haber was experimenting with

[2] As the use of gas in the fighting between Turkish and British Empire forces during World War I is not generally reviewed, it is worth collecting together some of the more accessible information about it here.

A London newspaper reported that the Turks had used gas on the British in November 1915 [319], but a German authority states that although Germany supplied Turkey with chemical weapons, it refused to use them [20]. Chemical weapons were sent out to British forces in Salonika, Egypt and Mesopotamia [20], but were only used on a small scale, in Palestine [320].

Expecting the Turks to use gas, the British had issued respirators to General Younghusband's force during the second attempt to relieve Kut in March 1916 [321]. There were warnings that gas shell would be used in the defence of Baghdad two months later, and although it was not, gas cylinders were subsequently found in the Turkish arsenal there [322]. In September 1917 there were reports that Germany was encouraging the Turks to use gas, and the official British war historians record that although both sides in Mesopotamia had hitherto refrained from using gas, the British commander maintained a reserve of gas shell in Basra for use in retaliation if this should become necessary [323].

In Palestine the British used gas shell during the second Battle of Gaza in April 1917: field howitzers were used to fire gas shell into the Turkish lines and against Turkish batteries [324].

[3] The only nation that fought throughout the whole of the war, and for which reasonably reliable casualty figures are available.

[4] The 10th Earl of Dundonald. His proposal is referred to in the footnote on page 126.

Table 2.1. Tonnages of CW agents used in battle during World War I

Thousands of tons

	1915	1916	1917	1918	1915–18
Germany	2.9	7.0	15	28	52
France	0.3	3.5	7.5	15	26
British Empire	0.2	1.6	4.9	7.7	14
Austro-Hungary	0	0.8	2.7	4.4	7.9
Italy	0	0.4	2.5	3.4	6.3
Russia	0.2	1.8	2.7	0	4.7
USA	0	0	0	1	1
Total	3.6	15	35	59	113

Source: Prentiss, A. M., *Chemicals in War* (New York, 1937).

Table 2.2. Proportion of total CW agent manufacturing output devoted to each of the four main classes of CW agents during World War I[a]

Percentage of total production

	Harassing agents		Casualty agents	
	Lachrymators	Sternutators	Lung irritants	Vesicants
Germany	4	11	70	15
France	2	<1	92	6
British Empire	7	<1	91	2
Austro-Hungary	5	0	95	0
Italy	2	0	98	0
Russia	4	0	96	0
USA	<1	0	97	3
All belligerents	4	5	82	9
Total tonnage manufactured (thousands of tons)	5.5	6.6	112	12.1

[a] See Chapter 1 for details of the agent classification used here.
Source: Prentiss, A. M., *Chemicals in War* (New York, 1937).

Table 2.3. Relative casualty value of gas and other weapons in World War I

	Total battlefield expenditure by all belligerents in WWI	Approximate casualties (*millions*)
CW agents	0.113 million tons	1.3
High explosive	2 million tons	10
Small arms fire	50 000 million rounds	10

Source: Prentiss, A. M., *Chemicals in War* (New York, 1937).

Table 2.4. Relative casualty value of the main categories of CW agents in World War I[a]

Agent class	Tonnages used (*tons*)	Casualties	Casualties per ton
Sternutators	6 000	20 000	3.3
Lung irritants	90 000	880 000	9.8
Vesicants	11 000	400 000	36.4

[a] See Chapter 1 for details of the agent classification used here.
Source: Prentiss, A. M., *Chemicals in War* (New York, 1937).

Table 2.5. Gas casualty figures for each belligerent during World War I[a]

	Total casualties from CW agents (fatal and nonfatal)	Fatal casualties from CW agents
Germany	200 000	9 000
France	190 000	8 000
British Empire	189 000	8 100
Austro-Hungary	100 000	3 000
Italy	60 000	4 600
Russia	475 000	56 000
USA	73 000	1 500
Belgium, Portugal	10 000	1 000
Romania	?	?
Bulgaria	?	?
Turkey	?	?
Total	**>1 297 000**	**>91 000**

[a] The figures given in this table are very rough approximations. Only in the cases of the UK and the USA are reasonably adequate casualty statistics available. For the other belligerents, the figures given are those estimated by Colonel Prentiss of the US Army Chemical Warfare Service after a careful study of all available material. His treatise, *Chemicals in War* (New York, 1937), should be consulted for further information about his estimates.

phosgene and arsenical grenade fillings[5] [4]. Yet whatever the military authorities may have felt about this and other CW work, it was clear that during the early months of the fighting neither the war nor the technology had developed to a point at which the work could usefully be exploited. The Cochrane proposal, much modified, was eventually put into practice by the British, not as lethal gas clouds, but as naval smoke screens [315]. Battlefield use by the French of tear-gas hand grenades was apparently initiated by a conscripted Paris policeman who brought some back to the front when he returned from leave[6] [6]. Toxic chemicals had no obvious part to play in

[5] Lefebure [17] refers to CW work under Professor Haber at the Kaiser Wilhelm Institut für Physikalische Chemie (Berlin/Dahlem) that began around August 1914, and to the interest in this work by the Prussian War Ministry. In a letter published in *Nature* on 12 January 1922, Professor Haber refers to Lefebure's comments on this, and states that military attention to the work of his Institute in August 1914 was related solely to the problem of "how motor spirit could be made proof against the cold of Russian winter without the addition of toluol". He went on to state that the "question of gas as a means of warfare did not begin to engage our attention until the first three months of the war had passed". There is no record of when Professor Nernst's interest in CW arose.

[6] The early history of the French irritant-agent weapons of World War I is obscured by a prolonged and acrimonious debate among French and German CW commentators in the 1920s on the question of which nation had initiated CW. Neither Florentin [281] nor Cornubert [282], both writing in 1920, refer to battlefield use of French tear-gas police weapons, even though Dr West of the US Chemical Warfare Service had done so a year earlier [317].

West had referred to French use, during the early stages of the war, of cartridges charged with ethyl bromoacetate for the 26 mm cartridge-throwing rifle. He implied

Table 2.6. CW casualties of the British Expeditionary Force in France during World War I

	Total battle casualties	*Battle dead as percentage of all battle casualties*	Total CW casualties[a]	*CW casualties as percentage of all battle casualties*	Total CW dead	*CW dead as percentage of all CW casualties*
1915	304 406	*26*	12 792[b]	*4.2*	307[b]	*2.4*
1916	636 146	*27*	6 698	*1.1*	1 123	*17*
1917	727 022	*29*	52 452	*7.2*	1 796	*3.4*
1918	768 603	*25*	113 764	*15*	2 673	*2.4*
1915–18	**2 436 177**	**27**	**185 706[b]**	**7.6**	**5 899[b]**	**3.2**

[a] This includes both fatal and nonfatal casualties. The figures are based on admissions to medical units in France. They do not include: (1) CW casualties captured by the enemy; (2) minor CW casualties returned to their units from field ambulances without treatment; (3) CW casualties dying in the field; and (4) nonfatal CW casualties killed by other weapons before evacuation.

[b] The figures for 1915 refer to British casualties only, while those for the later years include British Dominion casualties as well. The 1915 figures thus do not include the heavy Canadian CW casualties during the Second Battle of Ypres. Allowance was made for such unrecorded casualties in the figures published by Colonel Prentiss which were used in table 2.5.

Source: Mitchell, T. J. and Smith, G. M., *Official History of the Great War: Medical Services: Casualties and Medical Statistics of the Great War* (London, 1931).

	Principal chemical weapons used by German forces		CW casualties		*CW dead as percentage of all CW casualties*
	Munition	CW agent[c]	Total	Fatal	
April 1915–May 1915	Gas cylinder	Chlorine	>7 000[d] (10 000)	>350 (3 000)	*(30)*
April 1915–July 1916	Projectile	Tear gas	550	2	*0.4*
Dec. 1915–August 1916	Gas cylinder	Chlorine and phosgene	4 207	1 013	*24*
July 1916–July 1917	Projectile	Diphosgene	> 8 806[e]	>532	*6*
July 1917–end of war	Projectile	Diphosgene	ca. 18 134	1 859	*10*
		Arsenical irritants	ca. 18 134	0	*0*
		Mustard gas	> 124 702[f]	2 308	*1.85*

[c] See Chapter 1 for details of the agents.

[d] Precise casualty figures are not available; the ones given are based on admissions to medical aid posts. They probably do not include Canadian casualties, and they do not include the large numbers of casualties dying in the field. The figures given in parentheses are those estimated by General Foulkes, the commanding officer of British chemical troops [20].

[e] These figures do not include the substantial numbers of gassed killed-in-action, nor those casualties returning directly to their units from forward medical aid posts.

[f] These figures are known to underestimate the mustard-gas casualties.

Source: Macpherson, W. G., et al., [*Official*] *History of the Great War: Medical Services: Diseases of the War* (London, 1923, vol. 2, Chapter 9).

the sort of fighting generally anticipated or which took place during the opening campaigns, and in principle their use was obnoxious to the professional code of the military, a distaste symbolized in the somewhat vague proscriptions that had emerged from the Hague Conferences some time before.[7]

As the war progressed, irritants were the first CW agents to attract field commanders or general staffs. These substances were seen to have application in certain limited tactical situations. They could be used to upset the aim and coordination of cannon and machine gun crews in fortified positions; the French apparently put their ethyl bromoacetate cartridges to this use [317]. They could also be used to smoke enemy soldiers out of cover. A number of British officers returning from the front in the winter of 1914 had enquired privately about the possibilities of stink bombs for clearing dug-outs; chemists at Imperial College, London, had looked into the matter and eventually offered ethyl iodoacetate, another irritant, to the Commander of the British Expeditionary Force. This agent was not considered sufficiently poisonous to contravene the Hague rules, but it was rejected for fear that the enemy might also be led to use it. [20] The British did not consider irritants again until after the Second Battle of Ypres, six months later. In Germany, where chemists commanded rather more attention than elsewhere, the possibilities of irritants were examined more thoroughly.[8] By the autumn of 1914 two techniques for their employment were being developed, both exploiting artillery shell.

Certain senior German army officers were sufficiently convinced of the potential worth of these new weapons to begin planning for their use in artillery operations. The first weapon actually to be put to such use was Professor Nernst's Ni-Schrapnell,[9] of which 3 000 rounds were fired against the French at Neuve-Chapelle on 27 October 1914. According to one post-

that these cartridges had in fact been developed for military purposes, subsequently being adopted for police use.

Hanslian [18], however, stated that ethyl bromoacetate had been used since 1912 by a Paris police force in tear-gas hand grenades, and that the success of these grenades had led the French Army to procure 26 mm cartridges filled with the agent: 30 000 of these were said to have been available for field use by August 1914.

Whatever their provenance, there is little doubt that the French Army were using ethyl bromoacetate hand grenades and rifle cartridges soon after the war began.

[7] The Hague Conferences are described in Volume III of this study. The 1899 Conference had produced this resolution: "The Contracting Powers agree to abstain from the use of all projectiles the sole object of which is the diffusion of asphyxiating or deleterious gases." At the 1907 Conference, the following rule was formulated: "In addition to the prohibitions provided by special conventions, it is especially forbidden to employ poison or poisoned weapons."

[8] Professor Baeyer, the organic chemist, had alluded to the possible military utility of lachrymators in his lectures as early as 1887 [17].

[9] See page 27.

war German commentator, it was used in retaliation for the French use of ethyl bromoacetate cartridges. The French were apparently unaware that anything out of the ordinary was being used against them, but the same German commentator wrote that "although the irritation produced was weak and of short duration, the munition aided in the capture of Neuve-Chapelle by forcing the enemy to keep low" [1]. The weapon was not used again.

The second irritant weapon used by the Germans was more auspicious. This was the T-Stoff shell;[9a] it was expected to produce startling effects and was used first at Bolimow on 31 January 1915 against the Russians. Eighteen thousand rounds were fired, but the results were disappointing to the advocates of the weapon; not only had its efficacy been greatly over-estimated, but also the weather was too cold to allow adequate vapour concentrations of the irritant to build up [4, 5]. The weapon was not abandoned, however, and its improved results in better weather eventually led to its extensive use on both the main European fronts. On the Western front, it was first used at Nieuport in March 1915, at about the same time as the French introduced their first irritant artillery shell [2]. Its design formed the basis of many subsequent German chemical projectiles, both irritant and lethal.

The Germans quickly realized that the value of irritants increased with the scale on which they were used. If irritant-agent harassment of enemy troop units was to disrupt supply lines or lower battlefield performance significantly, the agents would have to be used over a wide area and for prolonged periods. The scattering of a few irritant shell over enemy positions had nuisance value only, given the inefficiency of early weapon designs. It was for this reason that such a remarkably large number—for that early stage of the war—of T-Stoff shell was used at Bolimow. [5] As General Schwarte put it in 1920: "The French commenced [the gas war] with gas grenades, but the Germans were the first to recognise the tactical value of mass effect" [326].

Once the German Supreme Command had become accustomed to thinking about and using irritants on a large scale, it was probably only a matter of time before it began to do so for more lethal chemicals as well. This process was accelerated by battlefield events. After the Battle of the Marne the mobility of both armies had been destroyed by the appearance of trench warfare; with its enemies dug in from Switzerland to the sea, Germany had soon almost exhausted its entire pre-war stockpile of high explosives, and to very little effect. Furthermore, the blockade at sea was depriving it of the raw materials needed to manufacture explosives, primarily nitrates from

[9a] See page 28.

Chile. At this point the German Supreme Command became particularly ready to listen to the nation's industrial chemists, for, as there was no shortage of iron or steel, only they could resolve the ammunition crisis. Ludendorff, Chief of the German General Staff at the time, refers in his memoirs to a General Staff conference held then and attended by the heads of Krupp's and of IG Farben, the great German combine of chemical industries that held a virtual world monopoly not only in dyestuffs, but also in the majority of organic chemicals. The purpose of this conference was to reorganize munitions production; during it the IG Farben representatives promoted the idea of using chemical agents to injure or to kill rather than to harrass, and succeeded in having it discussed in detail at the highest level. [327]

Gas was seen not as a substitute for explosives—Professor Haber was developing his process for manufacturing ammonia, and hence explosives, from air—but as a possible way of breaking through the stabilized front: an entrenched enemy was comparatively safe from projectiles and fragmentation weapons but vulnerable to airborne poisons. The decision was accordingly taken to try chemical casualty agents on the battlefield.

At first the intention was to load the chemicals into artillery projectiles as was being done with irritant agents, but at the time the output of shell was small and in any case the Supreme Command doubted whether large-area effects could be obtained from them [7]. These doubts were subsequently vindicated by the failure of the T-Stoff shelling at Bolimow. Professor Haber, who was in charge of the development work, then suggested that the gas might be discharged at the enemy directly from cylinders emplaced in forward trenches, relying on the wind to blow the gas cloud towards the enemy. This proposal was adopted, and by January 1915 [8] successful field trials had been carried out, the necessary matériel procured, and suitable troops seconded for training. The chemical agent selected was chlorine, a lung irritant whose physical properties were well suited to the chosen method of dissemination. The Supreme Command also chose, from a study of prevailing winds, the most suitable part of the front for the experiment: the Ypres sector of the Western front was to be the proving ground.

Although the contrary has been argued, it seems doubtful whether the German Supreme Command regarded the forthcoming chlorine attack as anything more than a battlefield trial of an experimental weapon. The local field commanders were not enthusiastic about gas, and their requests for augmentation of ammunition supplies and reserves to exploit such success as it might achieve were turned down. [8] Further, it seems doubtful whether the Supreme Command expected startling results from the experiment, for it was apparently prepared to risk premature disclosure of the new weapon although justification of its proponents' claims depended on massive surprise. A belief in the superiority of the German chemical industry and in the inability of its English and French counterparts to provide the means of retaliation would surely not have been adequate reason to take this risk: chlorine was one of the simplest industrial chemicals to make, and indeed was being made in Allied factories, albeit only on a rather small scale in liquefied form.

The details of the Ypres chlorine attacks have been described in Chapter 1. In all, a total of 498 tons of chlorine was discharged from 20 730 cylinders to produce many thousands of casualties [2]. The German Supreme Command regarded the experiment as successful: "The impression created was colossal and the result not inconsiderable, although it was not fully utilised from the tactical point of view" [7]. They were sufficiently impressed to have the weapon developed further. So were their enemies. At the beginning of May the Allies decided to retaliate in kind. By June 1915 Sir John French, commander of the British Expeditionary Force, was asking for 10 per cent of his future supplies of artillery shell to carry a chemical payload (nearly two years elapsed before the Ministry of Munitions supplied anything approaching this) and for aircraft gas bombs (this request was ignored), as well as for the gas cylinders which were to be used at the Battle of Loos in the coming September [328]. The Russians and the French concentrated at first mainly on artillery-delivered munitions. All the belligerents saw clearly that the gas-cylinder emplacement was an over-cumbersome weapon, useful only under special circumstances: it depended too much on the vagaries of the weather, but could be extraordinarily potent if these were amenable. A good two years were to pass before any nation could develop a really flexible range of chemical weapons. During this intermediate experimental period, gas played a very subordinate role in the fighting and could compete only rarely with conventional weapons. This was due mainly to the characteristics of the CW agents employed: at that time they were effective only at high dosages, and thus imposed enormous logistical burdens if anything other than a local harassing operation was intended. But in July 1917, during the preliminaries for the Third Battle of Ypres, the Germans introduced mustard-gas shell, and this was such an improvement over previous weapons that within a few months gas was competing with air-power as the most rapidly expanding weapon of land warfare. On both the Western and the Austro-Italian fronts all belligerents were using CW agents to the limits of their production capabilities. By July 1918 a typical German divisional ammunition dump contained 50 per cent gas munitions [16], and, by the following month, both the British and the US Expeditionary Forces were calling for 20 to 30 per cent of their future artillery munitions to be gas-filled, with higher percentages still for the 1919 campaigns [20].

The uses to which chemical weapons were put during World War I

Trench-warfare conditions prevailed during the greater part of the fighting on the Western front; not until after the great German offensive in the spring of 1918 was any degree of mobility reinstated. In terms of CW agent employment, however, the gas war straddled both types of fighting almost equally; in this account, therefore, the battlefield uses of gas during World War I are considered under the two headings of static CW and mobile CW.

CW ON A STATIC FRONT

In trying out chlorine at Ypres, Germany intended testing the possibilities of gas in breaking the deadlock of trench warfare. The pattern of chemical-weapons employment over the next three years or so was that of increasingly frustrated attempts to develop these possibilities, and of a gradual degeneration of CW into yet another tactical aid in a war of attrition.

Broadly speaking, the mechanism by which trench warfare imposed static conditions lay in the combination of the physical barricades of earth works and barbed-wire entanglements plus their protection by riflemen and machine-gunners. If a way could be found to disarm or disable the latter, then the former would become mere ditches and fences, comparatively easily traversed [329]. Gas provided one such solution, but to defend the individual rifle-man or machine-gunner against it was in principle a simple matter. By frittering away the essential requirement of surprise, the German experiment was a failure in the long run, even though it was a success in the short. The use of CW agents, at any rate those then available, was no longer itself enough to remobilize the front; henceforward they would have to be employed up to and beyond the limits of the ingenuity of the tacticians and weapons designers. The incentive for the necessary effort gradually disappeared as the gas war continued, due in large measure to a lack of enthusiasm for gas among the field commanders.

The reasons for this lack of enthusiasm are illustrated in the first British gas attack, at the Battle of Loos in September 1915. This was a cylinder operation, and for the future of CW its practical results were encouraging to the theoreticians. In this memoirs, the Chief of the German General Staff of the time records that "the English, on the first day of their attack, by the employment of gas, succeeded in occupying our foremost positions over a breadth of 12 kilometres" [330]. Many years later the organizer of the gas attack stated that the initial success of the Loos offensive was due precisely to the ability of the chlorine clouds to disable the German front-line troops, so that they could no longer effectively protect their wire, which had not been destroyed as it should have been by the preliminary artillery bombardment [331]. Here was a gas attack, therefore, that produced the results predicted by the underlying theory. But the seeds of the subsequent failure of the theory were also present. The use of gas, in that early stage of the chemical war, took the Germans by surprise. Official German documents, quoted by the official British war historians, suggest that the German troops had not been adequately trained in anti-gas discipline, and large numbers of them were gassed before they could mask [332]. They had, nevertheless, been issued respirators, and in due course their anti-gas training improved greatly. In the eyes of the local commanders of the British line, concerned more with the day-to-day tactical situation than an overall strategy, the use of gas had not been a success. Their trenches had been filled with newfangled, unreliable, and hazardous equipment, their timetables for the assault were full of gaps which could only be filled in by a meteorologist at the last moment, and through uncertain channels of communication at that, and when finally the attack had begun, a lot of gas, seemingly all of it, blew back over their men.

By mid-1916 the only way to overcome, over a wide front, the reasonably good anti-gas defences deployed by both sides was in the use of higher and higher concentrations of cylinder-gas, preferably discharged at night when thermal air currents held the gas clouds close to the ground and the possibilities of surprise were greatest. The first of these requirements meant that a discharge could only be contemplated when the wind was absolutely right. (At Loos, when indeed a sizeable quantity of gas had blown back, some 2 500 British soldiers had been gassed as a result, ten fatally and fifty-five severely [16].) This requirement also meant that cylinder operations could only rarely be integrated into a large offensive, particularly if the second requirement was fulfilled also. In consequence, fewer and fewer of the large gas operations were given infantry support, and in time their almost sole objective was in the attrition of the enemy by causing casualties, demoralization and the fatigue inevitable from long periods of wearing masks. [244] When Livens Projector attacks began to be practised, infantry support became more feasible because the weather had less influence. But here the scale of operations was smaller than in a cylinder attack: no projector operation ever involved the discharge of more than 85 tons or so of gas, generally very much less, averaging about 14 tons, as compared with an average of over 100 tons for cylinder attacks. [2]

It was not until the end of the period considered here that the intentions behind artillery-delivered gas were anything other than to harrass the enemy or hamper his movements; the limitations of the munitions and their mode of delivery did not diminish until the later part of 1917. The following resumé of the manner in which German CW artillery techniques developed illustrates how these techniques grew in importance as the underlying technology improved.

By the summer of 1915 German batteries were firing irritant-agent shell sufficiently extensively to call for employment directives from the General Staff. These were issued in August 1915 by von Falkenhayn, the Chief of Staff. The orders distinguished two types of chemical agent shell filling, "persistent" and "nonpersistent", each to be used in specified tactical situations to "neutralize the enemy's effectiveness". To "neutralize" here meant to hamper the enemy's activities in an area by forcing him to mask, or to disable him if he could not mask. The nonpersistent agent was to be used to soften up an enemy position immediately prior to assault; the persistent agent was to be used against positions which were not to be occupied immediately. [16, 17, 333]

The German forces did not receive supplies of chemical shell intended for casualty effect until after these orders had been issued. They first began using these on a substantial scale at the first Battle of the Somme in July 1916 [16, 185], at which time von Falkenhayn's gas-shell doctrine was still in force. As a result, casualty agents were employed in the same way as harassing agents, but as the effective field concentration of a tear gas was very much lower than any concentration of casualty agent that was likely to build up into a casualty dosage, the casualty effects of the latter were largely wasted. Scattered area shelling, adequate for tear-gas neutralization, could not build up effective dosages of lung irritants, particularly with the then-current design of munition.

The second gas-shelling directive was issued in December 1917, by which time much improved shell designs were in production and artillery was the most widely used means for delivering CW agents. The new orders distinguished three types of fire. The doctrine of scattered area shelling was retained, but its tactical functions were downgraded from neutralization to mere harassment. Either casualty agents or lachrymatory irritants could be employed, although stocks of shell filled with the latter were running down and were not being replenished. Neutralization, as an objective, was retained in the doctrine of surprise-dosage shoots, in which sudden massive concentrations of casualty agents were delivered by the concerted fire of several guns or batteries on to a comparatively small target. The targets were to be chosen carefully; they might be points of troop concentration such as billeting areas or assembly points; they might be working parties building trenches or wire entanglements; they might be enemy battery positions, if their exact location could be established; and so on. Mustard-gas shell was to be used to contaminate terrain and so deny it to the enemy, or force him out of it, and to disorganize the enemy's rear. [16, 333]

From a doctrinal point of view, the surprise-dosage neutralization type of fire was the most important of these orders, because casualty-agent shell were now allocated a role which was both effective and in keeping with their capabilities. Neutralization fire against enemy batteries was especially important, for here was a tactical situation particularly well suited to gas. The prime object in counter-battery fire was to remove, or at least slow down and disorganize, artillery support for infantry assaults, and with HE shell this could only be achieved by direct hits. The area-effectiveness of gas, if used in sufficient quantity, greatly reduced the need for such accuracy.

The British also had realized the importance of the counter-battery gas shoot. They first used it during the opening of the Battle of Messines in June 1917, when an artillery barrage of 2 230 guns and howitzers, firing a high proportion of gas shell for a period of thirty minutes, largely succeeded in removing the German defensive barrage from the advancing infantry and allowed the British forces to cross no-man's-land relatively unimpeded. The gas was fired in concentrated three-minute bursts of casualty-agent shell (phosgene), interspersed with harassing shoots of PS and SK shell.[10] [334]

The second German gas orders also gave directives for the use of the recently introduced mustard-gas shell which, as we have seen, was one of the most important innovations of the gas war. At the time of the orders, however, the Germans had virtually exhausted their initial stockpiles of mustard gas and it was not until the following spring that its use again became intense.

CW ON A MOBILE FRONT

The change-over from a static to a mobile chemical war, although not sharply defined, was symbolized by the abandonment, in the face of the impending German Somme offensive, of the British plans for a gigantic retired-discharge cylinder operation in which nearly 6 000 tons of gas were to have been discharged.[11] Thereafter the opportunities for cylinder attacks were few: the Germans carried out none on any scale during 1918, and

[10] See pages 45 and 48 for a description of PS and SK shell.
[11] See page 32.

the only British ones all took place around Lens when the German advance had finally been halted [2]. Not even the small 50 lb cylinders tested by the British on occasions during 1917 [20] had a part to play while the front was shifting so swiftly.

Artillery was the delivery system most adaptable to CW under the new conditions, and was used by the Germans with considerable finesse. During the twelve days prior to the Somme offensive of March 1918, half a million gas shell were fired during the preparative bombardment, with a further two million during the battle itself [2]. Mustard-gas shell were used to complement lung-irritant and sternutatory shell and during this crucial stage of the war they were first integrated into gas operations to fulfill major tactical objectives [17]. Sectors of the Allied line which were to be targets of an infantry assault were bombarded in depth for several hours beforehand with massive mixed shoots of irritant and respiratory casualty agents. This was intended to neutralize both forward defensive positions and their support several miles to the rear. Flanking sectors of the front, which were not to be assaulted, were bombarded for several days with mustard-gas shell, principally to reduce the number of able-bodied men that could be called in to reinforce the attacked sectors. Mustard-gas shell were also used against those unoccupied areas in the vicinity of the sector to be attacked which the Germans had no wish to occupy, but to which Allied forces might wish to withdraw, either because they were good defensive positions, or because they were good jumping-off points for counter-attack. These tactics, according to one authority, as much as any other enabled the Germans to drive the British back 40 miles over a front of 50 miles [329]. The only tactical criticism subsequently made was that the Germans did not use enough mustard gas to contaminate important Allied lines of communication [17].

The tactics of CW in a mobile situation thus emerged as follows. Defended positions to be attacked were first to be weakened or neutralized with surprise-dosage shoots of a casualty agent which would have dissipated by the time the assault began. The position's supporting facilities and supply channels were to be blocked as far as possible by the use of a persistent agent to contaminate both terrain and matériel. Reserves and reinforcements were to be cut off, or their movements were to be restricted or channeled, by the contamination of terrain. And once the advance was under way, its flanks were to be protected by barricades of persistent agent. In all this, persistent, percutaneous agents were of far greater importance than the nonpersistent casualty agents which, in any case, were at the time only moderately effective.

Mustard gas, although inherently a substance best suited to territorial defence, thus had a crucial part to play and played it, in offensive operations. What would have happened had the Allies possessed as large supplies of it as the Germans during this period is hard to say. Sectors of the front which the Germans had attacked only with nonpersistent casualty agents were quickly recognized by the Allies as targets likely soon to be assaulted [17], and the assault could have been forestalled by laying down a barrier of mustard gas in the intervening no-man's-land. But at no point during the war did this type of deadlock appear. By the time the Allies had begun to acquire their own very limited supplies of mustard gas, Germany was on the defensive and its stocks of mustard gas in short supply also. Although it never did, mustard gas could well have been the CW agent which reversed the whole underlying logic of the gas war. Instead of mobilizing a static front, it could have slowed down a mobile one. Instead of disabling the men behind the barricades, it could have created new and more formidable obstacles. That it did not do so was also due to its low percutaneous toxicity. The obstacles it could be used to create were not physical ones: they were effective, not because the gas killed or immediately disabled anyone who entered the contaminated area, but because they threatened field commanders with delayed casualties on a scale that might be unacceptable. Another forty years passed before an agent was found which could come any closer to providing physical barriers.

The significance of gas during World War I

It is difficult to assess the importance of CW techniques during World War I. Gas was one new weapon among several, and like the tank, the submarine and the combat aircraft it was employed on an increasingly large scale as the war progressed. While it was not a battle-winning weapon, and certainly not a war-winning one, there were a number of engagements on the European fronts where the outcome would have been different had gas not been used. Instances of this can be found, for example, during the German offensive in France during the spring of 1918. [329] From this point of view, then, a diligent military historian might be able to detect some influence of gas on the overall outcome of the war. He would also have to consider the longer-term aspects of chemical techniques in the war of attrition as it developed in Europe—the debilitating effect on morale of forcing troops to operate for long periods in a CW environment, the encumberment of supply channels with CW matériel, and the further demands on chemical industries already stretched to the fullest extent to provide explosives and other necessities of war. Having done all this, it seems doubtful whether he would in fact conclude, as did two of the British official war historians, that "gas achieved but local success, nothing decisive: it made war uncomfortable, to no purpose" [335]. But these considerations are now largely academic. The facts of the matter are that some people felt gas to be an important weapon; that they were able to find ways of demonstrating its importance sufficiently convincingly for the initiation of large development, procurement and deployment programmes; and that by the end of the war gas had become a standard weapon, if not a universally popular one. Few people doubted that it would be used again in some future war, and because its technical and military possibilities had clearly not been exhausted it became a weapon to be taken seriously.

After World War I, the CW research establishments were consolidated and the lessons of the gas war assimilated. Much of the surplus CW matériel remained on the inventory of the victors, and it seems that in due course some of this was used in a number of the lesser conflicts of the next decade or so. Countries uninvolved in the war were also obliged to pay attention to the new weapon, and many of them set up research establishments of their own [1]. Some made haste to acquire their own CW capabilities, often employing CW experts from the Allied or Central powers to do so. These further sources of chemical weapons were also manifest on the battlefields of subsequent conflicts.

1919–1921: The USSR

Chemical weapons accompanied those Allied forces that intervened in the Russian Civil War, and were also supplied to some of the White Russian armies. The British, for example, equipped General Deniken, who was operating in the South, with gas shell, while they used gas in their own campaign in the North. At the beginning of 1919, for example, the M device[12] first saw operational use; it was employed as an air-dropped weapon against Red forces operating from the forests around Archangel. It is said that its reported results fully justified the faith which had been placed in the weapon in 1918. [20]

According to an ex-chemical officer who served in it, a unit of the Red Army made preparations in the spring of 1920 for a large gas-cylinder attack in operations near Kakhovka against General Wrangel's White Army, but the attack never took place [54]. General Waitt of the US Chemical Warfare Service, writing in 1941 [336], states that gas was used by "Soviet

[12] See page 38.

flyers in Turkestan". He said that it had not been possible to verify this report, and he did not quote his source for it.[13]

The early 1920s: Peace-keeping operations in British-controlled territory

There are reports stating that British forces used chemical weapons during peace-keeping operations in the Middle East and around the northwestern frontier of India. The Royal Air Force is said to have used gas on such occasions [336, 337]. CW experts are also authoritatively reported to have accompanied the British expeditionary forces to Dacca in Afghanistan and to Datta Khel in Waziristan; it was feared that some of the chemical weapons supplied earlier to the White Russian armies might have found their way into the hands of the dissidents [20].

The mid-1920s: Morocco

Spanish aircraft are said to have dropped mustard-gas bombs on the Riffs in the spring of 1925 [336, 337]. The French also were alleged to have used gas during the Moroccan wars, on the northern front around Fez, a few months later [338]. The latter allegation was strongly denied by the French War Office.

The early 1930s: China

Chemical weapons are said to have played a decisive role in northern China when the Governor of Manchuria, Chang Tso-lin, defeated insurgent forces led by his rivals Wu Pei-fu and Feng Yu-hsiang [339]. There is no information about the source of the weapons.

1935–1936: Ethiopia

According to Soviet commentators [122], 15 000 out of a total of about 50 000 Ethiopian army casualties were caused by chemical weapons dur-

[13] Soviet scholars say that no substantiation can be found in Soviet archives for General Waitt's statement. Similar poorly-substantiated allegations of the use of gas by Soviet forces inside the USSR include the statement by an ex-chemical officer of the Red Army that in the late 1920s "during the suppression of the rising in the Caucasus, chemical shells were used to destroy the defenders and the population of the mountain villages". He also states that "in the 1930s, during actions against the Basmatch tribesmen in Central Asia, Soviet aircraft sprayed ... mustard gas". [54]

ing the Italian invasion of Ethiopia. They state that the Italians brought about 700 tons of CW agents into Ethiopia during the war, of which 60 per cent were vesicants and 40 per cent asphyxiants.

When reports of CW appeared in the European press during the war, the Italian Government at first denied them, but later implicitly confirmed them by maintaining within the League of Nations that the 1925 Geneva Protocol did not prohibit the use of chemical weapons in reprisal against other illegal acts of war. The Italians had earlier circulated reports of Ethiopian atrocities: "... torture and decapitation of prisoners; emasculation of the wounded and killed; savagery towards, and the killing of, non-combatants; systematic use of dumdum bullets, etc ...".[14]

The main evidence available of the use of chemical weapons against the Ethiopians consists of reports and statements made by members of the various European ambulance units operating within Ethiopia and by European doctors attached to the Ethiopian Red Cross. They are augmented by the reports of newspaper correspondents covering the war and by Ethiopian communiqués purportedly based on the reports to Addis Ababa of Ethiopian army commanders. On this evidence, the use of chemical weapons proceeded as follows.

Apart from a dubious report given during the second week of October 1935 that chlorine had been used in the South, in the Ogaden [340], the first evidence of chemical warfare was that, in December 1935, Italian aircraft dropped tear-gas grenades on Ethiopian troops massing in the Takkaze Valley near the Eritrean frontier, in the Northeast [341, 342]. Some reports state that asphyxiating gas as well as tear gas was used on this occasion [341, 343]. By the end of December, mustard-gas bombs were in use: one such bomb has been described as torpedo-shaped, rather more than a metre in length, having a nose section breaking off on impact to release an inner container holding about 20 kg of mustard gas. Like their predecessors, these bombs appear to have been rather ineffective. Throughout the remainder of the war, mustard gas was usually sprayed from aircraft [344]. In his speech to the Assembly of the League of Nations, Emperor Haile Selassie described the spray-tank operations as follows:

> ... Towards the end of 1935 Italian aircraft hurled upon my armies bombs of tear gas. Their effects were but slight. The soldiers learnt to scatter. The Italian aircraft then resorted to mustard gas. Barrels of liquid were hurled upon armed groups, but this means also was not effective. The liquid affected only a few soldiers, and barrels upon the ground were themselves a warning to troops and to the population of this danger.

[14] The consideration given within the League of Nations to the reports of Italian use of chemical weapons is discussed in detail in Volume IV of this study. The legal argument advanced by Italy is discussed in Volume III.

It was at this time when the operations for the encirclement of Makale were taking place that the Italian Command followed the procedure which it is now my duty to denounce to the world. Special sprayers were installed on aircraft so that they could vapourize over vast areas of territory a fine death-dealing rain. Groups of nine, fifteen and eighteen aircraft followed one another so that the fog issuing from them formed a continuous fog. It was thus that as from the end of January 1936 soldiers, women, children, cattle, rivers, lakes and pastures were drenched continually with this deadly rain. . . . [342]

Once spraying operations had begun, the number of gas casualties rose enormously. By March 1936 several of the ambulance units were treating cases at a rate of a hundred or more a day. Those that issued reports were operating near the northern front in the foothills and bush around Korem, Alomata, Quabbo and Weldaya. The town of Korem itself was reported to have been sprayed on four successive days during the first week of April, producing many casualties among noncombatants. The last recorded CW incidents were on the Ogaden front, at Daggah Bur and Sasobani, during the second week of April 1936.

In the view of a Polish doctor serving with the Ethiopian Red Cross, three types of CW agent were in use. One he identified specifically as mustard gas; another was a lachrymatory and sneeze-producing agent; the third he could not identify: he did not agree with his assistant that it was phosgene. (He stated that it smelled of hyacinth.) Other reports, however, did speak of the use of phosgene, as well as mustard gas [345], or of asphyxiating gas [346], but none of the medical reports mention phosgene as a causative agent for the types of casualty being treated—predominantly skin and eye burns, and lung damage. A Norwegian doctor reported the use of mustard gas in admixture with some other agent.[15]

There is no good reason to doubt that the Italian expeditionary force did indeed use chemical weapons in Ethiopia. It will be useful now to discuss the reasons why it did so.

The functions of chemical weapons during the war

Two main features characterize the manner in which gas seems to have been used in Ethiopia. First, only aircraft-delivered chemical weapons were employed, and second, as far as the employment of mustard gas is concerned, the bomb quickly gave way to the spray tank as the principal means of delivery.

[15] Much of the evidence provided by doctors and ambulance units on the use of chemical weapons in Ethiopia is summarized in Volume IV of this study.

A possible conclusion from the first of these points is that, given the extended supply lines of its expeditionary army, the Italian High Command felt that while it was not worth giving its ground forces a CW capability, aerochemical weapons were worth having for some sort of ground-support role. Adoption of the spray tank as the principal means of delivery can be interpreted in terms of the growing appreciation of the possible ground-support functions of aerochemical weapons.

It seems probable that the initial use of gas bombs in and around the Takkaze Valley was purely experimental [347]. One commentator has explained it as a desperate move by General Badoglio to disrupt an imminent Ethiopian incursion into Eritrea [343]. This interpretation is belied, however, by the General's memoirs [348]: the field orders, battle plans, etc., of the engagement concerned—which he reproduces—strongly suggest that the Italian forces in the vicinity were fully capable of coping with the situation without having to rely on chemicals [349]. As for the mustard-gas bombs, one Ethiopian commander on the northern front is reported as having said that, although their effects had initially been considerable, his army rapidly became accustomed to them [344]. From a technical point of view, the performance of the bombs does not appear to have been very great: they provided gross ground-contamination within a radius of 10 or 20 metres, but the bomb fragments were generally clearly visible, and there was little aerosol effect. Ethiopian troops learned to avoid crossing ground in the immediate vicinity of bomb fragments, so that unless the bombs fell on top of troop formations they had little effect. Against mustard-gas spray tanks, however, evasive action was much more difficult. No protective equipment was available, at any rate not for the skin. If several aircraft were used to deliver the attack, the area covered by the spray was too great for people to escape contamination unless they were at its edges; and there were no bomb fragments to warn people against crossing previously contaminated terrain.

The Italians appear to have put their mustard gas to three main uses:

1. To protect the flanks of advancing columns. By laying down swathes of mustard gas on either side of an advance, the risk of ambush was reduced, the extended communication and supply lines were better protected, and the movements of Ethiopian forces were channeled so that they could not evade frontal assault [244, 349]. Furthermore, by spraying mountain sides along the line of advance, it became less necessary to picket the heights and thus reduced the Ethiopians' advantage that stemmed from their experience in mountain warfare [350].

2. To disrupt Ethiopian communication centres. The repeated mustard-gas attacks on Korem have been interpreted as part of the prolonged Italian

attempt to render untenable the nodal point of the Ethiopians' northern communications [351].

These two techniques are an extension of part of the mustard-gas artillery shelling doctrine established by the Germans during World War I.

3. To demoralize Ethiopian forces on the retreat. Mustard gas, with its delayed effect, could not be used to stem an Ethiopian advance, nor could it be used in close fighting. But once an Ethiopian assault had been repulsed and the Ethiopians forced to disengage and fall back, mustard-gas spray, in combination with HE bombs and air-to-ground machine-gun fire, could turn the retirement into a rout. The intention was to ensure that once an Ethiopian army had been defeated in the field, the casualty and demoralizing effects of the gas would permanently disrupt its unity. [349]

Some writers hold that CW had a decisive effect on the outcome of the war [122, 244, 352]; others hold that it was merely a useful tactical aid, not of any major significance by itself in determining the outcome [349]. The former group generally takes the view that Italy, harassed by the League sanctions, was anxious to bring the war to an end as soon as possible; its campaign had not progressed far enough by the time the rainy season was approaching and, as fighting would then become impossible, extraordinary measures had to be taken. Gas was therefore used to demoralize the unprotected Ethiopians, and to break their resistance once and for all. [352] "The use of gas definitely shortened the war by about nine months, or perhaps more" [244].

Whether or not the rains would have immobilized the Italian army, this view probably exaggerates the power of the League sanctions. Possibly if gas had not been used, the Italians might not have reached Addis Ababa in one campaign; but they would probably have got there sooner or later unless outside powers took much more drastic steps to stop them. [349] In addition, CW techniques were not introduced as suddenly as this explanation would require; rather, they were used to accomplish a gradually increasing range of tactical objectives in the face of unexpectedly stiff resistance. In this way the war was probably shortened, but its outcome was not seriously affected.

1936: Spain

There was no dearth of reports of CW during the Spanish Civil War, for the recently concluded Italo-Ethiopian War had demonstrated vividly the ability of such allegations, whether founded in truth or not, to stir public feelings. There were reports of shipments of gas from Hamburg [350, 354], and counter-reports of shipments from Black Sea ports [355]. Emergency appeals for supplies of gas masks were launched on several occasions by both right-wing and left-wing organizations throughout Europe.[16]

Nonetheless, the only report which has any ring of truth about it came during the early stages of the war, when a well-regarded London newspaper quoted both an insurgent spokesman and "an observer on the government side" on an incident in August 1936. Thirty-four guns of government artillery, it was stated, had fired tear-gas shell against insurgent positions on the Guadarrama front [356]. Subsequently, newspapers reported threats by the insurgents to retaliate with their own stocks of gas; the inhabitants of Madrid were stated to be expecting their city to be gas-bombed [357]. Reports in December stated that Madrid had been shelled with CW casualty agents and that in the previous month government forces had used gas on a massive scale [358].

1937–1945: China

A Soviet authority has summarized the part played by gas in the Sino-Japanese War as follows: "Japanese units active in China included 25 per cent chemical projectiles in the complement of artillery forces, and in the store of aviation munitions 30 per cent were chemical bombs. In several battles up to 10 per cent of the total losses suffered by the Chinese armies were due to chemical weapons." [122]

A post-war survey of the reports and allegations of CW that was made by the US Army refers to incidents between 18 July 1937 and 8 May 1945, and to the use of the following CW agents: CN, DA, DC, phosgene, diphosgene, chloropicrin, hydrogen cyanide, mustard gas and lewisite.[17] The weapons said to have been used included aircraft bombs, artillery shell and toxic candles. [53, 359]

The decision to use gas against the Chinese rested with the Chief of the Japanese Army General Staff [359], and by the mid-1930s chemical weapons had been sufficiently accepted by the military establishment to permit their development to an operational level. The performances of the weapons in the field were watched closely, and the lessons so learned assimilated into the courses of instruction at troop training centres. The Inspectorate-General of Military Education, for example, was issuing a series of pamphlets entitled *Lessons from the China Incident,* and these often included appreciations of particular engagements in which chemical weapons had been employed. [359]

However, none of these *Lessons* describe the use of any chemical weap-

[16] These reports are discussed further in Chapter 3.
[17] These agents are described in Chapter 1.

ons other than harassing-agent weapons, and Japanese officers under interrogation at the close of World War II denied that chemical casualty agents had ever been used. (But the imminence of the War Crimes Tribunal would hardly have encouraged veracity on this point if such agents had been used.) The use of irritant agents was freely admitted, however, but the Japanese did not regard this as being prohibited by international law, because it caused neither death nor permanent injury. [359]

The profusion of reports on the use of casualty agents by the Japanese, from a wide variety of sources, throws heavy doubt on these officers' assertions. Contemporary reports span the period from August 1937 to November 1943 [360–69]. On 14 October 1937, China raised the matter at the League of Nations, producing evidence to support its case from officials from the local Red Cross organization and the League Health Organization [370]. Ten months later it made a further protest, again alleging Japanese use of mustard gas, and cited a report by a British surgeon at Nanchang General Hospital who had treated nineteen gas casualties after fighting on the Yangtze front in July [371].[18]

The protests to the League were supplemented by numerous communications from the Chinese Foreign Ministry to the governments of the major world powers. One such communication, to the British Government in August 1938, stated that a night gas attack on two Chinese battalions in the Juichang sector succeeded in killing almost the entire complement of officers and men [372]. Toxic candles disseminating irritant agents were certainly being used on a massive scale at that time: *Lessons from the China Incident, no. 5* contains a study of an engagement in July 1938 in which 18 000 toxic candles were ignited over a 9 kilometre front, providing support and a screen for an infantry assault [359]. In all, the Chinese Government claimed 889 CW incidents prior to 1939 [51].

A CW incident in mid-October 1941 was extensively investigated by a US officer. It occurred on the Yangtze front at Ichang, and 1 600 Chinese gas casualties, of which 600 were fatal, were reported. Photographs of the casualties were released in Chungking on 26 November 1941 and subsequently appeared in US newspapers. [51] The incident is described in an evaluation of Japanese CW capabilities made in 1944 by a US intelligence unit [53]: the Chinese, having been forced out of Ichang, re-occupied it in the face of heavy mortar and artillery fire of irritant agent and HE shell; advancing further into the surrounding hills, they were then heavily bombed and shelled with munitions containing a mustard/lewisite mixture, and suffered extensive casualties.

[18] These and other appeals to the League, and the League's response, are described in Volume IV of this study.

The use of gas against Chinese civilian populations is also recorded. In central Hopei, for example, Chinese peasants took refuge from the invaders in the extensive caves and tunnels of the region, as they had done for centuries. Instances are reported of Japanese troops using CW agents to drive them out, or to kill them as they hid. In an account of one such operation against peasants in caves around the village of Peihuan in Ting Hsien on 28 May 1942, 300 Japanese soldiers are said to have surrounded the area and then discharged gas into the tunnels, killing some 800 Chinese people [373].

The Chinese were almost completely unprotected against gas, and were to remain so until after the USA had entered the war. Nonetheless, there is a report of Chinese use of gas against the Japanese. This is contained in an assessment prepared by a military intelligence unit of the Japanese Kwantung Defence Army, which refers to an artillery shoot of phosgene and diphosgene shell against Japanese divisions at Ch'ing Hua Chen in September 1938. No details of the shell, or their origin, are given. [374] They might well have been captured Japanese stores.

The functions of chemical weapons during the war

The principal advance in CW theory made by the Italians in Ethiopia may be said to be the demonstration with their aircraft spray tanks that mustard gas could be used to military advantage even with extended lines of communication and supply, provided that the enemy was unprotected against it, and provided that he lacked anti-aircraft defences. The Japanese experience in China supported this, and in addition showed how irritant agents could be effectively used by ground forces in mobile warfare situations, again provided that the enemy was unprotected.

The Japanese Army had begun training programmes in CW techniques in 1933 [359] and in the following year had begun production of CW agents, initially mustard gas, lewisite and diphenylcyanoarsine (DC) [50]. From the first, the emphasis was on ground weapons for CW, aerochemical weapons being developed rather late.

Gas appears to have been accepted by army commanders as a standard weapon, albeit without much enthusiasm and, as we have seen, the decision to use it against the Chinese rested not with the Emperor but with the Army General Staff [359]. In view of this, it was probably only a matter of time before gas was employed during the Japanese expeditionary campaign. According to US intelligence reports, the Japanese had established a field CW laboratory in Shanghai in October 1937 whose purpose was to collect information on the state of Chinese CW preparedness. It must have discovered quickly that this preparedness was minimal. By the spring of

1938 reports of Japanese use of chemical weapons were becoming more and more frequent. Japanese production of CW agents, notably of lewisite and DC, increased markedly in 1937–38. [50]

To judge from those of the *Lessons from the China Incident* that refer to CW, the Japanese Army CW establishment viewed the China campaign as a valuable opportunity both to verify its assessment of the possible uses of chemical weapons, and to secure their wider acceptance throughout the army. The *Lessons* contain glowing accounts of the various successes of gas, interspersed with accounts of its failure where it should have succeeded—all ascribed to ignorance or elementary blunders by the field commanders.

None of the *Lessons* deal with the use of chemical agents other than irritants. Possibly at the time of the invasion of China, casualty-agent weapons had not yet reached the same level of technical development as the harassing-agent weapons, and were not yet ready for doctrinal experiment. Alternatively, the functions of those casualty-agent weapons that were operational were perhaps considered too specialized or otherwise unsuitable for description in publications such as the *Lessons*. Possibly the instances where more lethal chemicals were used—assuming the reports to be true—were nothing other than technical field trials of experimental weapons: a US intelligence report, for example, refers to small-scale "experiments" with gas bombs in China—50 kg mustard/lewisite, phosgene and diphosgene bombs [53].

A 1944 US evaluation of Japanese gas tactics in China read as follows:

> [Gas] is said to have been employed in cases in which the Chinese were applying pressure and the Japanese wished to conserve manpower. In general, large amounts were used on small fronts, to support Japanese counter attacks. The chemical operations were never widespread but, rather, concentrated in certain areas and repeatedly used. . . .
>
> In all those Chinese operations where gas was employed it was concentrated on the most important section of the objective. Nonpersistent gases were used on the offense, and persistent ones on the defense.[19] Efforts were made to achieve surprise by firing chemical shells immediately after bombardment with HE, as well as by sudden gas attacks. . . . Smoke was used to hide gas clouds or to precede them. . . . [53]

The same evaluation described the Japanese gas tactics at Ichang as follows:

> In the Ichang action of October 1941, a heavy attack was launched by the Chinese to take the city and carry the heights beyond, where a defensive position

[19] There were reports of several occasions when the Japanese had defended their perimeters against the Chinese by spreading mustard gas around them. In one case an area 2 500 by 50 metres was contaminated in this way.

could be organized. Chinese reinforcements had been moved into the area in late September and early October in preparation for the attack. This movement was observed by Japanese planes, and new defensive dispositions were made, but no sizable Japanese reinforcements were moved up.

Japanese artillery and mortar fire increased in intensity, and considerable amounts of tear and vomiting gas were reported mixed in with the HE firing .... Between 5 and 8 October some additional mortar companies were reported, and indications are that the bulk of the chemical munitions were fired by them. Harassing gases only were used prior to the Chinese attack, which was launched about 8 October.

The city of Ichang was taken by the Chinese in this attack, and the Japanese retired to the semi-circular ridge beyond the city, fighting a delaying action.

When the Chinese pressed the attack to take this ridge, the Japanese launched counterattacks from both flanks, and great quantities of a persistent war gas were placed on the attackers and the low areas behind them. From 10 to 12 October, planes dropped gas bombs all over the area.

The Chinese troops were either barefoot or wearing straw sandals, without gas masks or protective clothing, and they were severely gassed and burned. Their reserves also were gassed heavily and received many casualties, most of which proved fatal.

Forced to abandon their attack the Chinese had to proceed through low areas to avoid machine gun fire and thus crossed heavily concentrated gas barriers. Laboratory tests of samples of the gas and parts of shells and bombs showed the agent used to be a mixture of mustard and Lewisite. [53]

The Japanese CW techniques so far described had little novelty over those used during World War I or the Italo-Ethiopian War. However, there was one other technique which they appear to have used frequently and which departed from existing practice. This was the use of irritants for purposes other than simple harassment of the enemy; in many respects, some of the employment techniques seem analogous to those later used by US forces in Viet-Nam.

The principal irritant was diphenylcyanoarsine (DC),[20] of which the Japanese Army manufactured some 2 000 tons between 1934 and 1945, about 60 per cent of this prior to 1942 [50]. It was used as a fine-particle aerosol (smoke), generated from candles, pots, mortar and artillery projectiles and occasionally from small aircraft bombs. Although it was not intended as a casualty agent, it seems to have caused fatalities; this is indicated in *Lessons from the China Incident, no. 7*: "When the [Chinese] soldiers came in contact with special smoke [i.e., DC aerosol], some seriously affected persons bled through their noses and mouths and died from asphyxiation." The Chinese were generally completely unprotected against it. The following quotations from *Lessons from the China Incident, no. 5*

[20] Chloroacetophenone (CN) was not manufactured by the Japanese Army until 1939, and then only in small quantities.

(October 1938) and *no. 7* (April 1939) illustrate the ways in which the agent was used:

Use of DC to support and screen advances:

> In the battle near Chü-Wuo waged by the 20th Division, some 18 000 special smoke candles were accumulated for use over a length of 9 km in front of the enemy's strongly fortified positions. On 6th July ... we started screening by some 6 to 7 000 special smoke candles for some 5 km in front of the enemy's left wing. ... Under cover of this screen we were able to penetrate about 3 km into the enemy's line and ... the enemy could do nothing to check our advance. ...

Similar usages to force river crossings are also described.

Use of DC to weaken enemy morale:

> Against an enemy poorly equipped with gas protective materials, a small amount of special smoke let loose in the course of battle will cause fear and kill morale in the enemy rear echelon, which will often lead to retreat, thus enabling a comparatively small force to capture a strong position held by an enemy of superior strength. ...

Use of DC to break contact with the enemy:

> At a certain spot along the Yangtze River bank, a trench mortar company and an independent engineer section were hemmed in by a strong enemy force and were in danger of complete annihilation, when an infantry section used only four special smoke candles to drive away the enemy and saved the troops.

Use of DC against fortified positions:

> In an attack upon the enemy's special firing posts, such as a pill-box, you will send the most daring and resourceful soldiers to sneak close to them and throw in special smoke candles. ...

Use of DC in conjunction with conventional weapons:

> The enemy ... machine gun resistance was obstinate and could not be silenced even by concentrated shrapnel fire from our mountain and heavy artillery. Only with the aid of special smoke shells projected by our mortars was their fire overcome. ...
>
> The 2nd Battalion of the 1st Regiment of the Hata detachment attacked the enemy frontally, but our right flank was threatened by the enemy artillery that continued firing from their position near Tä-Chao village. The detachment tried to overcome their artillery with ordinary shrapnel shells, but without success, as they were hidden in woods. At this juncture, our mortar company decided to use special smoke shells, and by firing ten rounds of special smoke shells succeeded in routing the enemy out of the woods into an open position near the village of Tä-Chao. As soon as the enemy came out into an open field, our mountain artillery annihilated them with ordinary shrapnel shells.

1939–1945: World War II

The principal nations engaged in World War I did not begin manufacturing chemical weapons on any scale again until the years immediately preceding World War II. When that war broke out, the belligerents all possessed modest chemical stockpiles; by the end of the war these had grown to an overall size considerably larger than the total quantity of chemical weapons used in World War I. Apart from certain incidents, detailed below, these stockpiles remained unused,[21] and were mostly destroyed after hostilities had ceased.[22]

The European theatre

In May 1942 German military authorities are reported to have stated that by mistake their forces had used gas once during the Polish campaign and

[21] See Chapter 5.

[22] Some of these disposal activities are described in Chapter 5 on page 305. A large proportion of the weapons were dumped at sea. British dumping grounds for their own and imported German weapons included a 100-fathom (ca. 200 metres) site 20 miles off the west coast of Ireland and a site in the Bay of Biscay, both of which were used to dispose of around 175 000 tons of weapons during the period 1945–48; the remaining British stockage of chemical weapons, about 25 000 tons, all manufactured during the war years and including about 6 000 tons of nerve gas (tabun) of German origin, was dumped during 1955–57 at a 1 000-fathom site in the Inner Hebrides [885–86, 889, 935–36]. Other German weapons, apart from those appropriated by the various Allied countries, were dumped in the Baltic immediately after the war. Full records of these operations do not seem to have been kept, but it appears that there were at least three sites at which not less than 20 000 tons of weapons were dumped. One was in the Skagerrak off the coast of Norway where around twenty ships whose cargoes included chemical weapons were scuttled by the British [937–38]. Another site was in the outer Bay of Kiel; ships that had been loaded with tabun weapons shortly before the war ended were scuttled here under Allied supervision. (In 1959–60, however, after mounting concern about pollution, the corroding weapons were retrieved by the West German Bundeswehr, embedded in concrete, and scuttled in the Atlantic off the Azores.) [939–40] A third site was 20 miles off the east coast of the Danish island of Bornholm: here the Soviet Navy is said to have sunk a large number of captured mustard-gas weapons by enclosing them in wooden crates, throwing the crates into the sea, and sinking them with machine-gun fire [940–41]. Fishermen and bathers in the Bornholm area have frequently suffered mustard-gas burns [937, 940–45]. Dumping grounds for French chemical weapons include a 1 000-fathom site in the Bay of Biscay, where 1 700 barrels of mustard gas were sunk in 1965 [946]; it is also reported that the French have dumped 24 000 tons of chemical weapons in the Mediterranean, off St Raphael [944]. Sea dumps of Japanese chemical weapons include a mid-Pacific site at Wake Atoll (from which, in 1968, the inhabitants of Peale Island were exposed to powerful airborne doses of chloropicrin [947]), and a site off the east coast of Choshi, where US forces dumped captured weapons at the end of the war, and where, as in the Baltic, local fishermen have recently been suffering mustard-gas injuries [948–50]. The US Army has been dumping obsolete, surplus or decaying stocks of chemical weapons in the Atlantic ever since the war ended, most recently in August 1970 [951]. The last occasion when World War II weapons were disposed of was apparently in August 1968, when a load of, *inter alia*, mustard gas was dumped at a 1 000-fathom site 200 miles off the east coast of New Jersey [947, 952].

again in the Crimea [375]. No further details were given, but a newspaper correspondent in Warsaw had reported that on 3 September 1939 mustard-gas bombs had been dropped on the suburbs of the city [376]. The Polish Government in exile also referred to the German use of gas against Warsaw [377].

These reports were complemented at the time by statements from Berlin that Polish troops had emplaced mustard-gas land mines around a bridge on the outskirts of Jaslo, in Galicia, which had subsequently gassed fourteen German soldiers [378–79]. This report was built up into a sizeable propaganda operation: leaflets posted around the world from Denmark and radio broadcasts all alleged that the mines had been supplied to Poland by the UK.

Further insight into the Jaslo incident is provided by an account of German CW preparedness in World War II which has recently become available [212]. It was written for the US Army Chemical Corps in 1948–49 by Herman Ochsner, formerly a Lieutenant-General in the German Army, commanding the German chemical troops [380]. Ochsner writes:

> A few days after the opening of the Poland campaign, reports arrived from the front that chemical warfare agents had been used at Jaslo, causing very serious burns. A committee of three (including the author) at once travelled by air to the spot. It was found that the Poles had undoubtedly used mustard gas when abandoning a bridge over the Wisloka river near the small town of Jaslo. When the committee arrived on the scene three to four days later it was found that the characteristic odour of mustard gas was still prevalent; the gas detector indicated mustard gas, and a chemical analysis of traces of the agent used proved beyond doubt that it was mustard gas. Of the soldiers affected, one or two died a few days later and a number remained in hospital with severe swellings and blisters, particularly under the armpits, in the region of the genital organs and around the eyes. The author personally saw them. The description given by the injured engineers was as follows: the bridge was blocked by means of personnel road blocks (Spanish Riders) and barbed wire entanglements. When the men commenced removing these obstacles, demolition charges, cans, and drums exploded, spraying the surrounding area with a fluid that had a peculiar odour. In the heat of battle the men affected did not stop to think of this incident and took no precautionary measures. When the bridge was cleared the troops crossed it. All this happened during the afternoon, and it was during the ensuing night, whilst sleeping in an overcrowded tent and in their dirty clothing, that the first effects became apparent in the affected engineers. Toward morning and in the course of the following day a number of men fell ill.
>
> It was with tense expectation that command headquarters waited to hear whether any further similar incidents were reported. No such reports arrived. However, similar cans were reported to have been found in other localities. It was discovered later that the cans contained an agent used by the Polish army in gas defence training, and that it contained a high percentage of real mustard gas.

This confirmed our first impression, which was that the use of mustard gas at the Jaslo bridge had not been ordered by the Polish supreme command. In the purely local use it would have been of no value either strategically or even tactically and would have apprised us, at comparatively low cost, of the nature of a Polish chemical warfare agent, while the Polish army would have been stigmatized as the first to have employed methods of warfare outlawed by public opinion in the world and by international agreements. This realization was a great relief to us. [212]

As regards the Crimean episode, TASS had reported the German use of chemical mortar bombs on 7 May 1942 [381]. During May 1942 the German forces in the Crimea also reportedly used poison gas against people sheltering in underground tunnels. According to a Soviet account, one such incident followed the encirclement of a Red Army unit in the Kerch Peninsula: the beleagured troops sought refuge in the stone quarries of Ajim-Ushkai, where they were joined by a large part of the local civilian population.[23] "The Germans sealed off all the exits and systematically introduced vast quantities of poison gas. . . . Five mass graves, with a total of more than 3 000 bodies, have been discovered in the quarry galleries." [382]

An incident reported to have occurred during the Allied operations at Anzio in Italy at the beginning of 1943 is worth mentioning here. Shortly after the landings, a German shell is said to have hit an Allied dump of chemical weapons maintained in the Anzio beach-head area. This apparently caused a cloud of CW agent to drift towards the German lines, and it is reported that the Allied commander warned the German commander about this, assuring him that the release of gas was unintentional. [383]

The use of poison gas in German concentration camps

Large quantities of poison gas were used as a means for killing prisoners in German concentration camps. Evidence presented at the Nuremberg War Crimes Tribunal indicates that gas chambers were used in the camps at Buchenwald, Auschwitz, Sachsenhausen, Neuengamm, Lüblin, Gross-Rosen, Ravensbruck and Treblinka. In the testimony of the commandant of the Auschwitz camp, two and a half million people at his camp alone were killed with gas between May 1940 and December 1943. The agents used in the camps were either carbon monoxide from internal combustion engine exhausts [185], or the composition known as *Zyklon B*. This latter material, consisting of hydrogen cyanide adsorbed onto a powder base, had been developed as an insecticide during the early 1930s [35]. Its supplier, the

[23] Ochsner [212] refers to the potential usefulness of gas for smoking Soviet troops and partisans out of "the catacombs in Odessa, the caves at Kerch, the innumerable bunkers in former Russian positions now behind our lines", but says that orders were issued specifically prohibiting such usage.

firm of Degesch—a partially-owned subsidiary of IG Farben[24]—supplied the following quantities (at least) to concentration camps:

Sachsenhausen	4 352 kg	(1942, 1943)
Neuengamm	607 kg	(1942, 1943)
Lüblin	1 628 kg	(1943)
Gross-Rosen	430 kg	(1943)
Ravensbruck	352 kg	(1943)
Auschwitz	19 653 kg	(1942, 1943)

The sizes of pre-1942 and post-1943 supplies are not known; it is recorded that by the end of the war 4.5 million prisoners had been killed at Auschwitz alone [996].

Inmates of certain concentration camps were also used as experimental subjects for work on CW agents. One such series of experiments was authorized by Himmler in a decree dated 14 July 1942 [385]; the work consisted of a study of possible chemotherapeutics for the treatment of mustard-gas burns complicated by streptococcal, staphylococcal and pneumococcal infections, and was performed at the Natzweiler-Struthof camp. Similar work had been going on at Sachsenhausen since 1939. Another programme at Natzweiler was to find out whether hexamethylenetetramine had any prophylactic value against phosgene poisoning. [386]

The war at sea

Initial German newspaper reports of the Battle of the River Plate stated that the battleship *Admiral Graf Spee* had been forced into Montevideo harbour, not because she was fleeing British cruisers, but because she had been shelled with mustard gas by the latter and needed to decontaminate and seek medical aid [387]. This allegation was subsequently shown to be unfounded by a medical commission appointed by the Uruguayan Ministry of National Defence, members of which examined the casualties put ashore from the battleship. [185, 388]

The Pacific theatres

The Japanese used sternutatory smoke candles, and apparently even hand grenades charged with hydrogen cyanide, on a number of occasions against US troops during the Islands campaigns. These attacks were always on a small scale, and were apparently undertaken by junior officers without the sanction of the Japanese high command [42, 51, 389], or by individual Japanese soldiers using whatever weapons they had on hand [390].

[24] Zyklon B was produced in a small pilot plant at the IG Ludwigshafen chemical works [384].

An unconfirmed report states that Singapore was bombed with mustard gas in December 1941 [391].

In Burma the Japanese alleged that both chemical and biological weapons had been used against them [392], but this charge may have been a riposte to similar Chinese allegations made during the Japanese advance through Toungoo [364].

1945–1949: China

During the Chinese Civil War, both sides made a number of allegations that their opponents were using gas [393–94]. The Nationalists' operations were reported to have been supplied from a large gas dump at Suchow in Northern Kiangsu, and it was implied that this dump had been filled with chemical munitions supplied by the USA [395].

1947: Indo-China

In January 1947 the French Foreign Minister described as "absolutely false" a report that French forces had used gas in fighting Viet-Nam nationalists. "I have given emphatic standing orders that under no circumstances should gas be used in Indo-Chinese operations. These orders have been followed to the letter. This is the third false report of the use of gas." [396]

1948: Israel

On 3 January 1949 an Egyptian charge that the Israelis had used poison gas against the Egyptian troops trapped at Faluja was emphatically denied by an Israeli military spokesman in Tel Aviv [397]. This charge succeeded others that the Israelis had made covert BW attacks on Egypt and Syria both before and after independence [398].

1949: Greece

During the later stages of the Greek Civil War, the Yugoslav news agency Tanjug reported that government forces were using poison gas against guerillas in the Taiyetos Mountains of the Peloponnese [399]. The Greek War Ministry, in a comment on the report, stated that clouds of a respiratory irritant had been used to drive guerillas out of caves. The agent was sulphur dioxide, generated from burning sulphur [400].[25]

[25] The first recorded military use of sulphur dioxide was also in this area, some 2 300 years earlier, when the Peloponnesians besieged the town of Platea during the Peloponnesian war [318].

1951–1952: Korea

There was some pressure within the United States and from US front-line commanders to use chemical weapons during the Korean War [546, 401] but this was apparently countered by fear that the USSR would provide the Chinese and the North Koreans with retaliatory CW matériel [402].

An official Chinese news agency report, quoted by Peking radio on 5 March 1951, stated that in the early afternoon of 23 February two US aircraft dropped bombs charged with "poison gas of an asphyxiating type" on North Korean positions on the Han River, about 20 miles southeast of Seoul [403]. Other aircraft and artillery CW attacks later in 1951 were alleged in a Chinese Red Cross publication dated 6 December 1951 [1001].

Other allegations of US use of chemical weapons in Korea are contained in a document prepared by a commission of the International Association of Democratic Lawyers. The document is entitled *Report on US War Crimes in Korea,* and was prepared after the commission visited Korea in March 1952. In addition to charges of CW, it also alleges US use of biological weapons; the contents of the report in this latter connection are discussed in Volumes IV and V of this study. The report referred to four alleged uses of chemical weapons in Korea. The first, and largest, of these was said to have taken place on 6 May 1951 when three B-29 bombers dropped gas bombs over a 0.3 km^2 area of Nampo City, causing 1 379 gas casualties, of which 480 died of "suffocation". The commission's report on this incident, purportedly based on eyewitness accounts and expert reports provided by the Nampo City People's Committee, is cited in Volume IV of this study. The three other incidents were said to have occurred: on 6 July 1951 at Poong-Po Ri village, south of Won San; on 1 August 1951 at the villages of Yen Seug Ri and Won Chol Ri, in Hwanghai province; and on 9 January 1952 at Hak Seng village, north of Won San. [404]

1957: Cuba

It is recorded that in Mexican newspapers during May 1957 Cuban émigré groups demanded a United Nations investigation of the alleged use of chemical agents by Cuban Government troops against guerilla forces. It was claimed that mustard-type CW agents had been used. [185]

1957: Algeria

At a congress of the International Confederation of Free Trade Unions held in Tunis in July 1957, a delegate of the General Union of Algerian Workers alleged that the French had been using poison gas against Algerian insurgents. This was subsequently denied by the French military command in Algiers. [405]

1958: Rio de Oro

A communiqué issued by the Liberation Army for the Moroccan Sahara in February 1958 accused French and Spanish colonial forces of using chemical bombs on the Spanish colony of Rio de Oro. The chemicals used were stated to have poisoned cattle fodder. [185]

1958: China

On 4 November 1958 Peking radio alleged that Chinese Nationalist forces on Quemoy had bombarded troops of the Chinese People's Army on the mainland with poison-gas shell. The Defence Ministry in Peking was quoted as threatening "severe punitive action" if the gas shelling continued. [406] The charge was denied by both Nationalist and US authorities in Taipeh [407].

1963–1967: Yemen

There are many reports that chemical weapons were employed by Egyptian forces during their intervention in the Yemeni Civil War. At least forty different CW incidents are reported in the press. As the majority of these reports originated from sources closely allied to the Royalist cause—the Egyptians themselves consistently denied using chemical weapons [408–15][26]—suspicions that they might have been fabricated to serve propaganda

[26] For example, on 1 February 1967 the Egyptian Minister of National Guidance issued the following statement in Cairo:

"World news agencies have reported a statement made in the House of Commons this afternoon by the British Prime Minister, Mr. Harold Wilson, who commented on the allegations disseminated by Saudi Arabia and some propaganda elements co-operating with it, that the U.A.R. used poison gas bombs against the village "Kataf" on Yemeni-Saudi border. The U.A.R. deemed it wise hitherto to ignore these allegations which turned out to be untrue. But the remarks made by the British Premier in the House of Commons gave them certain colour. Although the British Premier was vague when he said that his Government had reason to believe that the allegations were true, his words might give a wrong impression.

"In the name of the U.A.R. I have been entrusted to affirm once again and in a decisive manner that the U.A.R. has not used poisonous gas at any time and did not resort to using such gas even when there were military operations in Yemen.

"I have also been entrusted with announcing officially that the U.A.R. is ready to accept a fact-finding mission from the U.N. and is ready to make necessary arrangements for the mission to go to Yemen immediately. Yemen has agreed to give the mission all facilities to expose the anti-U.A.R. propaganda and those who undertake it in London."

This statement is referred to again in Volume V of this study.

ends are certainly justifiable. Be that as it may, three of the incidents subsequently received close scrutiny from disinterested outside parties, and a good many people believe that the reports which they made verify at least some of the allegations of CW. The reports are discussed in Volume V of this study. It must be stated, however, that the published literature does not completely substantiate any of the allegations.

Casualty figures were quoted for less than half of the alleged CW incidents. In total, these amounted to at least 1 400 dead and about 900 severely gassed. The alleged incidents are grouped into three periods: eight during June and July 1963; at least seven between January and July 1965; and the remainder from the autumn of 1966 until the end of July 1967, shortly before the bulk of Egyptian forces withdrew from the Yemen. Appendix 1 summarizes these alleged incidents.

Tear gases were said to have been the first CW agents to be used, in 1963 [416–18]. Employment of vesicants and lung irritants was rumoured from 1965 onwards but without much substantiation until 1967. Thereafter evidence from the International Committee of the Red Cross (ICRC) pointed to the use on different occasions by an unnamed party of a lung irritant such as phosgene, and of a vesicant such as mustard gas.

Those responsible for the allegations of CW have advanced a number of explanations as to why chemical weapons were employed during the war. One such theory was that gas was viewed as a means for neutralizing those enemy strong posts located within mountain caves that were invulnerable to conventional attack [419]. Another theory was that gas was seen as an efficient means for coercing tribesmen whose allegiances were vacillating between the warring parties; thus, a London newspaper supporting the Royalist cause reported that Radio Sana'a had frequently broadcast warnings that any village that went over, or gave support, to the Royalists would be gas-bombed [420–21]. A third theory was that the Yemeni Civil War provided attractive proving grounds for experimental chemical weapons [416]. The validity of these explanations is of course no greater than the authenticity of the reports to which they refer.

None of the publications that were based on ICRC sources gave any evidence that nerve gases had been used; and one of the ICRC documents specifically discounted their use [422]. Documents circulated by the Saudi Arabian Government around the UN Security Council in April 1967 [408] held that organophosphorus poisons had been used, but the accompanying evidence does not adequately support this claim. The report of a Dutch journalist that "expert observers" had found traces of V-agent nerve gas following a CW incident in June 1967 [416] likewise does not carry conviction.

Four theories have been advanced about the provenance of the chemical weapons that were alleged to have been used. The following newspaper quotations exemplify them:

1\. . . . In Aden. . . . reliable sources reported that the Egyptians were using a "certain type of bomb that causes nasty burns to the skin". Reports first reached London last month [June 1963] from Cairo suggesting that German chemists in Egypt had been experimenting with gas for warfare . . . . [423]

2\. Twelve Ilyushin heavy bombers attacked Katar, near Sada, with poison gas, killing more than 125 persons, sources reported at royalist headquarters here today . . . . It was believed here [Qara, Yemen] that the attack which took place on [7 January 1967] followed the shipment of 600 gas bombs from China to Arrahiba air base, 10 miles north of Sana, as direct aid to the republican regime . . . [424]

3\. . . . Moreover, in 1963, during the Yemen war, the Egyptians began using mustard gas against the Royalists . . .; by 1967 Egypt was using nerve gas, according to official, but little noted, United States reports and evidence accumulated by the US State Department and Central Intelligence Agency . . . .

At least two [British] Members of Parliament and one scientist connected with England's chemical and biological warfare effort have said privately that the mustard gas shells used by Egypt were manufactured by England and stored in Egypt during World War II. The Egyptians apparently have now begun to dig out the many tons of World War II munitions hidden by the English . . . .[425]

. . . The Egyptian use of mustard gas early in the Yemen War was prompted, according to English sources, by the discovery of an old World War II gas weapon depot by the Egyptians . . . . [426]

4\. United States officials have evidence that poison gas bombs dropped in an attack on two Saudi Arabian villages by Egyptian warplanes last weekend bore markings indicating Russian origin. Recovery of fragments of a gas bomb casing, seen by American officials, were stamped with Cyrillic letters, an alphabet used only by Yugoslavia, Bulgaria and Russia . . . . The bombs fell on the villages of Najran and Oizan [*sic*] near the Yemen border and three days ago the State Department said "there have reportedly been civilian casualties".

Charges that Egypt was using poison gas in the Yemen warfare have been made at intervals for the last three years . . . . It has been established that phosgene was the lethal agent in the earlier gas attacks, coming from British bombs of World War II stocks. Officials believed that the gas carried in the canisters dropped last weekend, bearing the Cyrillic lettering, was a much more modern type of lethal agent and was being used for experimental purposes by Communist scientists. The gas was a different kind from that used in an air raid Jan. 5 on the town of Kitaf . . . . [427]

Again it must be emphasized that the validity of these theories can be no greater than the authenticity of the allegations to which they relate.

1965: Iraq

In May 1965 at a press conference in London, a spokesman for the Kurdish Democratic Party stated that on at least two occasions during the previous six weeks the Iraq army had used gas against Kurdish forces. The gas, which had not been identified, was said to have been supplied to Iraq by a Swiss firm through its branch in Italy. It was also claimed that Germany had supplied gas bombs. [428]

These allegations were later denied by the Iraqi Government as unfounded propaganda. They had been preceded by rumours throughout the Middle East that the Iraq Government had suddenly begun purchasing gas masks. Reports in the previous September, for instance, said that the government had been making inquiries of various countries about the possibility of being supplied with some 60 000 gas masks. Eventually, it was said that 70 000 masks had arrived by way of Egypt, possibly originally from Switzerland. By March 1965 there was widespread surmise that the purchases might be connected with an imminent offensive against the Kurdish dissidents [429].

1961–1970: Indo-China

During the past ten years of the war in Viet-Nam and neighbouring territories, there have been frequent reports of the use of chemical weapons. The fact of massive use of anti-plant chemicals and harassing agents by US and South Viet-Namese Army (ARVN) forces is confirmed by official US sources, who maintain, however, that such usage does not constitute chemical warfare. Reports of the use of harassing agents by North Viet-Namese Army (NVA) and National Liberation Front (NLF) forces have neither been confirmed nor denied by their spokesmen. Allegations of the use of more lethal chemicals by one side or other, although fairly numerous if sporadic, remain unsubstantiated. In this section we discuss in turn the use of anti-plant chemicals, the use of harassing agents, and the allegations concerning casualty agents.

The use of anti-plant chemicals

Chemical anti-plant agents began to attract military interest at the time of World War II[27] but it was not until US involvement in Viet-Nam that they

[27] The US Army became interested in anti-plant agents shortly after its entry into World War II. By the end of the war, a research team at Camp Detrick—a BW research establishment—had examined the effects of more than a thousand different chemical agents on living plants. [88] Furthermore, in the words of a brief resumé

came to be employed on a significant scale in combat. Here they were used either to defoliate vegetation, thus removing natural cover that might conceal the enemy, or to destroy food crops.

The US military did not begin large-scale field tests of anti-plant chemicals until 1958–59 [433]; these were carried out under the auspices of the Fort Detrick BW establishment as part of a general programme on anti-crop warfare. The results were alluded to in budget testimony by the Army Chemical Corps in March 1961 [434]. Interest in the possible applications of anti-plant chemicals in Indo-China operations grew when the Department of Defense Advanced Research Projects Agency (ARPA) set up its *Project Agile* in mid-1961. In March 1962, during ARPA budget testimony, the involvement of Agile with anti-plant operations in Viet-Nam was emphasized: "Agile was responsible for the initial application in the field of defoilants [*sic*], which was then requested by the Chief of the MAAG in Vietnam for operational use." ARPA had set in motion a number of field studies of the effects of anti-plant agents on the types of vegetation found in Indo-China. Part of this work was contracted out to the Department

of this work, published in 1946 [88], "only the rapid ending of the war prevented field trials in an active theater of synthetic agents that would, without injury to human or animal life, affect the growing crops and make them useless". This could have been an allusion to the US Army recommendation of June 1945 that ammonium thiocyanate be used as a defoliant in the Pacific theatre (which was rejected at high governmental level on the ground that the chemical name of the agent was too similar to "cyanide", and would therefore carry strong overtones of poison gas warfare). [88] Alternatively, and more probably, it was an allusion to the planned use of anti-plant agents against Japanese rice crops; it is reported that in August 1945 a shipload of the materials needed for this was en route for the Marianas [430]. US anti-plant agents were first used in war during the final year of the Korean War and then only on a very minor scale [431].

The French Army has also had an interest in anti-plant agents. This is indicated by the publication of several dozen state patents on chemical plant-growth regulators and similar substances, covering inventions made by army personnel since the mid-1950s (e.g., FP 1193374, FP 1241178, FP 1284516, FP 1358627, and many others).

The British appear to have been the first to put anti-plant agents to military use, in Malaya during the late 1940s and the 1950s. Stocks of 2,4,5-T had been maintained in Malaya against the contingency of *Dothidella ulei* infection of the rubber plantations. (Had the disease appeared, a *cordon sanitaire* would have been created around the focus of infection by defoliating a ring of neighbouring rubber trees, thus reducing the risk of further spread.) [432] It may well have been this stockpile that was subsequently used by the military. The military usage in Malaya has been described as follows [432]: "The thinning of jungle cover along communication routes by the use of defoliants became a standard method for reducing the hazard of attack from hidden ambushes. The object was to increase visibility in mixed vegetation rather than to give uniform defoliation. ... Using sprays of the *n*-butyl ester of 2,4,5-T most trees were not completely defoliated, but refoliation was delayed long enough to make the operation effective." The agents are said to have been sprayed from helicopters [433]. Another authority, however, states that the British used ground sprayers, and not aircraft-mounted ones, for defoliation; but he does state that helicopters and fixed-wing aircraft (*Pioneers* and *Beavers*) were used for spraying anti-plant chemicals onto enemy cultivations [987].

of Agriculture; part was done in concert with the Army Chemical Corps. Testing stations then and subsequently included sites in Texas, Hawaii, Puerto Rico and Thailand; from July 1961 a site in South Viet-Nam was also used. [435–38] By the end of 1961 it had been established that a range of agents and disseminating techniques was effective against many types of Indo-Chinese vegetation and food crops: certain phenoxyacetic acid derivatives as jungle defoliants, for example, and cacodylic acid against rice [435]. It now remained to establish whether their effects in fact had useful military application.

In December 1961 President Kennedy authorized the Department of Defense to begin operational trials of anti-plant agents along certain lines of communication in South Viet-Nam [439]. With the concurrence of the South Viet-Namese Government, the US Air Force then began a test programme known as *Project Ranch Hand* [433]. Three C-123 aircraft,[28] designated the *Special Aerial Spray Flight,* and based at Ton Son Nhut, were fitted out with spray tanks to commence operations in the vicinity of Saigon in January 1962 [433]. The object was to determine whether the defoliation caused by aerial dissemination of anti-plant chemicals could increase visibility in forested areas to such an extent that ambush rates along lines of communication could be significantly lowered and target acquisition or reconnaissance capabilities significantly increased. From these points of view the early Ranch Hand experiments were apparently successful, for in August 1962 approval was given for tactical defoliation missions [436]. The first major operation of this type was conducted over the Ca Mau peninsula from 3 September to 11 October 1962 [436]. The Chief of the US Army Chemical Corps evaluated the results as "outstanding" [433] and defoliation operations continued. In mid-1964 an expansion of Ranch Hand was authorized, and an additional base was established at Da Nang; targets were allocated all over South Viet-Nam, from the Demilitarized Zone to the Mekong Delta. In January 1965 approval was given "to prestrike targets with fighter aircraft and to provide a fighter escort for the spray aircraft" [433]: the huge C-123s, travelling at only 240 km/hr, 50 metres above the trees, were easy targets for enemy ground fire [433, 440–41]. In March of that year one of the largest defoliation operations yet staged was conducted over the dense mangrove swamps surrounding the main shipping channels leading into Saigon: forty-two missions were flown and about 350 tons of anti-plant chemical sprayed. In October 1966, Ranch Hand was expanded yet again, parti-

[28] The C-123 is a large twin-engined cargo plane built by Fairchild-Hiller; it is also known as the *Provider*. The earlier experimentation had also made use of spray tanks mounted on C-47, CH-34 and A-1H aircraft, as well as ground-operated rigs [436].

cularly in the III Corps area around Saigon, and the Special Aerial Spray Flight was re-designated the *12th Air Commando Squadron,* by now controlling eighteen C-123 aircraft. Soon afterwards, it was given another major assignment, namely the defoliation of the southern half of the Demilitarized Zone. Besides defoliation missions, it was also assigned insecticide spraying missions over certain populated areas to control malarial mosquitoes and other disease vectors. [433] It is said that, in addition to the 12th ACS, another US Air Force unit to be assigned herbicide spray duties was the 309th Air Commando Squadron.

By 1967 the Ranch Hand project had reached its peak; while the area sprayed with defoliants during 1966 had been five times larger than in 1965, the area sprayed in 1967 was ten times larger. By the end of the year about 5 per cent of the surface of South Viet-Nam had received anti-plant agents. However, at the beginning of 1968 the "Tet offensive" curtailed operations, and in February the 12th Air Commando Squadron was put onto airlift duties, the spraying equipment being removed from its aircraft. It returned to normal, but further expanded, duties later in the year; in August it was renamed the *12th Special Operations Squadron,* with a complement of fifty-five pilots. By the end of the year, more than 19 000 Ranch Hand sorties had been flown since the project began; vast tracts of forest, particularly in War Zones C and D, had been defoliated repeatedly. [433, 437, 440] Thereafter, the scale of anti-plant operations declined, reaching a low point in spring 1970, at the time of the incursion of US ground forces into Cambodia, when again Ranch Hand aircraft were assigned airlift duties [953]. Around this time, it is said, a decision was taken to reassign all anti-plant operational duties away from the US Air Force to the Army: future aircraft spraying operations were to be on a much smaller scale, using helicopters rather than C-123 aircraft. However, the fact of this decision, if indeed it was taken, is not yet officially confirmed.

While the major part of Ranch Hand was concerned with defoliation, crop-destruction missions were also flown from its inception. It is reported that the South Viet-Namese Government was attracted to the idea of using anti-plant agents against enemy crops even during the early experimental period in 1961 [442–43]. Congressman R. D. McCarthy, for example, states that in 1961 "President Ngo Dinh Diem was arguing that the chemicals could be used more effectively against enemy rice fields" [443]. In January 1962 the *New York Times* reported that a "high Vietnamese official" had said:

> Defoliant chemicals would also be sprayed on Viet Cong plantations of manioc and sweet potatoes in the highlands. The exact locations of these plantations have already been plotted by aerial surveys. Tests have shown that manioc and

sweet potatoes die four days after having been sprayed. These are the two most important food staples for the communist bands in the mountains. [435]

It is reported that by 1963 South Viet-Namese aircraft were spraying US-supplied anti-plant chemicals onto enemy crops [443]. By this time crop-destruction missions were also being flown by US aircraft, initially on a small scale against isolated plots of rice. The practice grew up of retaining USAF insignia on aircraft used for defoliation but replacing them with RVNAF insignia for crop-destruction missions. As the Ranch Hand programme began to gather momentum, and as new strategies were introduced for anti-plant operations—these are described later in this section—the scale of chemical crop destruction increased. It was put onto a systematic basis in the spring of 1965, and by March 1966 the programme had become important [237]. During 1967 crop destruction accounted for more than a sixth of the total consumption of anti-plant agents, with more than 100 000 tons of food being destroyed, of which some two-thirds were rice. The scale of operations diminished after 1967 but continued at a fairly constant level into 1970, even after defoliation missions had been cut back.

Between 1961 and 1967 the scale of chemical anti-plant operations in Viet-Nam grew roughly in proportion to the overall involvement of US troops there. As noted above, a marked recession then ensued, as countervailing pressures began to constrain the programme. Four factors are said to have contributed to this [444]. First, the available commercial sources of anti-plant chemicals were becoming exhausted by the increasing military demands made on them. Second, many of those people within the US mission to Viet-Nam that were primarily concerned with the "pacification" programme were becoming increasingly alarmed that anti-plant operations might undermine their work by alienating farmers and other crop-growers. This aspect of the operations had been emphasized in a study prepared for ARPA by the RAND Corporation [445]: this had been based on a large number of interviews with South Viet-Namese in the course of 1967. Third, the scientific community was expressing mounting concern that the anti-plant programme might permanently distort important sectors of the Viet-Namese ecology. Finally, the view was expanding in the outside world that the combat use of anti-plant chemicals was contrary to the international laws of war.

The extent to which these factors were responsible for the 20 per cent cutback in Ranch Hand in 1968 and the further cutback in 1969 cannot yet be judged. There is no doubt, though, that they influenced at least some people within the US military command. In mid-1967, alongside the RAND study referred to above, ARPA commissioned the Midwest Research

Institute to assess the ecological effects of extensive and repeated use of herbicides. Soon afterwards the US Mission set up an Interagency Committee on Herbicide Policy; this was to provide the first broad analysis of the chemical anti-plant programme undertaken by the US Government. The Committee considered the military utility of anti-plant chemicals; the effect of their use on the "pacification" programme and on the Viet-Namese economy; such data as had been collected about lasting ecological damage; and the command structure behind the programme and its propaganda backup, including the indemnification arrangements for noncombatant farmers against damage of crops. Its report was ready in August 1968, and although it collected together a substantial body of information it drew no firm conclusion about the main points of concern. Thus, on the crop-destruction programme it concluded that it had been successful in accomplishing its stated objectives, but to an undetermined degree, and that at the same time the programme had had significant, but again undetermined, adverse political, psychological and economic impacts on civilians in enemy-controlled areas [437, 443–46].

The concern of the scientific community about possible ecological damage was allayed neither by the Midwest Research Institute report [435, 437] nor by the subsequent field study by Dr Tschirley of the US Department of Agriculture [447] (which constituted part of the input to the Mission report on herbicide policy). The Department of Defense, or at least the Senate Committee on Armed Services, conceded that further study was needed, but said that this would have to wait until the war had ended; in that eventuality, the National Academy of Sciences was to conduct a field study [439]. The Department also provided a certain amount of assistance to two small field studies that were actually mounted in South Viet-Nam: the first, in March 1969, was sponsored by the US Society for Social Responsibility in Science [448] and the second, by far the more extensive of the two, in August 1970, by the American Association for the Advancement of Science [449]. The latter was intended as an exploratory study to assist in the design of a full-scale post-war survey. Its preliminary results, which at the time of writing have just been announced, are referred to below.

New concern about the long-term effects of Ranch Hand arose in the autumn of 1969 when a research laboratory under contract to the National Cancer Institute (a branch of the US Government's National Institutes of Health) produced a report on the teratogenicity—the capacity for producing birth-deformities—in mice and rats of certain pesticides and industrial chemicals. This report succeeded a preliminary one that had been produced some months before. Among the chemicals studied were three of the anti-plant agents that were either being used or were recommended for use in Indo-

China, namely *2,4-D*, *2,4,5-T* (both of which were in massive use) and *Monuron*. It was concluded that at substantial dosages 2,4,5-T was probably a dangerous teratogen, that 2,4-D was potentially dangerous but needed further study, and that the observations made permitted no firm conclusions about Monuron. When the existence of these findings became public knowledge, a number of US Government agencies placed restrictions on the use of 2,4,5-T. The Department of Defense was among them: it said that it would restrict the use in Viet-Nam of 2,4,5-T "to areas remote from the population" [450]. On the following day, however, it announced that as this was already its policy, the new restrictions on 2,4,5-T would not affect the use of the agent in Viet-Nam [451]. After a period in which the findings of the teratogenicity report were being questioned,[29] a further report on 2,4,5-T, based on studies in a US Department of Health laboratory, provided further evidence of the teratogenicity of the agent. The Department of Defense then, in April 1970, suspended the use of 2,4,5-T in all military operations [452].[30] Meanwhile the possible teratogenicity of 2,4-D was being studied further, but to date the findings are apparently less convincing than those for 2,4,5-T. No restrictions have yet been placed on the military use of the agent. Even the continuance of the restrictions on 2,4,5-T was stated to depend on further study: the Department of Defense announced that it was compiling a report on the incidence of birth defects and stillbirths in South Viet-Nam to determine whether any of them could be connected with defoliation operations [446] as had been alleged [453–54, 954].[31]

[29] As regards 2,4,5-T, the findings of the report were challenged on the grounds that the sample of the agent studied contained an abnormally high proportion of a possibly teratogenic impurity, namely 0.0027 per cent of 2,3,6,7-tetrachlorodibenzo-p-dioxin. It was claimed that the 2,4,5-T sent out to Viet-Nam generally contained less than 0.0001 per cent of this dioxin. Volume II of this study contains a description of this contaminant; for the present, it may be noted that it is teratogenic, an apparently unavoidable impurity in 2,4,5-T, and at least as acutely toxic as the nerve gases. [456]

[30] It has been estimated that between 1961 and 1970 some 20 000 tons of 2,4,5-T were spread over South Viet-Nam [451]. The figure is probably nearer 30 000 tons.

[31] The issue of *Tin Sang* (Saigon) for 20 June 1969 reported that the head physician at Hung Vuong hospital had stated that during the first five months of 1969 there had been forty-nine cases of congenital abnormality among the 5 480 births registered at the hospital. No base-line data was provided from which to judge whether this incidence rate was normal or abnormal. The paper also printed photographs of deformed babies born to women who were said to have been exposed to herbicides. Since then, causations have been alleged between the herbicide programme and the incidence among the South Viet-Namese population of several types of birth anomaly that might have been caused by a chemical teratogen. Among the medical reports which have been published on this matter are those of an NLF-sponsored team of four health workers (February 1970) [457], a joint US Army-South Viet-Namese Ministry of Health team (later in 1970: their study is presumably the one alluded to above) [961], a team sponsored the Association Générale des Médecins de la République Démocratique du Vietnam (December 1970) [969] and the Herbicide Assessment

It appears that the restrictions were not in fact completely observed: tens of tons of 2,4,5-T were reported to have been used in crop-destruction and defoliation operations in South Viet-Nam between May and August 1970 [455, 955–56].

In August 1970 a group of US Senators attempted to stop chemical anti-plant operations in Viet-Nam by means of a pair of amendments to the FY 1971 military appropriations bill. They based their case on the long-term dangers of the herbicide programme and on the inconclusiveness of the evidence about its overall military benefits. The attempt failed; as regards the long-term dangers, they were unable to adduce sufficient evidence to show that long-term damage would or had occured, and as regards the military benefits, the available assessments, although patently disputable, were all classified. The counter-arguments used by the opponents of the amendments, based on military necessity, were emotively much stronger, although equally lacking in substantiating evidence:

> The [Senate Armed Services] committee considered that an end to our use of herbicides would be ill advised. It reasoned that the evidence regarding the ecological and physiological side effects of our herbicide program was inconclusive while the primary contribution of the program was indisputable: it has saved the lives of Americans in Vietnam. The committee believed that until more conclusive evidence as to side effects materialized, the safety of our troops had to be made an overriding consideration. [458]

The two amendments were defeated by votes of 62–22 (for the defoliation amendment [439]) and 48–33 (for the crop-destruction amendment [445]). In view of the failure of this attempt, many people were surprised to read in the *Washington Post* of 17 December 1970 that in the previous week the US Ambassador to South Viet-Nam, Ellsworth Bunker, and the Commander of US forces in Viet-Nam, Creighton Abrams, had together cabled Washington recommending that the chemical crop-destruction programme be stopped immediately; that there should be no further procurement of anti-plant chemicals; and that existing stocks of these chemicals in Viet-Nam should be used only for defoliation until they were exhausted. It was estimated that on this basis the stocks would run out in May 1971. [957] On 26 December, President Nixon announced that he had ordered curtailment of the herbicide programme. In the White House press release it was stated that "Ambassador Bunker and General Abrams are initiating

Commission of the American Association for the Advancement of Science (December 1970) [961]. None of these reports can reasonably be regarded as conclusive one way or the other. They are referred to below.

a program for an orderly yet rapid phaseout of the herbicide operations" and that "during the phaseout the use of herbicides in Vietnam will be restricted to the perimeter of firebases and U.S. installations or remote unpopulated areas" [958]. President Nixon said that this action had been ordered after the completion of a study by the Secretary of Defense that followed an earlier study on the effects of the herbicides by the US Surgeon-General's office and the Department of Agriculture [959]. At the time of writing, it remains to be seen how these orders will be put in effect; in particular, it is not clear from President Nixon's statement whether crop-destruction operations are to continue.

President Nixon's announcement coincided with the opening of the meeting of the American Association for the Advancement of Science at which the preliminary results of the field-study that the Association had organized into the effects of herbicide operations in Viet-Nam were due to be announced. Information about some of the findings had been circulating privately during the preceding months. The study had included investigations of the damage caused by the defoliation programme to Viet-Namese forests; of untoward health effects on the indigenous population that might have been caused by herbicides, including manifestations of teratogenicity; and of the possible effects of the crop-destruction programme on ethnic minority groups living in the hinterlands. [960] Some of the findings on these topics are described later in this chapter.

Anti-plant operations in Indo-China have been confined mainly to South Viet-Nam, but have also been conducted in Laos along the so-called "Ho Chi Minh trail" [459–60], and in Cambodia. The Cambodian Government alleged damage from US/South Viet-Namese anti-plant agents in a succession of formal complaints to the UN Security Council from 1964 onwards [461–66],[32] and in 1969 sought $7.5 million compensation from the USA for damage to rubber and fruit trees [466] after what appeared to be an unprecedentedly large incident. A joint US-Cambodian team was set up to investigate the claim, and it duly verified the allegation. Damage was found over an area of about 700 km^2 in Kompong Cham province. Part of this was due to anti-plant-agent spray drifting over the border from South Viet-Nam; the remainder appeared to have been caused by a direct spraying operation inside the border. [467] The military command in Saigon denied all knowledge of the latter, even though several tons of anti-plant chemicals were implicated. The Cambodian Government raised its claim to $12.2 million, but whether this has yet been settled, and out of whose funds, is not reported. [468]

[32] These complaints are described in Volume IV of this study.

The greater part of the anti-plant chemicals used in Indo-China have been disseminated from 1 000 gallon *A/A45Y-1* spray systems developed commercially for the US Air Force and fitted into C-123 aircraft. They can also be mounted on C-130 aircraft [469]. Each of them is capable of delivering an effective dosage of agent to more than a square kilometre of terrain. This normally takes about five minutes, but in an emergency the entire tank-load can be jettisoned in thirty seconds [435]. The spray-nozzles and operating conditions are designed to disseminate the agent in droplets of 350 microns mass median diameter at a typical rate of 200–250 gallons per minute. Normally this results in a rather sharply defined ground-level spray pattern which, for a single 1 000-gallon load, is a swathe about 15 km long and 85 metres wide, thus fulfilling the application-rate requirement of 3 gallons per acre. The precise area over which plants are affected by the spray, however, depends on prevailing weather conditions (notably temperature and wind velocity) and on the susceptibility of the targeted plant species to the agent being used. Although the spray for the most part comprises a rather coarse mist, an appreciable proportion of the droplets are sufficiently small in size to drift long distances downwind. In addition, the volatility of the agent may sometimes be great enough to create appreciable airborne vapour concentrations which again may travel downwind. While the concentration of agent in such drifting clouds will be small, it may nonetheless be great enough to damage particularly susceptible plant species for example rubber trees and certain types of food plants. In some instances, records of spray operations show that vegetation has been damaged over areas 40 per cent greater than expected. [467, 961]

Apart from C-123 equipment, other aerial spray systems include a 275-gallon unit for A-1E or A-1H aircraft, and a somewhat smaller unit for UH-1 helicopters; both of these were developed by the US Navy. The US Army conducts aerial spray missions with 200-gallon tanks mounted on UH-1 helicopters. Portable and vehicle-mounted spray systems have also been used. [236]

The anti-plant agents favoured in Indo-China have been *2,4-dichlorophenoxyacetic acid* (2,4-D), *2,4,5-trichlorophenoxyacetic acid* (2,4,5-T), *dimethylarsinic acid* (cacodylic acid) and *4-amino-3,5,6-trichloropicolinic acid* (picloram) [236].[33] The formulations in which they have been used are set out in table 2.7. 2,4-D is employed in admixture with 2,4,5-T in agents *Orange* and *Purple*, and in admixture with picloram in agent *White*. Cacodylic acid is the active component of agent *Blue*. The code names for these

[33] North Viet-Namese writers state that other agents have been used as well, namely *calcium cyanamide, 2,4-dinitrophenol, dinitro-o-cresol* and salts of *arsenious acid* and *arsenic acid* [470].

Table 2.7. US anti-plant agents used in Indo-China for defoliation and crop destruction

		Formulation of agent in terms of each active component		
Agent	Active components of agent	*Percentage by weight*	Acid equivalent, *kg per gallon*	Approx. weight *kg per gallon*[d]
Purple[a]	*n*-butyl 2,4-dichlorophenoxyacetate	*50*	1.91	2.4
	n-butyl 2,4,5-trichlorophenoxyacetate	*30*	1.0	1.25
	iso-butyl 2,4,5-trichlorophenoxyacetate	*20*	0.68	0.85
Orange[a]	*n*-butyl 2,4-dichlorophenoxyacetate	*50*	1.91	2.4
	n-butyl 2,4,5-trichlorophenoxyacetate	*50*	1.68	2.4
White[b]	tri*iso*propanolammonium 2,4-dichlorophenoxyacetate	..	0.91	1.7
	tri*iso*propanolammonium 4-amino-3,5,6-trichloropicolinate	..	0.25	0.4
Blue[c]	sodium dimethylarsinate	*27.7*	1.35	1.56
	dimethylarsinic acid	*4.8*	0.06	0.06

[a] *Purple* and *Orange* are general purpose anti-plant agents used for the destruction of broad-leaved crops, such as manioc and banana, and for the defoliation of forest and brush growth. For the latter, leaf fall occurs in three to six weeks, with refoliation generally delayed for seven to twelve months, if the plant has not been killed.

[b] *White* is used for longer-term forest defoliation.

[c] *Blue* is a desiccant occasionally employed for rapid defoliation but more usually for the destruction of rice crops, which it does without affecting regrowth.

[d] In the absence of detailed information on the purities of the active components used in each agent, these figures are approximate ones only. They have been derived by assuming 100 per cent purity and either calculating from the published acid-equivalent figures for each agent, or, in the case where the specific gravity of the agent is known (*Orange*), by calculating from the percentage composition.

As regards the former method, however, it has been observed that a commercial sample of 2,4,5-T claimed to be 97 per cent pure on an acid-equivalent basis was in fact only 85 per cent pure. [994]

Sources: US Department of the Army, *Employment of Riot Control Agents, Flame, Smoke, Antiplant Agents and Personnel Detectors in Counterguerilla Operations* (Department of the Army training circular TC3–16, April 1969), *and* House, W. B., et al., *Assessment of Ecological Effects of Extensive or Repeated Use of Herbicides* (Midwest Research Institute, December 1967, AD 824314).

compositions are derived from the colour of the stripe painted around the 55-gallon shipping containers in which they are received from the United States.

Agents *Purple* and *Blue* began to be used in Viet-Nam in 1961, but with *Orange* gradually replacing *Purple* because of its lower volatility. Agent *White* came into use in 1966, at a time when *Orange* was in short supply. It was recommended by representatives of a leading US chemical company, the sole manufacturer of *White,* who had been sent out to Viet-Nam to discuss ways of supplementing *Orange* [446]. It was also felt that *White* was superior to *Orange* in that its volatility was lower, so that it could be expected to produce the lesser downwind effects

Table 2.8. Official US figures for consumption of anti-plant agents in Viet-Nam

Thousands of gallons

Agent	1968	1969
Orange	2 338	3 269.5
White	2 241	943.5
Blue	510	345.7

Source: Hearings on Military Posture, Part 2 of 2 parts. (US House of Representatives, 91st Congress, 2nd session, Hearings before the Committee on Armed Services, Washington, February 1970.)

[471]. However, in 1968, when output of *Orange* had been stepped up, the use of *White* dropped off sharply [446]. At the end of 1967, it was reported that 90 per cent of the total agent sprayed had been *Orange, Purple* or *White*, with less than 10 per cent *Blue* [435]. Ninety per cent of the 1969 US Air Force procurement of anti-plant agents was planned to consist of *Orange* [472]. With the April 1970 restrictions on 2,4,5-T, and hence on use of *Orange,* the Department of Defense once again sought to procure *White;* with *Blue,* it was the only agent thereafter authorized for use.[34] The official US figures for the consumption of anti-plant agents in Viet-Nam during 1968 and 1969 are set out in table 2.8. [476]

All the anti-plant agents employed in Indo-China have been commercially-available herbicides.[35] In their civilian applications, emphasis is placed on selectivity of action and economy, so that they may be used in dilute solution. Military use of the agents, on the other hand, calls for rapidity of response and non-specificity of action. These military requirements have

[34] By 1966–67 the US military requirements for anti-plant agents were beginning to exceed US manufacturing capacity. In 1966 total US production of 2,4-D and 2,4,5-T had been 38 000 tons; of this, 25 900 tons of 2,4-D and 3 400 tons of 2,4,5-T had been for US agricultural requirements. This had been furnished from a manufacturing capacity of about 36 000 tons for 2,4-D and 9 000 tons for 2,4,5-T [435]. To meet its requirements, which by the end of 1967 were 36 000 tons each of 2,4-D and 2,4,5-T [435], the Department of Defense was forced to seek additional supplies from abroad and to erect its own manufacturing plant for these compounds [472]. (This later proved to be unnecessary and the plant—at Weldon Spring, Missouri—was not completed.) The Japanese chemical industry provided some of these [473]; supplies were also sought from New Zealand [474]. From April 1967 the Department of Defense procured the entire US production of 2,4,5-T and a high proportion of the 2,4-D. It also procured the entire 1967 production of picloram. These materials therefore began to disappear from the home market. In April 1968 some of the home-produced 2,4,5-T was allowed to re-enter the market, but all the June production was pre-empted. Controls were finally lifted in December 1968. During this period the Department of Defense had been building up stockpiles of anti-plant agents, and between December 1968 and August 1969 (at least) there was no further Department procurement. [437, 475, 988]

[35] Agent *Blue* is the preparation sold by Ansul Chemical Co. as *Phytar 560G;* agent *White* is Dow Chemical Company's *Tordon 101.*

Table 2.9. Recommended application rates for anti-plant agents used in Indo-China

Kilogram per hectare

Objective	Application rate, in terms of active ingredients		
	Orange	White	Blue
Defoliation of jungle, mangrove and scrub	18–36	15–26	8
Destruction of broad-leaved crops	12	15–26	8
Destruction of rice crops	60	15–26	4

Source: US Department of the Army, *Employment of Riot Control Agents, Flame, Smoke, Antiplant Agents and Personnel Detectors in Counterguerilla Operations* (Department of the Army training circular TC 3–16, April 1969).

Table 2.10. US armed services expenditure on anti-plant agents

US $ mn, fiscal years

1963	1.4
1964	1.7
1965	1.9
1966	20.4
1967	39.5
1968	31.4
1969	5.2
1970	10.0
Total	111.5

Notes and sources

1. In the budget for FY 1971, the Department of Defense requested $6 million for procurement of anti-plant agents [439].

2. The value of procurement contracts let between September 1965 and September 1966 [613] suggests that the average cost of anti-plant agents was around $6.1 per gallon. A procurement contract for White at $7.80 per gallon was let in July 1970 [989].

3. The figures in this table are from the General Accounting Office, Comptroller-General of the USA [138].

demanded application rates that are several times greater, sometimes by a factor of ten or more, than those used in civilian applications. The application rates recommended for operations in Indo-China are shown in table 2.9.

It was reported in the autumn of 1967 that US forces in Viet-Nam were planning to use long-term soil-sterilants along an "anti-infiltration barrier" stretching across Viet-Nam, south of the demilitarized zone [460, 477–78]. The agents were intended, so it was said, to prevent or retard regrowth of vegetation within the previously-cleared barrier zone. It is not reported whether soil sterilants have actually been used for such purposes in Indo-China, but the US operational inventory lists two soil-sterilant anti-plant agents, both of which are commercially available in liquid or dust formulations [236]. They are *5-bromo-3-sec-butyl-6-methyluracil* (Bromacil) and *3-(p-chlorophenyl)-1,1-dimethylurea* (Monuron). Their recommended military applica-

Table 2.11. US Department of Defense figures for areas of South Viet-Nam sprayed with anti-plant agents

Estimated area[a] sprayed each year (km²)

	Defoliation	Crop-destruction	Total
1962	20	3	23
1963	100	1	101
1964	338	42	380
1965	630	267	897
1966	3 001	421	3 422
1967	6 018	896	6 914
1968	5 130	258	5 388
1969	4 945	266	5 211
Total	**20 182**	**2 154**	**22 336**

[a] The areas are estimated from the quantities of agents used, their application rates, and the average width of the swathe sprayed by each aircraft. They do not include areas affected by downwind drift of agent.

Sources: Chemical-Biological Warfare: U.S. Policies and International Effects (US House of Representatives, 91st Congress, 1st session, Hearings before the Subcommittee on National Security Policy and Scientific Developments of the Committee on Foreign Affairs, Washington, December 1969), *and Congressional Record* 24 August 1970, p. S. 14062, *and Hearings on Military Posture,* Appendix (US House of Representatives, 91st Congress, 2nd session, Hearings before the Committee on Armed Services, Washington, April 1970).

Note: These figures refer only to C-123 sprayings. It is estimated that operations with other spray systems account for about 20 per cent of the total herbicide sprayed in South Viet-Nam [961].

tion rates, in terms of the active component, are 15–30 kg/ha for Bromacil and 20–30 kg/ha for Monuron [236].

Table 2.10 gives annual figures for the expenditure by US armed forces on the procurement of herbicides. The bulk of this was presumably intended for use in Viet-Nam.[36]

Annual figures for the areas treated with anti-plant agents are given in table 2.11; these are official US figures. They were stated to be higher than the total geographical area that had actually been sprayed because they were theoretical estimates based on application rates and the average width of spray-swathes and did not take into account areas that had been sprayed more than once. One authority, writing in April 1968, stated that retreatment areas represented about 10 per cent of the total [447] but higher percentages have been quoted by others. The corresponding figures published by NLF and North Viet-Namese writers [480] are given in table 2.12. It may be noted that, because the US figures are theoretical ones, they do not take into account unanticipated downwind drift of herbicides; in contrast, the NLF figures are presumably derived, at least in part, from

[36] One part of the world outside Indo-China where the US military have been employing significant amounts of anti-plant chemicals is South Korea. In 1968 some 80 km² of land around the demilitarized zone were defoliated, and about 15 km² in 1969. Part of this included the chemical sterilization of ground-cover near command posts. [962]

Table 2.12. North Viet-Namese figures for areas of South Viet-Nam sprayed with anti-plant agents, and for consequent casualties

	"Areas exposed to sprayings" (km^2)	Number of people "poisoned"	Number of people killed
1961	6	180	..
1962	110	1 120	38
1963	3 200	9 000	80
1964	5 002	11 000	120
1965	7 000	146 240	351
1966	8 765	258 000	..
1967	9 033	279 700	233
1968	9 893	302 890	..
1969	10 870	342 886	500
1970, Jan.–Sept.	4 150	185 000	300
Total	**58 029**	**1 536 016**	**1 622**

Sources: "The intensification of US chemical warfare in South Vietnam", a statement by the South Viet-Nam Committee for Denunciation of the Crimes of the US Imperialists and their Henchmen, presented at the Fifth Stockholm Conference on Vietnam, Stockholm, March 1970, *and* "Documents on the US imperialists' war crimes in Vietnam since Nixon's inauguration", a paper dated 3 July 1970, presented by the North Viet-Namese delegation to the International Commission of Enquiry into US Crimes in Indochina, Stockholm, October 1970, *and* "Report of the Commission for Denouncing US War Crimes in South Vietnam on the use by the US puppets of chemical weapons in South Vietnam during the period January–September 1970", presented at the World Conference on Vietnam, Laos and Cambodia, Stockholm, November 1970.

actual observations. This may go some way towards explaining the marked disparity between the two sets of figures.

In the early part of 1970, the US Department of Defense stated that around 11 per cent of the surface of South Viet-Nam[37] had been treated with anti-plant agents. The Department derived this percentage from the final figure given in table 2.11 after it had been reduced by rather more than 20 per cent to allow for areas sprayed more than once. [439, 458] It corresponds to a land area of about 19 000 km^2.

Taking the figure of 3 gallons per acre which the Department of Defense has stated to be the average application rate for anti-plant agents in Viet-Nam, it may be calculated from the data given in table 2.11 that something like 20 million gallons of anti-plant agents—around 90 000 tons—had been used since 1962. This is consistent with the expenditure figures given in table 2.10. On the assumption that something like 60 per cent of these 20 million gallons have been *Orange* or *Purple,* 30 per cent *White* and 10 per cent *Blue,* the data given in table 2.7 suggest that about 78 000 tons of actual herbicide have been disseminated during the period 1962–1969 (95 per cent of this during 1966–1969).

[37] The total area of South Viet-Nam is 172 540 km^2, of which about 30 per cent is forested [447].

If 78 000 tons of herbicidal chemicals have been sprayed over 11 per cent of the surface of South Viet-Nam, it means that this 11 per cent has received a total dosage of about 41 kg/ha, 95 per cent of it during a four-year period. For comparison it may be noted that the estimated consumption of herbicides in Sweden (a country of about three times the land area of South Viet-Nam) for 1970 is 2 450 tons; it is estimated that these will have been sprayed over an area of about 14 000 km^2 [963]. This corresponds to a mean dosage for 1970 of 1.75 kg/ha.

As regards the military rationale underlying the chemical anti-plant operations, the US Department of Defense has always been ready to expound on the defoliation programme. It has been markedly less ready to explain the anti-crop programme; as a result, the existence of this programme has been almost completely obscured from the public eye.

The functions of the defoliation programme were explained in the following manner during Congressional testimony deposed by a US Army spokesman in July 1969:

> One of the most difficult problems of military operations in South Vietnam is the inability to observe the enemy because about one-third of the country is covered by forest and jungle. As one method to help overcome this problem, defoliating herbicides were introduced in 1962. For widespread effects, herbicides require an unusually small investment of military effort. . . .
>
> Defoliating chemicals are capable of greatly improving vertical and horizontal visibility in the type of jungle found in South Vietnam. Herbicides are being utilized to improve the visibility around base camps and fixed installations in likely ambush sites along roads and canals, in suspected Vietcong base camp and rest areas, and this has resulted in increased security and conservation of manpower. Herbicides have deprived the Vietcong of his cover and concealment. This carefully controlled operation has proved its military worth. [481]

In earlier testimony [126], it had been stated that the ambush rate on main roads leading out of Saigon had been reduced by 90 per cent after defoliation had been carried out; the ambush rate in other, undefoliated, parts of the country had remained unchanged. A more detailed description of the defoliation programme was given to a Congressional committee in December 1969 by a Department of Defense witness:

> 1. *Defoliation of base perimeters*
>
> A portion of the small-scale ground based or the helicopter spray missions are used in improving the defense of base camps and fire bases. Herbicides are a great help in keeping down the growth of high jungle grass, bushes, and weeds which will grow in cleared areas near these camps. This clearance opens fields of fire and affords observation for outposts to prevent surprise attack and as such is truly a life-saving measure for our forces and our allies. Without the

use of herbicides around our fire bases, adequate defense is difficult and in many places impossible.

2. *Defoliation of lines of communication*

There are many instances of ambush sites being defoliated for better aerial observation and improved visibility along roads and trails. In 1967 there were also many requests for defoliation of VC tax collection points. In otherwise friendly territory there were points along well-traveled routes where the enemy could hide under cover and intercept travelers to demand taxes. Defoliation along these roads was very effective in opening these areas so that they can be seen from observation aircraft, and with few exceptions these roads were opened to free travel. The use of aircraft to spray alongside lines of communication proved valuable in clearing these areas and preventing costly ambush of army convoys with resulting friendly casualties.

3. *Defoliation of infiltration routes*

Areas used by the enemy for routes of approach, resupply or movement are targets for herbicide spray. Probably the most valuable use of herbicides for defoliation is to permit aerial observation in such areas. This is particularly true in areas near the border so that we can detect movement of enemy units and their resupply.

4. *Defoliation of enemy base camps*

We know from prisoners of war and from observation that the enemy will move from areas that have been sprayed. Therefore, enemy base camps or unit headquarters are sprayed in order to make him move to avoid exposing himself to aerial observation. If he does move back in while the area is still defoliated, he will be observed and can be engaged. [431]

During the August 1970 debate in the US Senate on the herbicide programme, it was emphasized that the US command in Viet-Nam believed that defoliation operations had been valuable. In December 1969 a US official stated that requests from field commanders for defoliation and crop-destruction always exceeded US spray capacity [431]. Unofficially, however, US military personnel in Viet-Nam have expressed a wide spectrum of opinions on the military value of defoliation. The leader of the AAAS Herbicide Assessment Commission, Dr Matthew Meselson, expressed this as follows after returning from the Commission's five-week inspection tour in Viet-Nam during August and September 1970:

My own impression when speaking to military personnel in Vietnam is that many of them are not sure of the effectiveness of herbicides. It is important to distinguish three roles in which herbicides are used. First, along lines of communication and defensive perimeters. One high official expressed the opinion that for this purpose herbicides are largely a failure. The reason is that the remaining branches, stems and trunks substantially limit visibility. Indeed, visibility is often extended to approximately the accurate range of enemy small arms, a very undesirable result. On lines of communication and perimeters, herbicides have been almost entirely replaced by plowing, diesel-oil applications, hand clearing or fire. The second use for herbicides is crop destruction. There is extreme skepticism regarding the military utility of this program among many high government officials in Vietnam. Furthermore, there is no doubt that it imposes very serious costs of its own. My own opinion is that it continues under its own momentum, independent of any rational analysis. Finally, herbicides are used to clear large forest areas. I do not have any analytical information regarding the effectiveness of this tactic. Its advocates claim that it helps reveal enemy fortifications, depots and supply lines. Its critics argue that it is too slow to act and too quick to be undone by regrowth to have more than marginal effectiveness, given the ability of the enemy to keep shifting his operations. After all, War Zones C and D, although repeatedly sprayed and located rather close to Saigon, still belong to the other side. [964]

At this juncture of the war, however, it is not possible for outsiders to challenge the claims made for the short-term military benefits of the programme. Too little information has been published. A number of obvious questions can be asked,[38] but they cannot yet be answered from available information. It is not improbable that even the US Department of Defense lacks the data needed to answer them.

Until very recently, the functions of the chemical crop-destruction programme had been alluded to only in the barest outline in official US statements. In 1962 newspapers were quoting US officials in Saigon to the effect that the USA was reluctant to join the crop-destruction programme being conducted by the South Viet-Namese Government. It was not until US ground forces had been committed to Viet-Nam that much more was heard about the programme. Newspapers then referred to it as "a politically delicate subject" and, quoting US officials, said that anti-crop missions were "aimed only at relatively small areas of major military importance where

[38] Thus, in a recent paper [44], D. E. Brown has this passage: "It is difficult to quantify the military gains derived from the spray program. It is possible to assemble precise information on the number and type of missions flown in an area and to chart trends in sightings of suspicious phenomena. It is also possible to count the number of engagements with enemy forces in an area, or the number of defectors, to screen prisoner interrogations for evidence, as well as to observe that vertical visibility improves in sprayed areas by 60 to 90 per cent and ground visibility by a lesser amount. But it is not easy to demonstrate a strong causal relationship among these phenomena. Quantification is hindered by the difficulty of holding constant over a period of time such factors as friendly and enemy strategies, troop deployments, or the influence of the weather. For example, a decrease in ambushes or apparent infiltration may result from a change in enemy objectives or an increase in sightings from more intensive reconnaissance; an increase in the defector rate [one of the benefits claimed for the anti-crop programme] could stem from a relaxation of enemy discipline or from heavy casualties, and so forth. Finally it has to be remembered that distortions occur in even the most carefully crafted reporting systems.

The few statistics that have been reported to date are disappointing, and unlikely to convince a skeptical analyst."

the guerillas grow their own food or where the population is willingly committed to their cause". In March 1966 the US Department of State issued a statement in which it was said that some 80 km² of crops had been destroyed to deny food to guerillas;[39] the areas involved were described as remote and thinly populated and "known from intelligence sources to be occupied by Viet Cong military units". [437] It was not until mid-1969 that anything approaching an official evaluation of the military benefits of the programme was released. A US Army training circular published in April 1969 [236] stated that: "Guerilla operations rely heavily on locally produced crops for their food supply. Crop destruction can reduce food supply and seriously affect the guerillas' survival." In July, during Congressional testimony, a US Army witness said that herbicides

> have also been used to destroy crops intended for enemy use in sparsely populated, enemy controlled locations in food deficit areas. This is one aspect of a comprehensive food denial program. The crop destruction effort has contributed to the degradation of enemy capability by causing him to divert combat troops to food production. [481]

During further Congressional testimony in December, a Department of Defense witness stated that:

> Crops in areas remote from the friendly population and known to belong to the enemy and which cannot be captured by ground operations are sometimes sprayed. Such targets are carefully selected so as to attack only those crops known to be grown by or from [*sic*] the VC or NVA. The authorization to attack crops in specific areas has been made by the U.S. Embassy, Saigon, MACV and South Vietnamese Government. . . .
>
> . . . In certain instances, we know the VC have been forced to divert tactical units from combat missions to food-procurement operations and food-transportation tasks, attesting to the effectiveness of the crop destruction program. In local areas where extensive crop destruction missions were conducted, VC/NVA defections to GVN increased as a result of low morale resulting principally from food shortages. . . .
>
> . . . Every year since we began the program crop destruction has been less than 1 percent of the total South Vietnamese food production. It is not a large program. [431]

Further details were given in August 1970 by the Chairman of the Senate Armed Services Committee during the Senate debate on the chemical anticrop programme [445]:

> [A]ttack on crops has been restricted to areas of small population and known to be controlled by the North Vietnamese or Vietcong. Rice fields around villages are not attacked—but rice fields around known enemy troop concentrations,

[39] In fact it is now known that by March 1966 some 300 or 400 km² of crops had been destroyed: see table 2.11.

fields which are miles from known habitations and known to feed enemy troops, are attacked. Of course, mistakes may have been made, and the crops of friendly people may have been damaged. The incidence of these has been small. At times it has been necessary for the Vietnamese Government to relocate hamlets and villages when it could no longer offer protection from the Vietcong. Their crops were destroyed rather than let them fall into the hands of the enemy. They could have been ploughed into the ground, perhaps they could have been burned, but they were destroyed by herbicides because that is the quickest method using the least resources. It is nothing but the scorched earth policy used by military forces since time immemorial.

He went on to give an assessment of the military effectiveness of the programme:

The Vietcong and North Vietnamese units are operating in a theater far removed from their base of support. The weapons, the ammunition, the supplies necessary to maintain units in the field must be trucked or carried over long trails in the jungle. One of the immediate results of denying local food products to these units is that they are forced to devote a significant part of their logistical capability to carrying food instead of weapons and ammunition. This curtails their ability to carry out combat missions against U.S. and Allied troops, and it means less casualties to our American soldiers, marines, and other forces.

Another result of denying food resources to the enemy is that it forces him to spend a considerable part of his time growing food or foraging for it. We know from captured documents that many North Vietnamese and Vietcong units have been ordered to grow their own food. The destruction of local crops and the interdiction of supply routes has made it impossible in many cases for the enemy to supply its units with both weapons and food, so it has resorted to supplying weapons and telling its forces to grow food. This process further detracts from the time the enemy units have for combat missions—many have become full-time farmers and part-time fighters.

Another result has been the location, identification and capture of many enemy troops. The necessity to clear land and plant crops leads to identification. If aerial reconnaissance suddenly shows a number of small rice plots scattered along a strip of previously uninhabited countryside, then we know several things. One thing we know is that people are working there who are not part of the known area population. We also know that an infiltration trail or an enemy base camp is defined by the location of the food plots, and we can direct military activities against these areas. I can assure you that a significant number of infiltration routes have been disclosed in just this way.

There is a great deal of evidence that the lack of food is one of the primary factors with which the enemy must contend. There are captured documents, interrogations of prisoners, and a swelling tide of defectors who rally to the government of the Republic of Vietnam.

Let me give you an example or two from the field:

"The 120th Farm Production Company, 20th Montagnard Communist Battalion, we[re] deployed to central Quang Ngai Province in December, 1969, to set up operations in a 36,000 meter [*sic*] rice field. After the farm was heavily damaged by herbicides, the unit produced only enough food for its own personnel. The unit has since been relocated."

Now I think that it is very important that the enemy has been forced to establish battalions solely for the purpose of producing food—not for the purpose of attacking our troops, but simply for producing food for their forces: "In four of the five provinces in I Corps tactical zone, helicopter crop destruction operations have been effectively employed to destroy small garden plots and rice plots in areas solidly controlled by NVA/VC. During a recent three month period in one province, 237 such garden plots were located. Many individuals have defected from these areas, and enemy units report low morale because of food shortages."

These are not isolated instances. There is report after report that the enemy units are receiving less and less food as time goes on. Many of them are at bare subsistence levels or less, and their military effectiveness is very substantially degraded.

The program to deny food to the enemy in Vietnam has been an important part of our military operations, and as the cumulative effect of all of these operations grows, the crop destruction becomes more important.

While the overall impression created by these statements is that the crop-destruction programme was primarily intended to harass the enemy's logistics, this had not always been the basic strategy. From a series of recent publications [431, 439, 442–46, 482] it is possible to form a rough idea of the manner in which US crop-destruction doctrine in Indo-China developed. However, as official sources on this are scanty, much of what follows must be read as conjecture.

Relying on statements by US officials, most commentators agree that initially the US military in Viet-Nam were reluctant to embark upon chemical crop destruction, and that the initiative for it came from Viet-Namese quarters. Be that as it may, the notion soon seems to have gathered credence that the enemy was on the point of capitulation, and that it only needed a small and novel type of offensive to precipitate his defeat: following the example which the British were thought to have set in Malaya, certain US military advisers recommended the chemical destruction of guerilla food crops as being the most economical method of securing this objective. This last-straw strategy did not work, but a recommendation was then put forward that carefully-planned crop destruction could significantly aid the various population resettlement drives that had been going on since the commencement of the Strategic Hamlet Programme in 1962. The idea apparently was that by destroying food crops in areas where the presence of noncombatant civilians seriously impeded operations, the noncombatants would be compelled to leave, and the forced relocation programmes would be facilitated. This doctrine was put into effect in 1965. This was a year in which the annual consumption of anti-plant agents for crop destruction rose by over 600 per cent, in contrast to an increase of less than 200 per cent for defoliation. (See table 2.11.) This doctrine was still in force in March 1966, at the time when the US State Department statement about the chemical anti-crop programme referred to above was issued; this statement went on to say that

> The Vietcong and any innocent persons in the area are warned of the planned action. They are asked to leave the area. They are promised food and good treatment when they move out. Those who have moved from Vietcong territory for this reason have been fed and cared for. [437]

The chemical crop-destruction programme doubled in size during 1966, and doubled again in 1967. By this time, however, the forced relocation programmes had created an acute refugee problem. In addition, the 1967 RAND study of the herbicide programme had concluded that crop destruction was hurting the civilian population far more than the enemy. It was then cut back sharply, and in 1968 it fell to below the 1965 level. A modified doctrine was introduced, apparently the one that remained in force thereafter. As formulated then, its objectives were to deny food to the enemy and enemy sympathizers, to divert enemy manpower to crop growing, and to weaken enemy strength and logistical capacity. Recently the US Department of Defense has stated that "since 1968 no crops have been destroyed in any areas known to be inhabited by civilians" [445]. Before that time, however, the destruction of civilian crops seems to have been commonplace, not only because of herbicide drift from defoliation operations, but also because they were deliberately targeted for attack. And as regards the latter, the statements by US officials that crop-destruction targets were in "remote and thinly-populated areas" have been strongly disputed by NLF publications.

During the US Senate debate on the crop-destruction programme in August 1970, it was argued that the military benefits from the programme were great enough to override whatever long-term ecological, physiological, economic or political damage it might be causing. The same argument was made in support of the defoliation programme. While there is little enough data available from which to judge the military advantages of defoliation, there is still less in respect of the anti-crop programme. However, it is reliably reported that in 1970 the US military command in Viet-Nam was reckoning that enemy forces grew about 1 per cent of their overall food requirements, the remainder being obtained by import, purchase, taxation or coercion [965]. In earlier years they had grown still less [445]. It may reasonably be asked whether food-denial operations that do not affect 99 per cent or more of an enemy's food requirements (for this is how it would have to be if US crop-spraying affected only enemy-grown crops) can produce much overall military benefit, even if the operations are confined to small areas of strategic significance. It may also be asked whether it is operationally feasible to apply crop-spraying techniques so precisely that a significant proportion of the food which the guerillas grow for themselves is destroyed, but civilian crops are not damaged. The available figures suggest that, for the programme as a whole, it is not possible. By far the most anti-crop operations have been aimed at rice (more than two-thirds in 1967). Rice yields in South Viet-Nam are in the range of 135–650 tons/km^2. On the lower limit of this range, 266 km^2 of rice paddy would yield about 36 000 tons of rice. Table 2.11 shows that, in 1969, 266 km^2 of crops were destroyed. Three-quarters of the food eaten in Viet-Nam is rice, and a Viet-Namese consumes about 550 grammes of it a day, or about 0.2 tons per year. During 1969, therefore, the first whole year in which there purportedly were restrictions on the spraying of crops grown by civilians, enough food to feed 180 000 people for one year was destroyed. As not more than 1 per cent of the guerillas grew their own food then, the total guerilla population in 1969 would have had to have been more than 18 million, if only guerilla-grown crops were destroyed. The total population of South Viet-Nam in 1970 was 17.5 million. Whatever the consequences of destroying civilian crops may have been for the US "pacification" programme in South Viet-Nam—and this programme is described as being an attempt to "win the hearts and minds of the people"—the military benefits of crop-spraying were nonetheless reckoned to compensate for them, and for any other adverse side effects.

As regards the magnitude of these side effects, the preliminary reports of the AAAS Herbicide Assessment Commission, referred to above, give an idea of the actual or potential damage caused by the herbicide programme. Thus, the crop-destruction programme seems likely to have affected the Montagnard populations of the food-deficit Central Highlands to a far more serious extent than the guerillas, for Montagnard cultivations, which lie in areas where most of the anti-crop operations have been conducted, are reported often to have been mistaken for those of the guerillas. As regards jungle defoliation, the reports estimate that about one-fifth of South Viet-Nam's forests of merchantable hardwood have been sprayed, many of them more than once, including some of the oldest and most valuable stands; an estimated $500 million worth of timber has thus been lost. As regards the mangrove forests along the coastal area of the Mekong Delta, it is estimated that something like half of these have been killed, with almost no regeneration as yet; attendant on this is a serious possibility of soil erosion and soil deterioration, with potentially grave ecological consequences. As regards possible health effects (it is estimated that something like 1–10 per cent of the population has been subject to direct herbicide spraying), the Commission's investigations permitted no firm conclusions; it collected enough information, though, to challenge the basis of claims made by a recent US army study [566]—presumably the one whose commencement is referred to above—which appears to exonerate herbicides from the charge that they have caused birth defects in South Viet-Nam. The Commission found no evidence of striking new congenital abnormalities (like those induced by thalidomide, for example) that might have been attributed to the herbicide programme. But in making this and other comments on the incidence of teratogenic effects, the Commission did so "with the recognition that much of the directly exposed population is unavailable for study at this time". [961]

The Commission's findings are discussed further in Volume II of this study, where there is a more detailed treatment of the possible long-term consequences of chemical anti-plant operations.

The use of harassing agents

The USA had been supplying irritant-agent weapons to the South Viet-Namese Government since the early days of its involvement in Viet-Nam. From 1962 hand grenades containing CN and DM had been included in the shipments of military stores sent out under the Military Assistance Program [442, 483–84]. In addition, according to Secretary of State Dean Rusk, stocks of irritant-agent weapons had remained in Viet-Nam from the time of French rule there [485]. The South Viet-Namese Army had put their supplies to occasional use, both in riot-control and combat situations [486–87]. It appears that US forces in Viet-Nam were not equipped with irritant agents until the latter part of 1964; in contrast to the South Viet-Namese, they were given CS, rather than the older agents CN and DM [431, 487].

The published information on the background to the decision to provide US ground forces in Viet-Nam—"military advisers" as they were still called —with special irritant-agent weapons is rather obscure. Right from the beginning there had been advocates for the use of chemical weapons, not all of them US Army Chemical Corps personnel, both in the USA and abroad [488]. One such advocate, writing in the *National Review* (New York) in April 1963 had said:

> ... The best way for the U.S. to achieve its military aims in Southeast Asia would be to rely on chemical warfare. ... A single helicopter equipped with a gas dispenser could flush out an entire band of guerillas in a few minutes of work. Gas also is effective on rough terrain where guerillas hide in caves and tall grass and where counter-guerillas cannot go except at high cost in human

> life. ... And a nation that has no qualms about training counter-guerillas in the art of knifing guerillas in nighttime operations certainly should have no objection to gas warfare, especially with gases that are non-lethal. ... Unless the United States is prepared to make use of its industrial and technical know-how, as in the case of chemical warfare, it will continue to fight at a disadvantage. [489]

It is reported that early in 1964 the US Department of Defense asked the Department of State to give a ruling on the legality of using "nonlethal" gases in South Viet-Nam, and that in response a memorandum was prepared saying that this would be legal provided a number of limitations —made explicit in the memorandum—were observed. In due course, so the report continues, after a series of consultations between the White House and the Departments of State and Defense, a decision was made to use irritant chemicals in Viet-Nam. [442] Recalling the decision some years afterwards, a Department of State official said that it had been a difficult one: "This was a problem. ... We're not overjoyed with the use of tear gas, but people have decided it represented a humane decision. ... When all the factors were weighed, we decided to use it." [442]

It will presumably not be known for some time whether the decision was in fact reached in the manner just described. One cause for doubt derives from a statement made in March 1965 by President Johnson's press secretary, George Reedy, soon after US employment of irritant agents in Viet-Nam had become public knowledge. Reedy said that the agents had been used without the President's knowledge: "That's not the sort of thing that comes up for that kind of approval. For many years this kind of authority has been delegated to area commanders." [483] The relevant US military manual—*Armed Forces Doctrine for Chemical and Biological Weapons Employment and Defense*—did indeed state that "Commanders are currently authorized to use certain chemical agents such as flame, incendiaries, smoke, riot control agents and defoliants." [490] The edition of the manual from which this quotation is taken was published in April 1964. Reedy's statement was strongly questioned at the time. One newspaperman reported that President Johnson had authorized use of irritants in December 1964 following a discussion within the National Security Council about whether the chemicals already in Viet-Nam should be used against the guerillas [491]. In addition, it is not unreasonable to ask what led the US Army to procure 170 000 kg of CS for "Southeast Asia requirements" during 1963–64.

Nothing is known of the types of usage that were initially authorized for irritant agents. The first reported occasion on which US troops in Viet-Nam used their CS was on 23 December 1964 in An Xuyen province [483] when grenades containing the agent were air-dropped during an attempt to rescue US prisoners. Shortly afterwards, the US military commander in Viet-Nam, General Westmoreland, told the Senior American Advisors in all four Corps areas that last-ditch use of CS might have saved some of their units that had been overrun by enemy forces. US military advisory teams were therefore directed to draw CS grenades and respirators for their own defence. [487]

In March 1965 a newspaperman in Viet-Nam noticed canisters of irritant agent in a helicopter in which he was traveling; he enquired about these and the press agency for which he worked duly put out a story stating, among other things, that US/South Viet-Namese forces were "experimenting with gas warfare". A US spokesman's views on the future of irritant agents in Viet-Nam were also quoted: "Even if it does work, there is a real problem in getting it accepted. ... The idea of it all brings back memories of World War I and mustard gas." [442, 487] Not surprisingly, this story caused a furore in the outside world. Popular reaction was immediate and hostile, and was exacerbated by the vacillations and contradictions of the early official accounts given by Washington and Saigon [492–93]. Newspapers gave prominence to accounts of the effects of exposure to DM, an agent initially described as a tear gas, but which can induce projectile vomiting.

US officials attempted to counter this reaction[40] by stressing the humanitarian possibilities of irritant agents. At a press conference in Washington, Dean Rusk stated that:

> Under the circumstances in which this gas was used in Vietnam, the desire was to use the minimum force required to deal with the situation to avoid death or injury to innocent people. ... We do not expect that gas will be used in ordinary military operations. Police-type weapons were used in riot control in South Vietnam, as in many other countries over the past twenty years; and in situations analogous to riot control, where the Viet Cong, for example, were using civilians as screens for their own operations. ... The anticipation is, of course, that these weapons be used only in those situations involving riot control or situations analogous to riot control. [485]

In Saigon, US officials stated that irritant agents had been issued to the South Viet-Namese Government after an incident in July 1964 in which guerillas had mixed with villagers and driven them forwards during an attack: government troops had killed a large number of women and children. [483]

[40] Many newspapers continued to print lengthy news reports, editorials and feature articles about the use of irritants in Viet-Nam for some time after 22 March 1965. The recent study by J. B. Neilands [494] contains a useful guide to these.

While these official protestations were well received in some quarters, they were greeted skeptically in others. A Saigon wire correspondent, on asking a US Army captain about the humanitarian advantages of irritant agents, received this answer: "What the hell, by pumping gas down there we can knock out groundfire, so that lets us get closer on the ground and from the air to kill all the more of the enemy. If women and children are down there at the time, it will be not better for them than it is now." [612] It is said that an order was quickly issued at top US governmental level against any further use of gas by US forces, and that an effort was made to discourage its further use by the South Viet-Namese. A new assessment of the costs and benefits of using irritant agents was then conducted. [487, 495]

It seems that use of the agents did not stop completely after the March events. NLF sources state that several people were killed by gas on 13 May at Tan Uyen village in Bien Heh province [496], and it is reported that the records of Quang Ngai provincial hospital document influxes of gas casualties at the end of May and the beginning of June [497]. However, it was not until seven months after the initial press furore that further irritant-agent operations again received wide newspaper coverage.

At the beginning of September, Saigon announced an incident in the Qui Nhon area, 260 miles to the north of Saigon, in which forty-seven canisters of tear gas had been used to flush suspectedly-infiltrated villagers from tunnels, as a result of which, it was later stated, fifty "Viet-Cong" suspects were separated from four hundred villagers. [498] The NLF alleged that thirty-five people were killed by the gas [499]; Peking also said there were many civilian fatalities [500]. Official US sources said that the field commander in charge of the operation, Colonel Utter, had used gas without authorization and that he would therefore be facing disciplinary charges [501]. A fortnight later he was exonerated [502]. With more inference than evidence, this event has been regarded by some people [442] as a trial balloon for the future of irritant agents in Viet-Nam. If the incident had provoked another public outcry, a scapegoat was available; if not, then irritant agents could continue to be used. There was no outcry. On 8 October a further irritant-agent tunnel-flushing operation was conducted during the opening stages of a massive sweep through the "iron triangle" area 35 miles northwest of Saigon: this was officially announced as the first authorized use of chemical agents for nine months. [503] Thereafter irritants continued to be used in the sweep [504]. The authorization was said to have been from the White House to the Department of Defense; details of the order have not been published, but it is understood to have forbidden use of DM, but permitted use of CN and CS [442, 495].

CS stores could be used for whatever purposes field commanders chose; their use was to be subject to constraints no different from those pertaining to other weapons [483].[41]

By the beginning of 1966 irritants were beginning to find widespread use in regular combat operations. In January, during a large sweep by the US 173rd Airborne Brigade through the northernmost section of the Mekong Delta ricelands, helicopters were used in the van of the advance to lay down irritants over snipers and suspected enemy positions [505]. In-line bomblet dispensers, reportedly used then for the first time, were employed to disseminate the irritants from the helicopters [506]. In mid-February, the US Department of Defense announced that irritants were to be used from helicopters against large area targets to force the enemy from cover immediately before B-52 airstrikes [507]. On the day of the announcement, one such attack took place, in Bindinh province. The target was 400 "Viet-Cong" soldiers dug in over a triangular patch of jungle some 300–400 yards across at its widest point. After the initial helicopter sortie with irritants, six B-52 bombers came in and "carpeted about 85 per cent of the target area", followed by an airlift of two battalions of gas-masked *Airmobile* troops. [508] The first report did not say how successful this new technique was, and no reports were published about it subsequently.

At the beginning of January 1966, it had been rumoured that the US Joint Chiefs of Staff were considering the use of CW agents more potent than CN or CS [498]. Shortly after this rumour, it was alleged that DM was again being used [509], and a French journalist stated that during *Operation White Wing* in March, Airmobile troops had used 3 000 air-dropped grenades containing the incapacitating agent BZ[42] in an action against a "Viet-Cong" battalion [510]. (BZ is also said to have been used in May 1968 in Hau Nghia province at Binh Hoa, in Kien Giang province at Chau Thanh, in February 1969 in the northern part of South Viet-Nam, and in February 1970 in Thua Thien province [966].) US officials in Saigon and Washington have repeatedly denied that BZ has been used in Viet-Nam [442]. Another agent which, according to NLF sources, was being used at this time was the irritant ethyl bromoacetate [967]. (Photographs purporting

[41] In a reference to this authorization during Congressional testimony in April 1970, a US Department of Defense witness provided the following information: "The Department of Defense with the concurrence of the Department of State obtained approval in November [*sic*] 1965 for the use of CS and CN in Vietnam. COMUSMACV delegated to his subordinate commanders authority to use these agents in military operations against the enemy. The commanders were authorized to further delegate this authority to the extent deemed suitable for ensuring both timely employment and proper control. In actual practice, division and brigade commanders usually authorize the tactical use of riot control agents." [476]

[42] See page 77.

to show a glass ampoule of this agent that had been among those used in Quang Tri province in October 1967 were circulated at the International Meeting of Scientists on Chemical Warfare in Vietnam held in Paris in December 1970.)

The quantity of irritants used in particular operations had risen steeply. In one operation, conducted in a densely jungled area 70 miles northwest of Saigon near the Cambodian border on 8 May 1966, three helicopters each spread rather more than a ton of CS onto a small area said to be occupied by enemy troops [511]. According to an NLF report, a total of 15 tons of the agent were disseminated over a particular area of Tay Ninh province during a two-week period from 23 April to 9 May [499].

Although CS continued in frequent use throughout 1966 and 1967, it was still largely an experimental or special-purpose weapon. Field commanders had not yet appreciated all its possible applications. A whole range of new CS munitions were being developed in the USA and sent out to Viet-Nam for testing, but it took time for appropriate employment doctrine to evolve. A powerful impetus to the further acceptance of CS came during the "Tet offensive" at the beginning of 1968 when CS was found to be both highly effective and easy to use in urban warfare situations. Great quantities of it were employed in Hué, for example, by both US Marines and South Viet-Namese forces: CS weapons repeatedly reduced well-defended positions that had resisted conventional assaults. [487] Thereafter, CS was employed on a greatly increased scale. During 1968 nearly twice as much CS was consumed as in all the previous years put together, and in 1969 there was a further 20 per cent increase. By the middle of that year, something approaching 7 000 tons of CS had been disseminated in all,[43] and a US Army witness was telling a Congressional committee that:

> . . . CS is very well accepted. It has been 3 or 4 years since we first introduced this over there. We have had several commanders and they have learned how to use these materials more effectively. . . . The requirement in terms of numbers of munitions and tonnages of material has indicated an acceptance. . . . [The troops] like it very much. It flushes out Charlie, gets him out of the bushes, and they are able to see who they are fighting. . . . [126]

Almost every type of weapons delivery system in Viet-Nam had a CS capability, so that CS could swiftly be spread over almost any size of target area, at any range and, if necessary, in close coordination with other forms of firepower. The range of CS weapons available to US forces is illustrated in table 2.13. Allied troops, or at any rate the South Viet-Namese, Koreans, Thais and Australians, also had US-supplied CS weapons, but these were

[43] Enough CS, in fact, to charge more than 200 million of the riot-control cartridges that the British were beginning to use at this time in Northern Ireland.

mainly hand grenades [431]. A multi-million dollar development programme was being pursued in the USA to provide new and better irritant-agent weapons [476]; it is worth noting that in June 1970 the US Army let a $1.2 million contract for the procurement of what seems to be a new irritant agent, code-named CD-1 [512]. Whether the authorization of irritant-agent weapons, at present covering only CN and CS, will be extended to CD remains to be seen.

Table 2.14 collects together official US figures on the annual procurements of irritant-agent weapons from 1962 to 1969 by US armed forces. In April 1970 the Department of Defense stated that use of irritant agents in Viet-Nam was decreasing [476].

For protection against irritant agents, US forces in Viet-Nam were initially equipped with M-17-series general service CW respirators. These were soon found to be excessively uncomfortable and inconvenient under the prevailing combat and weather conditions [513]. In that only particulate aerosols were in use, and not gases and vapours, much of the bulk and weight of the M-17 was unnecessary. Accordingly, around 1966 work was begun on a much simpler and lighter mask, containing a particulate filter only, which could be tucked into a soldier's belt or carried in his pocket. By the beginning of 1967 the new mask, the XM-28, resembling the M-22 civil-defence mask, was being massively procured [514–15]. By mid-1969 it was in its fourth modification [236]. The protection which it conferred was adequate but not entirely complete, for dense CS aerosols can have a strong irritant effect on bare skin, particularly moist or sweaty skin [516].

According to US and South Viet-Namese sources, use of irritant agents has not been confined to the South Viet-Namese side. In September 1965, the South Viet-Namese Government announced that enemy forces were using irritants [517], and in November 1966 it stated that several hundred Chinese-made irritant grenades had been captured in a dump near the Cambodian border [518–20]. During the fighting around Hué in February 1968, a South Viet-Namese unit was struck by enemy mortar rounds containing CS, and in March 1970 a North Viet-Namese Army unit used a large quantity of gas to cover its retreat from a position near Tay Ninh [487]. In August 1970 a North Viet-Namese Army unit was reported to have fired mortar bombs containing "nausea gas"—a designation often applied to DM, although CS can also induce nausea—against Cambodian forces to the north of Phnom Penh [521–22]. Most of the gas is believed to come from captured US or South Viet-Namese stores; in addition, dud CS weapons have been used as a source of CS for improvised grenades. The CS mortar rounds that have been used are reportedly 60 mm and 82 mm projectiles in which glass vials containing CS-1 have been substituted for

Table 2.13. US CS weapons in use in Viet-Nam and under development

Weapon	Delivery system	Agent payload (*kg*)	Approximate rate of CS discharge (*grammes per second*)
M-7A3 hand grenade, CS	Hand or rifle	0.12	6
M-25A2 hand grenade, CS-1	Hand	0.05	Instantaneous
XM-47 hand grenade, CS, nonhazardous[a]	Hand	..	..
XM-54 hand grenade, CS	Hand or a/c dispenser	0.12	6
XM-58 hand grenade, CS	Hand	0.02	1.5
XM-23 disperser, hand-held, liquid CS[a]	Hand	..	..
Cartridge, 35 mm, CS-2	..	..	..
XM-627 cartridge, soft-nosed, 40 mm	..	..	..
XM-674 cartridge,[b] 40 mm, CS	Hand, pistol or grenade launcher	0.05	2
XM-651 cartridge, 40 mm, CS	Grenade launcher	0.03	1
XM-630 cartridge, 4.2 inch, CS	Mortar	0.9	4, for each of 4 canisters
XM-629 cartridge, 105 mm, CS	Cannon	0.75	3, for each of 4 canisters
XM-631 projectile, 155 mm, CS	Howitzer	2.2	5, for each of 5 canisters
E-8 rocket launcher, and cartridges, 35 mm, CS	Portable	1.2	1.5, for each of 64 rockets[c]
XM-96 rocket, tactical CS	..	..	..
M-106 disperser,[d] CS-1 or CS-2	Portable	3.3 per hopper	200
M-2 bulk agent disperser, CS-1 or CS-2	Skid mounted	5	40
M-3 bulk agent disperser, CS-1 or CS-2	Portable	4	180
M-4 bulk agent disperser, CS-1 or CS-2	Helicopter or vehicle	22 per hopper	1 100
M-5 bulk agent disperser, CS-1 or CS-2	Helicopter	18 per hopper	900
Bomb, XM-925 burster system with 55-gal shipping container, CS-1 or CS-2	Helicopter	36	Instantaneous

Table 2.13. Continued.

Weapon	Delivery system	Agent payload (*kg*)	Approximate rate of CS discharge (*grammes per second*)
XM-28 bagged agent dispenser, CS-2	Helicopter	400	Instantaneous
E-158R2 canister cluster, 50 lb, CS	Helicopter or low perf. a/c[e]	5	1, for each of 264 canisters[f]
XM-15 canister cluster, 50 lb, CS	Helicopter or low perf. a/c[e]	5	1, for each of 264 canisters[f]
E-159 canister cluster, 130 lb, CS	Helicopter or low perf. a/c[e]	10	1, for each of 528 canisters[f]
XM-165 canister cluster, 130 lb, CS	Helicopter or low perf. a/c[e]	10	1, for each of 528 canisters[f]
XM-27 canister dispenser, CS	Helicopter	8.25	6, for each of 72 canisters[g]
M-3 canister launcher system,[g] 2.75 inch, CS	Helicopter	21	6, for each of 168 canisters[g]
XM-99 folding fin rocket, submunition warhead, 2.75 inch, CS	..	..	..
CBU-30/A canister dispenser, CS	High or low perf. a/c[e, h]	25	1, for each of 1280 canisters
BLU-52/B bomb	High perf. a/c[e, h]	..	..

.. = unknown; a/c = aircraft.
[a] Under development primarily for civilian application.
[b] Nicknamed *Handy Andy*; previously E-24.
[c] E-23 cartridges containing about 20 grammes of CS: 64 cartridges per launcher, 4 to each of the 16 tubes.
[d] Nicknamed *Mity Mite.*
[e] Low performance aircraft, e.g. propeller-driven tactical aircraft;
[f] E-49 canisters.
[g] XM-54 or M-7A3 grenades as the canisters.
[h] High performance aircraft, e.g. an F-100 Supersabre.

Notes and sources:
1. NLF sources refer to the use of 500 lb and 1000 lb bombs charged with CS [966]. At the International Meeting of Scientists on Chemical Warfare in Vietnam, held in Paris in December 1970, a photograph was circulated captioned "Bombe au 'gaz toxique' CS-2 de 500 pounds. Preuves des attaques aux gaz toxiques des Américains contre la région densemment peuplée de Tam Ky (Quang Nam), le 31/1/1970". However, the photograph shows the remains of what was clearly a high-performance aircraft spray tank of 75-gallon capacity, according to the markings visible in the photograph.
2. The sources of the table are references 126, 156, 236, 533, 975, 990–93.

part of the explosive charge. Reports that Chinese CS grenades have been supplied are not yet verified. All in all, NLF and NVA units seem to have only a limited supply of irritant agents, but, according to one US evaluation, they use it to good effect. From 1968 or so this usage appeared to be increasing. [487]

With increasing use of CS by their enemies, NLF and NVA units have been supplied with an increasing quantity of protective equipment. Almost all NVA units are equipped with Chinese two-piece respirators, together

Table 2.14. Annual procurements of CS and riot-control weapons by US armed forces

Fiscal year[a]	Weight of CS procured[b] (*tons*)				Expenditure[c] on riot-control weapons (*US $ mn*)
	CS in weapons	Bulk CS-1	Bulk CS-2	Total CS	
1963	..	..	..	..	2.4
1964	106	64	0	170	2.9
1965	42	83	0	125	1.1
1966	208	553	0	761	16.8
1967	231	350	0	581	17.3
1968	395	1 591	423	2 409[d]	66.3
1969	1 060	87	1 763	2 910[d]	80.5
Total	**2 041**	**2 727**	**2 186**	**6 954**	**187.3**

[a] 1 July to 30 June; thus, FY 1963 = 1 July 1962 to 30 June 1963.

[b] These are figures released by the US Army. The source is *Department of Defense Appropriations for 1970* (US House of Representatives, 91st Congress, 1st session, Hearings before a subcommittee of the Committee on Appropriations, Washington, June 1969, Part 6, page 124).

At about the same time, the US Army provided Congressman R. D. McCarthy with a similar set of figures for each annual CS procurement programme [443]. These were 2–5 per cent smaller than those given above, with the exception of FY 1968, which was 20 per cent smaller. They were extracted from "Exhibit P-lc, Department of the Army supporting data for appropriate FY budget estimate, S.E. Asia requirements". The procurement programme was said to be "a reflection of the usage factor, quantity being delivered to using units and amount due from contractors".

[c] These figures are from the General Accounting Office, Comptroller-General of the USA [138]. In 1969 the US Army was paying about $6600 per ton for CS, about $10 500 per ton for CS-1, and about $10 700 per ton for CS-2 [443].

[d] Programmed.

with a growing number (as of 1968) of the more efficient, but much heavier, Soviet hood-type field respirators. When these masks are not available, substitutes have been improvised from plastic, gauze and pieces of charcoal. [487, 523] The discovery of a Chinese anti-gas protective suit made of rubber was reported by a British journalist covering the relief of Khe Sanh in April 1968 [524].

As regards the military rationale underlaying US employment of CS, it has been noted above that the official US statements of March 1965 stressed the humanitarian possibilities of irritant-agent weapons. Secretary of State Dean Rusk had said that CS provided a minimum force option that could reduce noncombatant deaths, and that it would continue to be used only in operations analogous to riot-control situations. It is reported that at this period US forces saw a real need for new techniques for engaging enemy troops intermingled with civilians without causing excessive injury to the latter:

> Situations occur in which enemy troops or insurgents are mingled with civilians. With conventional weapons the military must go ahead and accept civilian casualties and fatalities. In Vietnam, one or two Viet Cong may be mixed with a hundred women and children in a cave, or a small number of

North Vietnamese may hide in a village; you either go ahead and burn down the village with the North Vietnamese usually running away, or you forego engaging the enemy. In general, the military prefers to engage the enemy where-ever they find him. It breaks them up terribly if they find the enemy mingled with civilians. Once an enemy figures out that you have created a haven for him, he is going to be more interested in finding mingled situations than he otherwise might be. The military is really bothered by the mingled situation because they find they have to make a trade off each time, whether they just go ahead and kill civilians or whether they let the enemy go. [213]

It is therefore not unreasonable to suppose that the rather small quantities of CS that were initially supplied to US forces in Viet-Nam—as opposed to the much larger quantities being sent out by 1969—were intended for use primarily against intermingled target populations. It was this ostensibly humanitarian rationale—the use of CS in order to minimize noncombatant casualties—that continued to be emphasized in subsequent official US statements. Thus, at the UN General Assembly in December 1966 the US Ambassador stated that: "It would be unreasonable to contend that any rule of international law prohibits the use in combat against an enemy, for humanitarian purposes, of agents that Governments around the world commonly use to control riots by their own people." [525] In a letter written in November 1967 to a US Senator, a Department of Defense official said that:

We have repeatedly weighed the pros and cons of using these materials. We are convinced that their use is not only militarily advantageous but has resulted in saving many lives among civilians as well as in our own and our adversaries' military forces. For these reasons we have no intention of discontinuing their use. [526]

In a letter to the editor of a Washington newspaper in January 1968, another Department of Defense official wrote: "The U.S. and its allies have employed riot control agents of the tear gas type in Vietnam from humanitarian motives chiefly." [527]

However, it became known at the end of 1969 that the authorization given in the autumn of 1965 for continued use of CN and CS in fact placed no restrictions on the manner in which these agents were to be used [431]. There was no directive that they should be used only for humanitarian purposes. They were to be regarded as a normal component of the available inventory of weapons. As regards the employment of CS in offensive combat operations, the March 1966 edition of the relevant field manual stated:

... CS munitions are used in offensive operations where it is desired to disable enemy troops for a limited period of time. These munitions may be used to "flush out" unmasked enemy troops from concealed or protected positions, to reduce their ability to maneuver or use their weapons, and to facilitate their capture or their neutralization by other weapons. [222].

It made no mention of the use of CS to minimize casualties. This point was carefully explored by a US Congressional committee during its cross-examination of a Department of Defense witness in December 1969. In his prepared statement, the witness, Rear-Admiral W. E. Lemos, had included a number of extracts from after-action reports from Viet-Nam that illustrated occasions on which CS had minimized casualties:

[Question]. Are there published regulations or guidelines to the commanders in the field with respect to the use of the riot control agents?

Admiral Lemos. There are. There are classified rules of engagement which include the use of riot control agents; yes, sir.

[Question]. Do they spell out in some detail the circumstances under which they can be used?

Admiral Lemos. The guidance is quite general. It is completely consistent with the U.S. policy that riot control agents have no prohibition in their use in such situations as we are facing in Vietnam.

[Question]. In other words, the guidelines are that they may use them in combat situations?

Admiral Lemos. Yes, sir.

[Question]. You outlined a number of specific illustrations of the use of the riot controls agents. The guidelines are not framed with that specificity, I gather?

Admiral Lemos. That is correct. . . .

[Question]. When you say they would be used as necessary in combat operations, there is no restriction either in the policy or in the guidelines that says they can only be used to lessen the number of casualties on both sides, or something of that kind.

Admiral Lemos. I am sure it does not say that they would be used only in circumstances where they would reduce the number of casualties, but it does give guidance that they would be used in the effort to reduce casualties. [431]

Lemos' last sentence referred to a commendation by the US military command of the use of CS in situations where noncombatants were intermingled with military forces. This was a guideline, not a directive, and field commanders were certainly not obliged to confine their use of CS to intermingled situations.

In fact the intermingled situation was becoming increasingly rare. This was a point made in a field-study on the use of CS that was prepared in the course of 1968 [528]. The authors of the report observed that although enemy units might invade a friendly or neutral village and then battle to hold it, the villagers themselves tended to remove themselves before the battle developed. As one commentary puts it:

Civilians hardly ever become embroiled in a firefight unless it develops very suddenly—and this is not a common occurrence. When the Viet Cong set up fighting positions in or around a village, they may force the villagers to help dig trenchworks, but they almost always permit the civilians to leave once the work is finished. The result is that before the battle begins the villagers are gone. As a matter of fact, it is well known among U.S. troops in Vietnam that one of the surest indicators that a patrol approaching a village can have of impending trouble is the absence of villagers from view. [487]

Thus, while the claims of official US spokesmen that CS could save lives in intermingled situations were no doubt true, the rarity of such situations meant that they accounted for very little of the total CS consumption [487]. It is clear that the increased deployment of CS during 1968 (see table 2.14) was not due to an increasing number of intermingled situations. Rather it was due to an increasing interest among field commanders in the combat possibilities of CS. Authorized as they were to treat CS like any other weapon, that is what they came to do. In the autumn of 1968, a US Army journal described this process as follows:

... As a newcomer to the battlefield in Vietnam, CS initially encountered considerable skepticism as to its effectiveness in combat support. This, coupled with unfamiliarity with its use and absence of proven field techniques, posed problems. But these were swiftly overcome as experience was gained. New uses and novel methods of disseminating the agent have rapidly developed. Commanders now find it a valuable weapon in combat situations where it is apparent that explosives are not the sole or the best answer. ... [529]

In Congressional testimony by the Department of Defense in June 1969, the point was made in this way: "... Now in terms of effectiveness, the troops who have used them and the field commanders feel that there are many situations where the use of CS has enhanced our military effectiveness. ..." [126] Thus, whatever US spokesmen at home or abroad might be saying, the US military was assessing the value of CS not in terms of its humanitarian applications but in terms of its contribution to the overall military effectiveness of US forces in Viet-Nam. An article in a US army magazine in October 1969, describing new ordnance trends in Viet-Nam, did not refer to the life-saving properties of CS at all, but illustrated the value of the agent with this example: "Another comparatively recent ordnance trend is the growing use of tear-producing CS gas and the proliferation of associated weapons and munitions. CS has proved particularly effective in Vietnam in flushing the enemy out of bunkers preceding high-explosive fire or infantry assaults." [530] In December 1969, Admiral Lemos opened his Congressional testimony [431] on the use of CS in Viet-Nam as follows: "Simply stated, riot control agents are used to save lives—American lives, lives of our allies, civilian lives, and enemy lives". He went on to describe the specific incidents referred to above where use of CS had indeed saved lives, and argued that the tactical value of CS existed because CS could save lives: "Since they save lives, riot-control agents have been treated as normal components of combat power. They add to a commander's flexibility and give him additional means of devising the best method of accomplishing his mission with minimum loss of life." As he expounded this argument, it became apparent that there were inconsistencies in his descriptions of just whose lives were being saved—those of noncombatants, those of enemy combatants, or those of US and allied combatants. Thus:

As the effectiveness of these riot-control agents in reducing casualties became increasingly evident in such situations as suppression of hostile firepower and clearance of fortified positions and underground facilities, American commanders at all levels began to see other ways in which the use of riot-control agents, particularly the new agent CS, could save many American and allied lives. As a result its applicability to other types of operations spread among U.S. units in Vietnam.

He concluded his prepared statement on CS with the words:

Perhaps the most valid indication of the effectiveness of CS in combat operations is that U.S. personnel continue to carry CS grenades in the field in lieu of some of their normal high explosive ammunition, and ground commanders often call for CS rather than high explosives. Riot control agents are a valuable aid in accomplishing our mission and in protecting our forces.

When the time came for the committee members to question Admiral Lemos on his presentation, they took up the matter of whose lives were being saved. The Admiral was asked to describe the guidance given to field commanders about the use of CS. In addition to the answers quoted above, he stated: "The guidance given to the commanders in the field is that CS will be used as one of their combat arms. The only specific recommendation is in their use against noncombatants, that is, their use in a situation where noncombatants are intermingled with military forces." When asked about the recommendations for situations that did not involve noncombatants, there was the following exchange:

Admiral Lemos: I have impressions that the guidelines for the use of CS are such that they are used in combat situation to save American lives.
[Question]: American lives?
Admiral Lemos: American lives, yes, in this situation.

The Admiral thus made no mention of saving enemy lives. When this point was raised, he replied: "[CS] is used to give the enemy the option of giving up his attack against Americans. . . . If the enemy chooses not to give up that attack, then all other means available to the commander will be used to prevent the enemy from continuing the attack."

It is difficult for anyone who reads the full report of these recent Congressional hearings to avoid being left with the impression that the principal reasons why the USA continues to use CS in Viet-Nam are (*a*) that it can be an effective operational support weapon; and (*b*) that it can keep down American casualties. Alongside these two assets, the ability of CS to reduce enemy or noncombatant casualties—a property which CS weapons can undoubtedly display, albeit in situations of unknown but probably low recurrence—is now apparently very much a subsidiary asset.

The basic doctrine for the use of CS weapons by US forces in Indo-China is set out in the April 1969 edition of US Army Training Circular TC 3-16. (The instruction given in this publication presumably derived from combat experience, and is considerably more detailed than the March 1966 manual quoted from above; it includes guidance on the application of CS in intermingled situations.)

> The employment of riot control agents (CS, CN) in counterguerilla operations is most feasible in tactical situations characterized by close combat in which rapidly responding systems are essential and permanent effects are undesirable. Riot control munitions can be used tactically to temporarily disable hostile troops, to suppress their fires, or to cause them to abandon their positions. Offensively, riot control agents can be used to "flush out" unprotected enemy troops from concealed positions or to reduce their ability to maneuver or use their weapons. Defensively, riot control munitions can be integrated into defensive perimeters to provide rapid CS delivery in case of enemy attack. [236]

In addition, the training circular also recommends the employment of bulk CS powder for area-denial functions. Under the headings of area-denial, offensive employment and defensive employment, the remainder of this section describes how CS has been used in Indo-China.

DEFENSIVE EMPLOYMENT OF CS

Among the very earliest applications of CS by US forces in Viet-Nam was its use by patrols for breaking contact with superior enemy forces [236,487, 529]. As a quick reaction to surprise attack, combat units have used CS weapons to disconcert attacking forces, thus gaining time to organize a counter-attack or to cover a withdrawal. In related roles, CS has often been used to secure helicopter extractions of combat units or downed airmen, and to provide a first line of defence against ambush [236].

As regards the latter, it has been common practice for convoys of vehicles moving through forested areas of Indo-China to have E-8 launchers mounted on the sides of some of the vehicles ready for immediate discharge against ambush positions. In addition, CS grenades and the smaller CS cartridges have been used to reconnoitre suspected ambush positions; the area effect of a CS aerosol can make these weapons better suited to reconnaissance-by-fire than conventional small arms. [236, 487]

Finally, CS has been widely used in perimeter defence. Concealed E-8 munitions with trip-wires or such-like to trigger them have been emplaced around base-camp perimeters. Bulk CS powder has been used for similar purposes: anyone attempting to pass through a contaminated area unprotected is likely to reveal his presence by sneezing and coughing when he stirs up the dust. The CS powder is sometimes mixed with oil to increase its persistency and to diminish downwind travel of the agent. This technique has been used to discourage civilian looters, as well as to surprise enemy attack. [236, 487]

CS FOR AREA-DENIAL

The last-mentioned technique is one of the area-denial applications of CS. Its employment to render terrain uninhabitable by the enemy for this and other purposes has accounted for the major proportion of the total CS consumption in Viet-Nam [487]. Several of the early press reports about CS described its use in preventing reoccupation of tunnels and underground bunkers [509, 531–32]. A US army magazine summarized this technique as follows:

> When more tunnels are located than can be destroyed quickly, CS is used to deny use of the complex until supporting engineer troops can be brought up to destroy it efficiently. . . . CS powder is blown into the tunnel. CS can also be forced in by connecting bags of the powder to an explosive charge, which renders the tunnel uninhabitable for at least a week and a waterproofed CS gives promise of extending this to several weeks. [529]

In such a role, persistency of the contaminant was important. Under moist conditions CS decomposes fairly rapidly and thereby loses its effectiveness. The need for a more persistent agent was often voiced [533]. Eventually CS-2, the "waterproofed CS" referred to above, was developed, coming into use in 1968.

CS-2 was also applicable to above-ground area-denial operations; while CS-1 had been used on occasions for this purpose, its rather rapid rate of deactivation demanded frequent reapplication, if area-denial for prolonged periods was called for, particularly over swampy ground. CS-2 thus extended the uses of irritants for area-denial. Typical targets for bulk contamination have been enemy base camps, rest areas, and routes of communication, supply or escape [236, 487]. An early technique for spreading the CS, one which came into frequent use early in 1966, was to air-drop 55-gallon shipping containers of the agent that had been fitted up with improvised explosive bursters time-fused to detonate just above the ground. A CH-47 helicopter can dispense thirty such drums per sortie, each containing about 35 kg of CS. Later on, a standardized burster for shipping containers became available, and a new system—the XM-28 bagged agent dispenser—was also introduced for helicopter use. The latter is a device for dropping paper bags of CS powder in a controllable pattern. [236, 487]

The most recent occasion on which area-denial employment of CS has been described in the press was during the US withdrawal from Cambodia at the end of June 1970: it was reported that large quantities of CS powder had been spread along jungle trails and inside bunkers and cache sites [534].

OFFENSIVE EMPLOYMENT OF CS

After area-denial, the next largest requirement for CS has come from its applications in the direct engagement of the enemy during offensive combat operations [487]. The Utter incident in September 1965 is an example; it was an early instance of CS being used to flush enemy personnel out of caves and tunnels. While this technique has obvious value if the tunnels are believed to contain noncombatants—the alternatives include flame, explosive or fragmentation weapons—it has also proved valuable against enemy occupied tunnels whose deepest recesses are not accessible to conventional weapons. In such cases clouds of CS have been blown in with portable air-compressors, such as the M-106 *Mity Mite,* or bulk-agent dispersers. [236, 487, 529]

A second type of application under this heading was the use of CS to prepare landing-zones for helicopters or amphibious assault craft. Shortly before the landing, area CS weapons were dropped or fired onto and around the zone to suppress whatever enemy firepower might be concealed there [236, 487]. The CS fire has often been combined with a preparatory bombardment of conventional fire. The 1969 US Army training circular describes this technique as follows:

> CS fire may be co-ordinated with HE fire in preparation of landing zones when enemy presence is suspected. Riot control agents should suppress hostile fire or cause it to be ineffective if the enemy is unprotected. . . . The riot control agent should be disseminated just prior to troop landing. The troops and aircraft crew must be equipped with protective masks so that the assault can take place with an effective agent cloud still in the area. . . .

The CS and HE are interspersed throughout the target area to gain maximum surprise and to suppress ground fire just prior to landing an assault force. [236]

A third offensive application of CS was in the canalization of enemy forces. The training circular describes this as follows: "Riot control agents may be used to canalize unmasked hostile personnel into routes, avenues or positions in which attacking forces can execute preplanned schemes of maneuver with less enemy resistance." [236]

In assaults on small targets such as an enemy bunker or weapon emplacement, CS has often been disseminated immediately prior to engagement. A popular weapon here has been the XM-651 cartridge, a 40 mm round for the M-79 automatic grenade launcher. [487] This can be fired through a window or port at ranges of up to 400 metres (although accuracy declines beyond 200 metres), and a succession of them can rapidly incapacitate the occupants of a fortification [236].

Area weapons disseminating CS have been used prior to assaults on more diffuse targets. Here the weapons used have included volley-fired 4.2-inch mortar bombs, the various aircraft-delivered CS clusters, and the E-8 launcher (in effect, a ground-launched CS cluster weapon). These weapons have been successfully used in cases where conventional artillery or air support has been unavailable or impractical, for example in the street-fighting situations during the battle of Hué in February 1968. They have also been used where preliminary fire with conventional weapons has been undesirable for other reasons, such as the presence of noncombatants or a requirement to take prisoners. [487]

As regards targets containing noncombatants, the training circular states that: "In addition to use against unmasked hostile forces, CS munitions may be employed as a most effective weapon choice against a target area containing mixed friendly-hostile or neutral-hostile populations where casualties are to be minimized." [236]

Finally, CS has been used on the offensive in close coordination with conventional firepower:

In still another application in Vietnam, CS is disseminated preceding attack on strongly fortified positions. Entrenched areas that had successfully resisted both aerial and artillery fire have been reduced in an hour or two by combining the use of CS with maneuver and firepower. [529]

This is the sort of situation for which the CS-filled artillery rounds listed in table 2.13 were designed, although other types of CS weapon are also applicable. The technique of disseminating CS aerosols over a target area immediately prior to B-52 strikes, first employed in February 1966, has been mentioned earlier.

One reason for the success of these types of operation is that against an unprotected, poorly protected, or badly disciplined enemy, the harassing effects of CS may cause him to leave his position to escape from the agent; once he does this he may become vulnerable to conventional fire.[44] A highly motivated enemy may be able to withstand the CS, but if he lacks protection he will be so incapacitated by it as to be unable to offer much resistance to a subsequent infantry assault. [236, 487]

A related technique of this type was described in the *New York Times* during September 1968:

> The officer generally acknowledged as having perfected the cordon and pile-on is Col. Henry Emerson ..., who commanded a brigade of the Ninth Infantry Division. ... Colonel Emerson used not only infantry patrols but also detectors and radar to find the enemy. Then he often pounded the area with tear gas in an effort to drive the enemy into the open. When the enemy's presence was confirmed, the colonel surrounded the area and called in bombers and artillery, followed by an infantry sweep. In one operation last month, his men killed 130 of the enemy.... [536]

The use of chemical casualty agents

Soon after the March 1965 furore about the use of "nonlethal" gases in Viet-Nam, NLF publications alleged that, in addition to CS, CN and DM, a number of chemical casualty agents had been employed by US and South Viet-Namese forces. On 5 April 1965 Hanoi radio claimed that ten weeks previously the United States had dropped "lethal asphyxiating gases" similar to those used in World War I on a hamlet in Phu Yen province; the gases were said to include "adamsite, alpha-chloracetophenone and ti-phosgen". A US Department of Defense official described the charge as "a bunch of damn lies". [537] It turned out from subsequent NLF publications that "tiphosgen", sometimes "thiophosgen", was a designation applied to CS [470], but by this time the use of agents such as CNS—a US Army code name for a formulation of CN containing chloropicrin—VX and LSD was also being alleged [470, 499]. US officials have consistently denied the employment of chemical casualty agents in Viet-Nam, including nerve gases and hallucinogens. Nonetheless, these and related allegations have found their way into a number of textbooks dealing with chemical warfare published in Socialist countries. Thus, Aleksandrov's *Otravlyayushchie Veshchestva* ("Toxic agents", Moscow, 1969) states that metal arse-

[44] It is estimated that against people lying on the ground, the effects of a typical 155 mm fragmentation shell would put target personnel at hazard over an area of 300 or 400 square metres. If they were standing up, as they would be in order to escape from CS, the effective area would be about 1 000 square metres. [535]

nides, which evolve arsine under humid conditions, have been used by US forces to cause mass casualties among men and animals in Viet-Nam; it also states that US forces have used phosgene and thiophosgene in Viet-Nam [538]. Likewise, the second volume of Franke's *Lehrbuch der Militärchemie* (East Berlin, 1969) repeats the allegations about use of VX and LSD [185].

While North Viet-Namese and NLF publications seem to have stopped alleging US employment of chemical casualty agents, there have been one or two recent reports in the Western press that such agents are stored in Indo-China by US forces, and that they have been used experimentally there [537, 539–40]. In May 1970, for example, a former US officer was reported as having seen nerve-gas weapons in storage at Bien Hoa Air Base during 1967 and 1968 [539]. This received an official denial.[45] In August 1970, a wire story put out from Saigon stated that in the summer of 1969 US Special Forces operating in Cambodia had assisted in a field experiment involving the nerve agent VX: weapons containing the agent were said to have been airdropped along a frequented section of the "Ho Chi Minh trail" in order to determine the casualty-producing ability of the ground contamination created by the weapons [540]. The story was not used at all widely by newspapers, despite its rather sensational character[46]—it claimed, for instance, that the experiment contributed to the events leading up to the

[45] It was later explained that what he had in fact seen were the letters "G. B." written on a storage tag, and that while these letters certainly constituted the US Army code name for the nerve agent sarin, they were actually being used as an abbreviation for something quite different.

[46] As published in the Swedish newspaper *Dagens Nyheter* [540], the details of the story are as follows: The operation formed part of a secret and long-established US Department of Defense experimental programme known as *Project Waterfall*. This programme was concerned with refining existing estimates of the capabilities of VX weapons; it had advanced to the point where use of an experimental venue that combined tropical conditions and human subjects would greatly expedite further progress. Waterfall workers asked for, and received, authorization from the Department of Defense to enlist the help of Special Forces personnel in conducting experimental work along a section of the Ho Chi Minh trail in northeast Cambodia known to be used by North Viet-Namese Army units. Involvement of US Air Force personnel was also authorized if the chance of affecting civilians was judged negligible. Work duly began in the summer of 1969 under the code-name *Operation Redcap*, and continued without the knowledge of the US commander in Viet-Nam. A series of VX devices were air-dropped throughout the experimental site, and the results were assessed by a group of fifteen South Viet-Namese and Americans who formed the B-57 detachment of a specialized branch of the 5th Special Forces Group. The commanding officer of the 5th Special Forces Group, Colonel Rheault, gave high priority to Redcap. The experimental site was located a few miles from a depot used by the 94th North Viet-Namese Support Group; NVA troops were accustomed to stop off there on their way south through Cambodia. Some weeks after Redcap had begun, it was discovered that information about it was being passed to North Viet-Nam. A Viet-Namese member of the B-57 detachment, Thai Khac Chuyen, thought to be a double agent, was believed responsible for this. His subsequent disappearance provoked the murder charges against Colonel Rheault and seven of his men—several of whom were from the B-57 detachment—that were later withdrawn in August 1969.

"Green Beret affair" in August 1969—and at the time of writing there has been no official US comment on it.

The Western press has also carried a number of stories about use of chemical casualty agents by NLF and NVA units in Indo-China. Thus, in November 1967 a US serviceman in South Viet-Nam, complaining about a shortage of respirators, reported that a "Viet Cong" gas attack at Daktu had killed thirty members of a company of the 4th US Infantry Division. While not specifically denying that gas had been used, a spokesman for the division later said that the report that the men had died because they lacked respirators had "no basis in fact". [541] In April 1970, a British newspaper reported that:

> Communist troops yesterday tried to penetrate the Dak Seang Special Forces camp 292 miles north-east of Saigon by using lethal gas, of an undetermined nature, against the camp guards.
>
> A violent mountain wind spoilt the Communist scheme, it was learned in Saigon yesterday. Military sources also said that a sweep of the area at day-break resulted in the discovery of 30 enemy bodies.
>
> It could not be confirmed whether the dead Viet Cong had been choked to death by the poisonous gas they themselves had spread. [542]

All in all, the infrequent reports about use of chemical casualty agents by either side in Indo-China seem to be comparatively trivial, and all are unsubstantiated. This is perhaps not very surprising, for quite apart from the dislike of lethal chemical weapons shown by most military people, the combat situation in Indo-China does not seem particularly suited to their use. No doubt special occasions have arisen for which chemical casualty agents might have been attractive, but it seems doubtful whether these could have been frequent. It therefore seems probable that if lethal chemicals have indeed been employed in Indo-China, it has been in the course of special operations of a peculiarly irregular kind, rather than during regular combat missions.[47]

While neither the chemical irritants nor the anti-plant chemicals in use in Indo-China have been intended to produce casualties among people exposed to them, there have been frequent allegations that such casualties have occured. As regards fatalities from irritants, one of the more explicit reports referred to the consequence of an employment of irritants

[47] It is certainly known that several countries have in the past developed both chemical and biological weapons for irregular operations, such as sabotage or assassination. Some of these are described in Chapter 1. It is not in the least inconceivable that the situations for which these weapons were designed have occurred in Indo-China. While rumours of their actual use have been about US employment, they are as likely to be valuable to one side as to the other.

to flush the occupants out of a cave,[48] it was contained in a letter to the *Saigon Post* during October 1967:

... About three and one half months ago I was involved in an attempt to be of assistance to some six thousand new refugees that had been created in Quang Ngai province by a forced evacuation of an area under NLF control. ... I took two of them, a ten-year old boy and a twelve-year old girl, by far the most seriously ill and drove the eight miles back to Quang Ngai. Emergency measures proved fatal for the boy, he was in the morgue next morning when I went to the hospital: he died from an overdose of tear gas. ... The victims reported that about twenty women and children did not even make it out of the cave. ... [546]

Another report of irritant agent deaths emerged from Quang Ngai hospital in the following month. This was a letter written by Dr Alje Vennema, then Director of Canadian Medical Services in Viet-Nam: [442, 547]

... During the last three years I have examined and treated a number of patients, men, women and children, who had been exposed to a type of war gas, the name of which I do not know. ... The patient usually gives a history of having been hiding in a cave or tunnel or bunker or shelter into which a canister of gas was thrown in order to force them to leave their hiding place. ... Patients are feverish, semi-comatose, severely short of breath, vomit, are restless and irritable. Most of their physical signs are in the respiratory and circulatory systems. Both lungs exhibit rales throughout, severe bronchial spasm, heart rate is usually very high and all of the patients had pulmonary edema. In most cases active treatment for pulmonary edema and complicating pneumonia was helpful and they survived. Those that survived developed a chronic bronchitic type of picture complicated by infections. ...

A reference to this report in a Washington newspaper [547] provoked a letter from the US Department of Defense containing the following [548]:

A check of Service medical authorities indicated that no report has been received of fatalities from any of these agents in Vietnam or elsewhere. ... Doctors

[48] When burning-type irritant grenades—or any other burning-type munition—are used inside tunnels, there is a danger that the occupants will also be exposed to carbon monoxide and other products of incomplete combustion [236]. The much-publicized death of the Australian soldier, Corporal Bowtell, in Hau Nghia province in January 1966 has been attributed to carbon monoxide poisoning. He died while searching a tunnel in which CN [543] grenades had been used [544], even though, like the six other men in his team, he was wearing a respirator. The original *New York Times* report of this, based on a wire story, made no mention of carbon monoxide poisoning; an Australian newspaper reporting the incident more fully, and using a different wire story, did refer to carbon monoxide [545]. The *New York Times* report was the more often quoted, however, and was frequently used to show that US "non-lethals" were not as innocuous as they were made out to be. It was not explained how it came about that the tunnel contained the massively high concentration of CN needed both to penetrate a respirator and kill the man wearing it, nor how it was that only Bowtell succumbed. The official Australian medical report on the incident is said to have confirmed carbon monoxide poisoning: service respirators are not designed to protect against this gas.

say that a person already suffering from severe respiratory desease could be hurt by the agents and, in theory, could even die of aggravation of their disease. ...

Since then, Dr Vennema has published a fuller account of his work at Quang Ngai provincial hospital [497]. In this, he describes twenty of the cases of "gas affliction" that passed through his hands between May 1965 and August 1968. Of these, nine died in the hospital, five of them children aged ten or less. He describes the circumstances leading up to one group of cases as follows:

The group ... had constructed themselves a bunker near their straw hut for protection against artillery fire at night-time. During the day, on the 6th of October [1965], when fighting erupted nearby, they sheltered themselves. As they were hiding, a canister of gas was thrown into their bunker and they were told in English to get out. They did not understand the language and got frightened. They remained inside for a while and later on crawled out and managed to get to hospital. ... One of the children, the child of eight, died the next morning. The four-year-old survived, as did the three adults.

The two *post mortem* examinations that he made revealed gross evidence of pulmonary oedema. He describes in some detail the clinical picture of the cases he treated, and the treatment which he gave. As regards prior respiratory disease, he states that "repeated respiratory disease as a complication of parasitosis is very common in Vietnamese children".

In May 1969, a US newspaper quoted an unidentified US Army chemical officer as follows: "He said field reports from Vietnam have told of instances where CS has apparently caused the deaths of enemy soldiers suffering from tuberculosis, a common disease among peasants in Asia." [549]

It is rumoured—and there is no substantiating evidence yet published—that lower-echelon field commanders in Viet-Nam have deliberately refrained from reporting CS fatalities lest further use of the agent be forbidden them; CS deaths have instead been ascribed to heart failure or other natural causes.

NLF and North Viet-Namese sources have published many allegations of irritant-agent fatalities in Viet-Nam [470, 496, 499, 550–53]. Among the most detailed of these is a document prepared by the NLF in October 1967 which lists some thirty incidents between 28 January 1965 and 5 July 1966 for which a total of well over seven hundred deaths due to chemical agents were recorded [496]. Another NLF publication refers to two incidents during January and February 1970 in which 150 barrels of CS (5 or 6 tons) were dropped over an area in Quang Nam province; it states that "as a result 150 persons have got pharyngitis, eye-sickness, dysentry, fever and vomiting, and 16 among them went mad and died" [968].

There is thus a considerable amount of allegation and documentation about irritant-agent deaths in Indo-China. No part of it is yet completely verified. CS may have killed people in Indo-China, either by its own toxic action or by exacerbating pre-existing disease. There can be no certainty yet about the truth of the reports: it is impossible for an outsider to form an objective judgement one way or the other.

Among healthy people, there can be little doubt that CS is lethal only at very high dosages, and that the dosages causing militarily-useful harassment are very considerably lower than these. With less certainty it can also be said that for healthy people there is also a substantial safety margin as regards nonfatal injury. Nonetheless, the characteristics of the CS weapons being used in Indo-China, together with the operational circumstances surrounding their use, must mean that field dosages of CS have frequently been created that are very much higher than the minimum harassing dosage. It is impossible to determine by experiment on willing volunteers what would happen to people exposed to such dosages, although intuitive inferences about this can be drawn from animal experimentation [554]. Given this fundamental scientific uncertainty, it would therefore be the height of arrogance for an outsider to dismiss out of hand all the allegations that have been made about CS casualties.

The question of the degree of hazard facing people exposed to CS is discussed in more detail in Volume II of this study. For the present, its magnitude is suggested by the following quotations from a US army publication [555]. (Some of the technical terms used in them are explained in Chapter 1.) This is the report of a study of the effects in rhesus monkeys of CS aerosol dosages in the range 2 700 to 80 000 mg-min/m^3 generated from M-7A3 hand grenades:

> The LCt50 for CS is estimated to be 61 000 [mg-min/m^3] for humans and between 92 000 and 165 000 for monkeys. Buildings, caves, or tunnels would be the only areas in which Ct's in the range employed in this study could be expected. Ct's of about 7 are considered sufficient to cause humans to flee from a cloud of CS. It is unlikely that man would voluntarily be exposed to Ct's in the range used in this experiment, even if he was highly motivated to resist flight. Injury or physical restraint of some kind, however, might cause people to remain in such atmospheres.

In the light of an observation of significant lung damage at a dosage of 2 700 mg-min/m^3, the study makes this observation:

> Although the toxicity of this agent is low, the present study gives evidence that lesions that might cause casualties in an active human population occur at lower doses than would be expected from the dose-mortality curve.[49]

[49] Estimated dose-mortality curves for CS in man have not yet been published in the open literature, but it is understood that the probit line is believed to be steep, with a slope of around five. As the first quotation above notes, one estimate of the dosage having a 50 per cent chance of killing a man is 61 000 mg-min/m^3.

It may be noted that an M-7 series hand grenade can put up a CS concentration of 2 000–5 000 mg/m^3 over a radius of several metres [556].[50]

Allegations about chemical-agent casualties in Indo-China also extend to anti-plant agents. The NLF has alleged that the US/South Viet-Namese herbicide programme has caused widespread disability among the inhabitants of treated areas. The figures given in table 2.12 have been published in this connection. It is not clear what combination of signs and symptoms justified inclusion in the "poisoned" category of these figures. No *post mortem* information is available on those victims alleged to have been killed by anti-plant agents, but the signs and symptoms of those people alleged to have been affected by them are described as "coughs, headache, fever, dizziness, dyspnoea" [499]; "nausea, haemorrhage, loss of consciousness" [480]; "vomiting, hard breathing, fever, headache, skin diseases, etc." [551]; in women "miscarriage, sudden loss of milk, or abnormal menstruation have been very frequent" [551]. A more detailed clinical account has been published by a team sponsored by the Association Générale des Médecins de la République du Sud Vietnam. Its report is based on examinations "of a group of South Vietnamese refugees to North Viet Nam" and states that:

As soon as the chemical cloud falls down onto the landscape, the patient feels irritation in his eyes with a great deal of tears and intense rhinorrhea. A strong smell of chlorine or of DDT seizes him at the throat, while a deep feeling of

[50] The concentration of aerosolized agent in the air of a confined space, such as a tunnel, falls off exponentially with time. Typical values for the decay exponent include 0.007 and 0.04 min^{-1}. The total dosage of agent which people would inhale if they remained in the tunnel for a time t is given by the relationship $c_0(1-e^{-kt})/k$, which is in units of mg-min/m^3 if the decay exponent k is in min^{-1}, t in minutes and the initial agent concentration c_0 in mg/m^3.

Take the case of an underground shelter 50 metres long, 3 metres high and 6–7 metres wide (i.e., having a volume of 1 000 m^3) and assume that it is so well ventilated as to display a k-value of 0.04 min^{-1}.

A single M-7-series CS grenade thrown into this shelter would quickly set up a CS aerosol whose initial concentration might average out to 60–100 mg/m^3. If the occupants of the shelter were prevented from escaping in less than half an hour or so, they could have inhaled more CS (per unit body weight) than did the monkey whose lungs were damaged in the experiment cited above.

If, instead of the grenade, a single ten-pound hopper of micronized CS powder were blown into the shelter from an M-106 *Mity Mite* disperser, the initial average concentration of CS might be as high as 3 000 mg/m^3. Using the human lethality estimates quoted above, it may be calculated that 5 per cent of the shelter occupants would receive a lethal dosage of CS unless they escaped within quarter of an hour. If the occupants could not get out in less than three-quarters of an hour, half of them would probably die. It must also be noted that at CS dosages as high as those likely to be experienced under these circumstances—and the figures just calculated would also apply in the case of a single M-7 series grenade thrown into one of the small protective shelters that are commonplace in South Viet-Namese households—there would be a substantial probability that the occupants of the shelter would very quickly become so incapacitated as to be immobilized.

heat, similar to that of chilli, comes up his nostrils. The patient sneezes ceaselessly and begins to vomit, to have a splitting headache and an intense asthenia: this last feeling is often referred to during the interviews.

These symptoms begin to reduce after 24 hours, but only after 3 or 5 days the patient has a better sensation.

Other patients have oedema-swelled eyelids, giddiness, sensation of burns with phlyctenules on the skin.

As regards secondary effects, the report states that "31 out of 109 adults ... say they had generalized asthenia: some of them had to be confined to bed for two to three months and were afterwards unable of sustaining effort. Along with asthenia there is insomnia, headache, sexual impotency in many cases, and troubles of menstruation for women". The reports also describes observations of chromosome alterations among adults, and congenital abnormalities among babies, including instances of microcephalia. [969] This and other publications concerning the possible long-term effects of herbicides are discussed in Volume II of this study.

1968: Guinea-Bissau

In August 1968 Mr Diallo Telli, Secretary-General of the Organization for African Unity, accused Portugal of using war gas against the rebels in Portuguese Guinea. He said that OAU investigations had established that Portuguese troops were waging chemical warfare against the whole of the country's population. [557] Portugal's response to this charge is not known.

1969: Palestine

In Amman at the beginning of January 1970, the Palestine Armed Struggle Command accused Israel of having used poison gas against Palestinian guerillas during a clash in the Jordan Valley on 31 December 1969. One guerilla was reported killed, four wounded and two affected by gas. [558] The Israeli response to this charge, if any, is not known. It is perhaps worth noting that at least one recent report exists of Palestinian guerillas having equipped themselves with gas masks [559].

1970: Angola

A statement issued in Dar es Salaam on 21 July 1970 by the Popular Movement for the Liberation of Angola included alleged eye-witness accounts of chemical anti-crop operations in eastern Angola. The report stated that in May five Portuguese aircraft had circled a "liberated" area and that three of them had sprayed anti-plant chemicals over fields of cassava and sweet potato crops. [560–61]

During the 25th UN General Assembly, a group of thirty-three delegations (mainly African and Asian) in the Fourth Committee sponsored a draft resolution introduced on 6 November 1970 which contained the following:

> 9. *Condemns* the Government of Portugal for the use of chemical and bacteriological methods of warfare against the peoples of Angola, Mozambique and Guinea (Bissau) contrary to the generally recognized rules of international law and to General Assembly resolution 2603 (XXIV) of 16 December 1969, and demands that the Government of Portugal desist from these criminal activities: [970]

This passage was subsequently amended to:

> 9. *Calls upon* the Government of Portugal not to use chemical and biological methods of warfare against the peoples of Angola, Mozambique, and Guinea (Bissau), contrary to the generally recognized rules of international law embodied in the Geneva Protocol of 17 June 1925 and to General Assembly resolution 2603 (XXIV) of 16 December 1969: [970]

The draft resolution was submitted to the plenary session, and in his comments on it, the Rapporteur of the Fourth Committee said:

> The Portuguese Government, desperate at the force of the liberation movement and the firm determination of the people under its domination to fight until they attain their freedom, has dangerously stepped up its military activities against the local population and has even used criminal means of war, including chemical and bacteriological weapons. [971]

The resolution was adopted on 14 December 1970 by a vote of 94–6. Those voting against comprised Portugal, Spain, South Africa, Brazil, the UK and the USA. [971]

On 9 December 1970 it was reported in the *New York Times* that US diplomats in Angola had found indications that the Portuguese authorities had employed anti-plant chemicals against insurgent food crops [972]. On 13 December the US State Department denied this report, but it is understood that the denial referred to the conclusiveness of the indications, rather than their existence [973]. The anti-plant agents involved were believed to be normal agricultural chemicals sprayed from C-47 aircraft.

1970: Rhodesia

The Lusaka headquarters of both the Zimbabwe African People's Union (ZAPU) and the Zimbabwe African National Union (ZANU) have alleged that on several occasions Rhodesian authorities have introduced poison into certain tributaries of the Zambesi River in the belief that these waters were essential to guerilla bases in the area [974].

Police and quasi-police use of irritant agents

Tear-gas weapons are nowadays on the inventories of many police forces around the world, and reports of their use are commonplace. The French were apparently the first to adapt irritant agents to police use; the ethyl bromoacetate grenades that were employed in Paris in 1912 have already been referred to. The experience gained with lachrymators and sternutators during World War I promoted the civilian applications of these substances, and in the post-war years other countries soon followed the example of France. For peacetime purposes irritant agents were, and are, used by police forces to control riots and lesser civil disturbances, and to cope with situations such as those where an armed criminal barricades himself to resist capture. In some countries, for example the United States and South Africa, the agents are freely available commercially in "personal protectors" and similar devices; in other countries their unauthorized possession is illegal. [975–76]

The following list of countries where police forces have used irritant agents was compiled during a cursory scanning of newspapers while this study was being prepared; while it is undoubtedly incomplete, it suggests the extent to which the world's civil authorities have come to rely on irritant-agent weapons: Argentina, Belgium, Colombia, Czechoslovakia, France, West Germany, Hong Kong, India, Italy, Japan, Malaysia, Mexico, New Guinea, Poland, Rhodesia, Solomon Islands, South Africa, South Viet-Nam, Sweden, Switzerland, Trinidad, the UK, the USA and the USSR.

In so far as Western countries are concerned, the United Kingdom and the United States appear to have provided the main stimuli for the increasing use and reliance on irritant agents. Both countries set up manufacturing plants for CN tear gas in 1922–23, and in Britain the subsequent demand for CN was such that by 1927 the manufacturing capacity had been increased twenty-fold [30, 60]. While the British have only recently come to apply irritants to the control of civil disturbances within the British Isles (in Northern Ireland, from August 1969 onwards), they have long used them for this purpose in their overseas dependencies. Between 1960 and 1965 CN and CS weapons were used on 124 occasions by colonial police forces; two-thirds of these were in British Guiana (now Guyana) in 1963 and 1964 [977]. It was in Cyprus during 1958–59 that the superiority of CS over CN was first conclusively demonstrated, leading to its subsequent standardization by, *inter alia,* the US Army. Nowadays CS weapons form a normal part of the equipment of British troops sent abroad on internal security duties; during the Anguilla operation in early 1969, for example, the British landing forces took some 2 000 CS cartridges and grenades with them [978]. The UK also supplies a substantial export market with irritant-agent weapons; it is reported, although without official confirmation, that around sixty countries purchase CS weapons from Britain [979]. The orders are handled by a commercial enterprise that makes the weapons according to the specification of a government patent [980] from CS manufactured in a government installation [589], and then ships them abroad under government export licenses [981]. Recipient countries in recent years have included Israel [982] and South Africa [850, 983]. The United States also supplies irritant-agent weapons to overseas clients, both on a commercial basis and under the various aid programmes organized by the Department of Defense and by the Agency for International Development [995]. The recipients of the weapons include not only police forces, but also military and paramilitary counter-insurgency forces in several Latin American and Asian countries.

The counter-insurgency uses of irritant-agent weapons occupy the boundary zone that lies between the police uses of chemical weapons, whose legitimacy is a matter for national legislators, and their use in war, which is subject to the proscriptions of international law, notably of the 1925 Geneva Protocol. The legal and other problems posed by the existence of this ill-defined borderline are discussed in Volumes III and V of this study. The following historical points have a bearing on the distinction between police uses and battlefield uses of irritant agents, and suggest some of the liabilities of the present situation.

(a) The rationale behind the use of irritant agents for riot control, as opposed to their tactical combat applications, is indicated by the following extract from the guide-lines which British technologists set themselves in 1956 when selecting CS as a new riot-control agent to replace CN: "[The new agent] should produce acute symptoms within 30 secs, and incapacitation within 1–2 minutes, to such an extent that the rioter is no longer interested in hostile activity and is capable only of escape; but *he must remain physically capable of escape*" [74, emphasis added]. In contrast to this, a recent US Army publication states that the essential requirements for the tactical employment of irritant agents, as opposed to their use in riot control, are:

(1) The concentration of agent must be dense over the desired target to be intolerable to unmasked personnel.
(2) The concentration must be extended around the target periphery in sufficient

quantities *so that escape* (by closing eyes and/or holding breath) *is difficult.* (3) The concentration must be capable of being established within a short time (1 minute or less). [236, emphasis added]

(b) When asked during a parliamentary question in March 1969 about the circumstances in which British troops were permitted to use CS weapons, the British Secretary of State for Defence stated that

> ... the instructions given to Her Majesty's Forces who are issued with these devices are not to use them except under extreme provocation in circumstances in which the only alternative is the use of other means of restraint which might cause more physical damage than the use of CS. [978]

(c) After examining the fragments of a bomb collected after an air raid on the village of Al Kawma in the Yemen in June 1963, experts at the British Chemical Defence Experimental Establishment concluded that the bomb had been constructed out of CN grenades that British forces had left behind when withdrawing from Egypt [161, 891].

(d) The earliest officially confirmed battlefield use of irritant agents in the Viet-Nam War involved CN and CN/DM grenades that had been supplied to the South Viet-Namese Government in 1962 and 1964 under the US Department of Defense's Military Assistance Program [442].

(e) In testimony to a US Congressional committee in October 1969, the Commander of the US Sixth Air Division, based in the Philippines, included this statement in connection with the US Military Assistance Program to the Philippines:

> In the spring of 1969, General Zerrudo, 1st P[hilippine] C[onstabulary] Zone, asked for ammunition and tear gas to be used against Huks who were hidden in cane fields. Some 2000 rounds of .45 calibre ammunition and 24 tear gas grenades were given to the PCs. It was reported that this netted several Huks killed. [984]

II. *Biological warfare*

Among the older military techniques that can be claimed as biological warfare is the use of corpses of men or animals to befoul wells and other sources of drinking water. Recorded instances of this date back to very early times: Lewin [303], for example, quotes instances from early Persian, Greek and Roman literature, and pursues the topic up to the twentieth century by way of innumerable European wars, the American Civil War, and the South African Boer Wars. Presumably the principal objective in operations of this type was to deny the enemy his water; but the use of infected or putrefying corpses must certainly have diseased many of the people who were forced to drink the contaminated water.

Related to this technique is that in which the corpses of diseased men or animals were either deliberately left in areas shortly to be occupied by the enemy or were thrown into besieged cities [562]. Varillas, in his *Histoire de l'hérésie de Viclef, Jean Hus et de Jérome de Prague* (Lyon, 1682), describes how the bodies of dead soldiers were thrown into Carolstein (together with 2 000 carloads of excrement) by besieging forces in 1422 [985]. A more significant operation of this type took place during the siege of Caffa, now Feodosia, in the Crimea in 1346. This almost impregnable town was a Genoese outpost on the trade routes from the east. It was successfully withstanding a besieging Tartar army when the latter was struck by the great plague epidemic that was spreading westwards from China. The besieging forces threw their plague victims into the town (using trebuchets for the purpose, or so it is surmised [563]) where the disease rapidly took hold and soon forced the survivors to flee back to Italy by sea. They took the plague with them, and, while this may not have been the first and certainly was not the only route by which the plague arrived in Europe, the Black Death took hold there very soon afterwards. [985–86] The last purported instance of this form of BW seems to have been in 1710 when, in the battle against Swedish troops in Reval, the Russian besiegers were supposed to have caused an epidemic of plague by throwing bodies of plague victims over the city walls [287].

A rather more sophisticated BW technique was that apparently used by the British in North America in the mid-eighteenth century. In June 1763 Sir Jeffry Amherst, British Commander-in-Chief in North America, wrote to a subordinate, Colonel Henry Bouquet, who was opposing the Indian tribes in the Ohio-Pennsylvania area: "Could it not be contrived to send the Small Pox among those disaffected tribes of Indians? We must on this occasion use every strategem in our power to reduce them." Bouquet knew from his own subordinates that small pox was present at Fort Pitt and Bouquet's reply on 13 July was: "I will try to inoculate the Indians with some blankets that may fall into their hands, and take care not to get the disease myself." However, on 24 June Captain Ecuyer of Fort Pitt had already attended to the matter: "Out of our regard for them [two hostile Indian chiefs], we gave them two blankets and a handkerchief out of the small-pox hospital. I hope it will have the desired effect." A few months later small pox was prevalent among the various Indian tribes in the Ohio area. [562] It is said that the Americans later used small pox against the British during the Revolutionary War [481].

Before embarking upon a review of more recent reports of BW, the following comment is to be noted:

The history of the use or alleged use of biological weapons in war is characterized by a remarkable circumstance, namely, that although allegations are many, not a single one can be called fully authenticated. In other words, no government, and no responsible government official who was free from duress at the time, has ever admitted waging offensive biological warfare. No other evidence could be fully acceptable to all concerned. [564]

For this reason, one quite frequently finds commentators mentioning, and thereby lending further credence, to one incident while omitting, and one assumes disagreeing on, another. In addition, the nature of the allegations of actual employment indicate that BW has not been used in any significant sense, and the incidents therefore are of little or no use as evidence of the present potential of BW.

1915–1917: World War I

Writing at the end of World War II, a US authority on BW stated [88] that: "This type of warfare [BW] was not unknown in World War I, although it was employed only on a very limited scale. There is incontrovertible evidence, for example, that in 1915 German agents inoculated horses and cattle leaving United States ports for shipment to the Allies with disease producing bacteria."

A second US authority [564] refers to several authors from the inter-war period who had alluded to German attempts during World War I to: inoculate horses with glanders[51] and cattle with anthrax, both at Bucharest in 1916 and on the French front in 1917 [252, 565–69]; and to spread cholera in Italy [567–68]. The only sources available on the second of these allegations seem to be French, dating from the late 1930s. On the first allegation there have been several writers apart from those just cited [239, 570–71]. One of these [571] also refers to other alleged German covert BW activities—a German agent's apparent attempt to spread plague in St. Petersburg in 1915, the arrest of another German agent with similar intentions in Russia in 1916, and an allegedly successful infection of 4 500 mules with glanders by a German saboteur in Mesopotamia in 1917.

The *Rapport présenté à la Conference des Préliminaires de Paix par la*

[51] Glanders was widespread in Europe during World War I. More than 58 000 horses in the French Army alone were affected by the disease from natural causes. Both acute and chronic forms produced high mortality rates among the animals, which were in critical need for front-line logistics and supply. Animals which survived infection with glanders were nonetheless rendered unfit for service for periods ranging from a few weeks to months. [562]

Commission des Responsabilités des Auteurs de la Guerre et Sanctions [572] mentions none of the above allegations, but refers to German well-poisoning with corpses in the Somme area in February 1917, and to the dropping of fruit, chocolate and children's toys infected with lethal bacteria into Romanian cities, particularly Bucharest, by German aircraft.

In 1929 the President of the Royal College of Surgeons in London referred to German aircraft bombs containing plague bacilli that had been dropped over British army positions during the war [573]. This provoked the following reply from the German Embassy:

> I have been authorized by the German Government to state that this allegation is without the slightest foundation. Both the former Commander of the "Flugzeugmeisterei", who was in charge of the technical side of the German Air Force and specially of the throwing of bombs, and the former Chief of the Medical Department of the Air Force have definitely stated that bombs thrown by the German Air Force have never carried plague bacilli of any kind, and that no attempt has ever been made to spread plague in this way. [574]

Despite the various allegations that had been made, and were later to be made, about German BW during World War I, it should be noted that the report on CBW prepared by a subcommittee of the Temporary Mixed Commission of the League of Nations, written in 1924, stated that "in contradistinction to the chemical arm, the 'bacteriological' arm has not been employed in war", although an allusion was made to the Bucharest glanders case. This report was signed by representatives of the British Empire, France and Italy.[52]

1939–1945: World War II

The principal body of information on the use of biological weapons during World War II concerns Japanese usage, but there are briefer reports or allegations of BW employment by other belligerents as well.

Alleged use of biological weapons by the Japanese

The Japanese Army has been accused of using biological weapons in sabotage activities against the USSR and Mongolia during 1939–40, against Chinese civilian populations during 1940–44, and against Chinese troops during 1942.

The first reports of BW against Chinese civilian populations, published in April 1942, came from Dr Robert Lim, head of the Chinese Red Cross, and Dr R. Pollitzer,[53] a League of Nations epidemiologist then stationed

[52] It is described in Volume IV of this study.
[53] Dr Pollitzer later (1954) wrote the definitive monograph on plague for the World Health Organization [575].

in Hunan Province [576]. In the same month, Dr P. Z. King, Director General of the Chinese National Health Administration, released a statement covering the first four investigated BW allegations against the Japanese [577].

The details of these first allegations are summarized in Appendix 2, which also includes an analysis of one of them. The two reports relate to five separate occasions between October 1940 and August 1942 and refer to Japanese aircraft disseminating pathogens over Chekiang Province (Ningpo, Chuhsien and Kinhwa), Hunan Province (Changteh) and Honan Province (Nanyang). The original report from Changteh—referred to in Appendix 2—was subsequently published in the report of an "International Scientific Commission" (ISC) [578], convened in Peking to investigate charges of US BW in Korea. The Changteh report refers to a sixth alleged BW incident in which the Japanese were said to have spread cholera and plague in "large-scale" operations along the Chekiang-Kiangsi railway in central China in the autumn of 1942. Likewise, the ISC report refers to further allegations, bringing the total up to eleven:

> Official Chinese records give the number of hsien cities which were attacked in this way by the Japanese as eleven, 4 in Chekiang, 2 each in Hopei and Honan, and 1 each in Shansi, Hunan, and Shantung. The total number of victims of artificially disseminated plague is now assessed by the Chinese as approximately 700 between 1940 and 1944. [578]

This total presumably refers to mortality.

It is significant that all these reports were careful to state that the investigators had been unable to culture organisms directly from the alleged means of BW agent dissemination. Nevertheless Dr King concluded that:

> The enumeration of facts thus far collected leads to the conclusion that the Japanese army has attempted bacterial warfare in China. In Chekiang and Hunan they had scattered from the air infective materials and succeeded in causing epidemic outbreaks of plague. [577]

Dr Lim's original statement [576] implied that these Japanese efforts had thus far been in the nature of experiments. The limitation of the epidemics was attributed to varying epidemiological factors. The *Chinese Medical Journal* was willing to consider that the cases had been "definitely proved, with bacteriological methods".

These allegations were reported at the time by a number of journalists [272, 579], and have subsequently been discussed by several commentators [272, 287, 562, 564, 571, 580]. One of these, Dr Theodor Rosebury [272], points out that the allegations concern areas in Central China where plague had never been known to occur since medical records were first kept: "There is no doubt that plague broke out in these areas, that one hundred and fifty or more cases of plague occurred at the time, nearly all of them fatal, and that the disease has persisted in these and adjoining regions of China down to the present [1949]." Rosebury considers the ability to isolate plague bacilli from the material dropped by the Japanese aircraft the critical element that would have proved the Chinese contentions, and quotes from the "Note to the Editors" in the official US press release that accompanied the Merck report [88][54] in 1946 that: "There is no evidence that the enemy [Japan] ever resorted to this [bacterial] means of warfare. . . ." This remark does not, however, appear in the Merck report itself in any of its several printed versions. The author of a 1963 article in the US journal *Clinical Medicine* [562] states that: "Although there is considerable circumstantial evidence, there is no material proof that the Japanese made a few attempts to employ biological weapons in China in the early 1940's."

In December 1949, four years after World War II ended, twelve Japanese prisoners of war, including the former Commander-in-Chief of the Kwantung Army, were tried by a Soviet military tribunal at Khabarovsk on charges of having prepared and employed bacteriological weapons. The proceedings of the trial were published in an English-language edition in 1950 [91]. The trial record contains detailed charges, especially against the so-called Ishii Detachment of the Kwantung Army; nearly all of these concern the Japanese production and test facilities at Harbin[55] and alleged use of Chinese and Soviet prisoners as subjects in BW experiments which resulted in thousands of fatalities. However, several small sections deal with the allegations of BW in China, and tie these directly to General Ishii's command:

> In 1940, a military expedition of Detachment 731, under the personal direction of Ishii Shiro, was sent into China, in the region of Nimpo, supplied with bacterial substances, the germs of typhoid and cholera, and also with a large quantity of plague-infected fleas. As a result of the employment of infected fleas by scattering them from an aeroplane, an epidemic of plague broke out in the region of Nimpo. . . . This criminal operation which brought in its wake thousands of victims among the peaceful Chinese population was filmed, and this film was later demonstrated in Detachment 731 to representatives of the High Command of the Japanese Army. . . .
>
> A similar expedition was sent out in 1941 (by Detachment 731) to the region of Changteh, where the locality was infected with plague-infected fleas scattered from an aeroplane.

[54] An official United States report on US BW research activities during World War II, published under the name of George Merck, who had been responsible for a large part of the BW programme.

[55] See Chapter 1, pages 112–116.

Dr Chen Won Kwei, the author of the Changteh report quoted above, had contended that the Japanese had used the human flea, *Pulex irritans,* as the means of plague dissemination in China. Though no such evidence could be demonstrated this might explain why no agent was isolated from the scattered grain and other materials. He repeated this contention in his essay included in the report of the ISC [578] (as it was again contended that the plague-infected fleas dispersed in Korea were human fleas). Dr Zhukov, who had been the chief medical expert at the Khabarovsk trial, confirms that the Japanese "used ... indeed infected human fleas" in the Chinese incidents.

During the Khabarovsk trial [91] the Japanese Army was also accused of using biological weapons against Chinese troops:

> In 1942, Detachment 731, assisted by Detachment 1644, sent another military expedition, also headed by Ishii Shiro, into Central China. In this case, the main object was infection on land for the purpose of creating an infected zone for the advancing Chinese troops. Here water sources and food were contaminated with typhoid and paratyphoid germs, and plague-infected fleas were also spread. ... On the retreat of the Japanese troops public water sources and the homes of local inhabitants were contaminated, and food products infected with typhoid and paratyphoid germs were distributed.
>
> In 1942 ... Detachment 731 ... disseminated the germs of severe infectious diseases on territory which the Japanese troops were forced to abandon under pressure from the Chinese Army.

It was also accused of using pathogens as sabotage weapons against the USSR and Mongolia:

> Over a period of a number of years Detachment 100 systematically sent bacteriological groups ... to the borders of the USSR. These groups carried out bacteriological sabotage against the Soviet Union by contaminating water sources on the border in particular in the Tryokhrechye area.

There was reference also to the use of plant and animal pathogens during these sabotage activities. Raška [571] summarizes this as follows:

> ... The Japanese already in 1939 tried to introduce abdominal typhus and other epidemics in their aggression against Russia and the Mongolian Peoples Republic. In the year of 1940 they started a succession of epizootics (rinderpest, anthrax, chicken pox among others). ... The Japanese managed to generate planned illnesses among people, animals and plants.

Alleged use of biological weapons by the British

In the weeks immediately preceding the outbreak of World War II, Dr Goebbels, the German Minister of Propaganda, in a broadcast from Munich accused the British of attempting to introduce yellow fever into India by transporting infected mosquitoes from West Africa and liberating them from aircraft over Indian cities. Dr Goebbels stated that the scheme was presided over by a high permanent official of the British Foreign Office [581].

On 5 May 1942 the special correspondent of *The Times* in Chungking wrote:

> ... In scathing denunciation of Japanese reports that the allied forces had resorted to poison gas and bacterial warfare, a spokesman of the Burma Government declared that the fabrication of such rumours by the enemy at the present time was doubly significant. ... It was done, first, to cover his own guilt in using these inhumane methods against China, and secondly to serve as a prelude to the use of them in the next phase of the war against the allies as well as China. [392]

Nothing further is known about the allegation.

Alleged use of biological weapons by the Chinese

A post-war US assessment of Japanese BW activities [254] included a translation of a Japanese document written by an intelligence section of the Kwantung Army, entitled *Defence and Security Intelligence Report no. 8: Chinese Employment of Chemical and Bacteriological Warfare Against the Japanese* (Research Section, Kwantung Defence Army, 3036 unit, 1 October 1941). This report opens with the words:

> There is evidence that during the China Incident the enemy has skillfully and secretly carried out chemical and bacteriological warfare activities against personnel, animals, natural resources, water and food supplies. It may be presumed that the enemy will become increasingly active in such methods. Therefore, security and defence measures must be thorough during advances and halts.

It goes on to present information about these purported CBW activities in tabular form, giving dates, places, CBW agents, methods, casualties and very brief reports of investigations. There are ten BW entries in the table, all relating to acts of sabotage from September 1937 to August 1939. Eight record the use of cholera, two of anthrax. Five relate to contamination of wells, one of a creek, one of a reservoir, and two of foodstuffs. The information presented is generally somewhat vague and imprecise; but one of the entries states that a flask containing anthrax bacilli was recovered from a contaminated creek. Another states that a cholera epidemic suspected of being initiated by well-contamination caused about 650 casualties; some 500 of these were local Chinese inhabitants, the remainder Japanese troops.

No further information is available from other sources about these reports of Chinese BW.

Alleged use of biological weapons by the USSR

After questioning a Japanese BW worker at the end of the war, a US interrogator recorded the following statement:

> Col. Masuda . . . requested permission to explain the stimulus for the initiation of Japanese BW activities. In 1935, the Kwantung Army was informed that many Russian spies, carrying bacteria in ampules or in glass bottles, had crossed into Kwantung Territory. Five spies were apprehended by the Kempei and on these spies were found several glass bottles and ampules. Such incidents were not the first nor were they the last, but Col. Masuda stated that he can personally vouch for this episode involving five individuals. The examination of the various containers revealed the presence of dysentery organisms (Shiga and Flexner) and bacteria—spore mixtures of B. anthracis and V. cholerae. He stated that he, personally, saw the anthrax organisms. [255]

A second Japanese captive under interrogation is reported to have made a similar statement, but no details are available. The whole question of why the Japanese Army started its BW programme is one on which statements by participants in it must be treated with caution, particularly in view of the imminence of the Tokyo War Crimes Tribunal.

Another account of purported Soviet BW activities is contained in the Japanese Army intelligence report quoted in the preceding section:

> According to recent reports it appears that the Soviet consul at Harbin, acting on instructions from his home government, has sent to agents who have infiltrated into the chief cities of Manchukuo, bacteria to be used in launching bacteriological warfare immediately should hostilities break out between Russia and Japan. The main targets include:
>
> Military—Commanders and technicians, while travelling and at garrisons.
>
> Local areas—Factories, government schools, trains, ships, laborers, and domestic animals, especially military horses.

On being repatriated from a Soviet prison camp in 1950, Major T. Iinuma, who had been a witness at the Khabarovsk trial, accused the USSR of using germ warfare against the Japanese in Manchuria during the war. This was reported in the *New York Times* as follows: "He said former Col. Torajiro Kitamura had told him in jail at Khabarovsk that the Russians threw cans containing anthrax germs into Japanese-occupied Manchuria. Iinuma said the incident occurred at a place called Shenho in 1944, before Russia and Japan were at war." [582]

Alleged use of biological weapons by and against Germany

No allegations of use of biological weapons were made against Germany at the Nuremberg Tribunal. (The use of prisoners of war by the Germans in tests and experiments involving various disease-producing organisms, which resulted in deaths or injury to the prisoners, has not here been included as BW. The same approach has been followed in regard to those portions of the Khabarovsk material dealing with similar use of prisoners of war.) A Czechoslovak authority refers to "... German [BW] diversion actions, intended to disturb the victorious advance of the Soviet armies" [583], and to a single case in May 1945 of a reservoir for over 10 000 persons repeatedly polluted with faecal material in northwestern Bohemia, "resulting in a great dysentery epidemic" [571]. The writer was the chief epidemiologist and investigator concerning this incident.

One report states that during the war the Germans dropped small bombs containing Colorado beetles onto targets of potato crops in southern England. The authority for this report is a prominent British naturalist who had been engaged in the defensive measures taken against these attacks; he says that during the war the fact of the attacks was kept highly secret by the government in order to avoid alarming the public. The bombs are said to have been made of cardboard and to have contained either fifty or a hundred beetles; the first one had been dropped in 1943 on the Isle of Wight. [584]

An official US source [30] states that:

> BW research in Germany had been aimed at devising defensive measures against possible Allied use of biological agents and specifically against the sabotage efforts of guerilla fighters that menaced the German Army in Poland and Russia. Among the biological agents reportedly used by guerillas against German troops in the Eastern theater were typhoid bacilli, botulinum toxin, typhus, dysentery, glanders, cholera, anthrax, and paratyphoid.

The documentation cited in support of this statement comprises a 1945 evaluation of German BW activities prepared by British and US members of the ALSOS mission. (ALSOS was an intelligence organization whose function was to locate and then gather information from captured or surrendering German scientists—particularly nuclear physicists—about their wartime work [999].) This report is not available in the open literature so it is impossible to assess the reliability of the statement. In the view of the Soviet scientists whom the present authors consulted, the statement is absurd and is based on unfounded propaganda [996].

1947–1948: Egypt

On 12 October 1947 a "well-known radio-commentator" in the USA stated in a broadcast that [585]: "The Russians have developed germ warfare. The cholera plague in Egypt is suspected abroad of being a Soviet experiment. There are some very suspicious things about that plague in Egypt, although there's no positive evidence either way." The likelihood of this claim was disputed at the time by Dr Rosebury and Dr Kabat [585], both of whom had been prominent participants in the US BW programme during World War II. The Soviet reaction to the claim is not known.

According to a *New York Times* report [586], a memorandum of the Palestine Arab Higher Committee dated 23 July 1948 said that:

> [T]here was "some" evidence, though it was not conclusive, that Zionists were responsible for the outbreaks of cholera in Egypt in November, 1947, and in Syrian villages on the Palestine-Syrian borders "about February, 1948". It then quoted from a communiqué by the Egyptian Ministry of Defense on May 29, 1948, saying that four "Zionists" had been caught trying to infect artesian wells around Gaza with "a liquid which was discovered to contain the germs of dysentery and typhoid". The Egyptian Government obtained a confession from one of them, it was charged, and planned to communicate the facts to the International Red Cross.

No other relevant information is available. In 1969, a paper by two Egyptian authors in a professional scientific journal [587] brought up the charge again: "Due to the fact that the imperialist aggressors produced artificial cholera epidemics in Egypt in 1947[56] . . . we feel obligated to seek safer measures to protect the peoples exposed to such aggression against this type of warfare." They also alluded to cholera epidemics deliberately initiated in Iraq in 1966; this is referred to below.

1949: Canada

In 1951 *Krasnyi Flot,* the newspaper of the Soviet Navy, stated that the Americans had tested bacteriological weapons against Canadian Eskimos in the summer of 1949, causing an epidemic of plague [588]. Nothing further is known about this allegation.

1950: Germany

A report from the GDR Ministry of Forestry, dated 15 June 1950, has recently been quoted [589] in which it was apparently stated that US aircraft had scattered Colorado beetles over certain parts of Germany during May and June 1950. Other commentators [590–91] have referred to accusations that the USA dropped beetles on the potato crops in eastern Germany.

Nothing further is known about this.

1951–1953: Korea and China

From early 1952 until about mid-1953, a stream of allegations issued from official sources in Moscow, Peking and Pyongyang that US armed

[56] The source given for this statement—which the present author has not been able to consult—is A. H. Kirdi in *Journal of the Royal Egyptian Medical Association* 31: 289, 1948.

forces were using biological weapons against targets in North Korea and China.[57] These allegations attracted extremely wide attention and alarm throughout the world, and although the US Government issued repeated denials of their authenticity, a considerable residue of belief in them still persists.

The allegations will not be described here. Instead, a detailed discussion of them in relation to problems of verifying allegations of CBW is given in Volume V of this study. Two comments are worth making here however.

First, whether the allegations were true or false, they caused the United States a loss of international good-will, even though US requests for impartial investigation were rejected. This fact, coupled with the evident power of BW allegations, whether verified or not, to stir public opinion, is to be kept in mind when the accounts of the more recent BW allegations noted in the following pages are read.

Secondly, although it cannot be said that the allegations have been conclusively proved true or false by the evidence available, the following statements appear in the recent report of the UN Secretary-General on CBW:

> 5. Since the Second World War, bacteriological (biological) weapons have also become an increasing possibility. But because there is no clear evidence that these agents have ever been used as modern military weapons, discussions of their characteristics and potential threat have to draw heavily upon experimental field and laboratory data ... rather than on direct battlefield experience. ...
> 38. There is no military experience of the use of bacteriological (biological) agents as weapons of war, and the feasibility of using them as such has often been questioned. ... [297]

This UN document was the unanimous report of representatives of the following fourteen nations: Canada, Czechoslovakia, Ethiopia, France, Hungary, India, Japan, Mexico, Netherlands, Poland, Sweden, the UK, the USA, and the USSR.

1957: Oman

It is reported that in 1957 the British were accused in the Eastern European press of having employed biological agents during the Oman conflict [287]. No further information is available about this, although a recent publication from the German Democratic Republic refers to British counter-civilian use of incendiaries in 1957 and of unspecified chemical agents in 1959, both in Oman [185].

[57] The first such charge was in fact made in May 1951, but a substantial body of accusations did not build up until February 1952.

1957-1963: **Brazil**

While perhaps not strictly biological warfare, recent events in Brazil may be recorded here. A number of Brazilian land owners were due to stand trial in spring 1970 on charges of complicity in deliberately introducing biological pathogens into Indian tribes in order to clear them from valuable rubber lands. In 1969 the Brazilian Ministry of the Interior and the National Foundation for the Indian disclosed some of the evidence to be used in the trial [592-94]. These disclosures referred to voluminous records accumulated on the deliberate dissemination of small pox, chicken pox, tuberculosis, influenza and measles organisms among several Indian ,tribes in the Mato Grosso between 1957 and 1963. Several of these records, for example the following extract from a Ministry of the Interior report, are strongly reminiscent of the eighteenth century British technique against North American Indians referred to earlier:

> The refinement of their criminal penetration brought bacteriological warfare to the backwoods by means of "gifts" to the forest inhabitants of clothing impregnated with the microbes of small-pox. . . . [592]

1961:China

In the summer of 1961, an English-language newspaper in Hong Kong, the ***South China Morning Post,*** reported a cholera epidemic in the southeast of Kwantung Province. The newspaper is quoted [595] as having said that a recent arrival from the mainland of China had reported that Chinese officials at mass meetings in South China had accused "agents of the American bacteriological warfare bureau of plotting the cholera epidemic." It is not clear what "plotting" an epidemic means, but the US Department of State "emphatically rejected" the accusation [596].

1964: Cuba

In June 1964 the New York ***Times*** published the following:

> Premier Fidel Castro said today that he suspected the United States of conducting germ warfare against Cuba. A communique issued this afternoon said that last Friday a number of balloons descended on the province of Las Villas. It said they had released "a gelatinous substance . . . similar to what is used in bacteriological cultures". . . . "We are taking into account the probability that imperialism is trying out the use of . . . bacteriological and virus weapons against our economy and our people." [597]

The charges were of a tentative nature and contained as well the unusual admission that the Cuban Government was not in a position to prove them. The US Department of State immediately stated that it considerd the Cuban charges "absurd and preposterous". [597–98]

1964: Colombia

In July 1964 *Pravda* published the following report, based on a TASS despatch from Bogota:

> For three months Colombian troops and the U.S. Military Commission in Colombia have carried on a brutal war of extermination against peasants in the mountains near Marquetalia who have cultivated soil owned by nobody. The peasants have sent a letter to the Colombian National Congress, saying that during the time for this "operation" hundreds of bombs and even containers with pathogenic bacteria have been dropped on the peasants' villages. Houses and crops have been burnt down with napalm.
>
> The authors of the letter have urged the International Red Cross to send representatives to Colombia in order to convince themselves that biological weapons have been used against the population. [599]

Official Colombian or US reaction to this statement is not known.

A recent Swedish publication [600] has stated: "It has several times been confirmed that BW agents in the form of bacteria, viruses and insects have been used against certain population groups in Bolivia." It has not proved possible to find any further documentation on this.

1966: Iraq

In 1969 the Egyptian authors of an article appearing in a professional scientific journal [587] remarked: "Due to the fact that the imperialist aggressors produced artificial cholera epidemics in Egypt in 1947 and in Iraque in 1966 we feel obligated to seek safer measures to protect the peoples exposed to such an aggression against this type of warfare." In support of "Iraque in 1966", the authors cite only a standard textbook on cholera [601], and this book's sole reference to Iraq/1966—on the page in fact cited by the Egyptian writers—reads as follows:

> In 1966, cholera was present in Indonesia, Thailand, Vietnam, Cambodia, India, East Pakistan, and it had invaded Iraq where the strenuous and prompt efforts of the government succeeded in bringing it to a standstill by the time of this writing (October). The infection came to Iraq from the Iranian border, a route that had not been followed by cholera in the past. Iraq had usually been invaded through the southern (Basra) area. Cholera proceeded from the northern hills to the south, along the rivers. The district of Baghdad reported most of the cases.

1969: Korea

In February 1970 the Seoul Government accused the Pyongyang Government of plans to launch BW attacks against South Korea. It also accused the North Koreans of having caused the epidemic of cholera that had affected southwestern Korea during the summer of 1969. [602]

These accusations were connected with an acrimonious controversy between the Japanese and South Korean Governments that had stemmed from reports that a North Korean concern had placed an order early in 1969 with a Japanese trading firm for anthrax, cholera and plague bacteria. In South Korea it was thought likely that the cholera bacteria supplied to meet this order had been used to initiate the cholera epidemic, which was said to have coincided with a period of increased North Korean guerilla activities inside South Korea. In response to this the Japanese Government stated that its investigations had shown that although the trading firm in question had indeed received an order for pathogenic bacteria, that order had never been fulfilled. It also pointed out that the order was for, *inter alia,* the *asiaticae* strain of cholera vibrio, whereas the South Korean epidemic was had been caused by the *el tor* strain. [479, 603]

The Pyongyang Government denied that it had imported germs from Japan, and dismissed all the Seoul accusations as calumnies generated by war hysteria. [602, 604]

1962–1968: Indo-China

In 1962 a US Chemical Corps officer wrote: "On the biological side the Viet Cong rebels have used a crude form [of BW], according to reports. They have used spear traps and hidden spikes tipped with animal waste. This technique produces casualties by causing infection instead of a merely annoying injury." [605] Similar statements have been made by a number of other commentators; in November 1967 *The Times* referred to use of "sharp sticks, their fire-hardened tips poisoned ... with ... human excrement" as a booby-trap hazard for US forces in Viet-Nam [606].

The US press has carried another item concerning BW in Viet-Nam but with more innuendo than accusation [607]: "A mysterious outbreak of black water fever in South Vietnam has led Army doctors to wonder whether the communists are resorting to germ warfare."

For the opposite side, a 1968 broadcast to Asia by Moscow's Radio Peace and Progress[58] has been quoted by a US newspaper as follows:

[58] The broadcast quoted from is apparently that made in French on 6 March 1968 and in English on 7 March [608].

Keyed to "reports of sudden epidemics of plague and cholera in three provinces near Saigon", the broadcast, made in English, asserted: "The spread of these diseases is not accidental, since bacteriological weapons are included among the Pentagon's strategic plans." ... The broadcast alleged that recently the United States Army secretly sent "a special mobile group" from Japan to South Vietnam to work out "practical methods of using bacteriological weapons". ... The Moscow broadcast further alleged that "wherever this group appears cases of Texas fever were registered among the local population".... [609]

The newspaper also stated that US Department of State officials

derided Moscow's charges as "nonsense", adding that they are as "baseless" as those made during the Korean war. ... [The broadcast] identified the group as "from the 406th unit of the United States Army in Japan". A Pentagon spokesman said tonight that there is no chemical, biological, radiological unit in Japan, but the Army long has maintained there the 406th Medical Laboratory Detachment which sends out treatment and research teams to areas of epidemics. [609]

These particular allegations from Moscow coincided with another allegation, apparently originating in India, that was also quoted on Moscow radio.[59] The allegation emerged from a letter, purportedly signed by Mr Gordon Goldstein; copies of the letter were circulated to Indian newspaper editors. Goldstein's signature was endorsed "Co-chairman of the Office of Naval Research" and the letter was written on what appeared to be US ONR stationery. The copies of the letter referred to a charge that US biological weapons were responsible for a bubonic plague epidemic in Viet-Nam. The Calcutta correspondent of *The Times* sent in a dispatch which was printed on 7 March as follows:

Rumours that the storage of American weapons of biological warfare at special bases in Thailand is carried out in an incompetent manner have been denied by the American Navy Department in a letter to newspaper editors here.

But in denying the rumours—said to have been put about by "undercover agents" of China—the department admits by implication that the United States has moved such weapons into Vietnam and neighbouring countries.

Referring to a charge that the weapons are responsible for a bubonic plague epidemic in Vietnam, the letter says that "at every special base the delivery, storage and supervision of biological warfare weapons is assured through the most up-to-date technical means". The letter is signed by Mr. Gordon Goldstein, Co-chairman of the Office of Naval Research. He urges the editors to refute

[59] Although this allegation refers to the spread of a plague epidemic in a combat area purportedly having been initiated by biological weapons, it makes no accusation that the weapons were deliberately used for such a purpose. It is therefore not strictly an allegation of biological warfare. It is referred to here primarily to illustrate how the most devious allegations may still attract attention if they have anything to do with BW and, relatedly, to illustrate the willingness of the press to propagate BW-related rumours of the most dubious provenance. This particular rumour attracted widespread attention and comment throughout the world.

rumours spread by communist agents to slander America's "sacred struggle for peace and freedom in south-east Asia". [610]

On 15 March the US Consulate-General in Calcutta stated that there was no such person as a co-chairman of the ONR and that the letter was a forgery [611]. On 30 March *The Times* printed a note accepting that the letter was a forgery, together with a letter from Mr Gordon Goldstein in which he denied authorship of the original letter.

The account of this incident is a fitting place to close this section on reported instances or allegations of BW. One may believe that the original Indian allegation was true, or that the Goldstein letter was indeed a forgery; if the latter, then one may also believe either that the substance of the letter was a complete fabrication as well, or that it was an elaboration around some small nucleus of fact. Whatever one believes, one is faced with precisely the same sort of uncertainty over most, if not all, of the recorded instances of BW noted above. The longer the period between the report of an alleged BW incident and its investigation, the less likely is it that conclusive evidence one way or the other will be found. When the point is passed beyond which a search for evidence is bound to be fruitless, one is left with the unverifiable report and its unverifiable denial; which of these one then believes can depend only on personal bias.

Chapter 3. Popular attitudes towards CBW, 1919–1939

Many writers on CBW, among them the draftsmen of a number of UN resolutions, have suggested that a substantial body of popular opinion exists around the world that is peculiarly hostile towards CBW. It has also been suggested that this hostility can be a powerful constraint on courses of action involving CB weapons. The purpose of this chapter is to examine the growth of popular attitudes towards CBW, and the bearing this may have had on national CBW policy making.

A full study of these questions is beyond the resources of the present authors. Instead, an account is given of the manner in which the general public, primarily that of the UK and the USA, became concerned about CBW during the period between the two world wars, and of the more obvious instances where it appears that aroused public opinion might have influenced national policy making. This account is broken into three sections, covering the years 1919–1926, 1926–1934 and 1934–1939. Drawing from this historical account, a concluding section speculates in general terms on the manner in which public opinion might be expected to influence CBW policy decisions.

I. *The aftermath of the Great War, 1919–1926*

It is probably true that at the close of World War I CW was a subject in which only military scientists or theoreticians were particularly interested. Specialized aspects of weapons technology were of no great concern to the public at large, at least not to the extent that they can be nowadays. CW was just another of the many new implements of fighting that had emerged during the war. Noncombatants did not know very much about it, and what they did know was generally confused, for most of their information had come through the wartime propaganda machineries, with considerable distortion in the process.

In mid-1915 the Allies had portrayed the employment of asphyxiating gases by the German Army as an act of inhumanity contrary to all codes of civilized behaviour [614–18]. Going further, Allied propagandists described it as yet another of the many atrocities that Germany was perpetrating [619–20]. In the course of this propaganda, many gruesome accounts of the effects of gas were published; it is worth quoting a typical example here, for these early press reports were frequently used in later years to illustrate the horrors of CW. This one is a description of gas casualties in a forward medical aid post; it was provided by an anonymous correspondent, described as "an authority beyond question", to *The Times* (London):

Their faces, arms, hands were of a shiny grey-black colour, with mouths open and lead-glazed eyes, all swaying slightly backwards and forwards trying to get breath. It was a most appalling sight, all these poor black faces, struggling, struggling for life, what with the groaning and noise of the effort for breath. . . . The effect the gas has is to fill the lungs with a watery, frothy matter, which gradually increases and rises till it fills up the whole lungs and comes up to the mouth; then they die; it is suffocation; slow drowning, taking in some cases one or two days. . . . [616]

The Germans, for their part, maintained that gas was a legitimate and humane weapon [621]. The *Frankfurter Zeitung* for 26 April 1915 argued for the humanity of CW as follows:

But however destructive these bombs and shells may have been, do the English and the other people think that it makes a serious difference whether hundreds of guns and howitzers throw hundreds of thousands of shell on a single tiny spot in order to destroy and break to atoms everything living there and to make the German trenches into a terrible hell as was the case at Neuve Chapelle, or whether we throw a few shells which spread death in the air? These shells are not more deadly than the poison of English explosives,[1] but they take effect over a wider area, produce a rapid end, and spare the torn bodies the tortures and pains of death. [621]

The *Kölnishe Zeitung* for 26 June 1915 contended that the CW practised by the German Army did not contravene the international laws of war. (It is interesting to note the distinction it made between gas delivered as drifting clouds from cylinders and gas disseminated from artillery shell.)

The basic idea of the Hague agreements was to prevent unnecessary cruelty and unnecessary killing when milder methods of putting the enemy out of action suffice and are possible. From this standpoint the letting loose of smoke clouds, which, in a gentle wind, move quite slowly towards the enemy, is not only permissible by international law, but is an extraordinarily mild method of war.

It has always been permissible to compel the enemy to evacuate positions by artificially flooding them. Those who were not indignant, or even surprised, when our enemies in Flanders summoned water as a weapon against us, have no cause to be indignant when we make air our ally and employ it to carry stunning[2] gases against the enemy. What the Hague Convention desired to prevent was the destruction without chance of escape of human lives en masse, which would

[1] This was an allusion to the noxious fumes produced by *Lyddite*, an explosive based on picric acid that was used in certain Allied munitions.

[2] "Betäubende".

have been the case if shells with poisonous gas were rained down on a defenceless enemy who did not see them coming and was exposed to them irremediably.... [622]

The British, on beginning to use gas themselves three months later, announced that they had been "compelled to resort" to it [623]. Dispassionate accounts of its performance as a weapon and of its effects on exposed troops did not exist. At the beginning of 1916 the Germans began to spread stories that they had developed a gas shell that would produce certain death for everyone within a hundred yards of the shell burst: these stories were apparently intended to demoralize the French troops at whom the great Verdun offensive was soon to be launched [17]. For the next two years, as the gas war began to gather momentum, neither side allowed much to be published on CW either about its own results with gas or its opponents, for this would have constituted valuable intelligence for the enemy. At the beginning of 1918, the International Committee of the Red Cross (ICRC) appealed to the belligerents to stop using gas, fearing that it would soon be used against civilians; their appeal was widely publicized:

> ... We are shown[3] projectiles charged with poisonous gases which will deal out death horribly not only in the ranks of the combatants, but also in the rear, in the midst of the unoffending population, destroying every living creature throughout wide zones.
>
> We protest with all our heart against this fashion of waging war which we can only describe as criminal. And if, as is probable, a nation is obliged to have recourse to counter-attacks or reprisals in order to force the enemy to renounce this odious practice, we foresee a struggle which will surpass in ferocity and brutality anything yet known to history.... [624]

Nothing came of it, though, and the employment of chemical weapons continued to increase without, however, being directed specifically against non-combatants.[4] The only effect of the appeal was to renew the propagandists'

[3] After the war it was suggested that this initiative on the part of the ICRC was deliberately stimulated by Germany, whose CW agent manufacturing capacity was being overtaken by that of the Allies, and who was therefore beginning to be at a disadvantage in the gas war [20]. However, a German commentator writing at the time of the appeal held that it had been encouraged by the Allies, who felt that they would never overcome Germany's CW superiority [625]. But there is no good reason to suppose that the ICRC appeal was anything other than purely humanitarian and purely spontaneous.

[4] Although gas was never used specifically to attack civilian populations, there were nonetheless a substantial number of civilian gas casualties during the war. In his book *The Nation at War*, General Peyton March, Chief of Staff of the US Army during and after the war, recalls visiting a hospital in Paris and seeing "over one hundred French women and children who had been living in their homes in the rear of and near the front, and who were gassed. The sufferings of these children, particularly, were horrible and produced a profound effect on me."[626] It is recorded that during a German bombardment of Armentières in April 1918, there were 675 civilian mustard-gas casualties of which 12 per cent were fatal [185].

debate about who had used gas first [627–29]. When the war went into its closing stages, Germany was saying that the use of gas "simply arose on both sides out of the requirements of the situation" [627] and that its effects had been greatly exaggerated [630], and the Allies were extolling the performance of their chemical industries in beating the Germans at their own game [628].

In 1919, then, those of the general public who could recall anything of the wartime publications on CW might have adopted any one of a number of assessments: gas as a humane weapon, gas as a terror weapon, gas as just another weapon as horrible as any other. The accounts of demobilized war veterans might support any of them, depending on the types of chemical weapon that they had faced. There was certainly no consensus of opinion, and during the Russian Civil War there appears to have been no outcry about the use of chemical weapons or their supply by the intervening powers.

In the military establishments chemical weapons were viewed with mixed feelings. The experience of the war had shown that in some tactical situations their use by well-trained troops could be extremely advantageous, and that against an unprotected enemy they could be overwhelming. Yet however varied they might be, their functions remained specialized ones and only rarely could they substitute for more conventional weapons. They could be used, therefore, only at cost of an extra logistical burden, which might be great, particularly if the enemy were expected to retaliate in kind. If retaliation were likely, still more attention had to be paid to educating the troops in anti-gas discipline. In a future war, then, gas might turn out to be either a decisive weapon or an expensive liability. A defensive capability of some sort was probably essential for the future, but the need for an offensive one was not obvious.

In addition to these battlefield considerations, most military leaders had strong personal feelings about gas, often of extreme antipathy.[5] Many felt that the use of poison as a weapon was directly contrary to their professional code of behaviour. Indeed, this was a sentiment that had been codified in Article 23 of the Hague rules of 1907. For example Sir John French, Commander of the British Expeditionary Force in France, commented on the German use of gas in his dispatch on the Second Battle of Ypres: ". . . As a soldier, I cannot help expressing the deepest regret and some surprise that an Army which hitherto has claimed to be the chief exponent of the chivalry of war should have stooped to employ such devices against brave and gallant foes. . . ." [618] Such a reaction was heightened by the

[5] Echoing these in a letter to *Chemical Age* in May 1921, the Professor of Physic at Cambridge wrote: "What chivalry can a gasman show to a suffocated enemy? What personal prowess is there for a turn-cock? What occasion for a fine gesture?. . .'

traditional military attitude of hostility towards innovations which still prevailed at that time, particularly if their introduction was in any way the responsibility of civilians.[6] All in all, this meant that advocates of CW would have an uphill task in persuading their military establishments to develop offensive CW techniques and equipment, even if, at the time, they would not have to contend with hostile non-military attitudes.

During the Versailles Peace Conference the first deliberate attempts were made to mobilize public opinion on CW outside the context of wartime propaganda. The Allied delegates were agreed on two points relating to CW: first, that Germany should be forbidden to manufacture chemical weapons and, secondly, that an attempt should be made to weaken its ability to evade such a ban. Agreement on a clause in the draft treaty was quickly reached on the first point (Article 171), but there was less unanimity on the second. Germany's strength in CW during the war had rested on the sophistication of its organic chemical industry, which had been built up before the war into something approaching a world monopoly, particularly in the case of dyestuffs and pharmaceuticals. Clearly Germany could speedily improvise a powerful chemical arm as long as this monopoly remained. Britain proposed that an article should be included in the peace treaty that would require Germany to divulge details of the manufacturing processes it had used for the production of war materials; this would of course mean the disclosure of many of the carefully guarded commercial secrets on which the monopoly was based. The British proposal was opposed by President Wilson and his delegation who felt that such a stipulation would be excessively unfair, and who suspected that what were essentially military negotiations were being used to unjustifiable economic ends. This may or may not have been true, but the leaders of chemical industries in the Allied countries certainly appreciated that the treaty clause along these lines could

[6] This tendency was characterized—and castigated—by the late J. B. S. Haldane as "Bayardism". The Chevalier Bayard, whom his contemporaries described as "sans peur et sans reproche", was the soul of courtesy to captured knights, and even bowmen, but musketeers and other users of gunpowder who fell into his hands were invariably put to death [632]. When gunpowder first was introduced, the first clumsy bombards are said to have been described as noisy, stinking engines that spoiled good archery. When the matchlock was used, it was claimed that soldiers were struck down by abominable bullets that had been discharged by cowardly and base knaves who would never have dared to meet true soldiers face to face and hand to hand [46].

Another example of Bayardism is the rejection by the British Ordnance Department in the 1850s of Lord Playfair's proposal for an incendiary weapon containing a spontaneously inflammable mixture of white phosphorus, carbon disulphide and petrol. When the proposal was repeated some ten years later, it was accepted for development, for this time its sponsor was a soldier [633]. A similar reluctance by the German High Command to accept Professor Haber's proposal for chemical warfare in 1914 is also recorded [634].

confer very considerable commercial assets in their competition with German industry. A campaign was therefore mounted to increase pressure for acceptance of the British proposal. A powerful US lobby was organized to influence President Wilson directly, while the British delegation was strongly supported by an equivalent British lobby. In the UK these activities received assistance from influential newspapers: *The Times,* for example, duly carried articles bringing the issues involved to the public eye. The Annual General Meeting of the Chemical Society, which fell in the middle of the debate on the controversial clause, was unusually fully reported; the Presidential address on "Chemistry in the National Service" [635] was quoted extensively [636]. Many of the points made in the address were among the arguments employed by the US lobby: the importance of CW in a future war, the need to encourage growth of the national chemical industry to ensure a reliable production base for CW agents against a future emergency, and the great and dangerous expansion of the German chemical industry during the war. The US lobby also produced evidence to show that agents and representatives of German chemical firms in the USA had constituted an espionage network [17, 51]. President Wilson remained adamant, however, and the final clause in the treaty, Article 172, satisfied no one.

The British and US chemical industries then turned their attention towards securing national legislation that would provide protective tariffs and even embargos against the import of certain chemical products. In the USA several associations of chemical manufacturers, notably of dyestuffs and other organic chemicals, embarked on a publicity campaign aimed jointly at the consuming public, the consuming industries, and the legislators. The campaign was massive in scope and lasted from 1919 to 1925: its theme was a magnification of the dangers that the USA would face in the future without a large chemical industry. [51] Experience gained during the lobbying at Versailles had shown that the danger to which the US public was most responsive was that of chemical warfare. The emphases in the arguments used then were now shifted slightly, but the main points remained much the same: the crucial importance of chemical weapons in a future war and the need to nurture the industry which would supply them. These were drummed into the public whenever the opportunity presented itself or could be created—in newspaper articles and trade journals, in specially commissioned books, in public addresses, at shareholders' meetings, and so on. In the UK a similar process took place, with the continued support of influential newspapers. In the space of a single month *The Times,* for example, carried three long feature articles captioned respectively "Dyes the Key of War" [637], "Military Value of Dye Industry" [638], and "Dyes as the Key to Gas Warfare" [639]. The first was by Dr Herbert Levinstein, prominent in the British dyestuffs industry and a wartime manufacturer of mustard gas; the second and third were by an anonymous "Special Correspondent", whom it is reasonable to suppose, from internal evidence, was Major Victor Lefebure, a wartime CW expert holding an executive post in Imperial Chemical Industries Ltd.[7] The War Office did not remain entirely aloof: in a long answer to a question on CW in the House of Commons, on the day fixed for the second reading of the Dyestuffs (Import Regulations) Bill, its Parliamentary Secretary expounded on the military value of a developed chemical industry: "... For the purposes of national defence, a chemical industry highly developed and well organized in all its branches is an asset of the greatest value..." [643].

In the USA the campaign was given powerful support by the Army Chemical Warfare Service (CWS), an organization which at that time was seeking to maintain its independent status within the army command structure. By providing technical information and impressive military assessments of chemical weapons, the CWS increased the credibility of the campaign. The US public was not then used to receiving confidences from the armed services and listened with a respect that under the circumstances was perhaps not entirely warranted.

The CWS was a mushroom growth of the last months of the war. The American Expeditionary Force (AEF) had arrived in Europe in mid-1917 almost completely unprepared for CW. It took some time to persuade the War Department in Washington of the gravity of such a situation. The Department's response, when it came, was to distribute CW duties among the existing service branches of the Army—respirators to be designed and procured by the Medical Department, chemical munitions to be manufactured by the Ordnance Department, chemical operations to be conducted by the Corps of Engineers, and chemical alarms to be provided by the Signal Corps. [267] This did not prove to be an efficient arrangement; the different branches viewed their new responsibilities with varying degrees of enthusiasm, and as a concerted effort between them was needed to cope with many of the basic problems, these as often as not remained unsolved. By the summer of 1918 the War Department had been convinced that a unified gas corps was needed, and at the beginning of July the CWS was

[7] This is not to suggest that in writing his articles Major Lefebure was motivated by a desire to advance the interests of I.C.I. Lefebure was an ardent advocate of disarmament, and at the same time was extremely preoccupied with the ultimate dangers of CW. This is apparent from his books and other articles on the subject [17, 640–42]. His perception of the threat posed by chemical weapons convinced him of the dangers to Britain if it lacked a chemical industry, and if the threat was not more widely appreciated.

created. Even so, up to the last weeks of the war the AEF had to rely almost entirely on British and French CW matériel.

At the time of the Armistice the CWS was employing about 20 000 people, but had not in fact reached its authorized establishment [267]. This fact apparently encouraged the War Department to make a rapid start on demobilizing CWS troops and facilities [51]. Within six months the establishment was down to 800 men, and the future status of the CWS as an independent technical service was uncertain.

The men who strove to establish the CWS in 1917 and 1918, notably Brigadier Fries, fought for it again in 1919. Their efforts to convince the War Department General Staff of a continuing need for a separate service were unavailing: as war theoreticians, members of the General Staff were not convinced of the value of an offensive CW capability in peacetime, and, as professional soldiers, they were hostile both to the idea of gas warfare and, at that time, to the aggrandizement of technical services. They saw a need for a defensive capability, but felt that this could safely be entrusted to one of the more established technical branches, such as the Corps of Engineers. Brigadier Fries then went outside the military bureaucracy and sought the assistance of Congress. He did this with energetic diligence, employing professional publicists and canvassing the support of influential groups—the Military Affairs Committees of the House and Senate, the American Chemical Society, veterans organizations and so on. [51] The issue on which he fought was closely related to that of the chemical industry's campaign for German commercial secrets and protective tariffs: national CW preparedness through a strong Army CW organization. In July 1919 a one-year restraining order in the appropriations bill passed by Congress postponed a decision about the CWS, and by June 1920 the future autonomy of the CWS was assured in the new National Defence Act.

The CWS began by publishing glowing accounts of its activities during the war, stressing the importance of gas during the fighting. Its articles in the chief technical journal of the US chemical industry occupied some seventy or eighty closely spaced pages from January to August 1919 [43, 644–51]; they summarized in some detail the results of most of the activities of each branch of the CWS. Each article was prominently headed "Contribution from the Chemical Warfare Service, USA", and when the historical series came to an end this heading continued to be used to introduce more specialized articles on particular CWS research projects or on battlefield aspects of CW. In September the journal devoted an eleven-page editorial to the future of the CWS. Captioned "Beware the Ide(a)s of March!", it was a polemic against the Congressional testimonies of General Peyton March (Army Chief of Staff) and Mr Newton Baker (Secretary of

War) which recommended the abolition of the CWS. It closed with the words:

> ... Bestir yourselves, chemists of America! The country glories in the services you have already rendered it in peace and war. Opportunity for further service now presents itself. ... Whether we will it or not, gas will determine peace or decide victory in future war. The Nation must be fully prepared!

It provided the journal's readers with a list of members of the Congressional Committees on Military Affairs [652].

Apart from their immediate effects on their audiences, these and related publications provided a store of technical information about CW and a comprehensive collection of the arguments in favour of it for the use of subsequent publicists. A good proportion of the US reading public must by this time have become thoroughly muddled about CW; on the one hand readers were being confronted by the growing barrage of propaganda put out by the chemical industry, while on the other they had to cope with the counter-arguments of the increasing number of people who objected to all that the CWS stood for. But however confused the public might be, its interest had been aroused and its opinions mobilized.

In the UK this mobilization of opinion took rather longer. In the first place the British Expeditionary Force had not been affected by gas quite so obviously as had the American Expeditionary Force, for the arrival of the latter in Europe coincided with the beginning of great improvements in the effectiveness of chemical weapons, resulting in an abnormally high proportion of AEF gas casualties. In the second place, there was no institutional controversy comparable to that over the CWS; this factor, coupled with the strict secrecy generally maintained in CW matters, meant that there was less hard information to be had. However, by 1920, with the dyestuffs industry in vociferous pursuit of protective tariffs, and with US CW literature circulating, the mobilization of British public opinion began. As in the USA, the public was caught in a confusing crossfire of propaganda and counter-propaganda.

In addition to the various pressure groups at work within different countries, a number of international organizations had taken up CW. First and foremost, the Council of the League of Nations announced in October 1920 that it was going to propose that its member governments should study the question of the sanctions that should be applied in the event that any nation infringed "the rules of humanity imposed upon all" by using chemical weapons. [653] In the following month the ICRC addressed a letter to the General Assembly of the League proposing various armament-limitation measures, including "absolute prohibition of the use of asphyxiating gas, a cruel and barbarous weapon which inflicts terrible suffering upon its victims" [654]. Six months later, the tenth International Conference of the Red Cross resolved to urge all governments to consider supplementing the Hague rules by an additional agreement that would make the ban on the use of chemical weapons more explicit and more extensive [631, 654]. With activities such as these, initiatives for a new international agreement outlawing CW began to gather support.

A nervous member of the public could by now have alarmed himself horribly if he read the right literature. Had not gas caused 30 per cent of the wounds suffered during the war by one of the belligerent armies [655]? Did not gas "condemn its victims to death by long drawn-out torture" [656]? Was one not "bound by sheer intelligence to comprehend that chemical science has only begun to fight" [657] and that far more potent chemical weapons would soon be made? Was it not inevitable that civilians would be early targets for attack in a future war, and that it was now possible "to ruin whole cities in the space of a breath drawn in the middle of the night" [657]?

These fears were stimulated by a further carefully contrived exposure of secret information by the CWS.[8] It announced that it had discovered a liquid poison so strong that three drops would kill anybody whose skin it touched. [658] The publicists quickly exploited this: the new poison, lewisite, "had fifty-five times the 'spread' of any poison gas hitherto used in war"; it was "invisible", and if inhaled "it killed at once" [215]. The disclosure of lewisite was useful in convincing the US public of the dangers to their own personal safety in a future war—an idea difficult to put across to a nation separated by two oceans from possible enemies: lewisite was advertised as being well suited to aircraft delivery. During the war there had been few, if any, instances of aircraft being used to spread gas, and since then no technical information had been published on its feasibility. However, during the accounts of its wartime activities the CWS had fleetingly referred to work on an aircraft gas bomb. [645] This was apparently enough to allow the publicists to present as an accomplished fact the potential marriage of aircraft and chemical weapons systems: "An expert had said that a dozen lewisite air bombs of the greatest size in use during 1918 might with a favourable wind have eliminated the population of Berlin." [215] Further-

[8] In the preface to a book on CW, its two authors, one of whom was Brigadier Fries (by then Chief of the CWS), wrote in August 1921: "Those familiar with the work of the CWS will discover that the following pages contain many statements which were zealously guarded secrets two years ago. This enlarged program of publicity on the part of the Chief of the Service is being justified every day by the ever-increasing interest in this branch of warfare. Where five men were discussing CW two years ago, fifty men are now talking about the work and the possibilities of the Service today." [39]

more, lewisite was a percutaneous agent: "Falling like rain from nozzles attached to an aeroplane, [it could] kill practically everyone in an area over which the aircraft passed" [658].

The ease of manufacture of CW agents, and the virtual impossibility of controlling such manufacture, was one of the points often made by publicists for the chemical industries: during the war, phosgene "was produced by a simple expansion of existing plant used in the production of some of the common dyes. ... Mustard gas production proceeded almost automatically by the expansion of existing Indigo plant. ... The Blue Cross penetrating substances found a ready means of supply in the Azo houses of the dye factories. ..." [638] As for lewisite, the CWS said that, as nearly every nation possessed practically an unlimited supply of the necessary raw materials, the only limit to the quantity that could be made was the amount of electric power available [658].

British chemical industrialists also had secrets to divulge, but did so much more discreetly. The President of the Society of Chemical Industry, for example, spoke of a new CW agent against which respirators were no protection and which was so potent that it would stop a man at atmospheric concentrations of one part in five million [659]. This was presumably an allusion to DM, aerosols of which could penetrate some of the current models of gas mask, and which was the basis of the secret British M device being manufactured at the time of the Armistice.[9]

News of these new poisons, their ease of manufacture and their adaptability to aircraft delivery increased the alarm about CW, especially in Europe. Even in the USA it began to look as though the various publicity campaigns were pushing the issue of CW too hard, and that the reaction might rather be an international attempt to prohibit all CW activities instead of national drives for greater CW preparedness. The US Secretary of War, for instance, was on the record as saying that in his belief CW would be prohibited in the future: "I think we will not permit gas warfare as we get more civilized" [661]. The pro-CW lobbies began to give more emphasis to one of their earlier themes, the relative humaneness of chemical weapons [655], and the CWS supported this by advertising the usefulness of

[9] See page 38. Technical details of DM had in fact already been published by the Italians [660], but without attracting attention. The Americans, who called the agent adamsite, had discovered it independently of the British. Together with lewisite, it was one of the agents in production in the USA at the close of the war. With these agents, the CWS boasted the superiority of its research over German research: the Germans had not manufactured any agents which were not known before the war. In fact, DM had first been synthesized in a German laboratory in 1913 [29], while lewisite had been rejected as a candidate agent by the Germans in 1916 [3]. The British were the first to publish details of lewisite, to the alleged annoyance of the CWS [44].

irritant CW agents in riot control and crime prevention, and by developing tear-gas weapons for police use [662]. One of the most skillful expositions of the theme was made in England, in May 1921, by the President of the Society of Chemical Industry [631]. After assembling the arguments based on casualty statistics, relative degrees of suffering and so on, he pointed out that the weapon that had caused far and away the most suffering and loss of life during the war was preventive medicine: had it not made possible the maintenance of twenty million men under arms? He rather spoiled this line of argument for some of the lobbyists by concluding that humanity considerations would be irrelevant in the face of issues of national security. Throughout the year he continued to impress on audiences his views on the humaneness of chemical weapons and their crucial role in ensuring national security, and by September he was coming under attack from other scientific organizations, notably the British Association for the Advancement of Science which was pressing for an international ban on CW. [663] Newspaper editorials were beginning to call for clear-headed appraisals of CW: should the government extend its CW preparedness programmes, or should it press for an international ban [664–65]? Pressure for the latter was mounting fast. The public did not seem to be impressed by the humanity argument, and its attention to CW was being maintained by a number of issues, such as the question of whether university scientists should do secret CW work for the War Office,[10] controversy over who had invented which method of making mustard gas first,[11] and a number of court cases in which the defence had rested on the accused's lack of moral control resulting from wartime gas injuries [671]. The situation came to a head at the time of the 1921–22 Washington Conference on the Limitation of Armaments.

The Washington Conference had been called by the United States. Its sponsors wanted a formulation of arms-limitation proposals for the newly developing aerial, submarine and chemical weapons systems. Disarmament was not necessarily to be a theme of the conference and its delegates convened on this basis.

After some initial discussion within the procedural committee of the con-

[10] Two questions were involved: should university facilities be used for secret research and should eminent scientists sit on War Office committees? The former attracted the strong hostility of many individual scientists [666–68], and of the Union of Scientific Workers [669]. The latter involved lesser issues, and was suggested by one scientist to be unimportant: "... Can ... any means for discouraging the application of scientific study to war ... be suggested ... so entirely efficient as the placing of the matter in the hands of a large Governmental Committee composed exclusively of eminent persons?" [670]

[11] This controversy, at first between different British scientists and later between different groups of Allied scientists, was initially conducted in the technical literature [672–82], but when the Royal Commission on Awards to (wartime) Inventors began its hearings on the matter, it reached the daily press [683–85].

ference, CW was referred to a subcommittee for further consideration. The subcommittee reported that:

> ... The only limitation practicable is wholly to prohibit the use of gases against cities and other large bodies of noncombatants in the same manner as high explosives can be limited, but that there can be no limitation on their use against the armed forces of the enemy, ashore or afloat. [686–87]

The view taken in the subcommittee was that neither R & D in chemical weaponry nor manufacture could be controlled. Furthermore, in the case of a conflict that did not engulf large numbers of noncombatants, there was no difference between a war waged with conventional weapons and one waged with chemical weapons that justified a special concern about the latter.

This report in fact coincided with the negotiating policy advocated by the US War Department and with the position that had been adopted initially by the US delegation [51], but when it came to be discussed at the conference itself, the US delegation strongly opposed it.

As a way of ensuring subsequent ratification of any treaty that might emerge from the conference, the US Secretary of State, C. E. Hughes, had formed a number of prominent Senators and senior officers of the armed forces into an advisory committee for his delegation. This committee had produced a report that urged the total prohibition of use of CW agents, "whether toxic or nontoxic", saying that their use should be classed "with such unfair methods of warfare as poisoning wells, introducing germs of disease and other methods that are abhorrent in modern warfare" [686]. It is reasonable to suppose that, despite the inclusion of military personnel (some of whom were in any case among the opponents of the CWS), the advisory committee had been affected by the various propaganda campaigns in the USA. Thus, they reported that:

> The frightful consequences of the use of toxic gases, if dropped from airplanes on cities, stagger the imagination. ... If lethal gases were used in ... bombs [of the size used against cities in the war], it might well be that such permanent and serious damage would be done ... in the depopulation of large sections of the country as to threaten, if not destroy, all that has been gained during the painful centuries of the past. [686]

But there can be little doubt that their views reflected those of a great many of their countrymen. A national opinion survey, conducted in the last months of 1921, covered the subjects of the conference agenda. Of those of the sample that expressed views on CW, 366 975 were reported to have wanted abolition, while only nineteen wanted retention with the limitations on use that the conference CW subcommittee had recommended. [688]

In addition to the report of his delegation's advisory committee, Secretary Hughes had also received reports from an Army and a Navy committee. The former recommended that: "Chemical warfare should be abolished among nations, as abhorrent to civilization. It is a cruel, unfair improper use of science. It is fraught with the gravest danger to the noncombatants and demoralizes the better instincts of humanity." [686] The latter also recommended the abolition of CW, on grounds of risk to noncombatants and unnecessary suffering, and because it threatened to become "so efficient as to endanger the very existence of civilization". It was also hostile to chemical harassing agents such as tear gas; although these might be nonlethal, they too caused suffering and their use in war might quickly escalate into the use of more lethal agents. [686]

The US *volte face* apparently took the other delegations by surprise, but they nonetheless accepted the subsequent US proposal for a treaty prohibiting the use of chemical weapons. As a treaty its main value was as an indication of the state of customary law as it concerned CW at the time. It went little further than the Hague rules and contained no safeguard against violation. The British delegation said when the treaty was announced: "It would not relieve nations from the necessity of preparing themselves against the use of gas by an unscrupulous enemy." [689] The US delegation, however, felt that public opinion would provide a sufficient deterrent sanction:

> We may grant that the most solemn obligation assumed by governments will be violated in the stress of conflict; but beyond diplomatists and beyond governments, there rests the public opinion of the civilized world, and the public opinion of the world can punish. It can bring its sanction to the support of a prohibition with as terrible consequences as any criminal statute of Congress or Parliament. [686]

In the Senate debate on ratification of the treaty this idea was expressed in somewhat less confident terms:

> This clause in the treaty is not expected to prevent the use of poison gases at present. It is expected to do something toward crystallizing the public opinion of the world against it, and trying to make that public opinion more effective. ... In some way we want to build up public opinion, and the attempt was made here. ... If the world is cursed with another such war I dare say they will break out and use poison gas again, but there is always the hope that the opinion of the world may be so crystallized that it will prevent it, as public opinion alone has practically prevented the poisoning of wells or the giving of no quarter to prisoners. [690]

The treaty was duly ratified, embodying as it did the recommendation of the advisory committee.

The position had now been reached where a wide segment of public opinion had been mobilized on the subject of CW into an attitude that was both fearful and hostile. Diplomatists from France, Italy, the UK, Japan and the USA had apparently put sufficient faith in the vehemence of this attitude to sign a treaty against the violation of which public opinion was to be the only sanction.

All this had repercussions in the military establishments of many countries. Although the view generally taken was that a defensive capability would still be essential in the future, no establishment was prepared to argue against the tide of opinion by overtly seeking funds for an offensive capability. Even before the treaty the incentives to develop and manufacture new chemical weapons had been weak, although the question of a retaliatory option had complicated the issue. The US War Department issued a general order restricting CW research to the development of anti-gas equipment [51, 691], and the allocation of funds to the CWS was reduced to a bare subsistence level. The British Parliament was assured that the War Office CW budget was being devoted entirely to defensive work [691–92].

The Washington Treaty encouraged further work on an international level to abolish CW preparations. Moves toward this objective came both from the League of Nations and from outside it. A conference of Central American republics produced a convention, signed in Washington on 7 February 1923, which contained the following:

> The contracting parties consider that the use in warfare of asphyxiating gases, poisons or similar substances, as well as analogous liquids, materials or devices, is contrary to humanitarian principle and to international law, and obligate themselves by the present convention not to use said substances in war.

A year later the fifth International Conference of American States, held at Santiago, Chile, adopted a resolution containing the following statement:

> The Fifth International Conference of American States resolves ... To recommend that the Governments reiterate the prohibition of use of asphyxiating or poisonous gases and all analogous liquids, materials or devices, such as are indicated in the Treaty of Washington dated February 6, 1922.

The USA subscribed to this resolution.

Within the League of Nations, in May 1920, the Council had asked the Permanent Advisory Commission on Military, Naval and Air Questions (PAC), to study the question of CW "with a view to some agreement being reached internationally". In October the PAC had reported rather discouragingly that peacetime restrictions on the manufacture of CW agents would not prevent CW in wartime, and that CW was "barbarous and inexcusable" only when practised against noncombatants. [693] In this, their view was similar to that later taken by the CW subcommittee at the Washington

Conference. However, with the signing of the Washington Treaty, the League took up the matter with renewed zeal. The Assembly urged the adherence of all states to the CW provisions of the treaty and asked its Temporary Mixed Commission on the Reduction of Armaments (TMC) to consider CW further, in particular the feasibility and usefulness of some of Lord Robert Cecil's ideas on practical measures.[12] It continued to do so for the next few years, issuing a number of reports in the process. From the point of view of public opinion, the most important of these was published at the end of 1924. It had been drafted by a special committee of the TMC, and was based on the answers to questionnaires sent to leading world scientists. The object had been to furnish an accurate scientific appraisal of the effects of possible use of chemical and bacteriological weapons. The report considered the main classes of CW agents in some detail, including their toxic effects on individuals, and said that their delivery by aircraft did not seem to be impossible technically. It reserved judgement on BW, feeling that for the present its feasibility was doubtful but that in the future it might pose a formidable threat. [693] It concluded with the words:

> Noting, therefore, on the one hand the ever-increasing and varying machinery of science as applied to warfare, and, on the other, the vital danger to which a nation would expose itself if it were lulled into security by over-confidence in international treaties and conventions, suddenly to find itself defenceless against a new arm, it is, in the opinion of the Commission, essential that all nations should realise to the full the terrible nature of the danger which threatens them.

The fears of the general public about CW thus seemed to be confirmed by eminently respectable authorities and, with the looming possibility of biological weapons, yet another cause for anxiety was appearing.

The next major international event to do with CBW arose out of the Conference for the Supervision of the International Trade in Arms, Munitions and Implements of War, held at Geneva during May and June 1925. Although the Conference was organized by the League, the USA was represented. Its purpose was to solicit agreement on certain proposals to regulate the international arms trade that the TMC had salvaged, and redrafted, from the abortive St. Germain Convention of 1919. Under these terms of reference its results were insignificant but, during the deliberations, the US delegation introduced a proposal that went beyond the original agenda into the issue of CW. It proposed a prohibition of international trade in chemical weapons. With the failure of the Washington Treaty, which was not ratified by France, the US Department of State was seeking further ways to strengthen the prohibition of CW, and the other delegations were suffi-

[12] These are referred to in Volume IV of this study.

ciently sympathetic to this to debate the proposal, however improper it might be procedurally. [694] It was soon agreed that the suggested prohibition was unacceptably discriminating against nations that could not produce their own chemical weapons, should circumstances necessitate them. Several alternative proposals were discussed and in the end the participating nations agreed to sign a protocol appended to the final convention; it was drafted much as the CW clause of the Washington Treaty had been, but with an additional prohibition of BW.[13]

The signing of the Geneva Protocol of 1925 was the high-water mark of the hostility of public opinion towards CW. The titillations of publicists had brought out the subconscious fears of individuals towards a creeping, hidden death by choking. Military men were beginning to feel that their professional honour had become impugned by association with the agencies involved. These two currents, one of revulsion and one of rejection, had merged, and the statesman concerned with international relations and the lawyer concerned with international order had found common ground. The ancient customary-law prohibition of fighting with poison, that had levered itself on with the treaties of Strassburg, St. Petersburg, Brussels and the Hague against the ground-swell of a rising military technology, after being severely weakened by the chlorine cylinders of Ypres, had suddenly recovered and expanded and made a new imprint on the public conscience, before declining again on the battlefields of Ethiopia, China and Viet-Nam. But this prohibition in conventional international law, the Geneva Protocol, has remained and for this the publicists are owed a debt of gratitude.

To anyone who was prepared to consider the potentialities of CW dispassionately, it would have been clear that the chemical threat did not differ markedly from that posed by high explosive weapons. Against well-equipped and well-disciplined troops, the chemical weapons of the time would never be overwhelming: if anything, their efficacy had declined since 1918, for respirator filters had now been designed that could cope with particulate aerosols of the kind used to disseminate DM and CN,[14] and textile impregnants were beginning to appear that held out promise for air-permeable skin protection against percutaneous agents such as mustard gas and lewisite. The new CW agents were either only marginal improvements over existing ones, or turned out later to fall far short of the expectations initially made of them. Lewisite was in the latter class. It had gone into production in the USA in 1918 solely on the basis of relatively meagre laboratory data, with no field trials whatever. [42] As CWS activities were

[13] See Volumes III and IV of this study.

[14] CN was the new US tear gas, developed soon after the Armistice following an inadequate examination before it [48]. (See page 59.)

curtailed after the war, the agent was not fully evaluated in the USA until 1942. On the basis of tests on dogs, the CWS was estimating that the percutaneous dosage of the liquid that would be lethal to man was around 2.6 grammes (a figure later thought to be an overestimate) [42]. If "three drops" of the agent on the skin were to kill, on this estimate they would have had to be remarkably large drops, on the order of a centimetre in diameter. It would certainly not kill anyone instantaneously, even if inhaled; and the lethal airborne dosage was almost certainly too high to be attained on a battlefield, particularly a humid one. Lewisite was essentially a blister agent with a potency comparable to that of mustard gas; by no stretch of an informed imagination could it be seen as a super-weapon.

In most countries, a capability for waging "aerochemical warfare" was still a good way into the future. The CWS, which had encouraged rumours of its high level of development, had designed a crude bomb or two and had carried out some rather unsuccessful trials of a small and clumsy aircraft spray tank; but in no sense had the combination of gas and aircraft yet developed into a strategic weapon.

Some groups of people were perfectly aware of these facts, and had indeed said so publicly. Their evaluations were the basis of the reports on CW made by the League PAC in 1920 and the CW subcommittee at the Washington Conference in 1922. The protagonists of CW preparedness could use these alternative assessments of the dangers of CW to enlist the support of those decision-makers who were beginning to wonder whether they had let public feelings dictate an unwise policy. Such an instrument would have to be used rather carefully in the lobbies, for if it were felt that too much fuss had been made about nothing the CW establishments would remain as much in need of support as they had been before. The new approach was therefore diluted with inflated estimates of future CW developments and with modified arguments for the relative humaneness of chemical weapons [632, 695–96], and pressed into service alongside the old theme of national preparedness.

These new lobbying activities seem to have had little effect on the attitude of the public at large towards CW. Peacetime preparations for war were not an issue that aroused much sympathy outside circles where they were the prime concern, for the times were peaceful and war seemed remote. For the last five years the British public had been told that the possibility of war was at least another decade away; for them and the rest of Western Europe, harmonious agreements were being reached at Locarno. The USSR was preoccupied with domestic policy and the USA had withdrawn into isolationism.

The immediate target for the pro-CW pressure groups was to prevent ratification of the Geneva Protocol. In Europe there is little evidence that much lobbying was done to this end, and after some delay all the major governments ratified the treaty. But in the USA, where chemical weapons were more likely to be less of a danger to the citizenry than an asset to the armed forces, the lobbying was sustained and successful. In the first place, the War Department had not been formally consulted during the Geneva Conference and had no forum other than the Senate to air its doubts about a decision that might affect military policy. In the second place, the Department of State had not followed the practice of involving the Senate in the treaty negotiations to ensure subsequent ratification. Furthermore, the anti-CW groups had not anticipated a battle over ratification.

The anti-ratification groups had the best part of a year to organize their campaign after the Protocol was signed and before it emerged for debate from the Senate Committee on Foreign Relations. During this period the CWS succeeded in obtaining enthusiastic support against the Protocol from several war veterans' organizations [51]. The American Chemical Society was also against the Protocol [51]: its Executive Committee declared that "the prohibition of chemical warfare meant the abandonment of humane methods for the old horrors of battle" [697]. Brigadier Fries mobilized support throughout the Army, skillfully presenting the fight against ratification as a fight for general military preparedness.

In the Senate debate on the Protocol, the Chairman of the Committee on Military Affairs opened his attack with this reference to US ratification of the 1922 Washington Treaty:

> I think it is fair to say that in 1922 there was much of hysteria and much of misinformation concerning chemical warfare. I was not at all surprised at the time that the public very generally—not only in this country but in many other countries—believed that something should be done to prohibit the use of gas in warfare. The effects of that weapon had not been studied at the time to such an extent as to permit information about it to reach the public. There were many misconceptions as to its effects and as to the character of warfare involved in its use. [687]

He then went on to argue that gas was both a humane and a valuable weapon, and that whatever treaties a country might have signed it would certainly employ all possible methods of fighting if it faced military defeat. As for the humanity of gas, he supported his case with the answers to questionnaires sent out to 3 500 physicians around the country: these apparently showed that in comparison with more conventional weapons, gas caused less suffering, both during exposure and during its after-effects. Other Senators joined him in attacking the Protocol and quoted resolutions against the prohibition of CW that had been adopted by such organizations as the

Association of Military Surgeons, the American Legion, the Veterans of Foreign Wars of the United States, the Reserve Officers Association of the United States, and the Military Order of the World War [687]. Although the Protocol was almost identical to the CW provisions of the treaty that the Senate had ratified unanimously four years earlier, it now seemed that the Senate tended to view gas as being both militarily more effective and more humane than conventional weapons, and considered that its use could be advantageous to the United States, whose chemical industry was now expanding fast. It also seemed that the Senate was beginning to doubt the force of public hostility towards CW as an effective sanction against violation of the treaty. When the Department of State realized this, it withdrew the Protocol before a vote had been taken, planning to re-submit it at a more opportune moment. The United States has still not ratified the Protocol, although, at the time of writing, it has again been submitted to the Senate for advice and consent.

II. *The growth of Pacifism, 1926–1934*

The public had now been educated in CW. To most of those who had undertaken the task, it was immaterial that popular estimates of the power of chemical weapons were a good forty years too advanced. But to a new generation of publicists, this over-estimate had sensitized public opinion for easy stimulation and exploitation. Pacifists[15] could present CW as a symbol of the horrors of war; right-wing political propagandists could point to CW preparedness efforts in socialist countries as an indication of the evils of communism, and vice versa. It had become a comparatively simple matter to arouse widespread feeling on an issue if that issue could be shown, however tenuously, to increase the risk of a chemical war being waged. Yet when international organizations tried to introduce practical measures for reducing that risk, the support provided by popular opinion was not entirely an asset.

The League of Nations was preparing for its world disarmament conference. CW had been discussed in the Preparatory Commission since May

[15] "Pacifism" is a term that has acquired several meanings. Nowadays, the designation "pacifist", when not used as a term of abuse, generally denotes people who either believe in unilateral disarmament by their own governments, or who hold to the Quaker resolution never to use personal violence. In the context of this chapter, however, "Pacifism" is used solely to describe the trend of feeling that grew in strength during the 1920s and 1930s — particularly among ex-servicemen — in support of (*a*) the total abolition of war, and (*b*) multilateral world disarmament under international control. In no country was unilateral disarmament or non-resistance to violence regarded as a practical policy by those who supported this trend of Pacifist feeling, at any rate not before 1936 or so.

1926, at first from the point of view of strengthening the prohibition, but later from a specifically disarmament angle. The initial discussion had been constrained by a fear of prejudicing the validity of the newly signed Geneva Protocol, which had then not yet come into force. [693] CW had therefore been referred to a pair of subcommissions who were asked to report, first, on the question of sanctions against violation of the prohibition, and secondly, on certain of the technical problems of chemical disarmament. The main theme under the latter heading had been to examine the widely-held view that chemical industrial power was speedily convertible into chemical warfare power. The report had upheld this view: commercial chemical plant was readily convertible to the production of chemical weapons and, furthermore, little could be done to impede its convertibility. [693] Following the report of the TMC in 1924 on the effects of chemical weapons, the League had thus in 1926 confirmed another of the tenets on which the popular fear of CW was based.

The Preparatory Commission was considering CW then from much the same premises as had been offered to the general public, but the Commission's recommendations to the Disarmament Conference proper were remarkably weak. In its draft Convention for the Reduction and Limitation of Armaments, at Article 39, the Commission merely suggested that the contracting parties should undertake to abstain "subject to reciprocity" from CW and "unreservedly" from BW [693]. There were no clauses on agreed CW force levels, on control procedures, or on sanctions against infraction. All these subjects had been debated at length; different delegations submitted their own separate proposals to the Disarmament Conference, but there had been little opportunity to reach unanimity within the Preparatory Commission.

Until 1932 discussions within the League of practical measures for coping with CBW had centred around the Geneva Protocol. Many proposals had been made for increasing its scope with disarmament stipulations and giving it force with provisions for inspection and penalties. The main ones were the joint Belgian-Czechoslovak-Polish-Romanian-Yugoslav proposal of April 1927, the Soviet proposal of April 1929 which embodied a rudimentary inspection procedure, and a French proposal simultaneous with and similar to the Soviet one [693]. These are described in Volume IV of this study. The British had concerned themselves mainly with trying to establish a uniform interpretation of the wording of the Protocol, notably on the subject of tear gases and other irritant CW agents [698–99]. The different initiatives within the Preparatory Commission and later within the Conference itself for expanding the Geneva Protocol into a disarmament treaty were all remarkably alike and indicated at least a latent consensus of feeling. Had there been opportunity to debate the comparatively minor differences between the various proposals further, the draft for a generally acceptable CB disarmament treaty might quickly have emerged. With hindsight, therefore, it can be argued that CB disarmament might well have been achieved as a result of separate negotiation outside the framework of negotiation for general disarmament.[16] During the late 1920s no military establishment was seriously committed to a belief in the value of a CBW armamentarium; and what a country does not particularly want it may be ready to negotiate away. But when CB disarmament was proposed as part of a scheme for general disarmament, the chances for securing it were lessened.

This is not the place to discuss why the League's Disarmament Conference failed; it is sufficient to note that there were powerful undercurrents of opinion and vested interest that were hostile to its success. Once the subject of CBW got entangled with these, the inevitable formal imperfections in the draft CB disarmament and sanctions clauses were exposed to exploitation or to having undue importance attached to them, thereby complicating the overall disarmament negotiations. While it cannot be said that the controversy over the CBW clauses contributed directly to the failure of the Disarmament Conference—CBW was a very minor issue in the overall debate—it can certainly be argued that the controversy has had a harmful influence on subsequent approaches to CB disarmament. It has led, for example, to a gross exaggeration of the importance of formal verification in CB disarmament and of its technical difficulties.

This arose as follows. In February 1932 Lord Robert Cecil introduced the concept which was later to be called "qualitative disarmament", and which was accepted as one of the bases for negotiation. It comprised augmenting the framework of quantitative disarmament with provisions for the abolition of all those weapons that had been specifically forbidden to Germany in the Treaty of Versailles. The formula to be used was that all nations would be asked to disarm themselves completely of those weapons that were (1) the most specifically offensive in character, (2) the most efficacious against national defences, and (3) the most threatening to civilians.

There were probably no other weapons that public opinion throughout most of Europe and America considered more threatening to civilians than chemical weapons. The Special Committee appointed by the General Commission of the Disarmament Conference in May 1932 to study CW duly reached unanimous agreement on this. From 1920 or so onwards, several groups had contended that in combination with the aircraft, gas was a highly important strategic weapon, as we have seen. Since then this view had

[16] This is not to say that it is necessarily desirable that future CB disarmament negotiations should be kept separate from general and complete disarmament.

been stimulated by other publicists. Pro-CW propagandists had been joined by protagonists of the aircraft and of the tank, both fighting for development funds and for degrees of institutional autonomy within the military establishments. In the UK, Colonel Fuller—one of the most influential of the early theoreticians of tank warfare—had portrayed the tank as being about the only feasible way of manoeuvering on a battlefield contaminated with persistent CW agents [696]. In the USA, Brigadier Mitchell, like Brigadier Fries, had made extravagent claims for aerochemical weapons in Congressional testimony [208]; one writer went so far as to suggest that the aircraft involved would be pilotless, inaudible and invisible [242].

As the tank and the aircraft were considered to be specifically offensive in character, and as they could apparently be used to spread gas, some members of the Special Committee felt that chemical weapons should be considered for qualitative disarmament on the first criterion also. On the second criterion the recent ICRC conferences on civil defence, held in Brussels in 1928 and Rome in 1929, had predicted that civilian casualties could not be held to tolerable levels in the event of aerochemical attack [51]. Thus, mainly on the basis of a view that chemical weapons could be delivered by aircraft to devastating effect, and were likely to be used in this way, the Disarmament Conference began its deliberations on CW, confirming the attitude of the general public towards gas yet again in the process.

As for BW, the Special Committee felt that it was "so particularly odious that it revolted the conscience of humanity more than any other form of warfare", and that it should therefore be included in the disarmament discussions irrespective of the three criteria [693].

It is difficult to tell now how good the delegates' technical information was about the current state of CW. Governmental CW work and assessments were generally closely guarded secrets, and even if the individual members of the Special Committee knew them they would have used them only with extreme discretion in an international discussion. Quite possibly only a few, if any, governments of the time had made appraisals of the potential of aerochemical warfare that went beyond a scanning of the burgeoning non-professional literature on the subject. Looking back on what is now known about the national CW efforts of this period, very few countries had any sort of programme of chemical-weapons development. It may well be, then, that the Special Committee's perception of CW was no better informed than that of the general public.

Once the Disarmament Conference was committed to this perception, the discussion of practical CB disarmament measures was forced onto an altogether higher and more clearly-defined plane than hitherto. These were weapons that the delegates had agreed could crucially affect national security. Their prohibition must therefore be accomplished with great circumspection, taking all possible precautions against violation. In a situation where CB weapons were regarded as of rather doubtful military value, a less than perfect disarmament scheme might have been acceptable; but in the present context this would not do. The conference debate about the difficulties of verifying the observance of chemical disarmament agreements, which reverted again and again to the question of convertibility without ever resolving it, has left its mark on all subsequent discussions of the problem.

As the movement for multilateral disarmament and the total abolition of war began to gather momentum throughout Europe, CW became an obvious focus for the literature of the various Pacifist organizations; for with a public that was fully prepared to accept the blackest estimates of the effects of chemical attack, gas was a ready-made symbol of the horrors of war. This idea had been made explicit at the twelfth International Red Cross Conference held in Geneva in 1925.

> The more we familiarise the world through the Red Cross societies, through the millions of members that you represent here, Messrs Delegates, with these facts [of the best measures of assisting gas victims], the more we shall make known the horrors of chemical warfare, and the more we shall make pacifist propaganda, the best propaganda against war itself. [700]

This idea was reiterated in a final resolution from the ICRC conference on civil defence at Brussels in 1928 [51]. By the early 1930s there were few Pacifist writers who had not described the possible effects of chemical attack on cities; they ranged from the authors of overt science fiction [701], through such prominent figures as H. G. Wells [702] and Sir Norman Angell [207] and on to the publicists of influential international bodies [703]. All these writers had the facts and figures provided by the propagandists of the early 1920s to work from, and these were easy to expand from the commentaries of public figures and professional strategists (particularly General Douhet, the Italian protagonist of air power). In the UK an often-quoted estimate was that a single large gas bomb dropped in Picadilly Circus, in the middle of London, would kill every man, woman and child in Central London from Regents Park to the Thames [216], or, in an alternative version of the same estimate, that 40 tons of one of the new CW agents would destroy the whole population of London [207, 703].[17]

[17] These figures were derived from a newspaper report of a lecture given by a CW expert to a military audience in 1928 [704]. To show that it was not inconceivable that a city might be blanketed with a gas cloud, the lecturer had quoted official statistics to the effect that a typical London fog contained about a pound of particulate material per million cubic yards of air. Hedging with all manner of operational and meteorological qualifications, he then estimated that an aerial CW attack disseminating about a quarter-ton of particulate CW agent per square mile might set

The efforts of the ICRC to encourage research into civil-defence problems sustained both the "pacifist propaganda" and the public's attention to it. At the 1929 Rome conference, it was assumed that in future counter-city attacks high explosive would be used to penetrate collective shelters and homes and incendiaries to drive the population into the streets where they would be killed by gas. The delegates then produced a model civil-defence plan for a typical European city and found that it would cost around $160 *per capita*. They therefore concluded that civilians could be defended effectively only at prohibitive cost, and that the only way left to ensure that they would not be killed by gas was to strengthen the prohibition on its use. The ICRC accordingly urged the national Red Cross societies to press for wider ratification of the Geneva Protocol, and to encourage their governments to continue the study of civil-defence measures. [51] As an inducement to non-governmental scientists to assist in the latter, they offered a prize for the best mustard-gas detector, and spoke of plans for subsequent competitions for the design of civilian anti-gas equipment [706].

Many governments by then in fact had active research programmes in civil defence, including anti-gas defence. In the USSR, for example, the programme had advanced to the stage of actual manoeuvres involving civilians. In June 1928 thirty aircraft carried out a simulated gas attack on Leningrad, dropping powder bombs onto a well-briefed public equipped with gas masks. Somewhat disappointedly, *Izvestia* reported that the populace had regarded the exercise as an ordinary street sight, rather than a serious manoeuvre. [707] A similar exercise took place in Kiev five months later [708]. But at this time, the international situation still seemed sufficiently stable for the main European governments to regard research into civil defence as an insurance policy for the future, rather than an urgent need of the present. To alarm the public by teaching anti-gas drill might cast doubt on the good faith of the increasing number of ratifications being deposited for the Geneva Protocol [709] or of the delegates at the Disarmament Conference. It might also have a destabilizing effect on the international situation, and would certainly upset the national electorates: in their receptiveness for sensational stories about gas, many people probably found a rather perverse comfort, for CW seemed so horrible that it was hard to

up a similar concentration. The fog concentration was around one part per million, and he said that this was well above the physiologically active concentrations of some of the newer organoarsenicals, such as DA or DC. Although an aerosol of this type would only rarely be lethal, this fact was generally ignored by subsequent commentators. In a parliamentary debate five months later [705], a wartime Minister of Munitions transposed the lecturer's calculation into the estimates cited above; his speech was widely quoted, both by himself and by others impressed with his voice of authority.

visualize anyone waging it, and, by association, war itself seemed that much more remote.

III. *The expansion of national armaments, 1934–1939*

With European armaments expansion getting way after the failure of the League's Disarmament Conference, there were reorientations of popular attitudes towards gas. As an element of anti-Fascist propaganda, stories of CBW preparations were used to arouse hostility, and as a widely recognized threat to individual safety, governments used them to secure attention to civil-defence measures. In both these roles the subject of CBW was being used yet again as a vehicle for the promotion of causes which had nothing much to do with CBW. Over the past fifteen years these had pushed CBW further and further into a realm of unreality, and it is perhaps not too surprising that when chemical weapons were used in Ethiopia, on an increasing and well-reported scale over a period of some six months, public opinion proved incapable of translating itself into restraining action, despite the high hopes that had been held out for it by the US delegation at the Washington Conference.[18]

Germany had been forbidden to manufacture chemical weapons under the terms of the Versailles Treaty, and this ban was among those supervised by the Inter-Allied Control Commission. When Germany entered the League of Nations, as a prerequisite for the opening of the Locarno talks, the Control Commission departed, as it was felt that any alleged violations of the Treaty could be handled by the League. The chemical-weapons ban was embodied in new national legislation, the War Material Law of 27 July 1927. [705] Like many provisions of the Versailles Treaty, the ban was being evaded both by the military establishment and by industrial concerns. The evasions were not on a massively obvious scale, and were never drawn to the formal notice of the League, but they nonetheless attracted the attention of political groups, and were used with varying degrees of exaggeration to further their political ends. Reports of the creation of a network of CW military research establishments appeared in British newspapers in November 1924 [710]. These and similar reports were among the accusations made by the Social Democratic Party two years later when it was trying to reduce the political influence of the army; alleged violations of Versailles

[18] Public opinion on the Italian invasion of Ethiopia was, of course, far more mobilized against Mussolini's act of aggression than against his use of gas. There was widespread protest about the latter, but only to supplement the general demand that his aggression should be stopped and his troops ejected from Ethiopia.

Treaty clauses were a focus of attack. Another focus was the collaboration of the German and Soviet armies in weapons-development programmes, including work on tanks, aircraft and poison gas [711]. The Social Democrat press carried articles disclosing shipments of poison gas from a German-built factory in the USSR to Hamburg [711–12]. Such reports did not attract much attention outside Germany until May 1928, when a large quantity of phosgene escaped from a storage tank in Hamburg attached to a factory managed by Dr Stoltzenberg, whose name had earlier been quoted in connection with a German CW agent factory in the USSR. The incident aroused considerable concern in France and the UK, for although surprisingly few Hamburg citizens were killed the incident seemed to provide concrete evidence that Germany was evading the Versailles poison-gas ban. Dr Stoltzenberg contended that the phosgene was a legitimate commercial commodity, and his defence, which he supported by a claim to the Hamburg court for compensation for the destruction of his remaining stocks of phosgene, served to intensify the debate about the convertibility of a peacetime chemical industry into a base for chemical warfare [240, 705, 712–17]. In Germany, the incident was used by the Communist Party to attack the chemical industrialists [717].

After the rise of Hitler, and with the beginnings of overt German rearmament, a number of publications appeared in the UK asserting that intensive preparations for CBW were being made in Germany. Wickham Steed's articles in 1934 on this subject [257–58], widely quoted throughout Europe and America, among other things sought to establish a continuity between the work of the new administration in this field and that of its predecessors, particularly in the matter of plans for aerochemical attacks on French and British cities. Here the emphasis was on the alleged cooperation of the Reichswehrministerium with the German aircraft industry. Other writers spoke of a similar cooperation with the chemical industry. [206, 243, 245] The overall picture presented was one of a nation controlled by evil men whose aggressive intentions and disregard for humanity were clearly apparent from their interest in CBW.

Under conditions of international tension, allegations of offensive CBW preparations were now beginning to establish their value as weapons of international propaganda. In the spring of 1936 their value increased, for in Ethiopia, during its "sacred mission of civilization", Italy demonstrated that at least one Fascist government had not only made such preparations, but was ready to put them into practice. Immediately after the failure of the Hoare-Laval Pact, or possibly even before it [340], General Badoglio authorized the use of the stocks of chemical weapons that had been building up at Massawa over the previous six months [718], first tear-gas grenades, then asphyxiant and mustard-gas bombs, and finally mustard-gas spray tanks [350]. This use of gas was reported extensively in Europe, mainly through the various European ambulances and Red Cross units that were providing the Ethiopians with virtually their only medical aid, and also through the appeals from Ethiopia to the League of Nations [340–41, 345–47, 719–30]. At first the Italian Ministry of Press and Propaganda denied these reports [731], but when the League, through the Committee of Thirteen, subsequently referred the Ethiopian complaints to the Italian Government, reminding it of the provisions of the Geneva Protocol [724], the reply was evasive. The allegations were not answered, and the competence of the committee to deal with them was questioned [732]. The committee then referred this issue of procedure to a panel of jurists and authorized the chairman of the committee and the Secretary-General of the League to examine such evidence as there was about the allegations [733]. The British delegation put in a memorandum summarizing the evidence [727]. While this was going on, *Il Giornale d'Italia* published a long commentary on the allegations, maintaining (1) that they were an intrigue to rob Italy of its fruits of victory, (2) that the photographs of alleged gas casualties might well depict Ethiopians affected by their own attempts to use gas, (3) that Ethiopia had been supplied with large quantities of nicotine for use in well-poisoning, (4) that the British Board of Trade had issued permits for the export of tear gas and mustard gas to Ethiopia, (5) that Ethiopia had received tear-gas and mustard-gas bombs from a British chemical firm, (6) that Ethiopian atrocities fully warranted reprisals, and (7) that gas had been used in past colonial wars without motives of reprisal, notably by the British and the Spanish [734]. These Italian countermoves disconcerted any action the League might have taken. Spain, whose delegate chaired the Committee of Thirteen, and the UK, who was the main advocate of action, had to cope with a barrage of damaging insinuation; the committee itself was thrown into perplexity by its panel of jurists, who said that although the committee was competent to consider the allegations, there was no formal machinery for actually verifying them. A powerful speech by the British delegate, Mr Anthony Eden, at this juncture jolted the committee into discussing the facts of the matter, and in due course it issued an appeal to the two belligerent governments to observe the rules of war. [735] After this mild reproof, nothing further was done on the matter by the League, or anyone else, even though, when it was raised again ten days later in the League Council, the Italian delegate tacitly admitted that the allegations were true [729].

Within three months of the last report of CW from Ethiopia, the Spanish Civil War broke out. By now it was inevitable that CBW would be deployed as a propaganda weapon, if not a military one, in a war of this type, particularly as it was known that at least two poison-gas factories existed in Spain [1]. In August 1936 the insurgents alleged that government forces had used gas and said that they too had large stocks of gas but refused to "break the international law which forbids its use" [256, 356]. In December, on the strength of reports from the International Brigade in Madrid that the insurgents were firing gas shell into the city, a member of the British Parliament appealed for gas masks to be sent out from England [358]. Shortly after this the British Government announced that it had sold a small consignment of gas masks to the Spanish Government, but denied that gas had been used [736]. In March 1937 it was reported that chemical companies were attached to the Italian troops aiding the insurgents, and that the Italians were carrying gas masks [353, 737]. The insurgents said that this was because they were expecting to have to defend themselves against gas [738]. A few weeks later it was reported that poison gas had been shipped from Hamburg for destinations in Spain [354]. Shortly afterwards, the British Government invited the Valencia and the Salamanca Governments to give assurances that they would not use gas [739], which they both did [739–41]. In July the matter of the alleged Hamburg gas shipments was raised again in London [742], while on the same day the insurgent forces announced that large quantities of intermediates for poison-gas manufacture had recently arrived in Spain from Black Sea ports, and that they were seeking more gas masks to protect themselves [355]. These last reports were widely quoted in the German and Italian press, and were denied by the Valencia Government [743]. Apart from one incident involving tear gas that might possibly have been correctly reported [356], the civil war ended without the use of chemical weapons ever being definitely established.

In Europe the implications of the Italian use of gas in Ethiopia seemed clear. The British Prime Minister voiced them in April 1936:

> ... If these allegations of the use of poison gas be true—and I have every reason to believe that they are true—the peril I see to the world is this: if a great European nation, in spite of having given its signature to the Geneva Protocol against the use of such gases, employs them in Africa, what guarantee have we that they may not be used in Europe? [744]

In the USA, on the opposite side of the Atlantic, the chief result was to confirm the view of gas as an inhumane terror weapon, and to resuscitate demands for prohibition of CW, so much so that in April 1937 the Department of State considered seeking US ratification of the Geneva Protocol once more [51]. But throughout Europe civil-defence programmes were being put into effect. The British programme may be taken as an illustration of these.

In May 1935 the British Government had been encouraging private organizations to study civil-defence techniques [745], and two months later the first Home Office booklet on air raid precautions (ARP) had been published [746]. From the beginning, ARP had been linked with anti-gas precautions and this first official ARP publication dealt solely with anti-gas defence. The Home Office appears to have followed a deliberate policy of emphasizing anti-gas precautions, and the process of educating the public in ARP seems to have been this: first, popular fascination with CW was to be directed to the possibility of city gas attacks; this was not a difficult task, and it had largely been done for the Home Office by others. Secondly, the public was to be assured that civilian anti-gas equipment was being designed [747–52], that anti-gas civilian training schools were being established [753–55], and that the Home Office was carrying out scientific experiments to determine precisely how gas would behave in an urban environment [756].[19] Thirdly, exaggerated estimates of the effects of gas on cities were to be deflated through series of lectures to public audiences and to civil-defence organizations, and through statements by public figures [757–59]. It seems to have been considered that most of the public was convinced that gas would be used in any city air raid, and that even if it were not there was a considerable danger that the citizens would assume that it had been, and panic. They would then both disregard the comparatively simple and effective anti-gas defensive measures that clear-headed people could adopt and neglect the bomb shelters that would be provided to meet what in fact was officially expected to be the main brunt of any attack, namely high explosive or fragmentation bombs. Until the public could be taught that gas was not a weapon against which it was defenceless, it was unreasonable to suppose that it would assimilate instructions for defence against other weapons. Conversely, people might not heed the latter instructions unless the threat to their personal safety could be graphically impressed on them, and this could be done most simply through predictions of gas attacks. Quite apart from these considerations, the problem of defence against gas was much more definable, and therefore easier to do something about, than defence against explosives or incendiaries.

The British Government at the time had sufficient information to show that the strategic gas bombing of cities was probably not an attractive military proposition to an aggressor. With the solid foundation of basic micrometeorological theory that had been developed at Porton since the early 1920s [760], supported by experimentation on the testing grounds there and at the Anglo-French station in Algeria, and later at stations in

[19] The citizens of London could sometimes observe these experiments taking place, in the form of smoke bombs detonated in the squares and streets. Parts of Southampton were sprayed with a molasses extract in simulated mustard-gas attacks.

northern India, the Middle East, Australia and Canada, the government was in a good position to make informed assessments of the efficacy of offensive CW. Although the assessments of the likely effects of gas attacks on cities remain unpublished, the indications are that gas was not regarded as being more effective against large targets than HE or fragmentation attack. For percutaneous agents, of which lewisite was probably the most toxic, it was demonstrated that the probability of death was about the same with gas bomb as with HE bomb of the same size. [761] Although the Italians had shown the effectiveness of spraying operations with percutaneous agents in Ethiopia, the limitations of such attacks were well known. With relatively involatile agents, such as mustard gas or lewisite, the probability both of accuracy and of adequate ground contamination fell off sharply above a spraying altitude of 100 or 200 metres, so that they could only be used in the absence of anti-aircraft defences. Against volatile agents, such as phosgene, which would have to be disseminated from bombs whatever the defence, citizens could protect themselves reasonably well by moving indoors and blocking off the ventilation routes. Some meteorological quirk of an urban environment just conceivably might make the gas persist for longer than was expected, but if this were thought a serious possibility, civilians could be equipped with simple respirators. The evaluation of gas as a strategic weapon thus rested on a comparison of the efficacy of equal bomb-loads of gas, explosives and incendiaries, in the knowledge that individual citizens could probably be protected against the effects of volatile CW agents. That gas was almost certainly outclassed in government assessments of this type emerges from the accounts of CW published by Professor Haldane in 1938 [762] and General Thuillier in 1939 [244]. The most favourable estimate of the capability of gas as a strategic weapon against masked civilians might have sanctioned its use in bomb-load mixes containing 60 to 90 per cent HE; and the later assessments of the efficacy of incendiary bombing would probably have made even this excessive. Apart from anything else, antipersonnel effects were less useful strategically than the destruction of factories and machinery, however highly regarded the demoralizing effects of gas might be. Gas was thus unlikely in any event to be an obvious weapon to an aggressor, and civilian anti-gas precautions would make it even less attractive.

It was probably on this basis, then, that official attitudes to civilian respirators were founded. The British public were kept closely informed of the progress made in their manufacture and of the arrangements for distributing them. In November 1936 the commencement of manufacture was announced [763]. By the beginning of April 1937, five million masks were in storage depots, accumulating at a rate of half a million per week [764]. Thereafter frequent progress reports were published [765–69]. During the last week of September 1938, on Hitler's invasion of Czechoslovakia, thirty million masks were issued to the public[20] [770]; when the risk of war afterwards temporarily receded, manufacture went ahead at an increased rate, and by May 1939 there were more than enough in the country for everyone except very small children [772].

It would have been surprising if so large an undertaking as the British ARP programme did not involve a good many misperceptions and blunders; it was certainly not without critics. The Labour Party opposed it from its inception, as did pacifists within and without the party, both on points of principle and on points of detail. The provisions for anti-gas protection were severely attacked, notably the Home Office recommendations for the construction of gas-proof rooms [773], and the inability of the civilian respirator to protect against aerosols [774]. The latter shortcoming was easily demonstrated at public meetings by blowing cigarette smoke through the respirator filter [383], and to a public that had been told that 40 tons of organoarsenical CW agent, disseminated as a smoke, could destroy the whole of London, this was disturbing. The Home Office was eventually forced to issue a particulate filter for attachment to the civilian respirator [775], knowing that an enemy was still less likely to use toxic smokes against civilians than other types of CW agent.

IV. *The influence of popular attitudes towards CBW*

The foregoing account gives some idea of the growth and exploitation of popular attitudes towards CBW during the period between the two world wars, particularly in the USA and the UK. It now remains to see to what extent these attitudes may be said to have influenced contemporary CBW policy making. Can it be concluded, for example, that the strength of popular hostility towards CBW was ever sufficiently influential to prevent usage of CB weapons? Or that popular disapprobation of CBW in any way affected the execution of national CBW preparedness policies?

The earlier part of this chapter contains some evidence that public opinion did indeed have a significant effect in both these respects during the period under consideration. But this evidence is circumstantial at best; it suggests that, had it been possible to examine the records of the relevant CBW policy-making bodies, indications would have been found that the decisions taken had been influenced by the attitudes of the general public, either

[20] The first issue of civilian respirators in Berlin took place in August 1937, under a scheme of compulsory purchase [771].

directly or indirectly. While the foregoing account is too limited to permit firmer conclusions than these, it does allow a series of hypotheses to be put forward about the manner in which public opinion on CBW might have been influential. These hypotheses fall into two groups: one group relates to the manner in which public opinion may restrain peacetime CB weapons development and procurement programmes; the other group relates to the manner in which it may restrain actual use of CB weapons.

There are a number of ways in which a climate of opinion that is hostile towards CBW might impede peacetime CB weapons programmes. The fact that CBW is unpopular outside the military establishments may make it harder for its protagonists to gain support within them. Popular hostility towards CBW may impede the voting of adequate public funds for a CB weapons programme. Public demands for the abolition of CBW may promote CB disarmament negotiations that may be difficult to conduct with any degree of credibility while an overt CB weapons programme continues. All these constraints would gain strength from the fact that the international laws of war prohibit the use of CB weapons.

It is possible to find support for these propositions from the various governmental actions that have followed the public controversies over CBW in many countries over the past two years.[21] As for evidence from the inter-war years, it will be useful to summarize the relevant parts of the discussion in this chapter.

From their initial mobilization at the hands of publicists and lobbyists, popular attitudes towards CBW throughout much of Europe and America were concerted in their hostility. As they gathered strength in the early 1920s, they had the effect of stimulating and sustaining international efforts to abolish CBW. There can be little doubt that many governments entered into the consequent CB disarmament negotiations in good faith, anxious to secure agreements that would diminish the likelihood of future CBW. A number of valuable treaties intended to restrain use of CB weapons were concluded as a result of this. As for the negotiation of actual CB disarmament agreements, it is possible to contend that popular demands for this were so strong as to be counterproductive: the vehemence of the hostility towards CBW, reflecting an underlying fearfulness that undoubtedly overestimated the military attractions of CB weapons, deflected the negotiations into unproductive paths that were directed towards securing extremely rigorous controls over CB disarmament. It can also be argued, however, that the general climate of hostility towards CBW, the demands for its abolition,

[21] For example, the British Government's initiative in directing the attention of the ENDC towards BW in 1968, and the public statement on US CBW policy made by President Nixon in November 1969.

the elaborations and enunciations of national CBW policy that were made by governments in the course of the various CB disarmament talks, all produced reverberations within national military establishments that made it easier for military authorities to give force to their own professional distaste for CBW by repressing or ignoring its protagonists. And even if there were enthusiasm for CBW within military establishments, it would certainly have been difficult, at least in the more democratic countries, to persuade the relevant political authorities to sanction CB weapons expenditure in the face of hostile public opinion. These latter points are illustrated more fully in Chapter 4, which describes national CBW policies and programmes during the inter-war years, and in Chapter 5 which discusses the level of offensive preparedness for CBW among the belligerents at the outbreak of World War II.

Two propositions can be made about the manner in which public opinion may restrain a governmental decision to use CB weapons in time of war. First, the reaction of the domestic public may weaken the government's popular support and lower the morale of its armed forces. Second, the popular reaction abroad within countries not directly involved in the war may lead these countries to withdraw whatever support they have hitherto been providing, or even to intervene or to give aid to the opposite side. Enemy propaganda can certainly be expected to encourage all these reactions.

As for the possibility of adverse domestic reaction, a government authorizing use of CB weapons may not have to worry unduly about the repercussions at home provided either that it has enthusiastic popular support for the war or that its continued existence in power is not directly dependent on the wishes of the domestic population. The possibility of adverse reaction abroad is generally likely to be more serious. Allusions to this have been made in several places earlier in this chapter. Thus, at the time of foreign intervention in the Russian Civil War, public feeling on CW had not yet crystallized, and chemical weapons could be used as the military circumstances dictated; but during the Moroccan wars, a few years later, the French were sufficiently mindful of popular hostility towards CBW to issue public denials that they were using chemical weapons. During the Italian invasion of Ethiopia, Ethiopia and its supporters were able to increase the fierce antagonism in the UK towards Italy by publicizing the gas attacks, and so to maintain British popular enthusiasm for the League sanctions. During the Spanish Civil War neither side used gas on any apparent scale; one explanation could well be that the military advantages of using gas were far outweighed by the likelihood of a damaging reaction from outside opinion. International attention was closely focused on this conflict, and both sides were relying on and soliciting outside support: the justness of their causes could have been besmirched by reports that they were pursuing them by ignoble means.

In this connection, three further points are worth noting. First, in a war which does not attract international interest or which, through geographical remoteness or poor communications, cannot do so, the fear of arousing hostile propaganda may not constrain use of CB weapons. Secondly, if one side uses CB weapons, the other side may abstain from doing so in order to reap propaganda benefits. To some extent, this was the policy followed by the Allied powers during the summer of 1915, but here the propaganda slant was less on their own abstention—they refrained from immediate small-scale retaliatory gas attacks in order to achieve massive surprise later on—but rather on the iniquities of their enemy. Thirdly, it may be possible to make propaganda capital by fabricating quite untrue accounts of the enemy's use of CB weapons, a policy that has certainly been followed on many occasions. The last two policies rely for their usefulness on a climate of international feeling that is easily aroused by CBW, even to the point of gullibility or a readiness to believe the worst of the impugned belligerent.

The constraint on initiating CBW that may be engendered by the possibility of provoking adverse reactions abroad may arise not only from considerations of popular attitudes towards CBW, but also from the fact that the international laws of war prohibit CBW. To some extent these two factors are one and the same thing, for international law may be regarded as one of the forms in which public opinion finds expression. Behaviour that infringes international law is likely also to flout public opinion, and the expected reaction of the latter, whether spontaneous or provoked by hostile propaganda, is one measure of the strength of the law. Thus, not only may public opinion contribute to the creation of international law, but it may also provide the sanction against its infringement. In this respect it may be noted that the leaders of Nazi Germany are reported to have had a respect for the Geneva Protocol that went beyond the military inexpediency of the Wehrmacht infringing it: thus, in his account of German CW activities during World War II, General Ochsner[22] frequently refers to the "stigma" that would attach to any nation that contravened the Protocol [212].

International law has several components, of which conventional law, as embodied in formal international agreements, and customary law are the most important. The description of the genesis of the 1925 Geneva Protocol given earlier in this chapter illustrates the manner in which public opin-

[22] See pages 154 and 296 n.

ion may generate new conventional law. The relationship between public opinion and customary law is also very close, and is worth exploring in some detail here.

Customary law is a way of describing certain of the tacit norms of behaviour that govern international relations. It refers to those established usages or practices of states that have come to be regarded as obligatory. As described in Volume III of this study, the customary law of war, in addition to conventional law, proscribes the use of CB weapons. Yet customary law is constantly changing: at first governments may observe practices or usages simply because they are expedient, but may later do so because they are thought to be obligatory. This is one of the processes by which customary law evolves, and the contribution to it of the opinion of an electorate may obviously be an important one. For example it is doubtful whether a US administration would ever think it prudent to disclose to the public the existence of a first-use CW policy directive, and since 1918 the declared policy has always been retaliation only. Divergences of declared policy from tacit policy on a particular practice make it hard for jurists to define what the actual government usage has been, so that the relationship of US Government practice on CW around 1934, when a first-use authorization was in fact in force, to the ban on CW in customary law is hard to establish. Yet it is clear that declarations of policy by one government are likely to influence the actual policies of other governments, and hence the development of customary international law.

The default of one government may not invalidate a rule of customary international law provided the practice to which the rule refers is observed by a sufficient number of other governments. This principle applies both to declarations of policy and to policy as it is put into practice, and if one government violates the customary law prohibition of the use of CB weapons, it does not follow that the prohibition will cease to exist. If several governments begin to use CB weapons in war, then the customary law prohibition may weaken, for just as it arose in part from the ascendency of obligation over expediency, so it can decline if this ascendency is reversed. To some extent, this is a question of numbers: ten violations may be the exceptions that prove the rule, but the eleventh may be the one that disintegrates it. In fact the situation is more complicated, for customary international law depends not only on government usage but also on government perception that the usage is obligatory: even if twenty European or American nations are using gas, African nations may still feel an obligation not to use it. Here again a strong and obvious climate of feeling among electorates will reinforce such perceptions of obligation by governments.

By the same count, unverified reports of CBW may not necessarily weaken the customary law prohibition, for it is not so much whether the reports are true or false, or how many there are, but rather whether governments believe them sufficiently to start questioning their obligations to the practice of non-use. In a tense international situation, with nations ready to believe the worst of one another, unverified reports of CBW may be damaging to customary law, and it would then become even more important that the reports should be publicly investigated. The broadcasting of a deliberately false CBW report is a mark of someone's high assessment of public hostility towards CBW, and if it is effective as propaganda, whether governments know it to be true or false, it is thus perhaps more likely to reinforce feelings of obligation than to reduce them.

This whole question of the scope and strength of the legal constraints on the initation of CBW is discussed more fully in Volumes III and V of this study.

The foregoing propositions about the influence of public opinion on national CBW policies are developed further in the course of Chapters 4 and 5 of this volume. Their validity under present-day conditions is discussed in Volume II.

Chapter 4. National CBW programmes and policies, 1919–1939

In this chapter we review what we know of national CBW policies and programmes during the period between the two world wars. This review is intended to complement Chapter 3, where certain propositions were made about the influence of public opinion on national CBW policy making. It is also intended to provide a background for the discussion in Chapter 5 of the non-use of CB weapons during World War II; for this reason it concentrates on the pre-World War II CBW policies of the principal nations involved in that war.

The scope of the review is greatly restricted by a shortage of information. Only in the cases of the USA and Germany has it been possible to illustrate particular trends. For Germany, our aim has been to provide an historical illustration of the range of organizations and activities that may be involved in national CW programmes. For the USA, we concentrate mainly on CW policy making, in particular the influence on it of public opinion in its various manifestations. For other countries we merely set out what we know. In the case of the UK, France, Italy and Japan, there is too little published information to do anything else; in the case of the USSR, the available source material is both too scanty and, with certain exceptions, too unreliable.

I. *The United Kingdom*[1]

Although actual manufacture of chemical weapons in the UK ceased with the Armistice [776], it seems that immediately after World War I there was no serious thought of stopping governmental R & D work in the field of CW, even though in April 1921 the War Office said that no final decision had yet been taken about the future of the Chemical Defence Experimental Station at Porton [777]. In 1920 the War Office invited some sixty scientists from the universities and industry to join representatives of the armed

[1] State papers for the period under discussion are now becoming open to public inspection, but the notes which follow rely primarily on the contemporary press and reports of parliamentary debates.

forces [778] on a CW advisory committee [666, 779], to "develop to the utmost extent the offensive and defensive aspects of CW" [667], and although this arrangement aroused much popular hostility at the time, the committee nonetheless functioned throughout the inter-war years despite recurrent harassment, generally in the form of parliamentary questions about the remuneration its members received [780–82]. By 1926 the committee was made up of twenty-five regular members and about ninety associate members, of which sixteen were connected with the chemical industry [783]. Besides the War Office, the Committee of Imperial Defence also had an advisory subcommittee considering CW [784].

Shortly after the conclusion of the 1922 Washington Treaty, the War Office stated that: "[T]he Government would be failing in its duty if it failed to take all possible steps which might be necessary to protect the forces of the Crown and the inhabitants of the country against gas attacks in time of war. . . ." [785] The Porton experimental ground would therefore not be closed down. However, all subsequent statements on official CBW policy up to about 1936 emphasized that the experimental work had been restricted to defensive studies [776, 786]. Governmental manufacture of CW agents was confined to the small amounts needed for this experimentation [776, 787–89], and it was stated that subsidies were not being paid to manufacturers for the production either of CW agents or of BW agents [790–92]. The armed services were being given no training in offensive CW [793–94].

The British signed the 1925 Geneva Protocol, but delayed ratifying it until nearly five years later. During the interim period, the government was called upon to explain the motives for its delay on several occasions [795–99]. In July 1928 a Foreign Office spokesman stated that the government was not prepared to ratify the Protocol unless all the signatories were ready to do so [795]: by that time, there were in fact only six ratifications. However, on 21 March 1929 the German Reichstag voted for German ratification [800] which was duly performed a month later. In the King's Speech at the opening of Parliament in May, the British intention to ratify was announced [801]. Yet this intention was not put into practice until April 1930. A month before ratification, the government announced its interpretation of the Protocol to Parliament: "Smoke screens are not considered as poisonous and do not, therefore, come within the terms of the Geneva Gas Protocol. Tear gases and shells producing poisonous fumes are, however, prohibited under the Protocol." [802] The government was aware, however, of indications that such an interpretation (at least insofar as it related to irritant agents) was not shared by all states, and, in a memorandum to the Preparatory Commission of the Disarmament Conference in November 1930 [698], argued for the desirability of a uniform construction. It reiterated its own construction both in the memorandum and in Parliament[2] [803-804].

That the Protocol would not alter the government's declared policy of readiness to meet CW attack was made clear by the War Office soon after the Protocol had been signed: "The Government does not feel that the [Geneva Protocol and the Washington Treaty] justify it in omitting to take all possible precautionary measures against gas attacks in war, and for this reason the [work at Porton] must continue." [806] This view was repeated both before [807] and after [808-809] the British signature to the Protocol had been ratified. The reservations made on ratification were that the UK would not be bound by the Protocol as regards non-parties, or as regards enemies (or their allies) who infringed the Protocol. In this, the UK, unlike Germany, Italy and Poland, followed the practice established by France, the USSR, Belgium, Australia, New Zealand and South Africa.

By 1932 some CW research work had been contracted out to laboratories in the universites of Oxford, Cambridge and London [791, 810-11] and arrangements had been made with industry for the assembly of respirators and for the production of "chemicals required for the testing of those respirators" [791]. The latter disclosure seemed ominously vague to many members of the public, but the War Office would not clarify it [781, 812]. An Order in Council, dated 8 June 1937, prohibited the unlicensed export of poison gas from the UK [813]; and the government said shortly afterwards that there was no reason to suppose that there had been any British export trade in CW agents since January 1936 [814].[3]

[2] The reiteration of the government's interpretation in Parliament followed a parliamentary question about the scope of the Protocol [804]. The question was addressed to the Foreign Secretary, and his written reply, which was given on 17 December 1930, was based on a Foreign Office brief that had been drafted by E. H. Carr, the historian, then at the Foreign Office. This brief, which is now open to public inspection at the Public Records Office in London [805] contained the following passage:

> "... The position in regard to the Gas Protocol is complicated by the fact that the Americans and others do not regard the prohibition as extending to tear gas, which apparently is harmless to health, and, in point of fact, have recently made use of tear gas in dealing with civil disturbances. We, on the other hand, as stated in the answer to a previous question, ... do regard tear gas as prohibited by the Protocol ..."

It thus appears that even though the Foreign Office was aware that some tear gases might be "harmless to health", it nonetheless took the position that British policy should be to oppose the use of such tear gases in war. The significance of this interpretation as regards the international laws of war is discussed in Volume III of this study.

[3] It seems probable that these references to the production and export of CW agents related to irritant agents. In 1923 the *United Alkali Company*—absorbed by *I.C.I. Ltd.* in 1926—had erected a 100 kg per month plant for manufacturing chloroacetophenone (CN); it did so after a British delegation had visited the US CW R & D

Table 4.1 collects together such information as is readily available on British CW expenditure during the period 1919–1936, together with some figures for the number of governmental workers involved at different times on the CW research programme.[4]

On the face of it, it seems that any idea of maintaining an offensive CW capability, whether for first use or retaliation in kind, departed from official British policy, insofar as it was made known to the public, at around the time of the Washington Treaty. It is reported that the contingency planning for war, as embodied in the War Books of the Committee of Imperial Defence from 1930 onwards, contained repeated reminders of the UK's commitments, including its obligations under the 1925 Geneva Protocol. [784] The acquisition of a retaliatory CW capability does not seem to have begun until quite late in the rearmament period: for example, it was not until October 1938 that the Cabinet sanctioned the procurement of mustard gas, and then only an order for 2 000 tons [815].

Government contingency planning for the procurement of CW agents during the period between the two world wars has been described as follows:

> Government policy was to rely on [the British chemical industry] for the bulk production of chemical warfare agents but to carry out in government establishments the research and development necessary to provide information for the design of the production plants. The industry undertook to design, erect and operate the necessary plants for making mustard gas from information supplied by the operation of pilot plants at the Chemical Defence Research Establishment, Sutton Oak, Lancashire. The staff needed to operate plants for making chemical agents were trained at this establishment. The creation of these sources of war potential involved a major effort on the part of the industry. It had to supply the design staff and other skilled personnel to translate the pilot plant practice used by the research establishment into large-scale production. The dangerous nature of the materials necessitated a different outlook on plant design from that current at the time in the chemical industry. The health and safety of the workers had to be given a high priority in design considerations; the safety of the public outside the factory had also to be ensured by special plant and factory layout which had no parallel in the industry as then organized. The

laboratories in 1922 to study the work being performed there. By 1927 I.C.I. had a plant capable of producing 2 000 kg per month of CN. The output went into small dispensers used for testing respirators, into field-training weapons, and into riot-control apparatus. [60]

[4] CW research work was the responsibility of the War Office, guided by committees of various sorts, and the experimental stations performed work for all three armed services. Throughout most of the period considered, the programme was directed by a central Chemical Defence Research Department in London, responsible to the Master-General of Ordnance. The CW budget was distributed between the manufacturing/research establishment at Sutton Oak, the London department itself (its funds apparently included those used to finance extramural work in the universites), the Anti-Gas Training School, and the research establishment at Porton (which alone accounted for most of the budget).

Table 4.1. Funding and establishment for British CW R & D, 1919–1936

	CDRD and all its subsidiaries, including the CDES, Porton		CDES, Porton	
Financial years[a]	Expenditure[b] (*£ thousands*)	Approved establishment[c]	Expenditure (*£ thousands*)	Approved establishment[c]
1920	..	410[d]	90	..
1921	..	..	54	..
1922	..	..	81	..
1923	169	..	87	..
1924	..	..	103	..
1925	..	..	115	..
1926	..	480	132	222
1927	148	..	..	266
1928	..	..	..	..
1929	..	..	..	..
1930	..	535	..	..
1931	ca. 200	553	..	..
1932	..	..	..	..
1933	..	..	..	..
1934	..	502	..	..
1935	..	..	..	..
1936	121	..	87	..

.. = unknown.
[a] Year ending 31 March.
[b] It was estimated [206] that the total CW R & D expenditure from 1919 to 1935 was rather more than £2 million. For 1935–36, the total expenditure of £121 310 was split as follows:

CDRD, London	£12 700
CDES, Porton	£87 000
Research establishment, Sutton Oak	£14 000
Anti-gas Training School	*£ 7 610*

[c] Number of staff on approved establishment at the beginning of the year.
[d] Excluding the Sutton Oak establishment, which was then still controlled by the Ministry of Munitions.
Source: See references number 206, 787, 843–49.

techniques for storing toxic material and for effluent disposal were developed by the government establishment.[5] [60]

At the outbreak of World War II, the British stockage of CW agents comprised about 500 tons of mustard gas, 5 tons of bromobenzyl cyanide, and a small quantity of chloroacetophenone. During the war the only other CW agents produced on a significant scale were phosgene and a higher sulphur mustard (T); a variety of candidate CW agents were made on a pilot-plant scale.[6]

While actual production of chemical weapons does not appear to have been resumed on a large scale until the winter of 1938/39, development

[5] Anticipating the discussion in Volume II of this study, it is worth noting that when British work on the nerve gases got underway, after World War II, it was deemed necessary to transfer pilot plant activities from Sutton Oak—situated in a densely populated industrial part of the country—to Nancekuke, on a remote stretch of the Cornish coastline.
[6] These included diphenylcyanoarsine, lewisite, sesquimustard, three nitrogen mustards (HN-1, HN-2 and HN-3), diisopropyl phosphorofluoridate and ricin.

work had certainly been continuing for some time before then. In April 1936 a War Office spokesman told the House of Commons that:

> No training in the use of poison gas as a weapon of war is carried out in the Army, but possible methods of the use of gas have naturally to be studied in connexion with training in defence against gas. Chemical experts have, of course, been closely associated with the Army in connexion with such training. [794]

The suggestion here was that defensive measures against CW attack could not be elaborated without careful study of the forms which attack might take. It is not known precisely when a policy of developing offensive CW techniques for their own sake was first put into practice, but it was presumably not much later than the statement quoted above: the chemical weapons that the British had on hand when World War II started were considerably more sophisticated than those of 1918, which must mean that a weapons-development programme had been going on for some time.

The establishment at Porton provided the principal proving ground for CW matériel, but other testing facilities were also available. These included the various out-stations of Porton and other army installations in British territories overseas, notably in northern India, Australia and the Middle East [816–17]. A certain amount of CW field work was also done in the British Isles at locations other than Porton: spray-tank experiments were conducted in the mountains of north Wales [818], for example, while in the early 1920s large-scale meteorological studies of the aerosols generated from naval toxic smoke floats had been carried out at sea in the vicinity of Scapa Flow [819]. More important than these, from the point of view of the development of actual weapons, was the liaison which the British established with the French CW authorities sometime before World War II broke out, for this made available the huge CW proving ground at Beni Ounif in the Algerian Sahara [63].

When the war started, British chemical troops comprised a number of Royal Engineer Chemical Warfare Companies.

The British did not begin any serious experimentation in the field of BW until around 1940; this has already been described in Chapter 1.

II. *The United States*[7]

Immediately after World War I, the prevailing sentiment within the US War Department was that the USA would not initiate CW in any future conflict,

[7] This discussion relies almost entirely on the recent study of US CW policy from 1919 to 1945 by F. J. Brown [51]. Brown had direct access to most pre-World War II US CW policy documents.

but would be ready to retaliate in kind and defend itself against any enemy use of chemical weapons. The dismantling of the Army CWS was advocated on this basis: readiness for defence and retaliation was not considered a sufficiently serious business to warrant the retention of a separate technical service.

Brigadier Fries managed to persuade Congress not only that a separate CWS was essential even under the War Department policy, but also that it could provide the basis for what he had succeeded in convincing many Congressmen was a more attractive policy, namely that of deterrence. The CWS *Annual Report* of 1920 stated:

> The knowledge among other countries that the United States is doing this [the mission assigned to it by the 1920 amendment to the National Defense Act, namely R & D, maintaining a stand-by production capability, and training its troops in offensive and defensive CW] will go a long way toward deterring them from forcing hostilities, knowing that the United States with its incomparable natural resources and highly developed manufacturing possibilites will be able to manufacture and deliver on the field of battle a greater quantity of chemicals than any other single nation, or indeed any other group of nations.

By suggesting that a national CW capability of the type sanctioned by Congress might deter not only the initiation of CW, but also war itself, the CWS clearly hoped to modify the retaliation-only policy of the War Department into one of first-use. The War Department would not accept this, and in its reorganization of the army it effectively ignored the wishes of Congress on the future of the CWS: chemical troops were denied an explicit combat mission, and the full amount of funds appropriated for the CWS, small though they were, were not always actually allocated by the War Department. However, by the end of 1921 the War Department was prepared to authorize the CWS to train all branches of the army in CW techniques, including offensive ones.

The reversal of US negotiating policy on CW during the Washington Conference of 1921–22 has been noted in Chapter 3. It led to a drastic revision of War Department CW policy, and in June 1922 new general orders forbade the CWS to give instruction in offensive CW, to carry out offensive CW R & D, or to procure chemical weapons, a policy that implied that the USA might not even retaliate in kind in the event of chemical attack. The pressure of opinion within the USA had thus gone much further than merely securing the government's signature to an international treaty which might well prove to be worthless: it had caused the War Department to put into practice a policy which was still further removed from CWS hopes for a first-use policy, and which would considerably delay, if not prevent, US initiation of retaliatory CW.

As new people came to the top within the War Department, the objections which the CWS made to the Department's CW policy began to receive more attention. By the time of the 1925 Geneva Protocol, the question of national preparedness to meet chemical attack, in particular the peacetime preparation that should be made to fulfill a retaliation-in-kind requirement, was receiving closer scrutiny. Opposition within the Department towards ratification of the Protocol, particularly by the War Plans Division, was apparently based not so much on a wish to adopt a first-use CW policy, but rather to avoid giving outsiders the opportunity to criticize the preparations on which retaliation-only policy had to be based. It was feared that it would be virtually impossible to allocate scarce military resources to increase CW preparedness when the use of chemical weapons in war had been prohibited. Before 1926, at the Washington and Geneva Conferences, the USA had publicly encouraged the development of world popular opinion as the primary constraint against violation of the CW prohibition, with CW preparedness being tolerated as an additional insurance against initiation of CW. But after 1926 proponents of preparedness as the dominant restraint began to find high favour.

This shift in policy was a gradual one, and took place mainly during consideration of the correct US negotiating policy on CW for the League's Disarmament Conference. The War Department recommendations led to a marked isolation of the USA during the eventual CW discussions. The majority of the European nations, in advocating a strengthened prohibition of CW, were prepared to disarm themselves of the capability to retaliate in kind against violations of the ban. The USA, reflecting the War Department views, was not prepared to put that much faith in the ban, and contrived to delay European plans to abolish CW throughout the first year of the Conference. In 1933, however, the War Department's views were overruled by newly-elected President Roosevelt, who gave his approval to the draft treaty that the British had tabled. *Inter alia,* this draft provided for an inspected ban on peacetime manufacture of offensive CW matériel and a prohibition of CW that explicitly outlawed use of harassing agents such as tear gas, and was not subject to the reciprocity reservations of the Geneva Protocol.

Although this initiative by President Roosevelt came to nothing, with his strong personal aversion towards CW he later provided a powerful restraining influence on War Department CW planning. It is not clear just how his views on CW were formed,[8] but he was presumably as open as anyone

[8] As Assistant Secretary of the Navy, Roosevelt had been a member of the Advisory Committee formed by C. E. Hughes to advise the US delegation at the Washington Conference [832]. (See page 243.)

else to the influences that had moulded popular hostility towards CW. His three predecessors in office had also been hostile to CW. President Hoover had publicly condemned gas as an aggressive weapon at the Disarmament Conference, while during the 1925 Geneva Conference President Coolidge had agreed to call a special conference in Washington to prohibit the use of chemical weapons. President Roosevelt's views were most vehemently expressed in 1937 when he vetoed a bill to change the name of the CWS to "Chemical Corps".

By 1933 the War Department had adopted the view that CW preparedness demanded not only defensive preparations but also an offensive capability poised for retaliation-in-kind. At the end of 1934 US CW policy hardened still further. As formulated by the Joint Board (the predecessor of the Joint Chiefs of Staff), it read:

> The United States will make all necessary preparations for the use of chemical weapons from the outbreak of war. The use of chemical warfare, including the use of toxic agents, from the inception of hostilities is authorized, subject to such restrictions or prohibitions as may be contained in any duly ratified international convention or conventions, which at that time may be binding upon the United States and the enemy's state or states.

By the following year, the partial rehabilitation of the massive World War I mustard-gas plant at *Edgewood Arsenal*[9] had been approved by the Secretary of War. The background to this radical change of policy by the Joint Board is not recorded.

Despite the new War Department enthusiasm for CW preparedness, which was put into practice by increased backing for the CWS, and despite support for the policy from Congress, nearly another decade passed before the army possessed even a modest retaliatory CW capability. As it happened, the War Department's enthusiasm was short-lived, and with a change of Army

[9] After failing to interest the US chemical industry in the production of CW agents, the US Army Ordnance Department began to erect a series of CW agent manufacturing and weapons-filling facilities at Edgewood, Maryland, towards the end of 1917. In May 1918 these installations were collectively designated "Edgewood Arsenal". A month later control of Edgewood Arsenal was assigned to the newly created Army Chemical Warfare Service. At the time of the Armistice, the USA was manufacturing about as much gas (chlorine, phosgene, chloropicrin, bromobenzyl cyanide, diphenylchloroarsine, mustard gas and lewisite) as France and the UK combined, and nearly four times as much as Germany, although little of it reached Europe in time to be used. The bulk of US production came from Edgewood Arsenal. After the war, CW R & D laboratories were established at Edgewood, together with limited proving-ground facilities, and the Arsenal became the headquarters of the CWS. A certain amount of field work was performed at the Ordnance Department's Aberdeen Proving Ground, Maryland. It was not until 1942–44 that the CWS began to acquire experimental facilities outside Edgewood, notably BW laboratories at Camp Detrick, Maryland, and the new proving grounds at Dugway in Utah, at Bushnell in Florida, and on San José Island off the west coast of Panama.

Table 4.2. US production of CW agents, 1922–1945

Agent	Total CWS procurement (*tons*)	CWS production facilities: Location	Year of completion
Chloroacetophenone	600[a]	Edgewood Arsenal, Md.	1922
		Edgewood Arsenal	1943
Adamsite	300[a]	n.a.	
Phosgene	18 200[a]	Edgewood Arsenal	1937[b]
		Edgewood Arsenal	1941
		Huntsville Arsenal, Ala.	1944
		Duck River CWS Plant, Tenn.	1945
Mustard gas (Levinstein)	79 300	Edgewood Arsenal	1937[b]
		Pine Bluff Arsenal, Ark.	1942
		Rocky Mountain Arsenal, Col.	1943
		Huntsville Arsenal	1943
Hydrogen cyanide	500[a]	n.a.	
Lewisite	20 000	Huntsville Arsenal	1942
		Pine Bluff Arsenal	1942
		Rocky Mountain Arsenal	1943
Nitrogen mustard (HN-1)	100	Pine Bluff Arsenal	1943
Iron pentacarbonyl	?	Huntsville Arsenal	1943
Cyanogen chloride	11 400	Owl (4X) Plant, Calif.	1944
Mustard gas (distilled)	4 100	Edgewood Arsenal	1945
		Rocky Mountain Arsenal	1945

n.a. = not applicable.
[a] Includes CWS procurement from commercial sources.
[b] Rehabilitation of World War I plant.

Source: Brophy, L. P., et al., *United States Army in World War II: the Technical Services: Chemical Warfare Service: From Laboratory to Field* (Washington, 1959).

Chief of Staff in October 1935 some of the old hostility towards the CWS revived. Furthermore with the country just emerging from the Depression, the funds were not available for extensive procurement of new equipment. In the late 1930s the army was little more prepared for CW than it had been in the 1920s, despite the revision of underlying CW policy.

Table 4.2 gives details of the US CW agent manufacturing programme from its resumption after World War I until the end of World War II. When the USA entered the Second World War, its stockage of CW agents amounted to about 500 tons, of which half was mustard gas.

Table 4.3 summarizes the Congressional appropriations of funds for the CWS during the period 1921–1942, and includes figures for its civilian and military personnel strength. Copious details of the organizational structure for CW activities in the USA during the inter-war period are to be found in the three-volume history of the Army CWS published as part of the official history of the US Army's role in World War II [30, 210, 267].

As regards BW, the USA did not embark upon a serious exploratory programme until around 1942. This has been described in Chapter 1.

Table 4.3. Funding and establishment of the US Chemical Warfare Service,[a] 1918–1942

Fiscal year[b]	Congressional appropriation (*$ mn*)	Personnel on CWS establishment at start of fiscal year	
		Civilian and military	Military only
1919	..	ca. 23 000	22 198
1920	..	..	..
1921	..	..	..
1922	1.35	..	602
1923	0.60	..	427
1924	0.70	1 247	494
1925	0.70	..	513
1926	0.91	..	496
1927	1.23	..	498
1928	1.30	..	531
1929	1.30	1 267	501
1930	1.25	..	491
1931	1.30	..	528
1932	1.25	1 240	498
1933	1.22	..	490
1934	1.26[c]	..	502
1935	1.26	..	533
1936	1.39	..	752
1937	1.48	..	864
1938	1.53	..	836
1939	2.87	..	894
1940	2.09	2 230	1 128
1941	60.09	..	5 892
1942	1 067.46	..	20 225

.. = unknown.

[a] The CWS, a US Army technical service, performed almost all US CW R & D during this period. The US Navy carried out additional but spasmodic CW work, both within its own establishments and through contracts let to the CWS. Navy CW expenditure, however, was negligible compared with that of the CWS. [51] Navy CW work accelerated in 1940 [850].

[b] Year ending 30 June.

[c] The CWS in fact received only $748 378 during FY 1934. In subsequent years, with increased Congressional support, its allocations matched the authorizations. In FY 1935 the CWS was actually appropriated and allocated more than it had requested. The total War Department authorization for FY 1933—the last pre-Depression budget—was around $340 million, and for FY 1934 around $240 million. [51]

Source: Brophy, L. P. and Fisher, G. J. R., *United States Army in World War II: the Technical Services: the Chemical Warfare Service: Organizing for War* (Washington, 1959).

III. *Germany*

The Versailles Treaty prohibited Germany from manufacturing or importing chemical weapons. Factories producing the weapons were closed and surplus stocks destroyed. Work on CW protective equipment was not prohibited, but with an upper limit on the size of the permitted armed services, few military personnel were available to carry out such work. The principal World War I CW R & D establishment—at the *Kaiser Wilhelm-Institut* in Berlin-Dahlem—had been closed in 1919, but members of its former Gas Defence Section continued to work on protective equipment at the *Hauptgasschutzlager* of the Reichswehr, located in Berlin until 1921 when it moved to Hannover. Their work was primarily concerned with the maintenance of wartime respirators: new respirators were procured from industry, primarily from *Auergesellschaft* in Berlin-Oranienburg [820].

As the supervisory powers of the Inter-Allied Control Commission began to decline after 1924, more exploratory CW research work became possible, but for some years this was severely limited by the shortage of funds that arose from both the economic plight of post-war Germany and the lack of interest in CW among higher military authorities [51]. However, in 1926 the Reichswehr established four new *Gasschutzlager* for the maintenance of CW protective equipment, in the ordnance facilities at Kassel, Königsberg, Ingolstadt and Berlin-Spandau. More significantly, it also established a central CW research laboratory in Berlin, at Spandau (Zitadelle). Here the first major project was to develop a new respirator, and in due course a much improved design was evolved and tested. It was eventually manufactured by Auergesellschaft who themselves did a certain amount of R & D work in the field of anti-gas protection. The small quantities of CW agents needed to test new defensive equipments were produced at the Technische Hochschule in Berlin-Charlottenburg starting in 1926. This laboratory was also engaged in the development of analytical techniques for CW agents, particularly detectors for mustard gas. At about this time the Charlottenburg laboratory also embarked on a search for new CW agents, and related work was begun at Würzburg University and at one other laboratory [820–21].

From about 1922, the Reichswehr had been building up contacts with the Soviet Army, and this had led to the creation of a number of secret joint Soviet-German weapons-development and troop-training programmes inside the USSR. Included in this programme were plans for joint work in the field of CW, both as regards the manufacture of CW agents and the operation of experimental establishments [711]. For the German part in this, the plans for CW agent manufacture seem to have been more of a commercial venture than one in which the Reichswehr was especially interested [711, 821]. The plans for joint CW experimental work, however, were encouraged by the Reichswehr, particularly after 1926 when the need for a substantial CW proving ground was becoming apparent. To this end, the Reichswehr had in fact considered cooperating in a joint German-Hungarian experimental project, but it had more confidence in the proposed arrangements with the USSR [820–22]. In due course detailed agreements were reached on this which led to the creation of the *Tomka* project at Shikhani, 15 km from Volsk [711, 823]. The German staff here numbered about thirty workers; most of them remained from 1928 until 1931, and some of them until 1933. They worked alongside a rather larger number of Soviet staff [823].

The Tomka project was primarily concerned with mustard gas, involving detailed study of its toxicology and its field behaviour under different environmental conditions. (The climate at Shikhani, where the temperature could vary between 45°C and −45°C, was well suited to this.) A variety of experimental weapons were constructed and tested there with different types of mustard-gas filling. Other developmental studies included work on protective clothing based on rubber, therapeutic measures against mustard-gas poisoning and skin burns, and analytical methods for detecting, identifying and estimating mustard gas [824].

Even though the work at Shikhani substantially increased the level of German CW expertise, the higher authorities within the Reichswehr remained largely uninterested in CW, so much so that in 1931 the Army *Truppenamt* considered proposing in its plans for 1933–38 that the acquisition of an offensive CW capability by the German Army would not be worthwhile, even as a precaution against possible enemy initiation. There were serious differences of opinion on this, mainly with the *Waffenamt* [711], and during the rearmament period after 1934 an accelerated CW programme was instituted [51].

A separate CW department was set up within the Waffenamt: this constituted section 9 of the Waffenamt division concerned with the development and testing of new equipments—*Waffenamt Prüfwesen 9* (Wa Prüf 9). This was followed in 1936 by the creation of a corresponding department within the Army General Office, the *Inspektion der Nebeltruppe und Gasabwehr* (Chemical Troops and Gas Defence Inspectorate, AHA In 9) [212]. Wa Prüf 9 was given control of the laboratories at Citadel-Spandau, the *Heeresgasschutzlaboratorien Berlin-Spandau,* and the newly established *Heeresversuchsstelle* on Lüneburg Heath—the pilot-plant manufacturing establishment at Munsterlager, and the 120 square km [825] of proving grounds nearby at Raubkammer [821]. An official decree was promulgated in 1935 requiring that samples of highly toxic materials discovered in the course of academic or industrial research be sent to the Berlin-Spandau laboratory for investigation, as part of the latter's search programme for new CW agents: by this means the Army first became aware of tabun and other nerve gases. Work at the Lüneburg Heath establishments continued the programme that had been begun with the Tomka project, but on a more ambitious scale. The Navy and the Air Force pursued their own CW programmes in parallel and sometimes in coordination with that of the Army [212].

In 1938 the *Heeresgasschutzschule* (Army Gas Defence School) at Celle, near Hannover, was opened alongside the *Nebeltruppenschule,* providing improved and expanded training facilities compared with those that had previously been relied upon in central Berlin. The courses given there were decided by AHA In 9. By this time the Army had six battalions of chemical troops, and over the next two years a further fifteen battalions were constituted [212, 380]. The majority of these bore the designation *Nebel Abteilung,* "smoke unit": this was both a reflection of the fact that smoke-screening duties, as well as CW duties, had been assigned to these units, and a carry-over from earlier days when CW instruction had been concealed under the guise of instruction in smoke techniques [826]. Both the Navy and the Air Force had CW training establishments of their own, the former's at Plön, and the latter's at Gatow, near Berlin [57].

Alongside these expanded CW troop-training activities, the procurement programme for CW matériel was also increased. The first concern was to provide adequate supplies of anti-gas protective equipment for the individual soldier; alongside Auergesellschaft in Oranienburg, the firm of *Dräger* in Lübeck manufactured the necessary respirators and other equipments. Offensive CW matériel was not produced on a substantial scale until much later. Large-scale production of CW agents seems to have commenced in 1938, accelerating after February 1939. For the most part the agents were produced in Army factories that were built and run by commercial enterprises set up specifically for this purpose. Especially prominent in this connection were the *IG Farbenindustrie* subsidiaries *Luranil-Baugesellschaft,* a construction company for CW agent production plant, and *Anorgana GmbH,* a CW agent plant-operating company. These and other IG Farben groups were involved in CW agent factories that were set up shortly before or during World War II at Gendorf (near München), Ürdingen, Ludwigshafen, Wolfen and Dyhernfurth (near Breslau). CW agent factories owned and/or operated by other sections of the German chemical industry were located at Hüls, Ammendorf (near Leipzig), Hahnenberg-Leese, Strassfurth, Berlin-Haselhorst and Hannover-Seelze. [52] The capacities of the various plants are given in table 4.4. By the time World War II had begun some 12 000 tons of CW agents were on hand, 80 per cent of which was mustard gas, but only a small proportion had been filled into weapons [51].

The involvement of the chemical industry in the German CW agent manufacturing programme was accompanied by its involvement in the CW R & D programme as well. The Leverkusen laboratories of IG Farben are said to have been prominent in this connection [52]. While most of the records of their CW R & D work were destroyed prior to Allied occupation, details of some of the projects were given to Allied interrogators. These included developmental work on respirator charcoals and on weapons fillings based on mustard gas, and studies of synthetic methods for fluoroacetic acid, the halogen fluorides, and various tabun and sarin precursors [827]. As regards

Table 4.4. German factories for CW agents, 1935–1945

Factory location	Time of completion	CW agent produced	Plant capacity[g] (*tons per month*)
Hannover–Seelze[a]	1937	Chloroacetophenone	120
Hüls	Pre-war	Mustard gas	600–1 400
Ammendorf	Pre-war	Arsinöl[e]	300
Strassfurth	1938	Arsinöl	180–270
Ludwigshafen	Pre-war	Chloroacetophenone	60– 90
Ludwigshafen	1940/41	Phosgene	290
Gendorf	1940/41	Mustard gas	1 000–4 000
Hahnenberg–Leese	1940/41	Arsinöl	400
Hahnenberg–Leese[b]	1940/41	Chloroacetophenone	500–550
Wolfen[c]	1941/42	Phosgene	270
Ürdingen	1941/42	Phosgene	130–140
Ürdingen	1941/42	Adamsite	200
Berlin–Haselhorst[d]	1941/42	Diphenylchloroarsine	100–150
Ammendorf	1941/42	Nitrogen mustard (HN-3)	50–100
Dyhernfurth	1942	Tabun	1 000
Dyhernfurth	1944	Cyanogen chloride	20
Dyhernfurth	1944	Hydrogen cyanide	20
Auschwitz (Oświeçim)	u.c. 1945	Phosgene	(700)
Dyhernfurth	u.c. 1945	Sarin	(100)[f]
Falkenhagen	u.c. 1945	Sarin	(500)

u.c. 1945 = under construction in 1945; ( ) = planned plant capacity.

[a] Fifty tons of chloroacetophenone (CN) were produced at Seelze in 1935 during pilot-plant development studies. The main plant was constructed early in 1937 [851].

[b] The Leese CN plant was a reserve installation that never in fact produced any CN; it was later converted to produce vanillin, saccharin and another synthetic sweetening agent [851].

[c] Another authority states that the Wolfen phosgene plant had a capacity of 600 tons per month, with much of the output being used for the production of smokeless powder, and that it had provided phosgene filled into 100 kg bombs for the Luftwaffe during 1940–41. [184]

[d] The Haselhorst diphenylchloroarsine (DA) plant was evacuated to Leese in 1945.

[e] *Arsinöl* was a crude product containing 50 per cent phenyldichloroarsine, 35 per cent DA, 5 per cent triphenylarsine and 5 per cent arsenic trichloride. It was used either as a freezing point depressant for mustard gas or as a raw material for diphenylchloroarsine [158].

[f] Another authority states that the capacity of the sarin plant under construction at Dyhernfurth was only 40 tons per month [98].

[g] A range of figures indicates that the plant was expanded after its initial construction.

Source: US Strategic Bombing Survey, *Powder, Explosives, Special Rocket and Jet Propellants, War Gases and Smoke Acid* (Oil, Chemicals and Rubber Division, Ministerial Report no. 1, Washington, November 1945, PB 27274).

tabun and sarin, which were first prepared by Dr Schrader in the IG Farben laboratories at Wuppertal-Elberfeld, it is worth recording that there is no published record that Dr Schrader continued to work on these agents after he had first encountered them and had reported their existence to Wa Prüf 9. Statements that he or his co-workers at Elberfeld were responsible for the initial development of the nerve gases [259], as well as their chance discovery, have been discounted both by himself [828] and by members of Wa Prüf 9 [821, 829], which was in fact responsible for the development of the new agents.

As regards German policy during the inter-war years, it is clear that Germany was not in a position, until well after 1934, seriously to contemplate initiating CW in the event of a future war; and the country would have found it difficult even to protect its troops against CW attack, let alone to retaliate in kind. Although a residue of earlier German expertise in this field remained from World War I that could have been drawn upon in an emergency, this would have necessitated an onerous programme of construction, training and development work. The terms of the Versailles Treaty, enforced by the Inter-Allied Control Commission, had destroyed the powerful manufacturing and administrative infrastructure that had supported the German CW effort during World War I, and for many years neither the incentive nor the financial support were forthcoming that would be needed to reconstruct it. When Germany ratified the Geneva Protocol in 1929, it presumably did so in the hopes that the treaty would indeed restrain potential enemies from waging CW against it. It is worth noting that, unlike France, the USSR and, later, the UK, Germany ratified the Protocol without reservation. Those who knew about the highly secret Tomka project,[10] which at that time was beginning to get fully under way, viewed it as a first step towards acquiring a retaliatory CW capability in case an enemy should initiate CW [822].

As for German CW policy after 1934, it has been suggested by one commentator that when the Wehrmacht finally embarked upon a concerted CW preparedness policy under Hitler, the residue of the earlier restrictions, lack of interest, and lack of funds gave rise to such a crisis of confidence that the people involved believed themselves to be at least fifteen development-years behind Germany's potential enemies. Even during World War II, German CW authorities believed the CW capabilities of their enemies to be far greater and more sophisticated than their own, although in fact the Wehrmacht was probably at least as well trained and equipped for CW as the Western Allies. After the war, General Ochsner, the wartime commander of the chemical troops, spoke of the situation in 1937–38 as follows:

> It became increasingly evident to the responsible German authorities that Germany, restricted as she was in all spheres of armament, had probably been left farther behind in the field of CW than in any other. It was also realized that it would be impossible for Germany within any reasonable time to catch up with foreign powers who had such a lead, either technically, in respect of producing capacity, or in the training of the Wehrmacht and the entire nation. This possibility was even more remote in respect of protection for the big cities for which the threat was most imminent. In view of all these factors the realization was forced home that it was of vital interest to Germany that chemical warfare agents should not be used in war. [212]

[10] The security measures maintained around the Tomka project were such that any of its participants who spoke about it to outsiders risked capital punishment [823].

The Army's exaggerated estimates of foreign CW capabilities contributed to this alarm [51], which must have been at least in part responsible for Hitler's declaration at the outbreak of World War II that Germany would observe the Geneva Protocol provided its enemies did [830–31].

It is also recorded that practically nothing was taught about the offensive use of gas at the Army CW training school at Celle.[11] The instruction given was almost exclusively concerned with the protective measures to be employed against enemy use of gas [57].

Notes on German BW policy and programmes have been given in Chapter 1. Concerted BW experimental work in Germany does not appear to have commenced until 1943.

IV. *The Soviet Union*

During World War I the Russian Army had suffered immense numbers of gas casualties, and from its creation the Red Army paid close attention to CW. During the Civil War it included companies of chemical troops under the command of the engineers. A decree of October 1920 ordered the creation within the Army of a military chemistry organization, and in the same year the Army set up the *Higher Military School for Chemistry* in Moscow. In 1924 the *Military-Chemical Army Administration* was formed, and command headquarters for chemical troops were established at each provincial army headquarters. Troop-training programmes in CW were conducted at the Leningrad Artillery Academy, the Military High School for Chemistry in Moscow, and an Army chemical school in Kalinin. The Army Academy for Military Chemistry was founded in Moscow in 1932. [54, 833]

National policy on CW at that time is not known, but as early as November 1920 the government had called for international agreement to prohibit the use of chemical weapons [834]. It continued to seek the prohibition of CW throughout the Geneva Conference of 1925 and the League Disarmament Conference.

In 1922 the Red Army and the German Army began their joint weapons R & D programmes; this was to include work on tanks, combat aircraft and CW. A Soviet-German company was formed to manufacture CW agents at Trotsk, near Samara (Kuibyshev), and although the factory was not completed until 1928, Deputy War Commissar Unshlikht spoke in March 1926 about vast Soviet plans for the production of CW agents. Agreement to construct a joint CW experimental establishment was reached at the

[11] But it is not reported to what extent the chemical troops themselves, as opposed to the Army in general, were trained in offensive CW techniques at their own training school.

end of 1927, and by the summer of 1928 Soviet-German CW field trials were in progress. [711] This was the Shikhani establishment, referred to earlier. The German element[12] here brought much of its equipment with it, even the building materials for its barracks and supplies of food; most of the German workers returned home during the winter months because the thick snow and extreme cold precluded experimental work [823]. One, or sometimes two, Soviet scientists were allocated to each German scientist, participating in all trials and experiments, and the Soviet element at Shikhani received copies of the reports of all German experimental results. The relations between the two national components at the establishment were kept to a formal level, the Soviet workers living in separate barracks. Cossack troops guarded the camp [835]. When the Germans left, in the spring of 1933, they dismantled and removed their barracks [824].

Soviet work there continued, however, with the proving grounds and other facilities being designated the *Central Army Chemical Polygon* (TsVKhP) [54].

The work at Shikhani attracted the interest of War Commissar Voroshilov who advocated an enlargement of the programme, notably to include more detailed study of cold-weather CW techniques and the artillery dissemination of CW agents. He proposed that the USSR subscribe half the funds needed to extend the facilities, but the German Army was unable to provide the remainder [708].

A published reference exists to CW experimental work at Orenburg (Chlakov) during the 1920s, again with Soviet-German cooperation [711], but the available information on this is scanty. If it did indeed take place with German participation, the German workers at Shikhani did not know about it [836]. The only Soviet-German CW work outside Shikhani which German workers there were aware of related to aircraft spray-tank trials with mustard gas conducted in 1927 at a proving ground 30 km from Moscow; this work was discontinued when the Tomka project began [837].

Soviet participation in the programme was directed by the head of the CW branch of the Red Army, Y. M. Fishman; a visiting German officer described him in 1928 as having a burning ambition to build up a powerful Soviet CW capability, and to make gas a valuable weapon of war [708]. It is not known how much support he received from the Soviet military establishment, nor how large were the programmes he had to control. Commissar Unshlikht's plans in 1926 for enormous Soviet production of chemical weapons could have been no more than an encouraging gesture for

[12] The German element at Shikhani comprised a senior commanding officer and two administrators, three chemists, one toxicologist, one meteorologist, one physician, one engineer, two pyrotechnists, five laboratory technicians, three aircraft pilots, eight automobile and aircraft servicemen and one male nurse [823].

German participation, while Commissar Voroshilov's enthusiasm in 1928 for the work at Shikhani might have been nothing more than a passing interest, even though in a speech made in February 1934 he urged the closest collaboration between the Army, the universities and the chemical industry to put the USSR far ahead of the USA, France and the UK in the field of CW. [1] The statement by a German CW writer that around 1936 there were seventeen factories in the USSR devoted to the production of CW agents [1] could have been just another faulty German assessment. Such arrangements as there were for the Red Army to fight a chemical war may have been affected by the Army purges of the mid-1930s: it is reported that Fishman himself died during these. [708] (In fact, he died in the early 1950s, and was buried in the honorific Novodevichi cemetery in Moscow [1000].)

An account of the Soviet CW programme during the inter-war years has been published by Colonel Pozdnyakov, a Soviet army officer who left the USSR for good after being taken prisoner by the Germans in 1942. He held various posts within the CW branch of the Red Army from 1920 until 1942. Pozdnyakov states that by 1928 a Soviet doctrine of CW had taken shape, and that gas was seen as a powerful and effective weapon, not only in trench warfare, but also under more mobile conditions. Its military value was regarded as being beyond doubt, and was seen to lie in the ability of gas to engage large-area targets, the high casualty rates obtainable with it, its comparatively low cost, and its uses as a persistent ground contaminant. An active development programme for offensive and defensive CW matériel was being conducted in military and civilian facilities. The Military-Chemical Army Administration assigned research tasks both to its own laboratories and to those of the Soviet Academy of Sciences, universities, and industrial concerns. Experimental chemical weapons were tested at the *Kuzminki Polygon* near Moscow, at a proving ground at Gorokhovetsky near Gorki, and at the *TsVKhP* at Shikhani; the latter establishment also contained pilot-plant facilities for developmental studies on CW agent manufacture. CW agent factories were erected in the 1930s; the principal ones were at Bandyuzhsky on the River Kama, Kuibyshev, and Karaganda. The agents manufactured included phosgene, diphosgene, chloropicrin, cyanogen chloride, hydrogen cyanide, mustard gas, nitrogen mustard (HN-3), chloroacetophenone, adamsite and diphenylchloroarsine.[13] [54] During World

[13] It has not been possible to check the information given by Colonel Pozdnyakov against official Soviet sources. His account was published in the UK in 1956 in a book on the Soviet Army to which a number of other Russian emigrés contributed. As regards the foregoing description of the joint German–Soviet CW programme, Soviet scientists whom the present authors consulted state that the information about this programme contained in Carsten's publications [708, 711] "does not correspond to facts" [996].

War II the Germans estimated the Soviet CW agent manufacturing output to be at least 8 000 tons per month [51].

General F. Manets, the present head of Soviet chemical troops, states that the Soviet Army entered World War II with well-trained chemical troops that were provided with advanced and reliable anti-gas protective equipment [833]. The German Army certainly regarded Soviet anti-gas equipment as being among the best they had encountered [59]. The Japanese, however, regarded the anti-gas discipline of the Soviet Far Eastern Army as poor, in 1938 at any rate [359].

As regards its CW policy during the decade before World War II, the USSR had ratified the Geneva Protocol in 1928. Like France and later the UK, it had reserved the right to retaliate in kind against enemy initiation of CW, and did not regard itself bound by the Protocol vis-á-vis countries that were not party to it. In a speech on 22 February 1938, Voroshilov made the following statement:

> Ten years ago or more the Soviet Union signed a convention abolishing the use of poison gas and bacteriological warfare. To that we still adhere, but if our enemies use such methods against us, I tell you that we are prepared—fully prepared—to use them also and to use them against aggressors on their own soil [838].

Little has been published about Soviet BW activities during the inter-war period. Some brief notes on this are given in Chapter 1.

V. *Japan*

Compared with the national policies described above, the CW policy of Japan after World War I rested on rather different foundations. In the first place, its armed forces had no first-hand combat experience of CW. In the second place, there was no great reason to suppose that a sudden strategic attack on the Japanese homeland was at all likely. Unaffected by the widespread feelings of revulsion and fear that gas had aroused in the West, Japanese CW policy could be based solely on considerations of the battlefield usefulness of gas, and untrammelled by doubts about possible repercussions on the civilian population. As gas had been a widely-used tactical weapon in a European war, Japanese military leaders took up a study of its possibilities as a matter of course, considering whether or not to equip their forces whit it.

In August 1919 the Japanese Army set up a scientific research establishment which included a CW section. By 1925 gas had been accepted by the Army as a potentially useful weapon, and a separate CW establishment created. In 1923 the Navy began its own assessment of CW, independ-

Table 4.5. Japanese production of CW agents, 1930–1945

Output in tons

Agent	Tadanoumi Arsenal Starting year	Tadanoumi Arsenal Pre-1942	Tadanoumi Arsenal 1942–1945	Sagami Arsenal Starting year	Sagami Arsenal Pre-1942	Sagami Arsenal 1942–1945	Total output 1930–1945
Mustard gas	1934[a]	3 082	978	1943[b]	30	470	4 991
Lewisite	1934		431	..	5	15	
Hydrogen cyanide	1939	138	117	n.a.	n.a.	n.a.	255
Chloroacetophenone	1939	40	12	1931	20	100	172
Diphenylcyanoarsine	1934	1 067	770	1933	30	90	1 957

.. = unknown; n.a. = not applicable.
[a] Experimental production had begun in 1928.
[b] Experimental production had begun in 1923.

Source: Office of the Chief Officer, GHQ' AFPAC, *Intelligence Report on Japanese Chemical Warfare* (Tokyo, March 1946, vol. 3).

ently of the Army; the Air Force did likewise eight years later, but with some degree of coordination with the Army. Development work on the manufacture of CW agents began in 1923 with Navy studies on mustard gas, and continued sporadically until the early 1930s when both the Army and the Navy began manufacturing programmes. The total output of CW agents, either before or during World War II, was not large, however, as table 4.5 shows. The Navy factories were situated in the *Sagami Naval Yard* at Samukawa, Kanagawa-ken, and the Army ones at *Tadanoumi Arsenal,* Hiroshima-ken. The Air Force procured its CW agents from the Army. Small quantities of phosgene and chloropicrin were procured by the armed forces from commercial sources, but the bulk of Japanese production of these two agents was consumed industrially. Respirators and other protective equipment were for the most part procured from industry. [50]

The principal Army CW R & D establishment, a component of the *Army Scientific Research Station* until 1925 and later designated the *Sixth Military Laboratory* of the Army Ordnance Bureau, was located at Yodobashi-ku, Tokyo, after it moved from Itabashi in 1922. Details of its size during the inter-war period have not been published but by 1945 it had an establishment of around a hundred military scientists, with 600 civilian supporting staff. In 1940 its budget was about 1.5 million yen ($0.38 mn), rising to 2.9 million yen ($0.73 mn) in 1945. It had an out-station in Manchuria, the *Chichihara Laboratory,* which was occupying about 300 workers at the end of World War II, and it made use of several weapons proving grounds in the home islands, Formosa and Manchuria. Its R & D activities covered all spheres of CW. It contracted a small number of research projects out to academic chemists and toxicologists at Hokkaido, Osaka, Tohoku and

Tokyo Universities and Nagoya Technical High School. [56] Training in CW techniques began throughout the Army in 1933.

Air Force CW R & D, primarily concerned with aircraft chemical weapons, was begun in 1931. It was conducted within the *Third Air Technical Laboratory* at Tachikawa Air Base, Tokyo. Some twenty scientists were employed there on CW work, and their annual budget was around 30 000 yen ($7 500). [56]

Navy CW R & D commenced within the *Naval Technical Institute* at Tsukiji near Tokyo. In 1931 the CW department there transferred to the *Naval Powder Factory* at Hiratsuka, Kanagawa-ken; thereafter it expanded rapidly, until in 1943 it constituted, together with the Navy chemical weapons factories, the *Sagami Naval Yard*. The R & D laboratories were employing some 300 people by 1945. The 1940 budget was 0.6 million yen ($0.15 mn), rising to 1.3 million yen ($0.33 mn) in 1945. A certain amount of work was contracted out to academic and industrial laboratories. [56]

During the invasion of China chemical weapons seem to have been employed as a matter of course; the decision to use them did not require high-level authorization [539]. Japan had not ratified its signature to the 1925 Geneva Protocol, and the only treaties to which it was a party that might have restrained it were the Hague Conventions of 1899 and 1907.

The Japanese assessment of biological weapons was apparently provoked at least in part by the attention given to BW by European powers at Geneva [255]. An experimental programme was initiated in 1935 by an army major who, by exerting remarkable powers of persuasion, succeeded in building up a research staff that numbered 3 000 people within five years of its inception. Here, however, non-military constraints seem to have been more active. The programme was conducted outside Japan in establishments in Manchuria, under conditions of strict secrecy that were intended at least as much to keep the programme concealed from the Emperor and his immediate advisors as from other nations [255]. The programme is described in more detail in Chapter 1.

Despite the considerable efforts given to the development of chemical and biological weapons, the combat possibilities of CBW did not succeed in arousing the enthusiasm of senior military officers [51]. The chemical arm was never built up into anything beyond a limited tactical capability [56], while the BW programme, despite its scale, did not yield practical biological weapons [255]. The preoccupation with the development of battlefield CB weapons led to an almost total neglect of the CB defence of the civilian population, a neglect that was to prove a grave liability during the latter part of World War II.

VI. *France*

Dr Rudolf Hanslian, a German CW authority writing in 1936, spoke of France and the USSR as being the two countries best prepared for CW in the event of a future war. He claimed that the French CW R & D effort of World War I had been continuing with little diminution during the post-war years. Within the French Army, CW duties were the responsibility of the *Organisation du Service des Gaz de Combat,* under the Inspector-General of Artillery, and CW officers within the various echelons of the Army were designated *Officiers Z.* Hanslian said that CW agents were in production in six state factories (at Angoulême, St Denis, Vincennes, Melun, Sorgues à Avignon and Aubervilliers) and twenty-four private ones [1].

While there can be little doubt that Hanslian exaggerated the French chemical-weapons programme, France was well prepared defensively for CW during the inter-war years. The anti-gas installations built into the Maginot Line, the construction of which began in 1927, illustrate French concern about CW during this period and the measures taken to provide anti-gas defensive measures. The fortifications constituting the Maginot Line were to be ventilated with air that had been passed through elaborate built-in filters, and the inside air pressure was to be maintained slightly above atmospheric pressure to prevent air which might have been contaminated from seeping through fissures and other openings in the concrete. [839]

During the later years of World War I, French supply arrangements for chemical weapons and protective measures had been controlled by the *Service du Matériel Chimique,* responsible to the Ministry for Artillery and Munitions. It had two branches, the *Inspection des Etudes et Expériences Chimiques* and the *Direction du Matériel Chimique de Guerre.* Within the Army, chemical operations were directed by the Service des Gaz. Most of the CW R & D work was conducted within sixteen university and industrial laboratories supported by four proving grounds, at Satory (Seine-et-Oise), Vincennes, Fontainebleau and Entressen (Bouches-du-Rhône). The *Polygone d'Entressen* was the principal chemical-weapons proving ground. For the most part, CW matériel was procured from industry, although specialized operations such as the charging of munitions with CW agents were done in facilities run by the Direction de Matériel Chimique de Guerre (at Vincennes and Aubervilliers). [840]

After World War I, in 1922, a central CW R & D establishment was created near Paris, the *Atelier de Pyrotechnie du Bouchet.*[14] It contained pilot-

[14] By the time of World War II, the Le Bouchet establishment had been renamed the *Poudrerie Nationale du Bouchet.* Nowadays it is known as the *Centres d'Etudes du Bouchet.*

plant facilities for developmental work on the manufacture of CW agents. [839] When the Germans advanced into France in 1940, the workers at Le Bouchet removed themselves, their records, and some of their equipment to Montpellier, the records subsequently being transferred to Toulouse. With the fall of France, offensive CW work ceased, being forbidden by the Germans. [59]

According to Dr Hanslian, the proving grounds at Satory and Entressen had continued in use for CW matériel after World War I, but he stated that the principal post-war CW proving ground was at Chalai-Meudon [1]. At least by 1939, valuable CW test facilities were also available in Algeria. These were in the Sahara desert, at Beni Ounif, 200 miles south of Oran. The size of the Beni Ounif station, nearly 5 000 square km, its remoteness from human habitation, its accessibility, and the fact that there was a prevailing wind, made it particularly attractive for experimentation in offensive CW techniques. The British used it alongside the French, and after the fall of France the Allies lost their most important chemical-weapons proving ground. [63] The Germans took it over and continued to use it [841].

By the outbreak of World War II, the French possessed a stockage of chemical weapons which they believed to be adequate for retaliatory purposes in the event of enemy initiation of CW. In common with the CW agent stocks of all other belligerents at that time, the principal CW agents were mustard gas and phosgene. The former was produced in state factories at Sorgues and at Angoulême. The phosgene was procured from industrial sources. [839] Semi-industrial-scale production facilities for adamsite, mustard gas and lewisite existed at Le Bouchet, while the Soussens plant, for the large-scale production of adamsite and lewisite, remained uncompleted at the time of German occupation [59].

French CW policy during the inter-war period was based on the position that France would not initiate CW in the event of a future war, but would be well prepared defensively against CW attack and ready to retaliate in kind against it. This policy was enunciated most clearly in 1926 when France was both the first country to ratify its signature to the Geneva Protocol and, on doing so, to reserve the right to retaliate in kind against an enemy that infringed it. This policy was declared once more in a joint Anglo-French declaration published on 3 September 1939 [830].

VII. *Italy*

The World War I CW R & D effort in Italy continued after the war, and in 1923 the Army established a *Servizio Chimico Militare*, with a *Centro*

Chimico Militare, responsible to the War Ministry, controlling CW research activities in several academic laboratories around the country. A proving ground for CW matériel existed in northern Italy. The Italian Navy also had a CW service, with laboratories at Spezia. [1, 212] The Italian Air Force gained experience with gas in Ethiopia during 1935–36.

A German evaluation of Italian CW capabilities at the time of World War II concluded that when the war broke out Italy's preparedness for CW was far from complete, although its experiences in Ethiopia had led it to believe gas to be a valuable weapon. A number of organizational structures for its chemical troops had been tried out, but no definite conclusions had been reached. The same uncertainty attached to the weapons with which the chemical troops were to be provided. Italian respirators and rubber protective clothing were considered to be very good, but the decontamination equipment crude. [212] There is little published information on the size or composition of Italian stockages of chemical weapons, but they are reported to have included substantial quantities of mustard gas and phosgene [30, 842]. A German chemical-weapons depot occupied by the British is reported to have included about 120 000 Italian chemical artillery shell, of several calibres; some of these bore red cross markings, others green and white crosses [162]. If it is assumed that the Italians followed the colour coding system used by the Germans before World War II, these markings suggest a stockage of lachrymatory agent and dichloroformoxime (or some other "nettle gas"), as well as phosgene and mustard gas.

Italy ratified the Geneva Protocol without reservation in 1928, but proceeded to use gas on a substantial scale against Ethiopia eight years later. Ethiopia had ratified the Protocol a month before the first CW attacks against it were reported.

VIII. *Other countries*

Little has been published about the CW capabilities or intentions of other countries during the period between the wars. In Europe most governments acceded to the Geneva Protocol, while at the same time following policies of CW preparedness. This took many forms: at one extreme it consisted of no more than a part-time scanning of the literature by military personnel; at the other extreme it involved the production of an actual offensive CW capability, coupled with an active programme of civilian defence against chemical attack. Brief accounts of individual national programmes are contained in Dr Hanslian's study of CW published in Germany in 1937

[1]:[15] apart from France, Italy, Japan, the USSR, the USA and the UK, Hanslian credited one other European country with an offensive CW capability. This was Spain, which was said to possess two state-owned gas factories. An earlier German writer had recorded that a German chemical manufacturer had been employed in the early 1920s by the Spanish Government to construct such a factory, and also that he had delivered a series of lectures to Spanish Army staff officers on the offensive possibilities of CW. The manufacturer was Dr Stoltzenberg, the man who had been engaged to build the gas factory at Trotsk in the USSR, and whose phosgene had escaped over Hamburg in 1928. The lectures were published in serial form by Dr Stoltzenberg in Hamburg from 1928 to 1930. [716]

During World War II the Allied powers encountered stocks of chemical weapons that had been manufactured in Hungary, Poland, Czechoslovakia, Yugoslavia and Greece [30, 52–3, 842]. The Hungarian weapons, like most others, included mustard gas; this was generally mixed either with carbon tetrachloride or phenyldichloroarsine [842]. The Czechoslovak weapons included mustard-gas land mines and irritant-agent candles, both arsenical and lachrymatory [53].

In Canada CW R & D activities did not begin until the mid-1930s, when, stimulated by the Japanese invasion of Manchuria and the worsening situation in Europe, the Department of National Defence instituted production of anti-gas protective equipment, based on British designs. The CW programme accelerated after the success of the German campaigns in northern Europe, and close liaison was established with the British programme. The gap created in Allied CW experimental capabilities by the loss of the Anglo-French station at Beni Ounif was filled in the summer of 1941 by the opening of a joint Anglo-Canadian establishment at Suffield, Alberta. This made available some 2 500 square km of proving-ground for work on CW matériel, particularly chemical weapons. The activities at Suffield were complemented by R & D work in a number of Canadian Army and academic laboratories around the country. Wartime factories in Canada produced substantial quantities of respirators, permeable impregnated protective clothing, and other anti-gas equipments, together with about 1 500 tons of mustard gas and phosgene. [63, 157]

[15] The following countries were credited with a CW organization included within their military establishment: Argentina, Austria, Belgium, Bulgaria, China, Colombia, Czechoslovakia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Japan, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, Turkey, UK (and the British Dominions), USA, and USSR.

Chapter 5. The non-use of CB weapons during World War II

At the outbreak of World War II, few people were prepared to say that chemical weapons would not be used at some point in the coming conflict. In the Far East, Japan was using gas in China, and three years earlier a European power, Italy, had been doing the same in Africa. Both sides credited their opponents with massive stocks of chemical weapons and with accelerated programmes for procuring more. Substantial sectors of the civilian population in Europe had been undergoing anti-gas training courses for the past five years. Yet by the time the war ended the massive arsenals of chemical weapons remained substantially untouched.

It is important today to form some idea about why these weapons were not used. Many of the constraints operating during World War II exist now, even if in some cases they have been modified by events during the intervening years. The main part of this chapter, then, will attempt to describe these constraints and their importance in preventing major employment of chemical weapons during the war.

On biological weapons there is less to be said; with the technology of the time it is doubtful whether pathogens could have been used for anything other than covert sabotage operations, even though by the end of the war biological weapons of a sort apparently existed in prototype form that might have been used with regular weapons delivery systems. A short section at the end of the chapter is devoted to biological weapons.

For present purposes, the various constraints on use of chemical weapons may be grouped into two broad categories: military and non-military; so may the incentives to use them. We will discuss the latter first.

I. *The incentives to use chemical weapons*

Military incentives

At the outbreak of World War II, most of the doctrine on the combat functions of chemical weapons was derived from the experience of World War I, expanded and modified by such lessons as had been drawn from the various occasions when chemical weapons had been used during the inter-war period. As regards land warfare, it was taught [53, 212] that chemical operations could usefully be integrated into offensive planning for the following purposes: (*a*) softening up an enemy position prior to assault; (*b*) neutralizing enemy artillery concentrations; (*c*) using persistent agents, such as mustard gas, to tie down an enemy-held area that was not to be attacked; (*d*) protecting the flanks of an advance with barriers of persistent agent; (*e*) using persistent agents to seal off reserves held in the enemy's rear, or to restrict their movement forward; and (*f*) using persistent agents to block enemy lines of retreat. Likewise chemical weapons could be used on the defence (*a*) to engage enemy troop concentrations massing for an assault; (*b*) to neutralize enemy artillery; and (*c*) to contaminate evacuated terrain. The advantage which gas was thought to possess in these roles as compared with conventional weapons lay, first, in the ability of toxic clouds to endanger rather large areas and to penetrate positions protected against conventional firepower, and, secondly, in the ability of persistent agents spread as ground contamination to threaten casualties long after dissemination. But these advantageous effects could be obtained only if both operational and meteorological circumstances were favourable. This crucial and discouraging limitation is discussed further below.

The CW specialists within the different belligerent armed services valued gas to different degrees. Thus, the US Chemical Warfare Committee (USCWC, the US committee advising the Allied Combined Chiefs of Staff on CW matters) tended to regard gas as a decisive weapon if dispersed in sufficient quantities at the right place and the right time. The British Inter-Service Committee on Chemical Warfare (ISCCW, the corresponding British committee advising the Combined Chiefs of Staff), however, regarded gas a supplementary weapon to be used in conjunction with high explosives and incendiaries. [267]

While a CW doctrine along the lines set out above could have been applicable in most of the ground fighting during the war, there were few occasions when the overall military situation seemed at all likely to override the constraints that prevented it from being put into practice. Some of these few occasions are noted below.

The invasion of the British Isles, had it proceeded as planned, would have been the first occasion during the war when both military expediency and the requisite material capability might have made the use of chemical weapons a strong possibility. As will become apparent later, the Germans had had no inclination to use gas during their earlier advances through Europe, and it appears that the countries which they attacked lacked the capability to use gas in defence. Had a German invasion force succeeded in establishing a foothold on English beaches, the British would have been placed in an exceedingly precarious position, and there is some evidence to show that in this extremity the British would have used gas [852]. It was considered that although the normal weapons of the three fighting services would almost certainly succeed in repelling the invasion, the importance of denying the invaders a lodgement was so overriding that any constraints on using gas could be disregarded.

The Germans realized this:

We had to reckon with the British, in the defence of their homeland and in an attempt to defeat our invasion, using every weapon and all means available to them that might hold out even the slightest hope of success. We had to allow for the possibility of our troops being attacked while approaching the English coast with non-persistent agents ... as well as with vesicants sprayed by airplanes. ... Another possibility was that immediately after landing our troops would come up against large scale vesicant agent barriers and that they might be subjected to further gas attacks from the air and by gas shells fired by artillery and chemical projectors. [212]

The next occasions when the use of gas appeared a strong possibility were in Soviet defensive actions against the German invasion of the USSR. No information is available on whether Soviet forces considered using gas, but it is known that the German Army frequently reckoned the probability that they would do so to be extremely high. Summarizing these fears, General Ochsner[1] writes:

The Russians even did not use gas ... in defence of their excellently prepared field fortifications within the rear defence lines, those for instance before Leningrad or in the middle sector in the so-called Stalin Line, and not even in the Summer of 1942 when countering our great offensive in the middle and south sectors, where they had enough time to prepare. In the Autumn of 1941 and the Summer of 1942, we thought it possible that the Russians might employ gas, because, as masters in the construction of positions and in position fighting, they had fully realised its value. This was known to us from the instruction manuals we had captured shortly after outbreak of war. [212]

The third set of occasions when the outbreak of chemical warfare appeared imminent was at the time of the Allied landings in Italy and France.

[1] This quotation is from the review of German CW activities written in 1948 by General Ochsner. (See page 154.) This review has been cited on a number of occasions in earlier chapters because it is one of the most comprehensive published sources of information on German wartime CW activities. As source material, it is open to the criticism that it represents the view of one man only, however closely involved in the German CW effort he may have been. (He was commanding officer of the German chemical troops during the war.) As for the suggestion that General Ochsner may deliberately have distorted the facts in his representation of them, it should be noted that his review was not written for the open literature or for international circulation: it remained a restricted US Army document for a considerable length of time after it had been written.

The Germans, like the British, were aware that amphibious landing forces presented particularly vulnerable targets to gas attack during disembarkation and while struggling to establish beach-head positions. Clouds of non-persistent agents could cause enormous casualties among the massed troop concentrations as they moved up the beaches, while persistent agents could greatly complicate the intricate supply arrangements needed to support the landing. Even if the landing forces were provided with protective equipment to counter the immediate effects of chemical attack, that equipment in itself would be a severe burden during the landing. [212]

It is said that the Germans considered using gas against the Allied landings at Salerno [218], but no further information is available.

In the case of the Normandy landings, there are reports that the Germans had issued orders to use gas, but that for a variety of reasons the orders were countermanded [144]. Allied commanders certainly feared that gas would be used; General Omar Bradley, for example, has the following passage in his memoirs:

> While planning the Normandy invasion, we had weighed the possibility of enemy gas attack and for the first time during the war speculated on the probability of his resorting to it. For perhaps only then could persistent gas have forced a decision in one of history's climactic battles. Since Africa we had lugged our masks through each succeeding invasion, always rejecting the likelihood of gas but equally reluctant to chance an assault without defenses against it. Even though gas warfare on the Normandy beaches would have brought deadly retaliation against German cities, I reasoned that Hitler in his determination to resist to the end, might risk gas in a gamble for survival. Certainly an enemy that could callously destroy more than a million persons in its concentration camps could not be expected to reject gas warfare as inhumane. When D day finally ended without a whiff of mustard, I was vastly relieved. For even a light sprinkling of persistent gas on Omaha Beach would have cost us our footing there. [853]

The Chief of the US Army CWS, writing in 1946, expressed the view that heavy gas attacks on the Allied beach-heads

> might have delayed our invasion for six months and made later landings at new points necessary. ... Such a delay could have given the Germans sufficient time to complete the new V-weapons, which would have made the Allies' task all the harder and England's long range bombardment considerably worse. True, we could have replied manifold, for we were prepared to deal a terrific gas blow. But the question poses: Would the delay of six months in our invasion have been worth it to the Germans? As things turned out I think it might have been but they didn't dare grasp the opportunity. [850]

The problem of providing anti-gas protection for the eventual Allied landings in France had been occupying joint British-US planning groups in London since 1942. In the final planning for *Operation Overlord,* the overall

CW policy provided that the assault forces would carry respirators and wear impregnated protective clothing, with provisions for extensive reserves of anti-gas stores in the supply line. [218] This policy was put into effect, although when it was realized in the weeks following the landings that the Germans were not going to use gas, cross-channel supply rates of defensive equipment were slackened off. By September 1944 gas defences were partially retracted from forward areas, and certain CW services were put onto secondary missions—clothing re-impregnation plant being converted into laundry facilities, and so on. Once the Western Allies had reached the German border, however, there was a new gas alert, with respirators being re-issued to all troops in forward areas, and with resumption of full-scale supply provisions. [218] The troop concentrations massing for the Rhine crossing were highly vulnerable to CW attack.

Although the incentives to use gas during the fighting in Europe perhaps reached their highest point when the Germans were trying to counter the Allied landings, the constraints were still more compelling, as will be described, and were to remain so for the remainder of the war in Europe. In the Far East, however, the situation was different. In the first place, neither Japan nor the USA was under obvious treaty obligation to refrain from chemical warfare; in the second place, the Japanese armed forces had recently gained experience with chemical weapons during their invasion of China. The balance of constraints and incentives thus differed markedly from that in Europe.

The Japanese, like the Germans, had had little need of gas during their initial advances, but when they began to suffer reverses during the Islands campaigns, and as the US advance gathered momentum, it was perhaps inevitable that the Japanese Army should reconsider the use of gas. It is recorded that the Army General Staff sought permission to initiate CW during the Marianas campaign [359]. The High Commands of both the Army and the Navy had realized that the battle for the Marianas was likely to be a decisive stage of the war [50]. The Army's request, however, was turned down by General Tojo [359].

For the US part, it is said that during the preparations for the Iwo Jima landing plans were made to use gas to spearhead the attack. The plans allegedly called for the island to be gas-shelled from offshore naval vessels; the landings were to take place when it was reckoned that the resultant ground contamination had cleared. The plan is reported to have been approved both by the US Joint Chiefs of Staff (JCS) and by Admiral Nimitz, the theatre commander, but to have been rejected by President Roosevelt. [92] However, the authenticity of this whole account has been strongly questioned [51].

Under interrogation by US Army Chemical Warfare Service personnel after the war, a number of Japanese Army officers are reported as having said that gas would have greatly aided the US assault on the island:

> Another well-informed Japanese officer stated that the use of mustard against Japanese troops on islands such as Iwo Jima would have reduced US casualties very considerably, and the Japanese forces would probably have been decimated to the point where American decontamination groups could have gone ashore and decontaminated the areas prior to the debarkation of the main body of troops. [854]

The enormous US losses at Iwo Jima strengthened the case of those who argued for US use of gas. On Okinawa, as on Iwo Jima, the Japanese had set up deep and heavily fortified defensive systems, using caves and tunnels where they came to hand. The idea of using gas clouds to reduce these defences apparently found favour with General Marshall, Chairman of the JCS [855].[a] Even though gas was not so used, General Marshall continued to keep its possibilities before the JCS, and as the war with Japan went into its final stages, US CW contingency planning began to turn towards initiation of CW. Thus, chemical weapons were considered for use in support of the proposed landings on Kyushu, albeit without much enthusiasm, and, on a much larger scale, for strategic employment against the Japanese homeland. As regards the Kyushu landings, General Stilwell, commanding the US Army ground forces in the relevant theatre, had recommended in May 1945 that consideration be given to US employment of gas [267]. Advocacy for the strategic use of gas came chiefly from the US Army CWS; they had estimated that extensive use of toxic agents in B-29 bombing operations could result in as many as five or ten million Japanese casualties. However, although US military and political leaders had by this time become less unwilling to consider US initiation of CW as a final, decisive act of the war [51], this did not take place, for nuclear weapons had become available.

Non-military incentives

Had CW been initiated on any of the occasions noted above, it could have been said that there were sound military reasons for doing so, at any rate in the short term. But there were other occasions when people of

[a] The US Army CWS had embarked on a study of the vulnerability of Japanese cave defences to CW attack a week after the war in Europe had ended. This was *Project Sphinx*. In the course of it, the CWS conducted a large exercise at Dugway Proving Ground in which they demonstrated to General Staff officers the potentialities of gas munitions disseminating volatile agents against simulated Japanese cave fortifications. [30, 51, 267] However, the War Department General Staff was not impressed by the results of Sphinx [856].

influence within the belligerent countries advocated the use of gas with arguments that were only indirectly based on the immediate military situation. These people apparently saw gas as a weapon of terror, national demoralization or vengeance.

The possible effect of CW on enemy morale was certainly appreciated within military circles. Indeed, General Ochsner states that in Germany the view was not only that the demoralizing effect of gas was likely to be far greater than that of any other means of combat, but also that it was of greater importance than the ability of gas to produce enemy casualties or contaminate terrain.[3] [212] He was speaking principally about the battlefield use of gas, but his remarks also applied to the use of gas against civilians. In so far as it was possible to make predictions about events so irrational as mass panic, it was argued that, given the sensational accounts of the effects of gas that had been appearing in the European press for the past twenty years, there was a considerable probability that a gas attack on a city could produce an effect on civilian morale out of all proportion to the weight of weapons used. These considerations were of course as applicable to one belligerent as to another, but in the case of Germany's predicament in the closing phases of the war, for example, the constraints arising from fear of retaliation were beginning to lose much of their force for the more extreme party leaders. Three occasions are recorded when this notion of gas as a weapon of terror or vengeance appears to have come near being put into practice.

[3] The foundations of this doctrine had been laid in lectures given by Professor Haber—the doyen of German CW in World War I—in 1924:

"All modern means of combat, although they appear intended to kill the enemy, actually owe their success to the intensity with which they affect the psychic stability of the enemy. The decisive battles of any war are not won by the physical destruction of the enemy, but by psychological imponderabilities which, in a decisive moment, induce the enemy to lose the will to fight and to feel defeated. These imponderabilities transform combat-effective troops into a crowd of despairing individuals.

"The most important auxiliary of combat in the production of such a psychic disequilibrium is the artillery. The effect of this is limited, however, because the sensation accompanying the explosion of the shell is always of the same kind, and finally results in a greater or lesser indifference. One shell can be two or four times as large as another, and may penetrate correspondingly further and produce a more terrifying sound, but in the long run the stimulus produced remains the same. ... Life in a trench subject to direct hit or cave-in is a terrific strain on human nerves, but the experience of the war has taught us that the strain becomes tolerable because sensitivity is deadened against any continuous stimulus on the human organism.

"Exactly the reverse is true of the means of chemical warfare. Their essential characteristic is the multifold and varying physiological effect on man and the sensations they produce in him. Any change in the impressions felt by nose and mouth affects the psychic equilibrium through the unknown character of its effect, and is a new strain on the power of moral resistance of the soldier at a time when his entire psychic strength should be devoted undividedly to his mission in combat. [857]

The first occurred during the UK's reaction to the V-1 "Flying Bomb" attacks on London, which began in June 1944. It was proposed that as retaliation against a "weapon literally and essentially indiscriminate" in its nature, poison gas should be used against the launching sites. This idea had in fact been mooted at a lower level before the attacks began [858], after British intelligence had realized what was in preparation. It was rejected, however, on the grounds that such a measure would involve, *inter alia,* an unacceptable diversion of the Allied air effort at a time when it was needed in full to support the invasion of France. General Eisenhower was decidedly against it. [859]

The second occasion was during the Allied encirclement of Germany in the autumn of 1944. Although the German military continued in their opposition to the use of chemical weapons, their attitude was not unanimously shared in political circles. Pressure built up to use the large stocks of chemical weapons that Germany had by then accumulated—notably the nerve-gas weapons—whatever the consequences. According to Speer's testimony at Nuremberg [860], those advocating the use of chemical weapons were "a certain circle of political people, certainly very limited. It was mostly Ley, Goebbels and Bormann, always the same three, who by every possible means wanted to increase the war effort. . . ." Speer apparently thought it probable that these people's views would eventually prevail[4] and, according to his testimony, he went to considerable lengths to divert raw materials and intermediates away from the CW agent factories, and to try to persuade Hitler of the folly of initiating CW in the face of Allied air superiority. [860] Speer recalls these urgings of German initiation of CW in his recently published memoirs:

Robert Ley, by profession a chemist, took me along in his special railroad car to a meeting in Sonthofen held in the autumn of 1944. As usual, our conversation took place over glasses of strong wines. His increased stammering betrayed his agitation: "You know we have this new poison gas—I've heard about it. The Fuehrer must do it. He must use it. Now he has to do it! This is the last moment. You too must make him realize that it's time." I remained silent. But apparently Ley had had a similar conversation with Goebbels, for the Propaganda Minister asked some of my associates in the chemical industry about the substance and its effect, and then urged Hitler to employ this novel gas. Hitler, to be sure, had always rejected gas warfare; but now he hinted at a situation conference in headquarters that the use of gas might stop the advance

[4] It may be noted that during the summer of 1944, the overall control of Germany's CW capabilities had been transferred from Field-Marshal Keitel to SS-Obergruppenführer Brandt, Hitler's former physician [212]. It is not improbable that with this shift of responsibility away from the army to the Nazi Party itself there was a corresponding shift in the balance of the incentives and constraints influencing the possible employment of chemical weapons.

of the Soviet troops. He went on with vague speculations that the West would accept gas warfare against the East because at this stage of the war the British and American governments had an interest in stopping the Russian advance. When no one at the situation conference spoke up in agreement, Hitler did not return to the subject. Undoubtedly the generals feared the unpredictable consequences. [861]

The third occasion was related to this one, and occurred immediately after the destruction of Dresden by British and US aircraft in February 1945. As the first news of this was received in Berlin, the initial reaction was to seek revenge by similarly illegal means. Among the alternatives considered was the demand by Goebbels that the nerve gases be used against the British. It is not clear how he proposed putting this into effect. [862–63]

II. *The constraints on employment of chemical weapons*

Military constraints

Before discussing the specific constraints that prevented the use of gas on the occasions noted above, it is necessary to summarize some of the principal characteristics of national CW policy during the immediate pre-war years. It will emerge that a major constraint on initiation of CW during the early part of the war was both a lack among the belligerents of the necessary material capability, and a general disinclination to acquire it. The cause of this has to be sought in the attitudes towards CW of military establishments before the war broke out.

By the end of the 1930s, military establishments within several of those nations that would soon be fighting World War II were still undecided about the military value of chemical weapons. Quite apart from the question of whether they should themselves be prepared to initiate CW—for some nations, a political decision had already been made against initiation, albeit not in all cases with the full agreement of the military—there was also the question of what their potential enemies were planning to do: what was the correct contingency planning to adopt against enemy initiation of CW? No military establishment doubted the need for an efficient anti-chemical defence, for the Ethiopians' experience at the hands of the Italian Air Force had re-emphasized its importance. But was it necessary to go a stage further and acquire some sort of retaliatory capability as well? The reservation of the right to retaliate in kind had been made by some, but not all, the major European nations when ratifying the Geneva Protocol, so that a retaliatory stockpile could be regarded as a sanction of the treaty as well as an insurance measure. In addition, if military arguments for CW ever reversed the political decision against initiation, a retaliatory stockpile could form the foundation for a more versatile CW capability. However, given the undecidedness of all but the most partisan military leaders about the value of chemical weapons, and given the political liabilities of an extensive chemical-weapons procurement programme, the overriding considerations in CW contingency planning were the intentions of potential enemies. The deeper enemy commitments to offensive CW preparedness appeared to be, the weaker was the case for relying solely on anti-chemical defensive equipment and a token retaliatory stockpile.

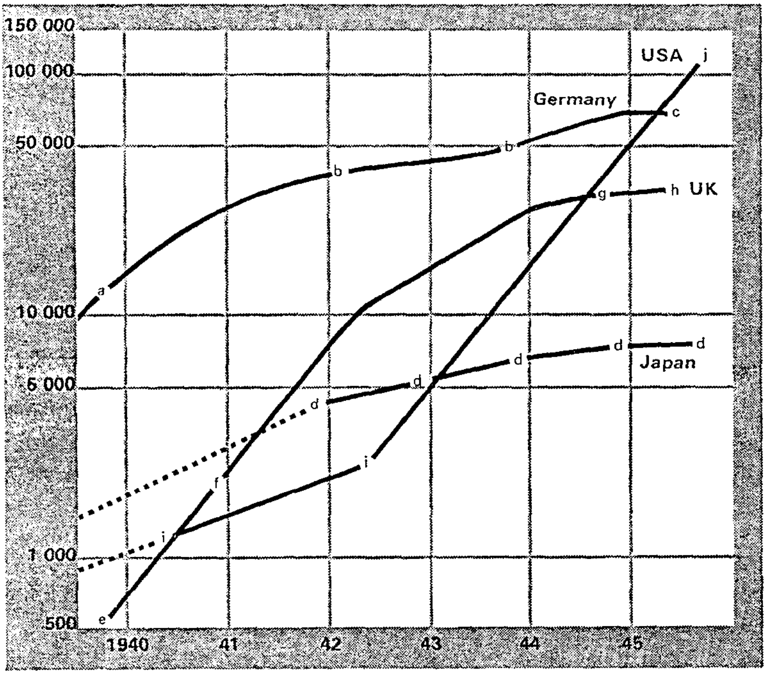
To outside observers, the major European nations all displayed signs of chemical-weapons procurement programmes. Italy had given the clearest indication of this in Ethiopia. From Germany, opponents of the government had provided a spate of rumours that IG Farbenindustrie was carrying out extensive CW research and development work for the German Army [206, 243, 245, 257–58], and no doubt the UK and France had more precise secret intelligence of these and related activities. Germany knew that the USSR had a chemical-weapons manufacturing capability even if it consisted only of those factories Germany had helped to build in the 1920s; Germany also had information that France and the UK were carrying out chemical-weapons trials in North Africa [212], as indeed they were. Probably these were nothing more than indications that the nations concerned were exploring possible retaliatory CW postures, but, in an increasingly tense international situation, many people must have been ready to believe that they indicated first-use intentions. The more such perceptions received support, the stronger was the case for building up retaliatory stockpiles, or even first-use stockpiles.

It seems that the snowballing effect inherent in this did not get under way until 1941 or so. Chart 5.1 shows the growth of German, British, US and Japanese CW agent stockages during the war.

The German stockage at the beginning of the war stands out in Chart 5.1 by its relative size, but it would be dangerous to draw too many conclusions from this. On the one hand, it was German policy to have available a large CW agent manufacturing capacity which could be put onto maximum output at short notice: throughout the war, the output in fact averaged only 10 to 12 per cent of capacity [52]. On the other hand, CW agents are not chemical weapons, and by themselves cannot constitute an offensive CW capability: a substantial proportion of the total German CW agent output was in fact stored in bulk, rather than filled into munitions, and later on in the war shortages of shell-casings and such greatly impeded the output of actual chemical weapons [52].

Chart 5.1. Stockages of CW agents by different belligerents in World War II

Tons; note logarithmic scale



Notes and sources

The fall-off in German CW agent output towards the end of 1944 is recorded by several authors, including the US Strategic Bombing Survey [52]. The fall-off in British CW agent output in the spring of 1942 is recorded by the official historians of the US Army CWS [210]. Churchill [864] records the cut-back at the beginning of 1944.

[a] Brown [51] quoting a US interrogation report containing figures provided by a German authority on CW agent production.

[b] US Strategic Bombing Survey [52] quoting captured German documents.

[c] (70 000 tons.) US Army CWS officer [211] quoting an evaluation by the Intelligence Division of the CWS. Other figures fot total German CW agent output have been published, however. Thus, the US Strategic Bombing Survey records a figure of 62 000 tons [52], but at the time this figure was quoted it is possible that not all the pertinent data had been collected. A Soviet commentary gives a figure of 250 000 tons [122].

[d] (7 500 tons.) A US Army CWS evaluation of Japanese wartime CW capabilities made in 1946 [50].

[e] UK Ministry of Defence [871].

[f] Churchill [815] quoted a figure of 1 485 long tons for UK stockage of mustard gas at this time. Around 500 tons may reasonably be added to this to allow for stockages of phosgene and irritant agents.

[g] Speer [861] quoting a memorandum on British CW capabilities prepared for Churchill in the summer of 1944.

[h] (35 000 tons.) This estimate is derived from official British figures for chemical weapons dumping operations after the war. See note 3 below.

[i] Brown [51] quoting US Army documents. He gives figures of 642 short tons for total

Even if the entire tonnage of CW agents that Germany had accumulated by the time war broke out had been ready for immediate use, it is most unlikely that the Wehrmacht intended it for the initiation of CW: it was almost certainly too small for this in the types of campaign they were contemplating. This is suggested by the US plans made in 1945 for the invasion of Kyushu which allowed for the possibility of Japanese initiation of CW: retaliatory stocks of chemical weapons were to be maintained, amounting to 23 500 tons of aircraft-delivered toxic weapons and 8 500 tons of toxic mortar and artillery ammunition. This was intended to suffice for sixty days. [51] This tonnage of weapons would have contained some 10 000–15 000 tons of CW agents. For first-use rather than retaliatory purposes, the JCS chemical-weapons requirement estimates were four times higher than these figures [51]. There is little reason to suppose that German methods of calculating chemical-ammunition requirements differed markedly from US methods: this is borne out by a German estimate that 25 000 tons of mustard gas was sufficient for about five months of retaliatory CW [52]. Quite apart from inadequate stocks of weapons, the German Army also lacked sufficient protective equipment to initiate CW, at any rate during the invasions of Poland and France [212].

What the disparity between the German and, say, the British stockages at the outbreak of war probably reflects is German misperception of its enemies' interest in CW, coupled with a feeling that because German CW

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mustard-gas stockage as of June 1940, and 1 250 short tons as of May 1942. It is reasonable to double these figures to allow for the stockages of other agents.

i (135 000 tons.) The official historians of the US Army CWS during World War II [30].

1. Figures for CW agent output in the USSR are not available. It is recorded that during the war the Germans believed the Soviet output to be at least 8 000 tons per month [51].

2. Other countries which were manufacturing CW agents during or shortly before World War II included Czechoslovakia, France, Greece, Hungary, Italy, Poland and Yugoslavia; see page 293.

3 A total of 102 857 long tons of German chemical weapons were captured by US forces in Germany [884]. It is not known what quantity was found in the Soviet zone, or in the zones occupied by the British or the French. The US-captured stocks were either destroyed *in situ* (ca. 32 000 long tons), scuttled at sea (ca. 32 000 long tons), shipped to countries outside Germany (ca. 30 000 long tons) or sold as scrap within Germany (8 450 tons, including 1 355 long tons of CN weapons). Nearly 8 000 tons of US-captured chemical weapons were shipped to the UK. [884]

During the period 1945–48, the UK scuttled some 175 000 tons of chemical weapons at sea [885], about 100 000 tons of this from Scotland [886], and the remainder direct from Germany [887]. During 1955–56 the British scuttled a further 17 000 tons of captured German weapons at sea, including 13 000 tons of tabun bombs [885, 888–89], the remainder presumably being mustard-gas weapons [890]. During 1956–57, a final scuttling operation disposed of the remainder of the current British stockage of chemical weapons; this involved 8 000 tons of World War II British mustard-gas and phosgene bombs and mustard-gas shell [885, 887–89]. If it is assumed that the 100 000 tons disposed of from Scotland were entirely British stocks, and that the 75 000 tons disposed of from Germany included no British weapons, it would seem that the British manufactured about 108 000 tons of chemical weapons during World War II. This would correspond to a wartime procurement of around 35 000 tons of CW agents.

R & D had been severely impeded by the provisions of the Versailles Treaty, Germany was many development-years behind its enemies: what it thought was lacking in the quality of its chemical weapons, it felt could only be made up by their quantity. [51]

It seems clear that, at the end of 1939, each of the major belligerents suspected its enemies of a readiness to initiate CW, whereas in fact none of them was prepared to do so. Under the stimulus of these suspicions, all were building up retaliatory stockpiles, with Germany apparently taking the lead. It was not until 1941 or 1942 that these stockpiles had grown to a point at which they provided a first-use option in anything other than last-resort situations. Had the incentives to use the weapons been stronger, this point would no doubt have been reached much sooner.

One explanation for the undecided and generally lukewarm attitudes adopted by military establishments towards CW is to be found in the inherent technical limitations of chemical weapons. In use, they depended closely on the weather, which meant that munitions requirements could only be calculated in advance within rather wide limits: quite a small change in the weather, or an unusual target topography, could demand a ten or twenty-fold increase in the weight of weapons needed for a given effect. As a corollary of this, the results of a given attack in terms of, say, the number of casualties could also vary between wide limits, so that in this sense the effects of chemical weapons were not closely predictable, particularly if there was uncertainty about the level of enemy anti-gas protection. The extent of the downwind hazard to which use of chemical weapons might expose friendly personnel would also be uncertain. CW would thus greatly complicate long-term operational planning. Furthermore, the logistical complications also arising from these uncertainties would be compounded by the need to provide anti-gas protective equipment, decontaminants, and special medical supplies in addition to offensive CW matériel. If enemy retaliation in kind were expected, these arrangements would have to be especially thorough, and backed up by increased medical services.

All in all, the employment of chemical weapons would very considerably aggravate command and control problems, while the sheer bulk of matériel called for would greatly inflate the supply services. These considerations undoubtedly provided severe disincentives to any military establishment contemplating the initiation of CW, at any rate against a major power. Additional military constraints will become apparent in the following discussion of battlefield situations in some of the theatres of operations.

Germany's initial campaigns in Poland and France depended on surprise for their success. With fast-moving armoured columns and ground-support aircraft, the resistance of the enemy was to be broken before he could contain the attack. Mobility was of prime importance. While gas might have some advantages over other weapons in occasional situations, those advantages could almost certainly only be secured by compromising mobility. This was likely for several reasons. (*a*) If gas was to be used along one sector of the front to aid the advance, time-consuming preparations would have to be made to coordinate its use with activities along adjacent sectors, both before and during the operation. (*b*) The residue of heavily-contaminated ground from an earlier action could gravely impede subsequent actions. (*c*) Gas could be used only at cost of expanding the supply lines or by reducing non-CW supplies. (*d*) If German forces initiated CW, the enemy could be expected to respond in kind; by skillful use of mustard gas, he could easily destroy the whole momentum of the German advance. [212] Above all, the use of gas, in that it demanded close coordination between flanking units, and therefore a considerable degree of centralized tactical planning, not merely before but also during the execution of a mission, was quite out of keeping with the existing German doctrine of *Auftragstaktik*. Furthermore, in view of known Polish and French anti-gas measures, the advantages obtainable with gas would probably only be slight.

That gas might succeed in slowing down or disconcerting the German advance had presumably also occurred to the Polish command, and subsequently to the French. While there is little information available about either Polish or French CW capabilities, it seems likely that they were either too limited to make much of a contribution to the defence of the homeland, or could not have been deployed in time. Furthermore, had they been used they would undoubtedly have affected noncombatants as well as the invading Germans. This constraint would also have applied to British and French forces operating in Norway and the Low Countries, and to Soviet forces facing the German invasion of the USSR.

There is apparently some evidence to suggest that Germany considered using gas against the USSR [382]; this was referred to in the correspondence between Stalin and Churchill in March 1942 [864] which subsequently led to Churchill's declaration in May 1942 that if Germany used gas against the USSR, the UK would use its "great and growing air superiority to carry gas warfare on the largest possible scale far and wide against military objectives in Germany" [865]. During the initial stages of the German advances, however, it seems highly improbable that the Wehrmacht would have gained any significant advantage from gas: CW was as ill-suited to the *Blitzkrieg* tactics used then as it had been in Western Europe. In General Ochsner's words:

Our intention was to shatter the Russian front (if the Russians succeeded in establishing a front at all in the face of our sudden surprise attack) by means of swift, powerful thrusts with our assault armies, supported mainly by Panzers and the Luftwaffe, then to envelop and annihilate entire army groups, and to follow up with a deep thrust into Russia in the direction of Moscow and the industrial centres. There the lifelines and sources of Russian might were to be mortally struck. The use of chemical agents could only have reduced the speed in operations of this nature: further, it would have strained to the breaking point our supply service, which was difficult enough anyhow in view of the poor railroad communications, the inadequacy of roads for modern motor transport, and the great distance from the German bases. We had to do everything possible to avoid this happening. Hence, under no circumstances did we dare commence the use of chemical agents. This applied equally to the opening stages of our 1941 campaign and to our offensive in the summer of 1942, which was planned along similar strategic lines. [212]

As the German advances were halted and finally reversed, different considerations came to the fore. Ochsner refers to the threat to German supply lines posed by the growing partisan movement operating in the German rear, and to suggestions made for using gas to counter this threat, particularly to destroy partisan groups hiding in underground tunnels, caves and bunkers. But by this stage in the war, the possibility of Allied retaliation in kind had to be taken increasingly seriously as Allied dominance in the air grew. On this Ochsner writes:

Of course we would have been successful in countering the partisans and thus would have lightened the burden of our forces locked in bitter conflict, and lives would have been spared. On the whole, however, we would but have furnished our enemies, who were vastly superior to us in material on all fronts in all theatres of war, with a good excuse also to use gas against our armies on all fronts, and perhaps even against our homeland. In such event, we would not have been able to retaliate as enemy air power was growing perceptibly. These sober deliberations not only justified the decision of our Supreme Command under no circumstances to use gas, but in fact made that decision obligatory. [212]

For the Soviet part, good military arguments could be made for the use of gas. As the Poles and the French might have done, had they been able, Soviet forces could have greatly slowed down and disconcerted the initial German advances with persistent ground contaminants, while surprise attacks with nonpersistent agents would have forced continuous attention to anti-gas discipline, thus imposing additional matériel requirements on already overburdened supply channels. In addition, the German rear must have been extremely vulnerable to gas, particularly as the communication and supply lines became stretched. Apart from the endangering of Soviet civilians, the military constraints which prevented Soviet use of gas can only be guessed at. Little is known about Soviet capabilities in CW, beyond the technical sophistication of much of the anti-gas equipment of the time;

German intelligence certainly credited the USSR with a highly developed offensive CW capability.[5] Ochsner advances the view that the Soviets were deterred from using gas by the memory

> of their experiences during World War I, where their losses through gas casualties were inconceivably high. ... Our experience showed that ... Russian soldiers were very unequally trained in the knowledge of antigas defence measures and their application: the uninformed or the malinformed were vastly in the majority. [212]

As for the possible use of chemical weapons during operations in North Africa, climatic conditions accentuated one of the principal limitations of

[5] The Soviet Union's cooperation in CW matters with its Western allies is reported to have been minimal. German intelligence assessed the size of the Soviet CW agent manufacturing output at a level of at least 8 000 tons per month, and perceived an intensive troop-training programme in CW. It also credited the Red Army with a readiness to use CW techniques under conditions of extreme cold. [51] This was particularly disconcerting for the Germans, who would have been virtually defenceless against cold-weather CW: the rubber used in their respirators hardened in the cold, causing the respirator to lose its airtight fit around the face, and the respirator exhaust valves tended to freeze easily. [212]

According to a wartime Red Army chemical officer writing after emigrating to the West, Soviet chemical troops comprised, before 1941, a chemical brigade, a chemical battalion, two chemical regiments and various chemical companies, together with a chemical battalion attached to most of the military commands. Within the field armies, chemical officers were established at all echelons down to company level; each regiment had a platoon of chemical troops, each division a chemical company and, by July 1941, each army a motorized chemical battalion. In 1943 the command structure for chemical troops was reorganized; by the summer of 1944 there were about thirty battalions of operational chemical troops. The chemical weapons available in 1941 included aircraft bombs charged with persistent or nonpersistent CW agents, bomblet dispensers charged with persistent agents, aircraft spray tanks, chemical artillery shell and mortar bombs charged with persistent or nonpersistent agents, chemical land mines, spraying installations for persistent agents mounted on motorized vehicles including tanks, and toxic-smoke generators. [54]

Soviet manuals captured by the Germans dwelt on the effectiveness of gas when sprayed from aircraft on troops or on important terrain sectors such as passes, wooded areas and river crossings; they also dealt with the use of tanks for contaminating ground in the enemy's rear after breaking through enemy lines. [212] Captured Soviet chemical weapons included different sizes of aircraft bomb (such as the *CHAB 500* bomb, holding 170–180 kg of phosgene); an in-line bomblet dispenser for small mustard/lewisite bomblets (the *AK-2* aerial release case); and several sizes of aircraft spray tank [866]. (One of these, the *Batt* (*VAP*) *1 000*, was designed to dispense about 700 litres of stabilized hydrogen cyanide; used at a low altitude with four tanks per aircraft, the weapon was said to be capable of setting up a ground-level concentration of 80 000–100 000 mg/m^3 hydrogen cyanide, sufficiently high to penetrate current German respirators [57, 866].) The German are also reported to have informed the Japanese that the Soviet Union had developed two new CW agents—dichloroformoxime and a nitrogen mustard—in addition to the well-known World War I agents [56]. All in all, the Germans feared Soviet CW capabilities more than those of any other Allied nation. In particular, they felt that the Soviet Union must have developed a nerve-gas capability in view of the long-established school of organophosphorus chemistry in Kazan, based on the work of A. Ye. Arbuzov: the Germans were, after all, using an Arbuzov-type reaction in one of their processes for making sarin.

offensive CW, namely its dependence on the weather. During daylight hours in the desert, the strong insolation would have demanded greatly increased munitions expenditure, both for volatile agents intended for respiratory effect and for involatile agents intended for ground contamination. During night hours operations with volatile agents might have become more feasible, but the increased restrictions on the times when chemical weapons could usefully be employed must have greatly reduced whatever incentives there were to use them. No doubt weapons intended for desert conditions could have been developed, but there was no great pressure to do so. Furthermore, the supply channels of the belligerent armies across the Mediterranean and the Atlantic were particularly vulnerable, and the need to load these with CW matériel, particularly anti-gas protective equipment, at the expense of other urgently needed stores weakened the case for employing chemical weapons in North Africa still further. The British, however, did maintain CW depots in Egypt, but the threat of enemy retaliation in kind against the British Isles provided an overriding sanction against their exploitation. In addition, by this stage of the war, planning for the Allied landings in continental Europe was going ahead: it must certainly have been appreciated that these landings would be highly vulnerable to chemical attack.

At no point did Japan have the capability to inflict severe damage on either the British or the Americans with chemical weapons [359]. While it could at a stretch have increased its output of CW agents, it had neglected its anti-chemical defences, particularly for the civilian population, and by 1944 Japan fully appreciated its vulnerability to US chemical attack. Even had it possessed adequate stocks of CW matériel, and had in fact decided to us them after its reverses in the Islands campaigns, Japan would have faced severe supply problems if it was to wage CW on any scale. As the historians of the US Army Chemical Warfare Service have remarked, a logistical system that failed to provide food for Japanese troops in New Guinea could hardly have supported gas warfare. [210]

The Americans were apparently unaware of Japanese deficiencies in CW preparedness, and as late as July 1945 regarded the Japanese as being capable of initiating large-scale CW. General Marshall recognized the possibility that the Japanese might use their offensive CW capability against civilian populations in China, Manchuria and Korea when the JCS was considering possible US use of chemical weapons during the planning for the invasion of Kyushu. [51] As is discussed further below, these considerations, coupled with general supply and logistics problems, appear to have been the principal constraints on US initiation of CW in the final stages of the war.

By way of recapitulation, the military constraints on employment of chemical weapons during the war may be summarized as follows. At the outset of the war, the stocks of chemical weapons available to most of the belligerents were small. This was chiefly due to a feeling in military circles that the complications of command and control procedures and the encumberment of supply lines attendant upon use of chemical weapons, meaning a possible compromise of mobility, would be insufficiently compensated for by their probably only marginal superiority over stores of conventional weapons, particularly considering that chemical weapons were dependent for their effect on weather, topography and enemy anti-gas precautions, which might seriously limit the occasions on which they could be used effectively. In addition, their weather-dependence introduced elements of unpredictability which could jeopardize long-term planning and could endanger friendly noncombatants to an unforeseeable and unacceptable extent. On top of all this, there was the danger that even a small chemical operation might provoke retaliation in kind against unprepared sectors of the front, against unprepared allied forces, against the civilian population at home or in allied countries, or against some future operation that might prove highly vulnerable to chemical attack. Finally, during the last stages of the war, when the dominant belligerents had succeeded in exhausting enemy strength to a point at which these constraints had lost most of their compulsion, the available offensive CW stockpiles were too small or too widely dispersed to be sufficiently useful or to exceed the attractions of other newly developed weapons.

Two of these constraints are worth looking at further. On the question of the paucity of offensive CW stockpiles in the later stages of the war, it must be remembered that it took many months to expand existing chemical-weapons factories, so that if a successful belligerent had anticipated a need for this, he would have had to invest the necessary labour and equipment during a period when his success was still in the balance. The turning points of the war occurred in late 1942 and 1943, which was when the Allies would have had to start expanding their chemical-weapons factories if they were to be in a position to initiate CW in 1944 or 1945. Only the USA had sufficient natural resources and undamaged or uncommitted industrial facilities to do this. Even if the UK had had the resources, the procurement of an initiatory CW capability would have had a very minor claim on them. From the British viewpoint at this time, the incentives for Allied initiation of CW were negligible while the constraints were overwhehning, and looked likely to remain so indefinitely. They could have been disregarded only if initiation of CW could have secured great and immediate strategic advantage. Given the level of anti-chemical protection available to German troops, such advantage could not be secured on the battlefield.

Chemical attack at the German rear might have been more productive, but there was no great reason to suppose that gas was superior for this purpose to conventional weapons. Indeed, for achieving anything other than demoralization of the enemy, it was probably greatly inferior: it could not destroy enemy manufacturing installations or transportation networks, and even for securing enemy casualties its superiority to fragmentation or incendiary weapons was questionable. [867] The fact of the matter was that gas was not a strategic weapon, and there was therefore no incentive to expand the chemical-weapons manufacturing base. Rear-Admiral Sir Anthony Buzzard, a British member of the joint planning committee that drafted the appreciation of whether or not the Allies should initiate CW in 1943, has recently recalled that it was decided not to do so mainly on the grounds that such an addition to the Allied strategic-bombing operations over Germany would not have been decisive, but that gas used against the Allies on the Normandy beaches would have been. [868]

The sources of the constraint provided by the threat of enemy retaliation in kind were these. If a belligerent were to initiate CW, enemy retaliation in kind might come anywhere along his front or fronts, or in his rear. It might not even be directed against him, but against his allies. It might not be immediate, and might be delayed until some particularly favourable opportunity for an advantageous gas attack arose. Fear of retaliation in kind thus provided a constraint because: (*a*) the retaliation might cause unacceptable damage; (*b*) it would become necessary to take precautions to minimize possible damage; and (*c*) it might not be possible to take all necessary precautions. While there were occasions when retaliation was feared because it might have a damaging effect on battlefield operations, the most common fear was that it would be an escalatory response directed against the civilian population at home or in friendly countries. The level of civilian anti-gas defences varied greatly among the belligerents. In the USA it was unnecessary. In Japan it was minimal: little anti-gas equipment had been distributed or instruction given [359]. In the UK it was well-developed: enough respirators had been manufactured for the entire population—and for the most part issued—and civilian anti-gas training programmes had been initiated nearly five years before the outbreak of war.[6] The UK, however, was perhaps the most vulnerable of all the belligerent countries to counter-city gas attack, and there can be little doubt that any really concerted German gas-bombing operation would have produced great numbers of British gas casualties. In Germany, civilian anti-gas measures

[6] See pages 260–262.

were not as highly developed,[7] but on the other hand, the German homeland was less accessible to attack, during the early part of the war, that is.

Whether a belligerent felt that retaliation in kind against his civilian population was a sufficiently constraining threat to prevent him from initiating CW depended chiefly on his assessment of enemy ability to deliver a sufficiently damaging gas attack. Whether the retaliation were against the elaborate British civilian anti-gas defences or against the virtually non-existent Japanese ones, it was to be expected that a large enemy bomber force, if it could penetrate the air defences, would secure great numbers of civilian gas casualties. Even the most confident civil-defence authorities could not be certain that this possibility could be ruled out. Two assessments therefore had to be made. First, could the enemy penetrate the air defences with sufficiently large bomber forces? Secondly, if he could do so, did he have a sufficient quantity of chemical weapons? The possible scale of attack was important: if it were known that only a small gas attack could be mounted, the threatened damage might not deter initiation.

From the point of view of superiority in the air, Germany had the initiative in counter-city CW in Europe until mid-1943 or so. Even thereafter it was not until the last months of the war in Europe that the Allies could safely assume that Germany was incapable of inflicting severe gas damage on Allied cities. There was considerable fear, for example, that the *V-1* and *V-2* missiles might carry chemical, or even biological, warheads, so much so that when intelligence reports on the imminent use of these weapons began to come in, in December 1943, the US JCS directed the Supreme Allied Commander in Europe to prepare CBW countermeasures. [451] (In fact, the Germans had decided against developing such warheads for these missiles [212].) In the Far East, US air superiority did not pose a CW threat to the Japanese homeland until after airbases had been established in the Marianas during 1944.

As far as possible Allied initiation of CW was concerned, it can probably be said that fear of escalatory retaliation in kind was the dominant constraint for the greater part of the war. This fear even constrained possible US initiation in the Far East: thus, General Marshall has been quoted as having said, in 1947: "The reason [gas] was not used [against the Japanese] was chiefly the strong opposition of Churchill and the British. They

[7] Overall German air-raid precautions were extensive, with the emphasis more on the provision of air-raid shelters than in the UK, and less on the evacuation of threatened populations. At least $200 *per capita* was spent on the shelter programme. Unlike the British, however, the Germans did not give any special emphasis to anti-gas measures, so that by the end of 1942, only 28 million "peoples' gas masks" had been distributed. By 1945, despite an accelerated manufacturing programme, 25 million Germans remained unprotected. [51]

were afraid that this would be a signal for the Germans to use gas against England." [855] Goering, under interrogation at the end of the war, stated that the Germans would indeed have done so [267]. It appears that a similar pressure was brought to bear on the Soviet Union [54].

For Germany, fear of retaliation in kind became the dominant constraint once it had lost air superiority. After this happened, it became acutely aware of its vulnerability to counter-city gas attack. Germany was faced with an inadequate supply of civilan anti-gas equipment at home, together with a deteriorating industrial capacity for expanding it, and by an enemy committed to a strategic bombing policy backed up by a rapidly growing force of long-range heavy bombers. Hence Speer's testimony at Nuremberg: "All sensible Army people turned gas warfare down as being utterly insane since, in view of your superiority in the air, it would not be long before it would bring about the most terrible catastrophe upon German cities, which were completely unprotected." [860]

Many instances are recorded where the belligerents went to considerable lengths to prevent their enemy being given justification to retaliate:[8]

(*a*) Soviet chemical units are reported to have been denied use even of smoke-screening materials during the early part of the German invasion of the USSR for fear that the Germans might thereby be given a pretext for alleging Soviet initiation of CW. [54]

(*b*) In 1940–41, Churchill was constrained from making public announcements that the UK would retaliate against German CW for fear that the Germans would interpret this as a threat of British initiation of CW [815]. This fear extended deeper: in a memorandum to the Chiefs of Staff Committee in January 1941, he wrote: "It is important that nothing should appear in the newspapers, or be spoken on the BBC, which suggests that we are making a fuss about antigas arrangements, because the enemy will only use this as part of his excuse, saying that we are about to use it on him." [219]

(*c*) The Japanese, in the summer of 1944, recalled all forward area stocks

[8] There was one occasion when an incorrect report that the enemy had used gas apparently led to preparations being begun for a retaliatory attack with gas. This occurred after a British bombing attack on Kassel in October 1943. More than 5 000 people were killed during the attack; 70 per cent of them were asphyxiated, being overcome by the carbon monoxide and oxygen deficiency resulting from the intense conflagration. It is recorded that "so many people had died of poisoning, and their bodies had turned such brilliant hues of blue, orange and green that it was at first assumed that the RAF had for the first time been dropping poison gas bombs in this raid; steps for suitable retaliation were taken; post-mortem examination by German doctors refuted this charge, and the air offensive was spared this hateful new development." [862] The following London newspaper report, published during May 1942, may also be noted: "German military commentators suggestively emphasize that unless Great Britain abandons the use of phosphorus bombs, the Wehrmacht would be justified in retaliating with gas." [854]

of chemical weapons to the rear to minimize the risk of an irresponsible field commander provoking US retaliation in kind. They were also fearful lest German initiation of CW in Europe provoke US retaliation on Japan. It is said that the Japanese were prepared to overlook small-scale tactical use of gas by the Allies to avoid general gas warfare. [359]

(*d*) Throughout the war, Germany made it a policy not to maintain stocks of chemical weapons outside its borders for fear that they would be used without authorization by local field commanders in extreme situations [212]. This policy was followed even though it could have considerably delayed German retaliation in kind, should it have become necessary.

Only the USA remained substantially undeterred by the threat of direct retaliation in kind; and it was only the USA that came at all near making a considered decision to initiate CW.

Throughout the war, assessments of enemy chemical-weapons stockpiles were generally much higher than the stockpiles in fact were, and this made an important contribution to the strength of the fear-of-retaliation constraint. The assessments exaggerated not only the size of enemy stockpiles, but also the potency of their contents. This was particularly true of German assessments. Germany could not believe that the Allies did not possess nerve gases such as their own tabun and sarin. [210] Their fear that the Soviet Union possessed them has been noted above; as for possible US possession, the story has often been quoted that the Germans interpreted discontinued US public reference to insecticide work as indicating discovery of the nerve gases, whereas in fact it was a security measure adopted to conceal the development of DDT [51]. In addition, the Germans mistook Allied preoccupation with the CW possibilities of hydrogen cyanide—as evidenced by captured Allied respirators containing novel charcoal impregnants—for an interest in some new class of CW agent that the Germans did not know of. For the Allied part, there appears to have been a certain complacency about the possibility that Germany might have discovered new CW agents, beyond a curious fixation that the Germans might have developed *dichloroformoxime* (CX) for war use. [869–70] Although Allied intelligence frequently received reports of new German CW agents with astounding properties, these reports were rated low in reliability, and little credence was given to them [211]. The Germans certainly maintained the closest secrecy around their nerve-gas work, and the Allies did not receive confirmed intelligence of it until the first stocks of tabun weapons had been captured.[9] The fact that each belligerent tended to over-estimate its ene-

[9] Even then (April 1945), the significance of the new agent was not immediately realized, since many Allied experts initially held it in rather low esteem. It was not until the subsequent discovery of the work on sarin that the importance of the nerve gases was recognized. [21]

mies' CW capabilities enhanced the threats made by Churchill and by Roosevelt when they declared in 1942 and 1943 that Axis initiation of CW would be met by enormous Allied retaliation in kind.

Non-military constraints

In addition to the military constraints on using chemical weapons, there were important non-military ones also. In many countries during the 1920s and 1930s the question of CW preparedness was an issue of considerable public controversy, as we have seen. As a consequence of this, decisions about the use of chemical weapons during the war had to take into account not only military considerations, but also a variety of political and other non-military ones—questions of public opinion, international law and political expediency. Because the decisions had these ramifications, they had been forced up to a high political level: they could no longer remain entirely in the hands of the military. Even in Japan, the decision to use gas against Western powers rested with the Emperor, although against China it had been made by the Army General Staff [359]. In the USA, the old Joint Board order of 1934 (referred to on page 276), authorizing use of chemical weapons from the inception of hostilities, was rescinded in 1942, and the decision to use chemical weapons was no longer one for theatre commanders, but for the President.[10] Certain political leaders in the belligerent countries held strong personal feelings about CW and, under these conditions, they exerted a powerful influence. It has been held that much of the US unpreparedness for CW in 1941, for example, was a direct consequence of President Roosevelt's hatred of gas. CW protagonists deplored his influence in this respect, and criticized his attitude towards gas as emotional and uninformed: it is recorded that it was only after Roosevelt's death that

> planners could evaluate the merits of the employment of toxic agents with the foreknowledge that any recommendation would be seriously considered at the highest level rather than being immediately rejected due to personal bias. After April 1945, the atmosphere in Washington suddenly permitted consideration of chemical warfare.[11] [51]

[10] The order was rescinded in April 1942 when General Marshall directed that no chemical weapons were to be employed without specific War Department approval. The authority to initiate retaliatory CW thereafter rested at the level of Chief of Staff, US Army, and Commander-in-Chief, US Fleet, until December 1942 when it became a Presidential decision. [51]

[11] One commentator has suggested that Roosevelt's hostility towards CW may have lessened in 1944 as a result of the bitter fighting in the Pacific and a desire to end the war as quickly as possible regardless of the means employed. If so, this shifting attitude did not alter CW contingency planning: those responsible continued to assume that the President would adamantly oppose initiation of CW. [51]

However, the official historians of the US Army CWS note that "military leaders would have presented arguments in rebuttal had they entertained any deep-seated doubt as to the wisdom of the Presidential view" [210]. Roosevelt's attitude was shared by his senior naval adviser, Admiral Leahy, who later became President Truman's Chief of Staff. Admiral Leahy regarded gas as a barbarous weapon, one which would "violate every Christian ethic I have ever heard of and all of the known laws of war" [872].

Hitler, like his predecessor as head of state, von Hindenburg, also had a strong personal antipathy towards CW, one which apparently stemmed from exposure to British mustard gas at the end of World War I [212, 873].[12] Although he does not seem to have made his views about CW felt during the pre-war period to such an extent as did Roosevelt, it was nonetheless apparently assumed within German military circles that his antipathy would prevent German initiation of CW [51]. However, some commentators have suggested that at the end of the war this antipathy may actually have provided an incentive to initiate CW: they take the view that once Hitler had embarked on his victory-or-destruction policy in 1945, the very horror of poison gas might have become a compelling reason to order its use. There is, in fact, an appreciable body of evidence—albeit inconclusive—to suggest that Hitler did actually authorize the use of chemical weapons in the final months of the war [51]. Other commentators have said, however, that Hitler was steadfastly against the use of gas throughout the war, and that in the final stages he continually turned down his advisors' recommendations that it should be used [874].

These personal antipathies towards gas may perhaps best be described in psychological terms, but this is not the place to attempt it. It is sufficient to note that similar psychological constraints also existed among senior officers in the armed services of the belligerent countries. This fostered their reluctance to interest themselves in the possibilities of CW. Thus, a civilian expert closely involved in the wartime CW programme in Germany subsequently wrote that:

> The German General Staff and the German general officers, with few exceptions, were not interested in chemical warfare. The lack of interest was not based on a lack of faith or on disbelief of its promises of success; the reason was simply that, first, chemical warfare was not understood, nor did the majority of generals try to understand it. [401]

In conjunction with the dubious military value of chemical weapons, their unpopularity with the general public, the financial restraints upon their development during the Depression years, and the strong taint of dis-

[12] On 14 October 1918 [20]. Hitler refers to this in *Mein Kampff*.

honour and unchivalrousness attached to CW, the psychological constraints impeded acceptance of gas as a standard weapon of war.[13] This served to preclude the acquisition, and hence the use, of initiatory CW capabilities at the outbreak of the war, and to delay serious consideration of the employment of gas on those subsequent occasions when substantial military advantage could perhaps have resulted.

An important set of non-military constraints on initiation of CW emerged from the various public declarations of national CW policy before and during the war. With the exception of Japan and the USA, all the principal belligerents had ratified the Geneva Protocol, and in September 1939 the governments of, *inter alia,* Germany and the UK issued declarations reaffirming their intentions to abide by its terms. [830–31] Although US CW policy was not so explicitly declared, President Roosevelt was on record as saying, in 1937, that it was the policy of his government to do everything in its power to outlaw the use of chemicals in war [51] and since 1927 the Department of State had considered the USA to be under a moral obligation not to initiate CW [51], suggesting perception of a prohibition in customary international law. As the war progressed, however, the binding force of these policy declarations diminished as the fighting became more bitter and departed further from earlier norms of wartime behaviour. Both Allied and Axis leaders reiterated their policy declarations, but gave increased emphasis to the reserved option of retaliation in kind.

Churchill's declaration of May 1942 has been referred to earlier: in full, it stated that:

> The Soviet Government have expressed to us the view that the Germans, in the desperation of their assault, may make use of poison gas against the armies and peoples of Russia. We are, ourselves, firmly resolved not to use this odious weapon unless it is first used by the Germans. Knowing our Hun, however, we have not neglected to make preparations on a formidable scale.
>
> I wish now to make it plain that we shall treat the unprovoked use of poison gas against our Russian ally exactly as if it were used against ourselves and if we are satisfied that this new outrage has been committed by Hitler, we will use our great and growing air superiority in the West to carry gas warfare on the largest possible scale far and wide against military objectives in Germany.
>
> It is thus for Hitler to choose whether he wishes to add this additional horror to aerial warfare. [865]

In the following month, after consulting with Churchill on the question, Roosevelt said:

[13] The whole question of the non-assimilation of gas by military establishments is discussed in detail by F. J. Brown in his study of US CW policy from 1919 to 1945 [51]. He concludes that non-assimilation was a more important constraint on initiation of CW during the war than fear of retaliation.

Authoritative reports are reaching this Government of the use by Japanese armed forces in various localities of China of poisonous or noxious gases. I desire to make it unmistakably clear that if Japan persists in this inhumane form of warfare against China or against any other of the United Nations, such action will be regarded by this Government as though taken against the United States, and retaliation in kind and in full measure will be meted out. We shall be prepared to enforce complete retribution. Upon Japan will rest the responsibility. [875]

In April 1943 the British Government repeated Churchill's earlier declaration [876], and in June, Roosevelt said:

From time to time since the present war began there have been reports that one or more of the Axis powers are seriously contemplating the use of poisonous or noxious gases or other inhumane devices of warfare. I have been loath to believe that any nation, even our present enemies, could or would be willing to loose upon mankind such terrible and inhumane weapons. However, evidence that the Axis powers are making significant preparations indicative of such an intention is being reported with increasing frequency from a variety of sources.

The use of such weapons has been outlawed by the general opinion of civilized mankind. This country has not used them, and I hope that we never will be compelled to use them. I state categorically that we shall in no circumstances resort to the use of such weapons unless the first use of them is by our enemies.

As President of the United States and as Commander-in-Chief of the American armed forces, I want to make clear beyond all doubt to any of our enemies contemplating a resort to such desperate and barbarous methods that acts of this nature committed against any one of the United Nations will be regarded as having been committed against the United States itself and will be treated accordingly. We promise to perpetrators of such crimes full and swift retaliation in kind, and I feel obliged now to warn the Axis armies and the Axis peoples, in Europe and in Asia, that the terrible consequences of any use of these inhumane methods on their part will be brought down swiftly and surely upon their own heads. Any use of gas by any Axis power, therefore, will be immediately followed by the fullest possible retaliation upon munition centres, seaports, and other military objectives throughout the whole extent of the territory of such Axis country. [877]

The German reaction to the first British declaration was to maintain that Churchill, "mad with desperation", had threatened to initiate CW against Germany, and that he was attempting to

mask his foul intentions by trumping up the lie that it was really Germany which contemplated this crime against humanity. But should Mr. Churchill disregard this solemn warning, the British people would suffer a fearful revenge, because German industry is infinitely better equipped than the British for gas war. The German Army has made the most minute preparations, and all civilian gas masks have been overhauled only a few weeks ago. [878]

In its response to the second British declaration, the German Government again termed it as provocative, and went on to emphasize that earlier German declarations on CW were unequivocal and still binding [879].

A Japanese response did not come until February 1944, and was apparently less a reply to Roosevelt's statements than to an article in the *New York Times* [880] speculating that the increasing brutality evident in the Pacific war might be increasing the possibility of US initiation of CW. The Japanese statement denied Japanese use of gas, and declared that Japan "would not make use of it in the future on [the] supposition that troops of the United Nations also refrain from using it" [51].

The motivation behind these public declarations was clearly an attempt by the governments concerned to increase the constraints on enemy initiation of CW. No belligerent was sufficiently prepared for CW offensively or defensively to perceive himself as being placed at anything other than a grave disadvantage if chemical warfare broke out. The declarations served two functions: to maintain attention to the legal constraints on initiation, and to emphasize the sanction of retaliation in kind. When Hitler said, in his Reichstag speech of 1 September 1939, "whoever fights with poison gas will be fought with poison gas" [881], the vulnerability of the Wehrmacht's *Blitzkrieg* tactics to gas must have been clearly in his mind. Likewise a realization of the extreme weakness of Japanese anti-gas defences against US gas attack must certainly have stimulated the Japanese statement of February 1944.

The declarations also served to impede initiation of CW by the governments that made them. When Churchill declared that the British "were fully resolved not to use this odious weapon unless it is first used by the Germans", any proponents there may have been of British use of gas would have had to delay arguing their case until Churchill could be given sufficiently good reason for changing his mind. The constraint in such a situation would have arisen both at a person-to-person level among the decision-makers, influenced by public opinion within the country as a whole, and from considerations of possible benefits to enemy propaganda.

The restraining influences on initiation of CW that might be exerted by public opinion have already been discussed in general terms.[14] However, during the total warfare conditions that developed during the war, and with the gradual abandonment of most of the previously accepted restraints on methods of fighting, it is unlikely that the attitudes of the general public towards CW either greatly influenced CW contingency planning, at least during the later part of the war, or even remained constantly hostile. In-

[14] See pages 262 to 267.

deed, on this latter point, there are indications that towards the end of the war Allied use of gas, particularly against the Japanese, might have received popular support. This trend in popular feeling in the USA is suggested by the treatment of the subject in the US press, following atrocity stories and accounts of the desperate fighting in the Pacific theatres. Some typical headlines read:

"We should gas Japan"—*New York Daily News*, 20 November 1943.

"We should have used gas at Tarawa"—*Washington Times Herald*, 20 December 1943.

"You can cook 'em better with gas"—*Washington Times Herald*, 1 February 1944.

"Should we gas the Japs?"—*Popular Science Monthly*, August 1945.

A public opinion poll conducted in the USA in September 1944 showed that 23 per cent of the respondents favoured the use of gas against Japanese cities, while in June 1945 another poll showed that 40 per cent of the respondents would favour the use of gas if the numbers of US casualties would thereby be reduced [51]. The size and nature of the samples are not reported. The US Government apparently took no measures to mould public opinion in favour of CW [51].

Neither Japan nor the USA was bound directly by the Geneva Protocol to refrain from using gas against one another, and the absence of formal treaty constraints on US employment of chemical weapons was emphasized in the 1940 edition of the US Army field manual FM 27–10 *Rules of Land Warfare*. Had the legal constraints on US initiation of CW been stronger, it is possible that the results of the public opinion polls, or the treatment of the subject in the press, would have been different. But this can only be speculation; there is no evidence one way or the other from, for example, comparable measures of British or German public opinion.

There is little that can usefully be said about the strength of the legal constraints on initiation of CW during the war. In the case of the USA, they can not have been much stronger than the perceived strength of popular hostility towards initiation: in the case of belligerents bound by the Geneva Protocol, they perhaps had a deeper—if no less imponderable—influence. It is probably true to say that if occasions arose where the arguments for using chemical weapons were neither especially compelling nor obviously overwhelmed by other constraints, the legal prohibition of CW would have had a deciding effect. But these occasions, if they occurred at all, must have been rare: the dominant constraints of lack of military interest in CW, fear of retaliation and lack of material capability made the legal constraints on initiation virtually irrelevant. By the same token, if enemy retaliation in kind had not been a deterrent on initiation, and if obvious military advantage would have resulted, the legal constraints would probably have been negligible, at least in the later stages of the war. The legal constraints were important, therefore, not because of any direct influence on the decision whether or not to initiate CW, but rather because of their influence in retarding acceptance of gas as a standard weapon of war, and hence in their contribution to the belligerents' overall unpreparedness to wage CW, and their leaders' unwillingness to authorize it.

III. *The balance of constraints and incentives*

In order to bring together the array of constraints that have now been described, and to assess their relative importance in preventing chemical warfare during World War II, it will be useful to reconsider the occasions noted at the beginning of this chapter when the incentives for using gas appeared to have been strong.

For the UK during the threat of German invasion

Although this is the most hypothetical of all the cases considered, some useful conclusions may be drawn from it.

The incentives for the British to use gas against the invading forces would have been very strong. With the country in mortal danger, the government would have been expected to authorize every means available that might have contributed to success, and against massed troops struggling to establish beach-head positions, gas would have been highly effective. Logistical problems would have been minimal, and adequate delivery systems were available: the principal weapon would have been the aircraft-mounted spray tank disseminating mustard gas, such as had recently become available for *Blenheim Mk.IV* fighter-bombers [882]. Although available stocks of mustard gas were low—little more than 1 000 tons—these would have been adequate for effective use against the first wave of the invasion.

The two main constraints would have been the possibly adverse effect that initiation of CW might have on influential neutral opinion, including US opinion, and the possibility of costly enemy retaliation in kind. The first of these could probably be disregarded: although the British Government had only recently reaffirmed its intention to observe the Geneva Protocol, the extremity of the country's predicament would certainly have justified infraction of the Protocol in the eyes of a large sector of neutral opinion, especially when it concerned tactical use against an invading army.

The second constraint was stronger, although not nearly as strong as it was to become later in the war. If the Germans were to retaliate in kind, the retaliation would have had to take the form of an aerochemical attack of the British rear: the UK had no allies at that time against which a less escalatory response was either possible or would have provided an effective deterrent. At this stage in the war, the constraints against bombing civilian targets were still high, and Germany could expect far more damaging propaganda and hostile neutral reaction from a retaliatory gas attack against targets containing noncombatants than Britain could from an initiatory gas attack against purely military targets.

There was also the possibility that German use of gas against British civilians, although retaliatory, might bring the USA into the war, even if a landing on English beaches did not. In addition, Germany would have had to contend with possible British counter-city gas attacks in response, if the German invasion were unsuccessful, and it was not at all clear which belligerent would suffer most from this exchange, at any rate in the long-term. On the one hand, Germany had four times as many bombers to deliver gas as had the UK, but on the other hand the UK had greatly superior civilian anti-gas defences. It is doubtful whether Germany would have believed it could benefit from unrestricted chemical warfare; apart from anything else, it was at that time struggling to erect production facilities for tabun and sarin weapons, under the erroneous belief that its enemies already possessed them. Even if Germany believed that it would benefit from unrestricted chemical warfare, it is not clear that the UK believed it would suffer severe damage from gas: the UK knew that its civilian anti-gas defences would substantially reduce civilian gas casualties, and in any case it rated gas low as a strategic weapon.[15] Under these circumstances, the threat of escalatory retaliation in kind might not have been a compelling constraint.

For the USSR during the German invasion

The following account of the constraints on Soviet initiation of CW on Germany's eastern front is taken from a description by Colonel V. V. Pozdnyakov who, until his capture by the Germans in 1942, commanded the chemical service of a Soviet army corps at the front:

> ... [I]n the first months of the war, in the period when the Soviet Army retreated and when there were mass encirclements and deep breaks-through, the Soviet Command did not resort to chemical warfare because the advanced stores of the Military-Chemical Administration were seized by the enemy, because

[15] Even in the absence of legal constraints on CW, the British did not anticipate that gas would ever be a primary weapon in enemy air raids. Estimates in 1937 were that German aircraft would drop at least three times as many HE or incendiary bombs as gas bombs, probably more [883].

the transport and the organization for using toxic substances was a complex matter, because the chemical discipline in the Army had deteriorated, and part of the means of protection was lost; and, above all, because retaliatory action by the enemy would have caused a still greater disorder both in the Army and in the rear. Later, in 1943, the Soviet Union was obviously influenced by the decision of her allies not to wage chemical warfare, while with the westward retreat of the German armies the situation for chemical warfare became more favourable for the enemy. [54]

No other information is available on the Soviet CW position during World War II. It is to be recalled, though, that the USSR, like Germany (but unlike Japan), was a party to the 1925 Geneva Protocol. War Commissar Voroshilov's 1938 declaration of continued commitment to the Protocol is quoted on page 287.

For Germany during the Allied landings in Normandy

The incentives for German use of gas to repel the Allied landings in France were considerable. General Ochsner has summarized them as follows:

The great decisive battle was approaching and all means promising any chance of success must be used in that battle. Were gases a suitable weapon for this purpose? At first glance, the answer must be in the affirmative. Entire sectors of the coastal front could have been rendered impenetrable for the enemy, or at least untenable unless he decontaminated them. To do so, however, he would have needed enormous quantities of decontaminants, innumerable vehicles, specialized units and forces, and these could only have crossed the Channel at the expense of combat units. Besides the gain in time and in manpower, there was the added factor that the morale of the landing enemy troops would have been seriously affected. The individual results could not be foretold, but definitely they would have been in our favour. ... In short, the idea seemed to hold out good prospects of success, and no technical difficulties were expected. [212]

The principal constraint was fear of Allied retaliation in kind against German cities, and in this case the constraint was far more compelling than it had been against possible British use of gas to repel the threatened German invasion. In the first place, the threat was far more credible: any restraints there had once been in strategic bombing operations had disappeared entirely, and the Allies held command of the air. In the second place, damage was assured: German civilians were poorly protected against gas, and German industry was in a state such that there was little hope of improving civilian protection to any great extent. Finally, the expected damage was great: Germany estimated the Allies to have sufficient stocks of chemical weapons to inflict enormous loss of life throughout Germany over an extended period of time. In short, Germany was effectively deterred. In point of fact, Germany over-estimated Allied capabilities, but there is no doubt that the Allies were ready to retaliate against German use of mustard or tabun on the beaches with massive gas attacks on German cities. Should Germany initiate CW, the plans were that two retaliatory operations were to be mounted within forty-eight hours, in each of which 400-bomber formations were to deliver 100 per cent gas payloads [51].

There were other powerful constraints as well. Retaliatory use of gas by Allied forces on a tactical level would have forced a CW environment onto the conduct of all future battlefield operations, and this would almost certainly have been to Germany's disadvantage. Although Allied supply lines were not sufficiently accommodating to cope easily with additional matériel, the German ones were still less so. The German transportation system, strained almost to the point of collapse, had been thrown into disarray by Allied bombing and by partisan action, and on top of this the country was suffering a dangerous petrol shortage.[16] In addition, it lacked many essential items of CW equipment: while its supplies of chemical weapons were adequate, it was drastically short of anti-gas equipment.[17] In fact, however, Allied leaders were probably just as reluctant to provoke battlefield CW as were the German leaders. Apart from the supply problems, most Allied commanders were repelled both by the technical complications of gas warfare and by gas itself. Furthermore, if mustard gas, phosgene, and so on were used on a large scale in France, large numbers of French civilians would inevitably be affected by it. It is worth noting that neither side even used harassing-agent weapons, even though both possessed large quantities of, for example, armour-piercing irritant-agent projectiles that were known to

[16] As a result of this, Germany was relying more and more on horse-drawn transport. According to a report of Goering's testimony after his capture, the awareness that this horse-drawn transport was extremely vulnerable to gas attack was a strongly felt constraint on German initiation of CW [92]. The shortage of rubber had prevented manufacture of an adequate supply of horse-respirators [51].

[17] By 1944, the Wehrmacht had a six-month supply of chemical weapons in stand-by stocks, and a CW agent production capacity whose output could theoretically be greatly increased at short notice. In pactice, however, an increased output would not have been easily accomplished because of competition with other sectors of the chemical industry for the declining supplies of raw materials and intermediates. Methanol, for example, was as much needed for explosives production as for tabun, and ethylene oxide as much for anti-freeze and powder production as for mustard gas, and both these materials were in short supply. [52] Furthermore, shell casings and bomb casings had been in too great a demand to allow much diversion to the chemical-weapon filling plants.

German stand-by stocks of chemical weapons would have partly compensated for these shortcomings, but deficiencies in the stocks of anti-gas matériel were much more serious. Output of anti-vesicant clothing had been retarded by a shortage of casein, respirators by a shortage of mica (for the exhaust valves), sheet metal (for the canisters) and asbestos (for the particulate filters), and decontaminants by a shortage of chloride of lime. [51]

The shortages of raw materials from 1941 onwards had led to strict rationing of industrial supplies, and the rationing had generally started with CW items [51].

be effective weapons against tanks. It is also recorded that, in France, US forces were willing to use irritant-agent hand grenades against French civilians but not against German soldiers. [213]

German leaders must also have realized that if they initiated CW, Allied retaliation might not be confined to German targets: the USA would be given justification to use gas against Japanese targets, probably to considerable advantage. Some writers claim that the Wehrmacht was further constrained from initiating CW against Allied forces by a perception of the efficacy of Allied anti-gas equipment and discipline [63, 157].

Behind all these constraints there remained the uncertain influence of Hitler's personal attitude towards gas.

For Japan

Japanese perceptions of chemical warfare differed markedly from those of Western nations. Under the militaristic regime of the pre-war years, CW had never become a political issue, and decisions about CW policy could be based solely on military considerations. Chemical weapons were possibly useful tactical battlefield aids that had been used by Western powers in World War I. They therefore needed evaluation for possible incorporation into Japanese arsenals. Their use against China can be seen as part of this process of evaluation. It appears that the results of this evaluation left senior military personnel almost as unenthusiastic about gas as their counterparts in the West. To judge from post-war US interrogation reports, the majority of senior Japanese officers saw no great merit in gas and were unwilling to spend time training their men in its use [359]. It might have some utility against a badly protected enemy, but not against sophisticated armies.

Accordingly, after the USA entered the war the Japanese armies carried little CW equipment. The major part of Japanese CW stores were with the armies in China, or with those that might be called upon to fight the Soviets.[18] Even if the Japanese armies fighting US troops maintained adequate CW stores, their battlefield successes would have provided no particular incentives to use them. As the Americans began to succeed in the Islands campaigns, however, it was to be expected that the Japanese Army General Staff would reconsider gas. It was, after all, a weapon that had occasionally achieved considerable success in China, and in an emergency it might be worth disregarding its various limitations in the hopes that any

[18] Japanese assessments in 1938 of Soviet CW preparedness credited the Soviet Far Eastern Army with a low level of CW training and discipline [359].

further successes with it might be decisive, or at least might contribute significantly to the success of future battlefield operations.

The overwhelming constraint appears to have been a lack of the necessary material capability, coupled with insurmountable supply and logistics problems. With the greater part of existing stockpiles of CW matériel dispersed around China, it would be necessary to rush through an accelerated manufacturing programme and ship the output to the Islands theatres, if gas was to be used on any scale. But by this stage of the war, Japan was beginning to feel the effects of Allied attacks on its shipping bases and transport convoys: with shortages of essential stores already being felt in forward areas, were convoys of CW matériel really justifiable? In addition, Japan was also being deprived of many of the raw materials that would be needed in the manufacturing programme—raw materials and intermediates for CW agent production, and rubber for respirators and protective clothing. Even if the CW supply convoys could be mounted, it might not be possible to provide the necessary cargo. Over and above all this, there was the decline in CW preparedness of the Japanese troops. For the most part, all CW-trained units were in action in China, or were being held in readiness in case the USSR entered the Pacific war, while the CW training programme for the army had been slackened off in 1942, and virtually terminated in 1943. [359]

Throughout 1944 a still more compelling constraint grew in strength, that of escalatory retaliation in kind. At no point before the war had the threat of strategic attack of the Japanese home islands appeared at all great. Furthermore, gas had been seen predominantly as a battlefield weapon, far less as a weapon suited to the strategic attack of civilian populations. For these reasons, Japanese civilians were badly equipped to face gas attack at the time when this became a very real possibility, after the Americans had established air bases within striking distance of Japan. Instruction in anti-gas discipline was rudimentary, there were no gas-proof collective shelters, and by the end of the war less than ten million civilian gas masks had been manufactured. [51]

Japanese perceptions of the likelihood of the Americans using gas seem to have veered between a remarkable complacency on the one hand, and great fearfulness on the other, with little ground in between. When a senior Japanese officer was being interrogated after the war about the reasons for the strange Japanese dispositions of anti-gas stores, he said "we knew that the Americans would not use gas warfare" [51], and this view was reflected during several other interrogations [359]. Possibly the Japanese were influenced by Roosevelt's various public statements about gas: more probably they drew their conclusions from the failure of the USA to retaliate against the continued Japanese use of gas in China, even after President Roosevelt's most explicit statement of US CW policy in June 1943.[19] If the Americans were apparently unprepared to institute retaliatory CW, it was most improbable that they would themselves initiate CW, particularly as the Germans would then be given justification to use gas in Europe. However, once the threat of strategic gas attack against Japan was realized, the Japanese went out of their way to avoid involvement in a chemical war. Their precipitate policy declaration of February 1944, the recall of such stores of chemical weapons as there were in the Pacific theatres, and the almost complete shut-down of chemical weapons production, were all signs of this. Japanese armies facing the US forces were deprived of a CW capability, even a retaliatory or deterrent one, and readiness was maintained against the USSR only. [51]

For the USA in the Pacific theatres[20]

Although the incentives for US use of chemical weapons were rising fast as the Pacific war came to an end, it seems that such high-level recommendations as there were for US initiation of CW were put forward only during informal exchanges between individuals, and never in the highest councils of war. US CW planning since Pearl Harbor had been concerned entirely with providing for the contingency of Japanese initiation. Individual interest in US initiation of CW, however, for the most part arose from this planning.

Had Japanese forces initiated CW against US troops in the field after mid-1944, the USA planned to retaliate with air-delivered gas attacks against Japan: an intense initial retaliatory effort, followed by continuing use of gas at a rate of 25 per cent of the total bomb tonnage. Of the gas bombs used, one-third of the tonnage would carry nonpersistent agents (phosgene or cyanogen chloride) and two-thirds would carry mustard gas [267]. For the latter, the principal weapons would have been the 100 lb and 115 lb mustard-gas bombs. However, even as late as mid-1945, the readily-available stocks of chemical weapons in the Pacific fell far short of those needed to support such expenditure rates—only enough gas was available apparently, to contaminate about 11 km^2 of terrain—for theatre commanders had been unwilling to use up valuable shipping space with CW equipment.

[19] The Japanese must have been aware that the USA knew that use of gas against the Chinese was continuing. After Japanese employment of vesicant agents near the town of Hengyang in June 1944, for example, the gas casualties were inspected by two US officers. [51]

The Japanese had even used gas against US troops. But these were all acts of desperation ordered by local field commanders in extreme predicaments, for example, the use of hydrogen cyanide hand grenades on Guadalcanal in January 1943. [51]

[20] This discussion relies principally on the study by F. J. Brown [51].

This deficiency in stocks was recognized during JCS planning for the proposed landings on Kuyushu, scheduled for 1 November 1945;[21] it was assumed that the Japanese would be more ready to use their CW capability in defence of Kuyushu than they had been against earlier US landings.

During the planning for these landings, it was calculated that it would take about forty-eight shiploads to make up the deficiency in stores of chemical weapons (113 500 tons). The JCS ordered procurement of the necessary matériel in June 1945, but issued no specific directives for its deployment: it was to be sent out from the USA in whatever shipping had space for it. At the time when the logistics of this operation were being considered, the possibilities of US initiation of CW began to be discussed at a high level. Was it really worth using up shipping space, port capacity and storage facilities on the scale that was apparently necessary if the preparations were solely for retaliation against an enemy action that might never take place? The question could be put another way: given the effort that had already been put into building up a CW capability, and the further effort that was apparently needed, why was it necessary to wait for a Japanese initiative? The Japanese had already provided justification for US chemical warfare.

The incentives for US use of gas were substantial. On a tactical level, gas appeared to be the most economical weapon for reducing fanatically-held Japanese cave defences. On a strategic level, gas could be used in a final *coup de grâce* that would terminate the war before it could drag on any further: had not the Chemical Warfare Committee calculated that unrestrained chemical warfare would force Japanese surrender within three months?[22] The constraints on initiation were rapidly becoming less and less compelling, and some of the constraints that had ruled out any question of US initiation earlier had disappeared entirely. The war in Europe had ended, so that neither Allied forces nor civilian populations in Europe were threatened with German retaliatory gas attacks. Public opinion, at least in the USA, was apparently swinging round in favour of US initiation. President Roosevelt was dead, and his successor, President Truman, was not known to be instinctively hostile to CW.

The lack of the necessary material capability in forward areas remained a powerful constraint, though. It was estimated that it would require a

[21] *Operation Olympic.* If it had gone ahead as planned, it would have involved five million men and the largest concentration of aircraft and ships used in a single operation during the war. The US Air Force planned to drop 80 000 tons of bombs during the first day. [51]

[22] The USCWC is referred to on page 295. The Operations Division of the War Department General Staff did not rate gas as the decisive weapon envisaged by the USCWC, however [267].

minimum of four to six weeks to bring US bases in the Pacific area up to their authorized establishment for retaliatory CW, let alone for initiatory CW. This was the time-lag calculated in January 1945; by June it had lengthened, for with the increasing deployment of B-29 bombers—having four or five times the payload of earlier bombers—the chemical-weapons expenditure rates authorized for retaliatory CW (25 per cent of the total bomb tonnage) would have required greatly increased quantities of chemical bombs. By mid-July it had been calculated that 1 139 000 chemical bombs would be needed in the first month of chemical warfare, yet only 248 000 were available in the Pacific area. If there was to be any question of full preparedness for CW during the Kuyushu landings, accelerated deployment and shipping priorities for CW matériel would probably have to be ordered before the end of July. Any further delay would involve significant diversion of resources from conventional force requirements for the landings.

Whether the USA would be in a position to initiate CW in November was thus predicated by a logistics decision that would have to be taken in July. No doubt chemical warfare could be waged before then with existing stocks, but the scale of operations would almost certainly be inadequate for significant results, and would in any case further lower preparedness for the Kuyushu landings. The decision was complicated by additional factors only indirectly related to CW policy. The procurement programme authorized to increase stocks of chemical weapons in forward areas would divert much of the output of bomb casings from the incendiary bomb programme, and on 9 March the US Air Force had demonstrated the capabilities of incendiary bomb operations against Japanese targets by producing, *inter alia,* 93 000 casualties in Tokyo during a single air raid. Should production of a weapon of such proven worth be delayed by one that was still unproven? In any case, it was not certain that the logistics problem was the crucial bottle-neck. The British would have to be given time to improve CW preparedness in their sectors of Southeast Asia: so would the Soviet Union following its entry into the Pacific war.

On this latter point, it was clear that the forthcoming Potsdam Conference would provide the most suitable occasion for joint Allied consideration of US initiation of CW. To delay inter-Allied consultations any further would add bureaucratic complications or worse to the logistical problems involved. The US JCS would therefore be required to decide on initiation of CW before 6 July, when the President was due to depart for Potsdam.

However, between 19 June, when they authorized increased procurement but without accelerated deployment, and 6 July, the JCS did not seriously debate initiation of CW. They were agreed that initiation in November appeared logistically feasible within existing programmes, and General Marshall, at least, felt that the decision to deploy the increased procurement would also be a decision to initiate CW. But they did not progress beyond this, and President Truman was neither asked to authorize US initiation, nor to debate the matter further at Potsdam.

This apparent procrastination on the part of the JCS can be explained in several ways. The Chief of Staff to President Truman, Admiral Leahy, had expressed his opposition to US initiation of CW as soon as he heard that plans for this were in the offing [267] and this must have discouraged the JCS. At another level, the JCS were perhaps tacitly submitting to the various constraints that had yet to be formally discussed. At a deeper level, there was the whole question of accepting gas as a weapon of war, with all the institutional and psychological disturbances that this would involve.

The remaining constraints on US initiation were still considerable. Quite apart from shortages of stores in the Pacific area, the general level of CW instruction throughout combat units was not entirely adequate and, in addition, there was a dearth of specialized chemical troops. On top of this lay the possible costs of incurring full-scale Japanese retaliation in kind. Even at this late stage in the war, US intelligence rated Japanese CW capabilities as being considerably higher than they in fact were, and it was felt that the Japanese would certainly be able to sustain chemical operations in defence of Kuyushu. In addition, it was estimated that Japan was capable of using gas to inflict severe damage on civilian populations friendly to the Allies, even with their greatly curtailed air power. It was thus felt that Japanese CW capabilities were sufficient to hold China, Manchuria and Korea hostage against US initiation, and to pose severe problems for US landing forces. There was also the possible reaction of world opinion to be considered, an aspect of the decision to which the Operations Division of the War Department General Staff had earlier drawn attention [267].

With these constraints in mind, the incentives to use gas diminished in attraction. Did the tactical assets of gas really justify its strategic liabilities? As an instrument of *coup de grâce,* was gas superior to physical occupation by invasion, starvation by naval blockade, or destruction from the air with explosives and incendiaries? This last point was conclusively resolved on 16 July when the Manhattan Project's first nuclear weapon was field tested.

Finally, there was the fact of declared US policy, stated so explicitly and publicly by President Roosevelt in June 1943. To reverse this within so short a time would not be in keeping with US aspirations for moral leadership of the world in the coming post-war years.

IV. *The non-use of biological weapons*

During the inter-war years, groups of individuals within all the major belligerent countries of World War II seem to have decided that potential enemy countries were interested in biological warfare. While this intelligence stimulated existing and nascent research programmes within the countries concerned, as far as published information goes only in Japan was there one of any size; in most other countries, it appears that BW was at most the part-time concern of very small groups of people.

Once World War II started, the various BW research efforts accelerated, as was described in Chapter 1. For the Axis part, the Japanese programme reached its peak in 1940, by which time some 3 000 workers were involved at the principal research centre, at Harbin in Manchuria [255]. The German programme was said to have been suppressed by Hitler; not until 1943—after German reverses in the USSR—was a research establishment set up to deal specifically with BW. For the Allied part, the initiative was taken by Canada and the UK, the latter establishing a small BW unit within the CW establishment at Porton in 1940 [263]. The USA began BW research on a rather haphazard and *ad hoc* basis in mid-1941, expanding and coordinating it somewhat in May 1942 at the urging of the British and the Canadians. The US programme did not gather momentum, however, until the beginning of 1944, reaching its peak in August 1945.

Several of the belligerents built up reserves (and production potential) of vaccines and antitoxins against the possibility of biological attack. The UK began to do so shortly after the outbreak of the war [261]; the USA built up sufficient stocks of botulinal toxoids "to protect large scale operations should this be necessary" [88], and, with Canada, developed mass-production techniques for rinderpest vaccine [88]; in 1942 the Germans sent a million doses of plague vaccine forward to the Stalingrad front after learning that Soviet troops had been immunized against plague [30].

At the outbreak of the war, BW was generally considered in terms of sabotage operations. Its past history had been one of alleged instances of well-contaminations and attempts by saboteurs to initiate epizootics among domestic and transport animals. To some degree, this attitude was to continue throughout the war, both as regards activities within the research programmes, and in the recurrent alarms about enemy actions. The British, for example, feared in 1940 that an unusual outbreak of brucellosis among three herds of cattle had been caused by enemy sabotage of cattle vaccines with *Brucella melitensis* bacteria [261]; the Americans and the Canadians were fearful of the initiation of epiphytotics and epizootics among their food crops, poultry and cattle [88]; the Germans suspected Polish and

Soviet partisans of using glanders, anthrax, botulinal toxin, and a variety of intestinal pathogens in sabotage activities against their occupying armies [30]; and the Japanese had almost certainly spent a considerable amount of effort on developing biological sabotage weapons [91, 255]. But some of the research establishments were also concerned with the possible use of pathogens in regular military operations, in much the same manner as CW agents, but exploiting their very much smaller effective doses. Even if the technical problems in developing such weapons seemed enormous, the danger existed that they had been surmounted in enemy BW programmes. Allied intelligence, for example, had received a number of reports about Japanese "bacillus bombs" [255], which suggested that the Japanese had made progress along these lines, while reports that the Germans had developed biological warheads for their missiles (later discovered to be quite unfounded[23]) were responsible in large measure for the expansion of the US BW programme in 1944 [30]. The work that was performed in this field forms the basis for current perceptions of the threat of BW: it showed that there was nothing inherently impossible in developing biological weapons that could threaten whole countries with disease and death.

This assessment, however, was never effectively reduced to practice by any of the belligerents: the indications are that no nation had produced a biological weapon by the end of the war that had any marked superiority over existing conventional or chemical weapons. All of the constraints that applied to the initiation of CW applied with far greater force to BW. With the possible exception of Japan, none of the belligerents gave any thought to using pathogens themselves in anything other than sabotage operations, and even here, again with the exception of the Japanese and perhaps partisan forces operating behind the German lines, the evidence that they actually did so is extremely slight. At the time of the war, microbiology as a science had not progressed very far outside the laboratories, and while the idea of using poison as a weapon of war was repellent enough, that of using disease was far more so. To military establishments that were reluctant to accept gas, biological warfare had little attraction. But, as with gas, misperceptions of enemy interest forced attention to BW.

V. *Summary and conclusions*

World War II thus ended with an accumulation of at least half a million tons of chemical weapons remaining virtually untouched by the belligerents.

[23] Allied investigators eventually concluded that "false reports of German intentions to resort to germ warfare had unquestionably been spread as a psychological warfare weapon" [30].

The claims of those few pre-war writers that chemical weapons were unsuited to global warfare had been vindicated, but not perhaps for the reasons generally advanced. Professor Kendall [352], for example, had argued in 1938 that military expediency would be the dominant criterion, and that the experience of the Italo–Ethiopian War had shown that gas would be resorted to only if a belligerent had some desperate reason and if enemy retaliation in kind were impossible: further, that gas was suited only to static warfare conditions, which it would tend to enforce, thereby prolonging hostilities to an unacceptable extent. For the most part, he was probably correct: fear of enemy retaliation in kind was certainly one of the dominant constraints, and the occasions when a belligerent appeared to be on the point of initiating CW were almost all when his homeland was directly threatened, and it was to his advantage to reduce enemy mobility—against *Blitzkrieg* advances on land or amphibious landings from the sea. But the fundamental reason for non-use of chemical weapons almost certainly lay at a deeper level than military inexpediency.

In the first place, there were undoubtedly some situations in which the military arguments for using chemical weapons would have been strong [157]. If military expediency were the dominant consideration in CW policy-making, material and troop capabilities would have been built up in readiness for such situations. But, in the immediate pre-war period and during the early part of the war itself, CW preparedness consisted for the most part of elaborate defensive preparations and more or less hastily improvised manufacturing programmes for chemical weapons: what little instruction was given to troops in CW was given grudgingly and unenthusiastically by the military establishments, and was almost exclusively concerned with the defensive aspects of CW. The situation was that senior military personnel were unwilling to see merit in gas as a weapon, but were prepared to believe that potential or actual enemies did—or at least were prepared to concede that use of gas might be sufficiently advantageous to an enemy to demand the preparation of defensive countermeasures, and possibly even some sort of retaliatory capability. The reluctance to accept gas as a useful weapon stemmed at least as much—probably far more—from institutional pressures and psychological constraints as from rational considerations of its military utility.[24] A general propensity to believe the worst about enemies, coupled with faulty intelligence, led to a willingness to believe that the other side favoured gas. As the war got under way the major belligerents all suspected their enemies of a readiness to initiate CW, whereas in fact none of them had any serious intention of doing so. Under the

[24] As F. J. Brown puts it, "gas was a weapon too technologically demanding and psychologically disquieting to be assimilated by the military profession" [51].

stimulus of these suspicions, the growing stockages of chemical weapons were advertised as retaliatory CW stockpiles in the hopes of constraining enemy initiation.

The idea of retaliatory CW stockpiles as deterrents for enemy initiation gained in strength as each belligerent came to realize that retaliation could well be escalatory: a chemical mortar action in some distant combat theatre, even with irritant-agent projectiles, might be met by the gas-bombing of a capital city. Each belligerent was aware of his, or his allies', vulnerability to counter-civilian gas attack, and each belligerent had over-estimated his enemy's offensive CW capabilities. Even though the belligerents' chemical-weapon stockpiles were in fact probably insufficient to cause significant damage—at least until the last two years of the war—each belligerent was sufficiently deterred through his own perceptions of them to become still more disinclined to consider initiating CW. It was only in the last months of the war that the nation with the largest deterrent stockpile, the USA, began to consider turning it to operational use. But it did so in the awareness that other weapons would probably be more useful, and without sufficient enthusiasm to overcome the constraints that it had created for itself: the logistical complications that had grown out of its theatre commanders' unwillingness to maintain forward-area CW stores, and the no-first-use policy that had been declared earlier by its leaders to enhance the credibility of its CW deterrent.

Yet although fear of retaliation goes a good part of the way in explaining why gas was not used during World War II, it was only one factor among several. As a constraint, it was undoubtedly strong, but in fact there was little for it to constrain. With the possible exception of the USA in the final stages of the Pacific war and of Germany facing the Allied landings in Normandy, the incentives for using gas were weak: neither on the Axis nor on the Allied side had the military commands formed any clear idea of the relative merits of gas as an offensive weapon compared with other weapons. Reluctant for psychological, political and institutional reasons to attach much weight to the claims of the proponents of gas warfare, they left the initiative to the enemy. CW capabilities for which there was little rational justification grew up on either side, generated at least as much by the momentum of past events as by considerations of possible future use. Their growth was perceived in exaggerated form by both sides, and both sides were content to be deterred by them. The war ended with the military establishments still unconvinced that gas was a generally valuable weapon.

Appendix 1. Alleged chemical warfare during the Yemeni Civil War, 1963–1967

The following notes summarize some of the alleged CW incidents during the Yemeni Civil War. The incidents, with place and date, are listed in chronological order; each entry gives whatever information is available on the following points:

(1) The source of the published reports,
(2) The type of injury allegedly caused by chemical weapons,
(3) The number of casualties allegedly caused by chemical weapons,
(4) Details of the chemical weapons and delivery systems allegedly used,
(5) Any other relevant information.

A discussion of the veracity of these allegations is given in Chapter 2 above and, more fully, in Volume V.

1963

June and July 1963: At least eight gas attacks on villages to the south of *Sadah,* including *al Darb, al Jaraishi, Hasan Bini Awair, al Ashash,* and *al Kawma* (see below) [419, 891].

(1) The Imam Mohamed al Badr [891]; Colonel Neil McLean, MP [419].

8 June 1963: *Al Kawma* [892–95]

(1) Colonel David Smiley, visiting al Kawma at the end of June as a free-lance journalist [891]; Richard Beeston, visiting al Kawma at the beginning of July as *Daily Telegraph* (London) correspondent [419]; McLean, visiting al Kawma with the Imam's investigating team on 3 July [419].
(2) Eye and lung injuries [891, 895].
(3) 28 casualties including 6 dead (children), according to Royalist headquarters in Jeddah (Saudi Arabia), quoting from the report of the Imam's investigating team [895].
(4) 4 bombs dropped from one Egyptian bomber [894].

(5) Smiley collected fragments of the bombs, the subsequent examination of which, at the British Chemical Defence Experimental Establishment, was reported to have revealed tear-gas residues [891].

1964

No incidents were reported.

1965

January 1965: *Beit Marran* [891, 896]

(1) The Royalist commander in the northwest.
(2) Injuries included eye injuries.
(3) 80 casualties.

January 1965: Several villages in the *Jabal Urush* [891, 896]

(1) The Royalist commander in the northwest.

Spring 1965: *Sharazeih* (northeast of *Sana'a*) [897]

(1) McLean, visiting Sharazeih shortly after the attack.

March and July 1965: Localities unspecified [416, 898]

(5) A Washington newspaper correspondent, writing in June 1967, stated that mustard gas was used during these months, for the first time [898]. A Dutch journalist, writing in November 1967, referred to the use of phosgene during this period [416].

1966

Autumn 1966: Several incidents in unspecified localities [899, 900]

(1) Wilfred Thesiger, a British explorer and Arab scholar, returning from a five-month tour of Royalist-controlled Yemen.
(2) Eye and skin injuries.
(3) Thesiger had seen at least 20 blinded casualties.
(5) Thesiger reported that two types of CW agent were being used—a "blinding gas" and a "blister gas"—and that the latter was probably mustard gas.

11 December 1966: *Halhal* (northwest of *Sana'a,* in the *Jabal Iyal Yazid*) [901]

(1) Eye-witness account by Mohamed al Yazali, a defecting Republican official.
(2) Eye, skin and lung injuries.

(3) 35 casualties, including 2 dead.
(4) 15 bombs dropped from two IL-28 bombers.
(5) One unexploded bomb was about 5 feet long and 2 feet across.

27 and 29 December 1966: The *Jabal Iyal Yazid* [901–903]

(1) The Royalist Foreign Minister, in a press release from Saudi Arabia [903]; the Royalists' public relations firm in London [902].
(2) Eye and skin injuries [902].
(3) "Scores of victims" [903]; at least 4 casualties [902]; 2 dead [901].
(4) 15 to 20 gas bombs dropped from two Ilyushin bombers [902].

1967

4 January 1967: *Hadda* [416, 898]

(1) A Washington newspaper correspondent, writing in June 1967 [898]; a Dutch journalist writing in November 1967 [416].
(5) Both journalists stated that "nerve gas" was used for the first time during this incident.

5 January 1967: *Kitaf* [411–12, 891, 897, 901, 902, 904–906]

(1) Official Royalist statements on the South Arabian Broadcasting Service, 11 January, and elsewhere; reports from a party of 20 journalists visiting Kitaf on 24 January.
(2) Lung injuries [408].
(3) Over 270 casualties including 140 dead [905]; 120–160 dead [904]; over 200 dead [902].
(4) 27 gas bombs dropped from nine IL-28 bombers [902].
(5) A Washington newspaper correspondent, writing in June 1967, stated that a V-agent nerve gas was used [898].

6 January 1967: *Beit Michlaf Doran* and *Beit Beni Salamah* [902]

(1) "Arab sources".
(3) No casualties but many livestock killed.
(4) 85 gas and incendiary bombs dropped from fifteen IL-28 bombers.

7 January 1967: *Katar* (near *Sadah*) [424]

(1) Royalist headquarters in Qara.
(2) Eye and lung injuries.
(3) More than 225 casualties, including more than 125 dead.
(4) Bombs dropped from 12 "Ilyushin heavy bombers".

17 January 1967: In the *Jabal Iyal Yazid* [902]

(1) Royalists' London public relations firm.

(3) No casualties.

(4) Four 100 lb and four 500 lb gas bombs dropped from one IL-28 bomber.

(5) Strong wind blowing; 4 bombs failed to explode.

9 February 1967: *Beni Salamah* [907]

(1) The Yemen Relief Committee, London.

(3) 70 dead.

3 May 1967: *Bassi* [416]

(1) A Dutch journalist writing in November 1967.

(5) "Nerve gas" said to have been used.

7 May 1967: In the *Arhab* tribal area [908].

(1) Prince Hassan bin Hussein, in Beirut.

(3) 200 dead.

10 May 1967: *Gadafa* (in the *Wadi Hirran*) [909, 910]

(1) ICRC, allegedly [909]; sources in Aden [910].

(2) Eye and lung injuries [910].

(3) 24 dead [910].

(4) Gas bombs dropped from 2 Ilyushin bombers [910].

10 May 1967: *Gahar* (near *Gadafa*) [419, 422, 891, 909–11]

(1) British and French Royalist mercenaries, eye-witnesses of the attack from a Royalist position in the Wadi Hirran [891]; the ICRC, purportedly [422, 909].

(2) Eye, skin and lung injuries [422].

(3) 79 casualties, including 74 dead, plus 200 dead livestock [422, 909, 911].

(4) At least 3 gas bombs [909] dropped from 8 Ilyushin bombers [910].

(5) The purported ICRC reports strongly suggest that mustard gas was the agent used.

12 May 1967: *Beit Marran* [912]

(1) Prince Hassan bin Hussein, Royalist commander in the west.

ca. 14 May 1967: *Najran* and *Oizan* (*Jizan?*) (in Saudi Arabia, near the Yemen border) [427, 913]

(1) Press Office of the US Department of State [427].

(5) Recovered fragments of a gas bomb casing were stated to be stamped with Cyrillic letters; "scientists were seeking to determine whether, as suspected, the gas was a new kind of nerve gas". [427]

17 May 1967: *Gadafa* [909, 911, 914–15]

(1) Royalist spokesman in Damascus [911]; "reports reaching Aden" [914–15].

(3) 100 dead [911, 914–15].

(4) 4 gas bombs [914].

(5) Victims killed while sheltering in a cave.

18 May 1967: *Beit Gadr, Beit Gabas,* and *Nofal* [909, 915]

(1) "Reports reaching Aden" [915]; purported eye-witness accounts given to ICRC team at Gahar [909].

(3) 143 dead [909, 915]; 34 dead [915].

(4) 5 gas and HE attacks by Ilyushin bombers [915].

23 May 1967: *Sirwah* [908]

(1) Prince Hassan bin Hussein, in Beirut.

(3) 50 dead.

28 May 1967: *Sirwah* [898, 916]

(1) Israeli sources [898]; Royalist spokesman in Beirut [916].

(3) Large number of casualties, including 72 dead [898]; 60 dead [916].

(4) Gas and HE bombs [898, 916].

(5) 30 surviving gas casualties evacuated to Saudi Arabia for treatment [898].

29 May 1967: In the *Beni Hushaysh* tribal area [916–17]

(1) Royalist spokesman in Beirut [916]; Radio Mecca [917].

(4) 50 gas bombs and 15 napalm bombs dropped from 5 Ilyushin bombers.

(5) Possibly the same attack as that listed for 28 May at Sirwah.

Beginning June 1967: *Bani Sahin* [416]

(1) Dutch journalist writing in November 1967.

(3) 45 dead.

5 and 6 June 1967: *Boa and Immed* (in the *Beni Hushaysh* tribal area) [908, 918]

(1) Royalist headquarters at Haradh.

2 July 1967: *Beni Saham* (south of the *Wadi Khiran*) [918–21]

(1) Smiley, from the Yemen [918]; Yemeni Royalist complaint to the United Nations [921]; "British Intelligence sources" [919].
(3) 45 dead and many dead livestock [918].
(4) HE and gas bombs dropped from 2 Ilyushin bombers [919].

4 July 1967: *Darb Ascar* [908]

(1) Prince Hassan bin Hussein, in Beirut.
(3) 52 dead.

15 July 1967: *Hajjah* [420, 919, 921–23]

(1) Yemeni Royalist complaint to the United Nations [921]; Royalist sources in Aden [919, 921–22]; "usually reliable sources in Aden" [420].
(2) Eye and lung injuries [420].
(3) Over 425 casualties, including 50 dead and 175 unlikely to survive [919, 922]; 507 casualties—150 dead, 157 dying, 200 with eye and lung injuries [420].
(4) About 60 bombs dropped from 4 Ilyushin bombers [923].
(5) On 15 July, Radio Sana'a broadcast a statement that gas bombs would be dropped on any areas harbouring Royalists [922].

16 July 1967: *Mabian* and *Nejra* (near *Hajjah*) [908]

(1) Prince Hassan bin Hussein, in Beirut.
(3) 217 dead.

23 July 1967: Unspecified locality [921]

(1) Royalist Yemeni complaint to the United Nations.
(3) 18 dead.

Note: According to *The Military Balance 1966–1967,* published by the Institute for Strategic Studies, the air force of the United Arab Republic contained 30 Tu-16 medium bombers, 40 Il-28 light bombers, and 150 MiG-15 and MiG-17 fighter bombers at the end of 1966.

Appendix 2. Alleged Japanese biological warfare in China, 1940–1942

The problem of attempting to analyse BW allegations long after the opportunity to gather evidence has passed is discussed in Volume V of this study, with particular reference to the allegations made against the United States during the Korean War. As a preliminary to that discussion of the problems of verification, it will be useful to look in more detail at some of the allegations made against Japan during World War II.

Some extracts from the first detailed report to be published alleging Japanese use of biological weapons in China [577] are presented here. The alleged BW instances are listed in chronological order. The details of incidents (1)–(4) come from the statement issued in April 1942 by Dr P. Z. King, Director-General of the National Health Administration in China. In his statement he alluded also to a further outbreak of plague, but was less certain that it had been caused by enemy action. The details of incident (5) are provided by the *Chinese Medical Journal* in which Dr King's statement was printed [577].

(1) October 1940: Chuhsien, Chekiang Province

On October 4, 1940, a Japanese plane visited Chuhsien, Chekiang province. After circling over the city it scattered rice and wheat mixed with fleas over the western district of the city. There were many eye-witnesses among whom was a man named Hsu, who collected some grain and dead fleas from the street outside of his own house. He sent them to the local air-raid precautionary corps for transmission to the provincial hygienic laboratory. The laboratory examination result was that 'there were no pathogenic organisms found by bacteriological culture methods.' However, on November 12, 38 days after the Japanese plane's visit, bubonic plague appeared in the same area where the grain and fleas were found in abundance. The epidemic in Chuhsien lasted 24 days, resulting in 21 deaths.

Available records show bubonic plague never occurred in Chuhsien before. After careful investigation it was believed that the strange visit of the enemy plane was the cause of the epidemic and the transmitting agent was rat fleas, presumably infected with plague and definitely dropped by the enemy plane. As plague is primarily a disease of rodents, the grain was probably used to attract the rats and expose them to the infected fleas mixed therein. It was regrettable that the fleas collected were not properly examined. Owing to deficient laboratory facilities, an animal inoculation test was not performed.

(2) October 1940: Ningpo, Chekiang Province

On October 29, 1940, bubonic plague for the first time occurred in Ningpo in Chekiang province. The epidemic lasted 34 days and claimed 99 victims. It was reported that on October 27, 1940, Japanese planes raided Ningpo and scattered a considerable quantity of wheat over the port city. Although it was a curious fact to find 'grain from heaven' yet no one at the time seemed to appreciate the enemy's intention and no thorough examination of the grain was made. All the plague victims were local residents. The diagnosis of plague was definitely confirmed by laboratory tests. There was no excessive mortality among rats noticed before the epidemic and, despite careful examination, no exogenous sources of infection could be discovered.

(3) November 1940: Kinhwa, Chekiang Province

On November 28, 1940, when the plague epidemic in Ningpo and Chuhsien was still in progress, three Japanese planes came to Kinhwa, an important commercial city situated between Ningpo and Chuhsien, and there dropped a large quantity of small granules about the size of shrimp-eggs. These strange objects were collected and examined in a local hospital.

The granules were more or less round, about one millimeter in diameter, of whitish-yellow, somewhat translucent with a certain amount of glistening reflection from the surface. When brought into contact with water on a glass slide the granule began to swell to about twice its original size. In a small amount of water in a test tube with some agitation it would break up into whitish flakes and later form a milky suspension. Microscopic examination of these granules revealed the presence of numerous gram-negative bacilli with distinct bipolar staining in some of them and an abundance of involution forms, thus possessing the morphological characteristics of B. Pestis, the positive organism of plague. When cultured in agar medium these gram-negative bacilli showed no growth and because of inadequacy of laboratory facilities animal inoculation tests could not be performed.

Upon the receipt of such a startling report from Kinhwa the National Health Administration dispatched Dr W. W. Yung, director of the Department of Epidemic Prevention; Dr H. M. Jettmar, epidemiologist, formerly of the League of Nation's Epidemic Commission, and other technical experts to investigate the situation. Arriving in Kinhwa early in January, 1941, they examined 26 of these granules and confirmed the previous observations, but inoculation tests performed on guinea pigs by Dr Jettmar gave negative results. It is difficult to say whether or not the lapse of time and the method of preservation of the granules had something to do with the negative results from the animal inoculation test, which is a crucial test for B. Pestis. At all events no plague occurred in Kinhwa and it indicated that this particular Japanese experiment on bacterial warfare ended in failure.

(4) November 1941: Changteh, Hunan Province

On November 4, 1941, at about 5 a.m., a lone enemy plane appeared over Changteh, Hunan province, flying very low, the morning being rather misty. Instead of bombs, wheat and rice, pieces of paper, cotton wadding, and some unidentified particles were dropped. After the all-clear signal had been sounded some of these strange gifts from the enemy were collected and sent by the police to a local missionary hospital for examination which revealed the presence of micro-organisms reported to resemble B. Pestis.

On November 11, seven days later, the first clinical case of plague came to notice, followed by five more cases. The diagnosis of bubonic plague was definitely confirmed in one of the six cases in November by bacteriological culture method and animal inoculation test.

(5) August 1942: Nanyang, Honan Province

On August 30, 1942, ... three Japanese planes dropped large quantities of kaoliang (sorghum) and corn which, on bacteriological examination, were found to be contaminated with the bacilli of bubonic plague.

Comments on the Changteh incident

In wartime, it may be expected that epidemiological factors and traditional patterns of population movement will be upset. Dr Pollitzer, in his 1954 monograph on plague [575], introduces this element into a discussion of wartime plague in China in such a way that some doubt is cast on the incidents alleged in Chekiang province, although he does not specifically mention these at all:

It has to be added that owing to intensified traffic over hitherto little-used routes during the second World War the two provinces of Chekiang and Kiangsi, formerly quite plague-free, became affected in 1940 and 1941 respectively. While the latter province seems to have been free from the end of 1949, a slight incidence of the disease continued during 1950 in Chekiang where Wenchow remains the only major port in the China coast still suffering from human plague.

He does, however, refer to the Changteh incident in terms of BW:

Likewise, when plague, believed to have been introduced by bacterial warfare, appeared at Changteh, Hunan Province, in 1941, no permanent harm resulted even though in the following year a rat epizootic was rampant in that town and almost 100 human cases occurred. The infection disappeared early in 1943 and since then Hunan has been as free from plague as it was before the end of 1941.

Dr Pollitzer also clearly points out the unusual historical absence of human plague in central China.

The absence of plague from central China or its failure to establish itself cannot be ascribed to a paucity of commensal rats or of *X. cheopis*, both of which abound everywhere. Likewise, as confirmed by the observations in Hunan, there is no reason to assume that plague-resistant rat strains prevail in Central China.

Dr Chen Wen Kwei, the author of the original report from Changteh (on which Dr King's account is based), similarly wrote:

Changteh has never been, as far as is known, afflicted by plague. During previous pandemics and severe epidemics elsewhere in China, this part of Hunan, and Central China in general, have never been known to come under the scourge of the disease. [577]

The nearest plague infected city to Changteh in 1941 was Chuhsien, 2 000 km away by land or river communication, whose earlier infection in 1940 was in fact also alleged to be due to BW attack, as noted above. Dr Chen Wen Kwei adds:

1. that epidemiologically plague spreads in China along the transport routes for grain from its coastal import sites in Fukien and Kwantung provinces;
2. that no cases had been seen en route between Chuhsien and Changteh;
3. that at the time communications with Changteh were only possible by boat or by footpaths;
4. that there was no antecedent epizootic in Changteh; and
5. that Changteh was a grain exporter and not a grain importer [577].

Dr Chen Wen Kwei also adds several interesting details concerning the wartime handling of his report by his colleagues and superiors in the Chinese public health administration who felt "that the evidence was not sufficient from a scientific point of view to incriminate the Japanese". Nevertheless, it was translated into English and distributed to ten foreign embassies in Chungking, and mentioned in the *Epidemic Prevention Weekly* under the names of Dr King and Dr Pollitzer. He states that in 1945 at the time of the war crimes trial in Tokyo, "an American judge . . . came personally to Chungking to call on me and ask me to give him the Report on the Plague Epidemic at Changteh. I was also asked to sign a copy of that report (which I did) . . ." [578].

The remaining difficulty is the epidemiological inadequacy of such sentences as:

"There had been no plague reported in Changteh for more than ten generations . . ." [576].
"Changteh has never been, as far as is known, afflicted by plague" [577].
"Available records show bubonic plague never occurred in Chuhsien before" [577].

The critical words are of course "reported", "as far as is known" and "available". In this connection, the following three points are relevant:
1. There exist atypical cases of human plague which do not lead to mortal infection, as well as cases in which the virulence of the particular strain

of *P. Pestis* will kill before superficial symptoms of plague may appear on the human body:

Man appears to possess no natural immunity against invasion by the plague bacillus. The disease, however, shows markedly different degrees of severity, ranging from the mild ambulatory type, always bubonic in character, to the almost inevitably fatal pneumonic variety. The mortality from bubonic plague, although very high, is less than generally supposed, ranging from about 30 to 60 per cent. As a rule, the healthier the individual attacked, the better the chance to recovery. [924]

2. In a rural community very few deaths would receive an autopsy, and unexplained death without suspicion of violence would go without being reported to public health officials. Dr Chen, the author of the original report from Changteh, writes: "Changteh now has a population of about 50 000. No mortality statistics are available." [578] It would be exactly such statistics, going back years before 1941, that would give validity to statements such as "Changteh has never been, as far as is known, afflicted by plague".
3. There are endemic foci of plague in wild rodents (sylvatic plague) which will not be known to exist unless they are explicitly sought. This situation has been recently displayed with great clarity for the western United States [925]. In another discussion of sylvatic plague, it is pointed out that: "Although field-rodent plague has given rise so far to comparatively little human mortality in most countries, in North Manchuria where the disease is endemic in the marmot or "tarabagan", virulent epidemics of pneumonic plague have occurred." [926]

If not directly relevant to the World War II China examples (and it may be), this ecological situation certainly seems relevant to the subsequent discussion of the allegations of the Korean War period, for in 1952 "North Manchuria" will be "Northeast China". The survey of two hundred rats in Changteh concomitant with the epidemic is definitely supporting evidence that the particular cases in question did not derive from a preceding epizootic. But it would be a far more definitive proof that plague was not endemic in the *area* if it could be shown that over the preceding years none of the potential wild rodent hosts had ever been infected. To make a certain, or at least a proper, evaluation of a BW allegation—barring a situation where the instigator is caught in the act and the origin of the purveyed material is beyond doubt—it is most desirable to have an epidemiological history of the area. Depending on the disease in question it may be desirable to have at hand information from previous surveys of antibodies for the disease in question in the human population, or of infection or lack of infection in the vector and intermediate host of *both* domestic and wild varieties. For plague in particular the antibody pattern may not be so critical, but it would be preferable to have had previous surveys of wild as well as domestic rodents. Though not intended as a negative reflection against the allegations, the rapidity with which endemic intermediate host populations may *shift* between different species of animals capable of harbouring the host should also be kept in mind.

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