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L. F. Haber

The Poisonous Cloud

Chemical Warfare in the First World War

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L. F. HABER

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Jacket illustration: men of the 2nd Btn.
Argyll and Sutherland Highlanders wearing mouthpads, 1915.
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ACKNOWLEDGEMENTS

THE book draws heavily on reports, memoranda, and letters in public archives. The material is bulky and is filed in boxes which line miles of shelving in the Public Record Office, the National Archives in Washington, and elsewhere. A small staff is employed to process enquiries and move the boxes from store to users. Although red tape is not unknown in these places, I have good cause to be grateful to these men and women who kept me supplied with the raw materials for my history. Thus, at the outset, I gladly acknowledge the help of the many unknown Civil Servants, particularly those in the old PRO in Chancery Lane, London, which was not designed to handle boxes quickly. Archivists and Librarians, of whom I got to know a good many, were ever helpful and patient with me. If I single out Rose Coombs, David Lance, and G. M. Bayliss from the Imperial War Museum, Archivdirektor C. F. Stahl from the BMA, and Oberregierungsarchivrat Dr Heyl from the BHSA, the reason is that I must on occasions have strained their endurance and their memories, both considerable, and belatedly I offer them my sincere thanks for the information they provided. A special word of thanks is also due to the staff at the Library of the University of Surrey, who dealt quickly and efficiently with my frequent requests for books and pamphlets from other libraries at home and abroad.

I have adopted the practice of referring to the help given to me by colleagues, research students, and friends at those points in the story where their intervention was particularly valuable. Here I want to remember those who have been involved with the project as a whole, who sent me their reminiscences or commented on outlines or drafts. Harold Hartley deserves pride of place, for it was he who launched me on this enterprise. Without his encouragement and his papers, I would not have got started. John Coates backed his reminiscences with correspondence notes and interviews on chemical warfare which he obtained during the 1930s when he prepared his lecture for the Chemical Society. He put all the documents at my disposal and so cleared up many questions concerning Haber's role between 1915 and 1918. Leslie Barley and J. Davidson Pratt talked to me and wrote at length, and I have used much of the material they provided. These eye-witnesses of chemical warfare in the First World War are dead. I remember them with affection and gratitude.

Two other helpers call for special mention. When one is researching and writing over a period of many years continuity suffers and repetition may become intolerable. My friend Peter Morgan volunteered to go through the typescript with the sharpness of mind and the critical judgement that have made his opinions so valuable to me for many years. I was particularly fortunate because he remembered his chemistry sufficiently to correct me on many details and his exposure to military life in Hitler's War enabled him to spot errors in my account of the Kaiser's War. Without his meticulous intervention at the final stage the book would be longer, frequently tedious and contain many mistakes. The University Press have their own rules and chemical warfare has

to conform to them: I can only marvel at the work that goes into the publication of a difficult book and I want to take this opportunity of thanking Rupert Christiansen for editing the typescript and in the process correcting the style and improving the general appearance.

The man who could have been of the greatest help, my father, died fifty years ago. He could have plugged many holes and, as Hartley wrote later, 'put the record straight'. There is still no comprehensive biography of Fritz Haber nor for that matter an official German, British, or French history of chemical warfare in the First World War. Hartley urged me to look at the evidence that had recently become available and in so doing describe my father's many-sided activities in those years: I have done that in this book which I dedicate to them.

London, L. F. H.
September 1984

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DIAGRAMS

ABBREVIATIONS AND GLOSSARY

The following abbreviations and technical terms have been used throughout the text of the book and in the index.

ADGS	Assistant Director Gas Services
AEF	American Expeditionary Force
BA	Bundesarchiv, Koblenz (Germany)
BASF *or* Badische	Badische Anilin- & Soda-Fabrik, Ludwigshafen (Germany)
BEF	British Expeditionary Force
BHSA	Bayerisches Hauptstaatsarchiv, Abt. IV, Kriegsarchiv, Munich
BIR	Bayerisches Infanterie Regiment
Blue Cross	German shell-marking to indicate it was filled with arsenical compounds. Used here as a collective noun for these materials
BMA	Bundesarchiv-Militärarchiv, Freiburg i.B. (Germany)
BRIR	Bayerisches Reserve Infanterie Regiment
cc	cubic centimetre
CCS	Casualty Clearing Station
CS-C	Chemical Sub-Committee of the Scientific Advisory Group of the Trench Warfare Department (later the Trench Warfare Research Department) of the Ministry of Munitions
CWC	Chemical Warfare Committee, London
CWD	Chemical Warfare Department of the Ministry of Munitions
CWS	Chemical Warfare Service, a branch of the USA armed forces
DA	Diphenylchloroarsine, code-named 'Clark' 1 by the Germans
DGS	Director of Gas Services, France
DM	Diphenylaminechloroarsine, also known as 'Adamsite' in Britain and USA
DMCG	Direction du Matériel Chimique de Guerre of the Ministère de l'Armement
FMA	French Military Archives, Château de Vincennes, nr. Paris
GQC	Grand Quartier Général, the GHQ of the French forces
gr	gram
HE	High explosive
IEEC	Inspection des Études et Expériences Chimiques, the French research and development organization for chemical warfare

IWM	Imperial War Museum, London
kg	Kilo or kilogram
KWI	Kaiser-Wilhelm-Institut für Physikalische Chemie und Elektrochemie in Berlin-Dahlem. Since 1953, Fritz-Haber-Institut der Max-Planck-Gesellschaft
m	metre
mg/m^3	milligram(s) per cubic metre
MoM	Ministry of Munitions
MoM History	History of the Ministry of Munitions, XI, part 2, 'Chemical Warfare Supplies', n.d. [1921?], unpubl.
NA	United States National Archives, Washington, DC
OHL	Oberste Heeres-Leitung, the German supreme command
ppm	parts per million
PRO	Public Record Office, Kew, nr. London
RA	Royal Artillery
RAMC	Royal Army Medical Corps
RE	Royal Engineers
Rgt	regiment
SBR	small box respirator, the standard-issue British respirator 1916–18
Stogas	Stabs-Offizier, Gas, the equivalent of the Chemical Adviser in the BEF
t	metric tonne. Quantities are expressed in t throughout the book except where the capacity or other details of the British or American chemical warfare effort need to be given with great precision, when the number will be followed by *ton, tons,* or *long tons*. (Note: American short tons have been converted to t or long tons as appropriate.)
TNT	trinitrotoluene, one of the principal HE shell fillings in the First World War
TWD	Trench Warfare Department of the Ministry of Munitions
tr.	translated by the author
UAC	United Alkali Co. Ltd.
Yellow Cross	German shell-marking to indicate that contents were dichlorodiethyl sulphide and solvent. Used here as synonym for mustard gas or Yperite

1

PERSONAL INTRODUCTION

ANOTHER book on chemical warfare when the literature on the subject is already considerable calls for an explanation. In this particular case personal interests and new material are so closely knit that it is necessary to describe how I came to be committed to the task and what I am hoping to achieve.

In 1968 at the formal ceremony to commemorate the centenary of the birth of my father, Fritz Haber, there was an incident in the lecture theatre of the University of Karlsruhe where he had taught from 1894 to 1911. Two young men appeared on the rostrum and unfurled a banner with the following legend:

Feier für einen Mörder
Haber = Vater des Gaskriegs

There was a brief, complete silence, then the Chairman said something apposite and soothing, the youths disappeared as suddenly as they had come, and the speaker resumed. Some thought the incident was a muted expression of that student militancy which swept through Western Europe in 1968. Others were indignant that a scientific occasion should be so inconsiderately disturbed. I was taken aback and my first reaction was that the slogans were lies or at least grossly exaggerated. On further reflection it seemed to me truly astonishing that after half a century, chemical warfare could still generate so much emotion. What were the facts, and was all the fuss really justified? There the matter might have rested, but for another personal and this time determining intervention.

Harold Hartley was an unusual man. This is not the place to sketch his biography, but to note his connection with chemical warfare which, in his prime, marked the turning-point for him. In civilian life he taught physical chemistry at Oxford, but after the outbreak of war he joined up and in June 1915 he became Chemical Adviser to the 3rd Army, but he did not play a prominent role until he was promoted to Assistant Director Gas Service, in short, ADGS (Defence) two years later. Hartley attained the top post in November 1918 when he was appointed Controller, Chemical Warfare Department (CWD). His personality was more significant than his official function and rank. He possessed a lively intellect, the ability to ask the right questions, and a genuine interest in other people's work. These attributes, combined with a good Balliol background opened many doors to him and he was better informed than many of his seniors on the Staffs or in Whitehall. That came to be recognized and while winding down the CWD in 1919 he led the British section of an inter-allied team which visited the occupied areas of Germany in February of that year. He was struck by the close relationship between German chemical

manufacture and the supply of munitions, the ingenious development of substitutes for materials in short supply and, specifically, by the existing facilities for war gas production. Hartley's views on the British chemical warfare effort were now carrying weight, his recommendations were listened to, and the German experience had taught him the significance of the industrial aspects of chemical warfare. As a result he played an indispensable part in the inter-war deliberations of the Chemical Warfare Committee. As part of Hartley's public, but not publicized, service he was asked to go to Berlin in 1921. In retrospect it seems odd that the British should have waited almost three years before 'debriefing' German scientists. But such had been the dilatoriness of the Reichswehr Ministry that repeated enquiries went unanswered or were left deliberately incomplete. A more subtle approach might yield better results. So, being a passable German speaker, a good physical chemist, an expert on chemical warfare and, not least, an honorary Brigadier-General and CBE he went to Berlin to speak, as he put it, to the 'great' Haber.

For Haber the war had been first the apex and then the nadir of his middle life. Appointed director of the newly created and privately endowed Kaiser-Wilhelm-Institut for Physical Chemistry (KWI) in 1911 he had moved from Karlsruhe to the Reich capital. The move from province to the centre underlined his growing fame as the man who had solved the problem of nitrogen fixation which had eluded other greater scientists. He was the embodiment of the romantic, quasi-heroic aspect of German chemistry in which national pride commingled with the advancement of pure science and the utilitarian progress of technology. Haber's patriotism was unusual even in an age when jingoism, into which it so frequently spills over, was condoned. He was a Prussian, with an uncritical acceptance of the State's wisdom, as interpreted by bureaucrats, many of them intellectually his inferiors. He was also ambitious, determined to succeed, and well aware that his Jewish origin was both obstacle and spur. At the outbreak of war he was in sole charge of a purpose-built centre for cross-disciplinary research into physics and chemistry. He immediately placed the facilities of the KWI at the disposal of the Government. In addition he became a voluntary consultant—behind the scenes—on what would now be called industrial mobilization. His involvement in chemical warfare began in December 1914 and was marked for the duration by strong purpose, great energy, a practical turn of mind, and outstanding administrative ability. Haber's greatest successes came in 1915—the year of the first gas attacks and the organization of gas-mask production—but his most important role was played in the last two years of the war when he tendered advice at the highest level and was officially in charge of German gas supplies and gas protection. His wide and burdensome responsibilities did not extend to the use of chemical warfare agents. Thus, powerful and yet powerless, he was early aware of the turning tide and the implications of defeat. His chemical weapon had failed, misused in other hands, but failed all the same.

The end of 1918 marked the end of Haber's active connection with chemical

warfare, though he was never allowed to forget what he had done. I shall leave his post-war activites to the last chapter and confine myself here to this talks with Hartley because they have a bearing on the genesis of this book. They met in June 1921: each was curious about the other. Haber about the man who had done less for his country's war effort, but had been more highly rewarded—forgetting the cultural differences and the advantage of being on the winning side. Hartley wanted 'to fathom what was in Haber's mind when we knew that he was directing the German use of gas'. These talks were more than an intelligence interrogation. They extended beyond the organization of chemical warfare, the primary objective, to the state of German science and the progress of physical chemistry, and, as Hartley wrote later, 'I like to think we parted as friends. It was a great experience to have enjoyed his intimate confidence.'[1]

The immediate and direct outcome of the meeting was a long report which was never published and remains, owing to the lack of German material, the most comprehensive document on the development of that country's chemical warfare, its organization and purpose.

Many years later Hartley proposed to incorporate the report in his account of chemical warfare. The plan had to be postponed because the pressure of business prevented him from devoting time to literary projects. However, Hartley's interest in the subject never ceased, indeed it was revived at intervals owing to his place at the centre of the British chemical warfare scene in the 1920s and 1930s and his links with Haber which continued to influence him for half a century. Surely an exceptionally long period for the germination of an idea! The details merit recording.

Upon Haber's death in 1934, the Chemical Society asked J. E. Coates, a former pupil, to give the memorial lecture. Coates was careful and conscientious. Through interviews and correspondence he gathered a mass of personal impressions so that he was able to appreciate Haber's commitment to chemical warfare which, however awkward, had to be presented to a large audience of British chemists.[2] Hartley was repeatedly consulted over this delicate task and his comments were invaluable because he knew at first hand almost everyone connected with chemical warfare from 1915 onwards. Later he drafted a note, based on his report, which was factual and fair, though often critical on technical matters. Later still he went through Coates's drafts and suggested further changes.

Then there was a long gap. Hartley seems to have toyed from time to time with the project of a history and may have intended to combine it with an autobiography. In 1958 he was writing to C. G. Douglas 'some day I hope I shall live long enough to go through the final [volume of the official] history and with my own records try and give a true picture for the sake of posterity.' Douglas encouraged him—'I wish you would write a history of the gas services . . . I don't think they ever had adequate recognition and there ought to be a trustworthy record'—but Hartley thought it was premature: 'I have a slight

feeling of reluctance to publish anything while Foulkes is alive as I don't want to upset him.'[3]

Coates, Douglas, and Foulkes will reappear later; they are introduced here to show that Hartley kept in touch with the participants. Soon afterwards there was another period of active interest. In 1960–1 he wrote at my request a chapter for Dr J. Jaenicke's biography of Fritz Haber which is still incomplete and remains unpublished. It was straightforward and factual, but often and deliberately anecdotal: Hartley thought that would add spice to the story, and so it did, but it also perpetuated myths. His correspondence at the time shows that he was anxious to put his story on record so as to correct what he considered to be the unfavourable bias of the Official History.[4] The deaths of collaborators and friends in the 1960s, among them Livens, Douglas, Auld, and Foulkes, reminded him that time was pressing. There were brief notes on gas warfare written in 1966, 1968, and 1969, but by then he was in his eighties and his energy was failing. He became very ill at the beginning of 1970 and I made it a habit to visit him regularly at his nursing home: our talks ranged widely and his interest in chemical warfare soon revived. He had ideas on the subject, a fantastic memory, and a mass of papers of which I will presently have more to say. According to Hartley, there was no definitive history of chemical warfare, and one was badly needed. I was unconvinced, at least until I had immersed myself in his papers. But there was another aspect: except for Coates's excellent memorial lecture[5] and Jaenicke's rather shorter eulogy of 1968, there is still no biography of my father. Novelists and others have indeed made him their subject, but—to put it charitably—their treatment of the war years has remained inadequate.

Hartley's powers of persuasion were notorious. Considering that I was insufficiently occupied he proceeded to 'hartle' me. The verb is active: 'I think', 'you do', 'it is successfully accomplished'.[6] He had charm, the ability to command loyalty, and a genuine interest in the activities of younger people. I set to work, read, interviewed him dozens of times, talked and corresponded with his surviving war-time colleagues, and eventually prepared a synopsis which, in its first version, embodied many of his ideas and some of mine. But towards the summer of 1972 his attention flagged—he was always tired, often in great discomfort, and too old and sick to find the strength to be committed to the project. He died in September of that year and I continued alone. The end result differs considerably from what we envisaged many years ago. That must be so, for one's ideas change as research and reflection open up new horizons. But I am grateful to Harold Hartley for having pointed me firmly in the general direction and for giving me this opportunity to do justice to one period of my father's life which he preferred to keep obscure and which no one has yet properly examined.

So far I have described the personal background to the book. Some would say that this is sufficient reason for writing it. But if one goes over previously

cultivated ground it is necessary to demonstrate one's claim to have uncovered and used new material. Hence the following review of the novelty and value of the information which came into my hands after Hartley enlisted me.

For some years after the First World War, German authors had something of a corner in chemical warfare literature. There are some advantages even to defeat: as you have been beaten you might as well make a clean breast of it, since the victor knows what you have been up to. But does he? Hartley's trip to Berlin (and he was not the first investigator) shows that the Allies were ignorant of many aspects. Of course Hartley could not disclose the extent of his knowledge, in the first place because the Official Secrets Act prevented him from doing so; secondly he was reluctant to discard his trumps at the beginning of the game. The Germans obviously took a different view: they were good at military technology, and after 1919 their revelations consisted of interesting technical details, known to the Allies even before the Armistice, but not divulged by them. The first in the field was General Schwarte. He was the editor of an oft-quoted book which was hastily prepared and while boosting German achievements ignored those of the Allies. Chapter XI of his book is divided into three sections on chemical warfare, by Captain H. Geyer of the General Staff and by F. P. Kerschbaum and H. Pick of the KWI, respectively in charge of its offensive and defensive sections; they had nothing to say about their enemies![7] Schwarte was followed by Hanslian, a former pharmacist with the XXII Corps. The first edition of his *Der chemische Krieg* appeared in 1925; this was a slim book of 200 pages, essentially an enlargement of what Schwarte had put together. The second edition appeared in 1927. It was more substantial and relied extensively on foreign sources, notably American reports and the papers given by British and French specialists on different aspects of chemical warfare. Hanslian, like others, was recycling information, and his book—though elaborately documented—was incomplete in many respects, lacked numeracy, ignored organization, research, and development, and failed to evaluate the effort put into this form of warfare and the gains achieved. The third edition was in two parts, but only the first—the military part—was published. It is vast, badly written, and repetitive.[8] The section on Ypres 1915 was shortened (because Hanslian had written a booklet on the attack in 1934) and that on post-war developments expanded to 500 pages. He had access to German material, but relied in the main on the United States Chemical Warfare Service (CWS) whose experience of the war was necessarily limited, and on Soviet publications which were propagandist rather than informative.

All inter-war writers on the subject relied on Schwarte and Hanslian, repeated their 'facts' and left the interesting questions unanswered. The official histories did not fill the gaps, nor were they designed as technical studies. In any case their publication was slow. The German volumes fell victim to political change, to another war, and were not resumed until the 1950s. The British did not reach 1918 until 1947!

The 'classics', official and others, are not of much use if one is looking for a

fresh approach. Hence the importance of the new material. It will be convenient to start with the Hartley papers and proceed from there to the national and specialist archives.

Hartley's collection on chemical warfare, which he kept in his room, comprised about twenty-five files, in no apparent order, containing the most diverse material.[9] I could not get him to explain either the sequence or the obvious gaps. Broadly speaking these files complement the material now at the Public Record Office. Four sets of papers are particularly important. First, the reports connected with the German cloud-gas attack at Ypres on 19 December 1915: this was the first occasion the Germans used large quantities of phosgene in the West and great care was taken by the Chemical Adviser and medical officers to record in minute detail the technical particulars of the discharge and the protective value of the British gas helmets. Secondly, there is a complete collection of *Gas Warfare*, a monthly bulletin which Hartley launched and edited after he became ADGS (Defence) in mid-1917. This was published by GHQ for circulation among gas officers, staff, and chemical warfare specialists in Whitehall. The interest and value of *Gas Warfare* lies in the dated reports on the use of gas by the British and German forces and in the statements of German prisoners to British intelligence officers which can be compared with the entries in German regimental diaries. Remarkable discrepancies between such statements and reports made elsewhere have thus come to light. Thirdly, there are the statistics on German gas bombardments and British casualties resulting therefrom between July and November 1918. Despite their considerable limitations the numbers permit at least a rough evaluation of the effectiveness of gas shells.[10]

Finally, there is the report on German Chemical Warfare Organization and Policy, a long undated document which, for the sake of brevity, I shall refer to as the Hartley Report. From internal evidence it would appear that the report was written in 1921–2, revised later, and duplicated for circulation in 1925. Owing to the significance of the document, its genesis and scope merit closer attention. The Treaty of Versailles required the Germans to supply technical information. As far as chemical warfare was concerned, the Allies were principally interested in manufacturing operations, the design of gas shell-filling equipment, the central chemical warfare depot at Breloh, the preparation of activated charcoal and the progress made with various organic arsenical compounds which were discharged as a particulate cloud.[11] The military branch of the Inter-Allied Control Commission had an Armaments Sub-Commission which endeavoured through questionnaires sent out in 1920 and 1921 to get information on these and other points. In this way Gen. E. Vinet, the French head of the Sub-Commission, his assistant Col. H. Muraour, and Dr H. E. Watts, an English chemist with chemical warfare experience, obtained many production statistics from the Germans. In July 1920 Vinet talked to Haber and drove with him to the chemical warfare establishments near Berlin. Vinet and his team concluded their investigations with typed reports, which in some

respects went over the same ground as Hartley's report. The first in two parts respectively dated June and December 1920, contained sections on the field ammunition depots and on the organization of German chemical warfare. Some of the material was incorporated in a later document dated 22 March 1921 entitled 'Report on the Present Condition of the Installations set up for the Manufacture of Asphyxiating Gases in the German Chemical Factories'. This dealt specifically with the progress of dismantling.[12]

The British were not satisfied with this information and Hartley was carefully briefed regarding what to look for when visiting Germany in June 1921. He was asked to discover 'as far as possible' the extent of the dismantling of gas production facilities, the lines on which the Germans were working at the time of the Armistice, especially particulate clouds, and 'some information regarding the German war organisation for chemical warfare. This is a subject on which we have very little accurate data.'[13] Such was the background to Hartley's enquiries which, as his notebook[14] and the report show, were extremely thorough. He visited Berlin, Breloh, Munich, and Stuttgart, talked to Haber for altogether seventeen hours and had meetings with Haber's collaborators at the KWI, among them Epstein, Freundlich, Hahn, Kerschbaum, Regener, Willstätter; he also talked to Duisberg and Nernst. He met with great co-operation, except from one man, not named, but probably Regener at Stuttgart, an acknowledged authority on particulate clouds. Hartley checked the answers against other information available to him and Watts subsequently dealt with some supplementary questions. 'There seems to be no reason to think that the information given was inaccurate or that the experts were holding back anything so far as their work in the war was concerned. In some respects their frankness was surprising,' Hartley wrote later.[15] Gaps do remain, especially on particulate clouds and events on the Eastern Front, but any reassessment of the industrial and organizational aspects of German chemical warfare would be seriously incomplete without the Hartley Report.

London has, so far as I have been able to judge, the largest extant collection outside Russia of chemical warfare documents from 1914 to the 1930s. The Imperial War Museum obtained a mass of papers of value to the military aspects of gas, offence as well as defence: they consist of instructions, circulars, leaflets, reminiscences, and a large collection of photographs which are invaluable if one wishes to follow the minutiae of chemical warfare. The documents at the PRO are different and consist of three main collections. The first are the records of the Ministry of Munitions, specifically its Trench Warfare Supply Department and the Chemical Warfare Department. The second are the records of the War Office which comprise the Gas Directorate (DGS) in France, the research centre at Porton and Allied information, chiefly French, which Lefebure, a most energetic liaison officer, secured in Paris and forwarded. The War Office papers also include the inter-war series, among them—under the reference WO 33/1072—the Hartley Report, unobtainable for almost half a century. Finally, the United States CWS sent duplicates of its records to London,

but for reasons which will emerge later I have only consulted a few of them. The British material at the PRO is daunting in its size. The Ministry of Munitions records comprise forty-one boxes, the Porton papers 387 boxes, and the DGS documents 154 boxes (about 700 files). A line had to be drawn somewhere: I examined the entire contents of all the Ministry and DGS boxes, but the Porton material was highly technical and I therefore confined myself to a search of forty-five boxes, taken at random.

The PRO papers became accessible after a change in legislation. The material just described was released from the late 1960s onwards and takes the story up to the 1930s. The unwary might think the collection is complete, but they would be mistaken. The more recent documents, say from the mid 1930s onwards, probably contain files which were not closed until after the Second World War, and therefore were not available to me when researching for this book. The earlier documents, from 1915 up to 1930 or 1935 are certainly not complete. The most charitable explanation is that in the rapid demobilization of the CWD in 1918–19 the clerks and their superiors were often careless and needlessly destructive. The gaps were widened by other causes: even Registries are not infallible and files sent out are not returned despite reminders. Thus documents get mislaid and disappear from circulation. They may also, of course, have been expressly secreted and may, at this time of writing, be collecting dust on some shelf, inadequately labelled and long forgotten. All the belligerents were obsessed by security in chemical warfare matters. The British and French codenames delighted their inventors, but probably confused the users more than they did the enemy. Whatever the reason, the incompleteness is apparent.[16] This can, in part, be made good by recourse to the Hartley papers, occasionally, interpolation (or, more crudely, guessing) will be justified and foreign documents sometimes provide valuable clues.

Last, but by no means least, there is the history of the Ministry of Munitions. Some people, under instruction from higher authority, meticulously preserved records of historical interest. These formed the raw material of a comprehensive history which was completed in small instalments, but was never published, and indeed did not become accessible to the public until the 1960s. The documents for the History of Chemical Warfare Supplies fill many folders and pride of length unquestionably goes to the 360 foolscap-page typescript by Major H. Moreland who had been in the Trench Warfare Supply Department in charge of 'Gas and Cylinders' from the outset and was promoted head of the Chemicals Section in 1916. Moreland gave his side of the story, and J. Davidson Pratt, who we shall meet later, wrote on the activities of the Chemical Warfare Committee. The drafts survive, largely confirm each other and enable us to see how chemical warfare was organized in the UK. Together with the Hartley Report, they illuminate the industrial – scientific – military relationship which previous writers perforce neglected.

It remains to note how far other archival material supplements the Hartley—PRO documents. Little has survived in Germany. Hartley used to tell of his

first meeting with Haber who greeted him in Berlin with 'Why have you been so long in coming? I was looking forward to discussing all our records with you, but there has been a most unfortunate fire and they are all destroyed. Look at that hole in the roof.'[17] Alas, the story is apocryphal. There was no fire and the papers had been removed to the Reichswehr Ministry in 1919. It is likely that the records were extensive as each section at the KWI had compiled an account of the work done. These large tomes were treated as top secret and except for one appear not to have survived.[18] Together with the papers of the German War Ministry they formed part of the military archives at Potsdam which were largely destroyed in an air raid on 14 April 1945.[19] The surviving documents were combined with others from the naval and air force archives and eventually formed the core of the Bundesarchiv-Militärarchiv collection at Freiburg. The material on chemical warfare is scanty, though some valuable inter-war documents and personal notebooks and diaries are available, have been indexed, and can be used to check data from other sources. The files and routine reports of Section A10 (Chemical Supplies) of the War Ministry have not survived, with the exception of a few fragments and curiously a single, complete report (dated 21 December 1917) which was captured, translated after the war, and found its way into the Hartley papers.[20]

Fortunately, the archives of the German states suffered little damage. For my purposes by far the most important has been the Bavarian. Chance played a considerable role: the staff papers of the Bavarian Army Corps and of Prince Rupprecht's Army Group—which faced the British in Flanders for most of the war—were sent to Potsdam in 1919; they remained there until March or April 1945. A Bavarian officer, working in the archives, decided to save what he could lay his hands on, got them into a lorry and out of Prussia.[21] The rest were destroyed. What the unknown archivist salvaged was necessarily incomplete, but nevertheless contains invaluable material (since it is nowhere else available) on some critical episodes of German chemical warfare which have not hitherto appeared in published accounts by either side. The regimental records and diaries never left Bavaria: they are complete and are the only means of checking the claims made in *Gas Warfare* and elsewhere of the success of British gas attacks. In its proper place I will compare the claims with the records and draw attention to the significance of this evidence.

In terms of content the French archives occupy a position mid-way between the German and the PRO. A recent change in policy allows the public access to First World War material. The Archives Militaires at Vincennes have about 70 boxes—containing thousands of individual pieces as well as complete files—which bear directly on chemical warfare. But the material has not been properly collated: excepting the boxes of Direction du Matériel Chimique de Guerre (DMCG) papers, the records are scattered among the miscellaneous documents of the war. Such dispersal, accompanied by careless muddle in sorting and filing, greatly diminishes the value of what there is. There are many breaks in the sequence of the documents and absence of order, and no attempt was made, so

far as I know, to prepare historical or general surveys as in Britain. One example will illustrate the general situation: the documents on cloud-gas discharges by the Germans and the French end with a report dated 21 October 1916,[22] but at the PRO there are official French reports on German gas attacks in January-February 1917. What has happened to the French papers at Vincennes? Similar remarks apply to the Archives Nationales in Paris where the parcels (!) of the Sous-Sécretaire d'État au Ministère de l'Armement (that is, the section corresponding to the Trench Warfare Supply Department of the Ministry of Munitions) are manifestly incomplete. They are deficient in material bearing on research, supply, and use, but most informative on gas masks and the state of the French chemical industry.

Personal circumstances caused me to take up the subject in the first place. The additional material, as it unfolded, then pointed my research into those areas where previous study enabled me to understand the problems involved and formulate questions which, even now, call for an answer. We can illustrate their nature by two quotations: 'Throughout the war the [German] enemy maintained an unbroken and unenviable priority in adopting and developing . . . offensive toxic substances'[23] Why? Secondly, in connection with the issue of British gas helmets which began on 10 May 1915: 'Henceforward, so far as concerned matters of defence, the initiative rested with the Allies'.[23] Again, why?

Previous writers have taken fundamental issues of offence and defence in chemical warfare for granted, and have launched themselves into tactical, moral, or personal aspects of poison gas. I do not intend to follow them, because these are outside my knowledge and experience. Moreover recent investigations have cleared up practically all remaining contentious issues in these areas.

So what particular contribution can be made towards a better understanding of chemical warfare by an economic historian, such as I am, with a special interest in the development of the chemical industry? It is, I think, to set out the new facts and comment upon them so that we can better appreciate the cause-and-effect relationship of a very sudden and extremely complex technological change with unique features in its application.

Technological change is profoundly influenced by the intensity and direction of research and development, and by diverse economic and social factors which form the background to chemical innovation and, in turn, are affected by it. In war the market economy becomes less important: supply is controlled, demand checked, and choice restricted. But development and application continue, indeed are pushed to the absolute limit of innovatory ability, because substitutes or passable alternatives, become essential. In recent years the mechanics of the process have become better known. We are, however, less familiar with the obstacles that the large-scale adoption of new techniques and processes encounter: 'where there is a will, there's a way', but the way will be

obstructed if the basic technological environment is backward and if the methods of dealing with innovation are imperfect. Historians have become increasingly interested in the technical and socio-economic constraints to industrial change in the twentieth century, but few have investigated them in the context of military technology and none with regard to chemical warfare. This is odd, for von Bloch, who considered himself an economist and was the first to apply economic statistics to military matters, had seized the point eighty years ago: modern technology, he argued, improved weapons and also the ability to defend oneself against them. Hence a future war would be longer and ultimate victory would depend on political, economic, and social conditions; to appreciate the import of these conditions required the tools of political economy and of statistics.[24] Both were ignored by writers on military affairs in Bloch's day and indeed until very recently. A. M. Prentiss, whose book appeared in 1937, was the first to extend the study of chemical warfare to the industrial potential and even attempted a cost-benefit analysis of this mode of warfare.[25]

Economic investigations are obviously strengthened by a quantitative approach. The impression given by the supply of war gases in 1914–18 is generally one of improvisation and muddle. A systematic approach to organizational problems and other management aides, notably operational research, barely existed and certainly were not applied to chemical warfare materials. Yet even then there were people who thought numerately. Lanchester's N^2 law governing the strengths of opposing forces was, as he himself recognized, inapplicable to land warfare owing to the multiplicity of targets.[26] But that did not invalidate the basic principles which were that the assessment of relative strengths must be numerical and entail the measurement of strength. In retrospect it is surprising how few attempts have been made by previous writers, with the exception of Prentiss, to deal with this side of the subject.

The book would be incomplete if it concerned itself solely with impersonal facts and ignored those who made them. Personal war reminiscences abound, but I am deliberately restricting myself to two particular aspects: firstly, the relationship between two groups of professionals, chemists and soldiers; secondly, the impact on combatants of a wholly novel weapon against which the only defence was absolute confidence in an entirely new protective device, the respirator.

The relations between chemists and soldiers were by no means harmonious and, looking back, the alternation between mutual understanding and incomprehension correspondingly contributed to the effectiveness and failure of chemical weapons. I write 'alternation' advisedly, for there is much evidence of what would now be called communications failures. The friction between the two cultures existed even then and was not lessened by the passage of time. The uneasy relations were not confined to the front; they extended well to the rear, into the bureaucratic complexes which eventually 'managed' the war. Science and war were indeed interacting and after 1914 the subject attracted sustained attention. Sir William Pope made it the theme of his Presidential

Address to the Chemical Society. He noted that the necessity for applying science had come to be accepted during the war, but he was afraid that in peacetime science could be treated parsimoniously. He warned that it was 'again leaving the hands of the scientific man and being resumed by the lay administrator.'[27] This has been a common complaint ever since, though the scale of operations has vastly increased, and science policy has so far failed to solve the problem. But gas warfare 1915–18 can serve as a case study, *in vivo* as it were, of professional relations, suddenly, briefly and even dramatically involved in the practical applications of chemistry.

That brings me to another 'human angle' familiar to many through Sargent's painting of the gassed men on their way to the Casualty Clearing Station on the Amiens Road.[28] Defence against gas was a most unusual mixture of discipline, morale, and applied physiology. At the level of moral judgement the beastliness of chemical warfare (as distinct from other forms of warfare) has attracted immense attention, but what was it really like? Artists, poets, and novelists have given one version. I put it to the test, under admittedly ideal conditions, with chlorine and mouthpads made of dry, as well as urine-soaked, socks—the recommended protection of May 1915. The experiment did not turn me into an expert, but caused me to look for another version. Hence interviews with those who had experienced cloud gas and gas shell between 1915 and 1918. These old men had unexpected reactions which led me to the conclusion that the effectiveness of chemical weapons cannot be measured in purely statistical terms and requires some consideration of the post-war attitudes to gas and their effect on defence policies.

Between the wars, and even later, old battles were fought over with the same ammunition by those who had taken part, and their prejudices affected their perspective. By contrast I have the advantage of that detachment which comes from lack of involvement—the generation gap has its uses. That does not mean that I shall be invariably unbiased: I have already declared my personal interest and reviewed the fresh material which determined my approach. If new light can be shed on past events it is the historian's duty not merely to produce the evidence, but also to evaluate its significance relative to what was previously known; in brief to reassess the validity of historical judgements. That objective governs the scope of the book and also the manner of dealing with the subject-matter. It will be convenient to discuss both under five headings.

First, the time-span: chemical warfare began officially in 1915 and ended in 1918. These four years will be my chief concern. Though gas has been used sporadically since then, I have not studied these instances, but have relied in the main on specialist publications and the work of the Stockholm International Peace Research Institute.

Second, the range of the material and its limitations: the story deals with gas; other quasi-chemical activities such as smoke-generation or flame-throwers have been excluded. The emphasis is principally on the Western Front and on the

activities of British, French, and German gas specialists and troops, the development of special research and development organizations by these three belligerents, and the resulting production of poison gas[29] and of gas masks. I am aware that on some occasions gas played a significant role on the Italian front and also in Poland, but the documentation was not accessible to me. Although there is some new material not available to historians writing before the late 1960s, it is not sufficient, except in rare instances, to alter received opinions. I would therefore have to go over previously trodden ground, and so have deliberately kept the discussion short. The review of the American chemical warfare effort is similarly limited, but for an entirely different reason: there is an abundance of information, but also a different timetable of events. US chemical warfare came very late: unimportant throughout 1917 and relying almost entirely on British experience and equipment, it only began to play a significant role at the very end of the war. Had the struggle continued into 1919 the American CWS would have occupied the principal position. However, during 1918 US soldiers exposed to German gas shelling suffered heavy casualties. Thus American experience in respect of offensive warfare is largely irrelevant and need not be stressed; but in respect of defence against gas it is interesting and meaningful and so given more emphasis.

Third, the chronology: it has been impracticable and often undesirable to keep to a strict date order. I am concerned with the manufacture and use of new weapons and the elaboration of defensive measures. This entails several studies in depth which are, in fact, essential digressions, deliberately inserted in the narrative at the point when their explanatory value is greatest, regardless of the chronological sequence. That explains why occasionally I have to backtrack, and sometimes to run ahead.

Fourth, the purpose: I intend to investigate the circumstances that led the Germans to be the pacemakers in offence (though not defence) and the obstacles which prevented the Allies from responding speedily and effectively. Chemical backwardness was one factor, organization another, the initial lack of special skills a third. To the extent that the difficulties were overcome, most quickly and impressively in anti-gas protection, the Allied position improved. Various factors, notably raw material shortages, were later to hamper the Germans and in some respects they were less competent than the Allies had anticipated. Each side tended to overrate the other. To understand why, it is necessary to consider the people and the organizational structures available to do the job, and in particular to describe the enforced collaboration of chemists and soldiers.

Fifth, the conclusion: gas was one of the very few genuine new weapons of the First World War and unique in that it was not used in the next. Why was a weapon unrestrainedly used between 1915 and 1918 unused in 1939–45? That question has been carefully examined by Brown in the context of power politics.[30] But it also raises another question: was gas not used because the belligerents had in the earlier war been moving towards a chemical and operational stalemate, inasmuch as gas attacks could no longer overwhelm the

defences against them? There were certainly signs of that in 1918. That, in turn, leads to another consideration: could it be that gas was a less effective weapon than its originators had expected and than its supporters later proclaimed it to be? The matter needs to be properly investigated: the resources devoted to gas production can be identified, and the industrial – military input side of the cost-efficiency model can even be quantified. The output side, that is the effect in terms of enemy casualties, ground gained, and extra strain on the opponent's resources is much more complex and the statistics are incomplete. In particular the data on casualties and the treatment of the gassed, which will be examined in a separate chapter, are unsatisfactory.[31] But the point that matters is whether the reliability of the numbers is sufficient to support the conclusions drawn from them. I think it is and will produce the evidence. The reader must then decide for himself. But it is not enough to write the conclusion as if it were an essay in descriptive statistics. Value judgements are surely relevant and have their proper place; suffice it to note here that the impact of chemical warfare on contemporaries was profound and cannot be ignored. Events and the personal reactions to them appear at first to be inextricably connected. In retrospect the facts and the impressions are often in conflict. Where does the truth lie? This is dangerous ground for an historian. But it is worth exploring, if only briefly in the last two chapters, in order to give a rounded picture of the effect of this extraordinary weapon.

2

FORERUNNERS IN FACT AND FICTION

THE gas cloud, first used in April 1915, had no precursors: it sprang, as it were, in its final form, on an unprepared enemy. This was certainly an unusual event in the history of military technology. With most other weapons the development can be traced over decades if not centuries. But gas, deadly or merely irritant, was different. As a weapon it existed principally in the imagination of writers. At rare intervals some ingenious and original mind would move from fantasy to reality, but the experiments were never conclusive. For had they been demonstrably successful they would have, we may be sure, encouraged other people to improve on the original. All the descriptions until 1915 are of unrelated incidents without antecedents and without sequel.

Thus there are a few reports of smoke from damp straw or other organic matter having been used occasionally in antiquity. Two millennia later Leonardo da Vinci described a shell containing very fine sulphur and arsenic dust which was to be thrown against enemy ships and galleys: details of this forerunner of irritants and so of tear gas are lacking. Then there is another gap, and the first evidence of a more sophisticated approach. Lord Dundonald's 'secret weapons' received a lot of attention because he was persistent, extremely long-lived and, according to his biographer, had 'achieved great results by small means'.[1] He proposed in 1811, 1845, and again in 1855 the use of smoke from burning coal tar and carbon disulphide.[2] For different reasons the French and later the Russians were spared these novel weapons. Similarly Stenhouse's combined stink and fire bomb of 1854 contained a liquid of which the active constituent was probably dimethylarsenious oxide, was not acceptable to the military.[3]

The above summary is not exhaustive, but digressions on technological curiosities do not alter the general picture that chemical weapons formed no part of military preparations. That conclusion is based not merely on the absence of mention in military treatises, but, more to the point, on supply constraints. The industrial-scale technology for making the gases and the means for delivering them did not exist until the very end of the nineteenth century. Consider the first war gases: chlorine and phosgene. Chlorine had been discovered towards the end of the eighteenth century and in aqueous solution had thereafter been used for many years as bleach. The bleaching liquor was replaced about the middle of the nineteenth century by bleaching powder (containing up to 35 per cent Cl_2) prepared from chlorine derived from hydrochloric acid (which, in turn, was a by-product of the Leblanc soda process and slaked lime).[4] While bleaching powder soon became an important industrial chemical, chlorine was

not an article of commerce and armies did not have movable plants to generate the gas. Liquid chlorine in cylinders, which gained such a notoriety in 1915, was first offered to German bleachers by Badische Anilin- & Soda-Fabrik in the late 1880s, and unsuccessfully put on sale by the company's American representatives in 1892. Chlorine made electrolytically from brine began to replace Weldon-Deacon chlorine from the turn of the century onwards, but in the USA as well as Britain it tended to be converted into bleaching powder, and liquid chlorine in cylinders did not generally become available in the USA until about 1909 and even later in Britain.[5] The commercial history of phosgene is more recent. It was discovered in 1812 by Davy who prepared it by reacting carbon monoxide and chlorine in daylight. The compound was not used until the 1880s when Alfred Kern mentioned it in his patent for the manufacture of crystal violet (1883). There were patent complications, but once they had been removed, this triphenylmethane dye became, and long remained, extremely important. Thus a sustained demand was created for the intermediate, known as Michler's ketone, made by passing phosgene into dimethylaniline. Initially phosgene was manufactured only in Germany and was sold in steel bottles.[6] By the eve of the war there was equipment for making the compound in Germany, France, and Britain.

The condition of the chemical industry and its product mix, combined with ignorance among the potential users were the determining factors in the failure to contemplate the use of gas before the war. However, such an explanation would have no relevance to the development of gas masks. Their evolution is elaborately documented because protection against dangerous substances, be it mercuric sulphide (vermilion) manufacture in the first century or bleaching powder packing in the nineteenth, was a matter of continuing concern, as distinct from the occasional use of smoke in war.[7] Rescue services in coal mines and fire-fighting in densely packed urban housing or factories created a need for dependable breathing sets. Mouthpads first described by Pliny were used to protect the Victorians, albeit imperfectly, against 'noxious' atmospheres. An alternative solution was a long flexible breathing-tube with a charcoal filter: though recommended for firemen, it cannot have been of much value, since that kind of filter will not adsorb the particulate matter of smoke. Hence the development of regenerative sets based on the principle that the wearer carries his own supply of respirable air. Appliances comprising a supply of oxygen, a carbon dioxide absorber, and an impermeable bag, together with valves, gauges, and tubes had been envisaged in the eighteenth century but could not be constructed at the time. The first practicable set was designed by Dr T. Schwann in 1852–3 and within the next twenty or twenty-five years several different types were introduced. By the beginning of the twentieth century firms such as Siebe, Gorman and Co. in Britain or Drägerwerke in Germany supplied dependable though bulky precision-built regenerative sets to collieries, fire-brigades, sewage works, many industrial users, and submarine crews. The flexible corrugated rubber tube and the non-return expiratory valve, which were

important components in the British respirator from 1916 onwards, had been introduced by Siebe, Gorman in the 1880s.[8]

We therefore have an interesting contrast in 1914: dangerous gases had been prepared, indeed chlorine and carbon disulphide were becoming industrial commodities, but militarily they were an unknown element. On the other hand protection against gases had reached an advanced stage. The equipment was available, and the manufacturers were improving it in the light of operating experience gained under the most diverse conditions. In principle then, defence was much stronger than attack, but given the state of knowledge among staff officers, the military significance of this fact was of no interest.

With hindsight it is easy enough to identify technological gaps, much more difficult to show the extent to which contemporaries appreciated the problem and consciously sought a solution. Military novels, and particularly science fiction, serve a useful role in this connection, if only as indicators of intellectual awareness. During the latter part of the nineteenth century writers often endowed their fictional belligerents with the most advanced technology. However, these literary fantasies wished away the obstacles, and not surprisingly, the defence was not allowed to develop sufficiently to cope with the attacks. Such reasoning remains incomprehensible, for it was based on the assumption that one side (the heroes) could learn, while the other (the villains) could not. Inconsistency may not matter among novelists who need not strive after logic, but the point is that in the 1890s and 1900s the facts were different: gas as a weapon was underdeveloped by comparison with the defences against it. Failure to remember this and continued wishful thinking on gas, based on the fallacies of science fiction, were shortly to lead to serious military blunders.

Alfred Robida, a well-known French engraver and caricaturist, first serialized and later (1887) issued in book form *La Guerre au vingtième siècle*, which was remarkably prescient: the enemy has chemists who prepare gas bombs and mines filled with *miasmes concentrées* and also with viruses; his specialist troops wear masks like helmets and oxygen cylinders. In short the pictures recall Dundonald's and Stenhouse's stink bombs, and the breathing sets then in use. The story next describes a French counter-attack with gas shells, the enemy retaliates with paralysing and asphyxiating chemicals and with itching powder. The French eventually discover a 'corrosive dew'—*du vitriol dans l'atmosphère*—which destroys the hostile batteries.[9] Although none of this was taken seriously at the time, Robida's fantasies became realities on the Western Front. H. G. Wells pitched *The War of the Worlds* (1898) in an altogether different key. He too had gas, 'Black Smoke', discharged from a portable rocket-launcher, which killed by inhalation and by touch; it was heavy, settled on the ground, and became innocuous in contact with water. The Martians cleared it with steam-jets, but they did not wear masks![10] Here again parallels may be drawn with mustard gas and the Livens projector with its phosgene projectile. Serving officers themselves occasionally took a hand. A group which included the

professor of military art and history at the Staff College and a rear admiral, published *The Great War of 189—: A Forecast* in 1893. They anticipated a conventional war, say vintage 1890, and the only concession to contemporary technology was the appearance of a rigid airship which dropped a large bomb filled with blasting gelatine and liquid oxygen. The explosion was formidable and partly destroyed the town of Varna.[11] Another professional was Capitaine Danrit, the pseudonym of E. A. G. Driant, a regular soldier and later Député: he was an outright anti-German and in his numerous novels French equipment was always superior to German.[12]

Clarke has made a study of 'military science fiction' and has shown that it was an expression of international rivalries. He lists no less than 221 imaginary war books between 1890 and 1914, three-fifths of them in the eight years before the outbreak of war.[13] The bulk was mere literary xenophobia and scientifically nonsensical but the influence of these novels was cumulative and, judging by Wells's fame, far-reaching. Science fiction at its best heightened awareness of the destructive power of novel weapons and it is not fanciful to suggest that it appealed to some chemists and engineers by drawing their attention to the potential of gas. When war did break out, literature supplied as it were a link between scientific vision and the needs of the moment. Hence a flood of suggestions which combined Robida's inventiveness with first-year undergraduate chemistry, a sort of Heath Robinson approach to chemical warfare, preposterous, impractical, ignoring technological obstacles and defence. Nevertheless, enough of these extraordinary proposals survived the scrutiny of General Staffs and were later tried out. They gave the early chemical warfare efforts an unusually imaginative and do-it-yourself character. In these original, indeed fantastic, and distinctly unconventional military aspects, gas can trace a direct descent from science fiction.

Attempts to define the rights and obligations of belligerents and formalize the rules of war were given a fresh impetus by Tsar Nicholas II who convened the first Hague Peace Conference in 1899. He had been advised that technical progress was bound to affect warfare. Hence the objective of Hague I was not merely to mitigate the hardships of a future war, but specifically to prohibit new, that is hitherto unused, weapons.[14] Jack (later Lord) Fisher represented Britain, Capt. Mahan the USA, and Col. von Schwarzhoff Germany. They were career officers, experts in their profession and, as has been perceptively observed, 'such men could not be expected to bargain away the basis of their careers and prestige, and they were quite adept at discovering and articulating technical and tactical reasons for rejecting the Tsar's proposals.'[15] Gas was on the agenda. The delegates had no chemical advisers and, more importantly, there was no point of reference, no recorded experience, except in science fiction. How to prohibit a non-existent weapon? The delegates dealt with the problem as follows: '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.'[16] The

clause caused much discussion, but all the delegations (save that of the USA) eventually agreed to the resolution, thereby gaining goodwill without foregoing any existing defence interest. The USA, however, stood apart, on the ground that the clause was unrealistic and Mahan said that he could not see any logical difference between blowing up people in a ship whence they could scarcely escape or choking them by gas on land.[17] The arguments with their moral overtones need not detain us at this stage. Hague I was a comforting, but loosely worded document: or more precisely a declaration of intent for the Convention was toothless, there being no provision for inspection, nor for control—in short, each signatory was in honour bound to do his own policing.

Gas turned up again at the second Hague Conference convened by President Theodore Roosevelt in 1907. Hague II reaffirmed the earlier abstention clause and another on the avoidance of projectiles, weapons, and materials which might cause unnecessary suffering. It widened the restraints by prohibiting the use of 'poison or poisoned weapons' (Article XXIIIa). Implementation, however, remained unchanged from Hague I, so that enforcement continued to be unilateral. By 1914 this later Convention had been ratified by all the European belligerents in the forthcoming war except Italy; the USA and Turkey adhered later.

The spirit of the Conventions was surely clear enough: to stop new and potentially more awful weapons. But the letter was obscure and open to widely differing interpretations. Thus Hague I and II were a moral force to be reckoned with and at the same time ineffectual. The resulting long-term practical consequences assumed great significance after 1915 and continued to operate throughout the post-war years. When the Germans used gas at Ypres, they were held to be in breach of the Conventions on several counts. Public opinion was aroused and the Germans had to justify themselves, always a difficult task for a pioneer in warfare and doubly so in this instance. They argued at the time, and later, that (i) the Conventions did not cover gas blown from cylinders, (ii) the Allies had used gas first, (iii) gases were not poisons, and (iv) after the war, gas shells were implicitly excluded because they were not causing needless suffering.[18] The arguments continued endlessly between the belligerents and, long after peace had been signed, remained inconclusive. In trying to exculpate themselves the Germans sought to draw attention to uses of gas before April 1915 and their tactic henceforward was to cast doubt on the Allied assertion of surprised innocence. That raises the question: did the Germans have precursors and if so who innovated what and when? The answers, as so often, are unclear, but it is worthwhile examining the evidence if only for the light it throws on the state of pre-war preparedness.

Many writers on chemical warfare have asserted that the French police either 'considered' or actually employed tear gas to capture a gang of violent criminals in April 1912.[19] The facts are as follows: Jules Bonnot, the leader of the gang, and an associate were tracked down to a shed in the Paris suburb of Choisy-le-

Roi. The associate was killed by revolver shots, but Bonnot held out. The police thereupon dynamited part of the building, a fire broke out, and the dying gangster was finally overwhelmed. The entire action lasted about four hours. It was reported in minute detail by the press; not one of the papers suggested or even hinted at the proposed use of tear gas or its possible employment.[20]

Evidence of the use of tear gas, especially on a well-publicized occasion such as the capture of the notorious Bonnot would have been invaluable for propaganda purposes on a later occasion. The sequel, however, was prosaic. Messrs. Kling and Florentin, two chemists at the municipal laboratory of the City of Paris, became interested in riot control, investigated the use of lachrymatory agents, and recommended them to the police. The materials employed (which were not described) were to be filled into cartridges or hand grenades. It does not seem that the French police adopted tear gas, but supplies were prepared for the French corps of engineers and, as will be seen in the next chapter, were issued to the troops soon after the outbreak of war.[21] During the war, Commandant Nicolardot, then head of the chemical laboratory of the Section Technique de l'Artillerie, told Professor Crossley that he had warned his superiors as early as 1900 that the Germans would use chlorine and bromine, and he had even designed a simple mask. In 1905–6 he had recommended chloropicrin as shell filling and made a study of those gases which he thought were permissible under the Hague Convention.[22] None of this came to anything. Nicolardot may well have inflated his own role: but in any case intentions are not acts and except for the unspecified tear gas I have not found any material on French gas research or production before the war. I do not claim that this is conclusive, merely that if anything was done, it was handled with extreme discretion.

From Germany there are reports of some activity. A chemist at the Hoechst company worked on smoke generators for the navy.[23] More to the point, a long memorandum written by Col. Bauer, who played an important role in chemical warfare and who will make his appearance in due course, mentions that the army conducted experiments with gas, type not specified, before August 1914. The outcome, he wrote, had been 'negative' and actually delayed later work because the experts believed that the pre-war trials had been inconclusive.[24] Bauer's report is to some extent confirmed by a letter which Haber wrote years later to a war-time colleague in which he stated that when the Germans began their first wartime gas tests at the Wahn artillery range, the chemists were told by some airmen stationed there that 'trials had taken place with aeroplane bombs containing phosgene before or after [*sic*] the declaration of war', but had been abandoned as impracticable.[25] The story is imprecise and while it represents the first mention of phosgene in a military context, it gives no date. All one can say with confidence is that work had gone beyond the mere desk study of possible uses of poison gas.

One turns, with relief, to the more informative and probably more dependable British reports. They show that some people in the War Office were sufficiently

interested in gas to put a carefully worded enquiry to the Foreign Office whether it was 'permissible' under Hague II to employ 'preparations giving rise to disagreeable fumes without causing permanent harm' and to introduce gas in high explosive shell. The Foreign Office ruled that both were admissible 'in view of indications that the subject was being considered in other countries'.[26] Accordingly 'stink pots' (possibly based on Dundonald's recipe) were investigated, but abandoned, and during 1913–14 the use of chloroacetone and benzyl chloride, both lachrymatory substances, in 'small' shell was studied. The Superintendent of Research reported unfavourably on the research on 29 August 1914 and the War Office stopped further work a month later.[27] The British efforts, despite the circumstantial reports, do not amount to much, though they indicate contemporary attitudes to the Hague Conventions. Indeed there was only one place where some working experience of gas was being obtained, and that unexpectedly was in Australia where arsenious chloride was being employed to destroy prickly pear. This interesting information, though no secret, did not reach the proper quarters until August 1915.[28]

The most one can say about gas and smoke is that by the eve of the war military awareness of chemicals had increased to the extent that some soldiers were willing to consider them and a very few, with a more innovating turn of mind, were even experimenting with various compounds. The substances used with the exception of phosgene, were not toxic. There were no military stocks of gases, nor of gas shell, save for very limited supplies of tear-gas grenades and cartridges in French hands. The forerunners were scientific curiosities and the belligerents of August 1914 had no conception of the practicalities of chemical warfare.

3

THE CHLORINE CLOUD

THE German advance of August 1914 into Belgium and France produced a rich crop of horror stories. Mutual antagonisms soon reached such a pitch that any allegation about the enemy's use of secret weapons (among them chemicals) was readily believed. Geyer wrote later that his colleagues at OHL when told of the use of gas by the French, dismissed the reports. Major Bauer, an important personage in our story and Geyer's chief, said the Germans had never concerned themselves with chemical warfare.[1] The claims and their validity will presently be examined in greater detail, meanwhile it is worth noting that the Germans were in a good position to check the accuracy of the allegations, for their troops came across abandoned French supply dumps, but they never found any French gas ammunition.[2] There was in fact a simple scientific explanation: the explosion of a shell or mine generates some carbon monoxide which in a trench or other hollow can build up to a dangerous concentration. Picric acid (trinitrophenol), widely employed by the Allies as a high explosive, when incompletely detonated has a peculiar odour, causes sneezing, and its bright yellow colour attracts attention. The German infantry were unfamiliar with it and therefore suspicious.

Nevertheless, within a few weeks of the outbreak of war several proposals were made in different countries to introduce unconventional weapons. These projects were vigorously promoted by individuals who badgered and bullied the professionals until the new materials were tested. The autumn of 1914 was, in this respect, the period of the scientific amateur and of science fiction. No more would have been heard of these fantastic plans but for the prestige of the initiators and the credulity of the officials they dealt with. In Britain, all these ideas were sifted by the Royal Society's War Committee, specifically by the Chemical Sub-Committee, and in this way cranks and specialists gained, as it were, some respectability. The proposals to use chemical weapons in some form or other need to be summarized, if only to show that the Western powers were interested in them, and indeed differed not in intent, but merely in the choice of materials and willingness to try them out.

We may conveniently begin where the last chapter ended—in Britain. Towards the end of September 1914 the War Office and the Admiralty prohibited the use of tear gas in shell, and on 16 October the former, when approached with the suggestion to drop bombs filled with aqueous hydrocyanic acid from planes, pointed out that this violated Hague II. Nevertheless the scientists busied

themselves. Sir William Ramsay recommended acrolein to the members of the Royal Society sub-committee. It was known to have the properties of a tear gas, and also to be toxic in large doses, but was rejected not on those grounds, but because it oxidized to acrylic acid—now more familiar as a paint base.[3] J. F. Thorpe and H. B. Baker at Imperial College then began to study the tear gases, and Thorpe, who had worked on o-xylylene bromide, proposed it as a lachrymator. Again, this was found to be unsuitable, and during the latter part of November and throughout December they investiaged 'stink-bomb' ingredients among which certain benzyl compounds were most promising, but had to be rejected on account of the toluene shortage. After dozens of other substances had been examined the choice fell on ethyl iodoacetate which required no materials then scarce. Tests were made in a trench at Imperial College. Col. (later Gen. Sir Louis) Jackson[4] came from the War Office to attend them. He was more resistant to tear gas than the academics (or maybe he just shut his eyes tightly), but eventually he too succumbed. Further confirmation of the efficacy of the compound was provided by a lad who happened to be passing by. So the substance was adopted: to commemorate South Kensington it was code-named *SK*.[5] Having thus, after several weeks of research, identified a practical tear gas in January 1915, nothing more was done. At about the same time, Maurice Hankey, then secretary to the Committee of Imperial Defence, was sending the projects of some cranks, which had somehow found their way to his office, to the War Office: one inventor wanted to set fire to the atmosphere, another to spray the Germans with amyl nitrate, an inflammable liquid. Neither was practical, but they caused Hankey to recommend the study of chemical warfare to the War Office, so as to be ready to retaliate if the Germans should start it. Such awareness of chemical warfare at that high level was significant, and it was sustained by the increasing number of intelligence reports on the subject. As a result, official adherence to Hague II weakened, and in March 1915 Earl Dundonald's advice on chemical smoke-screens was belatedly accepted: the material was tested on 9 April 1915 and a Committee set up to examine its use.[6]

The French, by contrast, made more progress. They had in August 1914 small stocks of tear-gas cartridges and possibly also of hand grenades of which the active ingredient was ethyl bromoacetate. But at first the army did not call for them. Later, when it did and the cartridges were fired from a specially adapted and inaccurate rifle, the tiny amount of tear gas (say 19 cc per cartridge) went undetected.[7] The stocks of *cartouches suffocantes* were apparently used up during the autumn and a fresh order was placed in November. Bromine, then readily obtainable only from Germany and the USA, was scarce, so the active ingredient was changed to chloroacetone.[8]

The interesting question is this: what caused the French to order more tear gas? The obvious answer is the onset of trench warfare. But it is incomplete, for the cartridges were useless, whereas hand grenades would only be effective

in large quantities and in close combat. The most likely explanation is that tear gas (regardless of the Hague Conventions) was going to be employed in the forthcoming spring offensive. The Germans captured a French circular, dated 21 February 1915, which described the chloroacetone cartridges and grenades, explained their use and while pointing out that in small quantities the chemical was not 'deleterious', recommended that goggles be worn for protection. Such written evidence of the proposed use of tear gas was of great value to the Germans and they later made the most of it. I have not been able to trace the genesis of this circular, so carelessly allowed to fall into enemy hands, but it is possible that it was premature and that it was distributed before the new weapon was available for field use. One document at Vincennes, dated 30 March 1915, refers to a large number of *engins suffocants* (i.e. hand grenades) having been ordered as well as 90,000 goggles—the latter to protect the French against German tear gas which had allegedly been introduced recently. Delivery was expected about 15 May.[9] There is evidence that these hand grenades were being manufactured during March–April 1915.[10] According to Trumpener, they were, by order of GQG No. 781 of 3 April 1915 placed at the disposal of the armies.[11]

The Germans claimed that the French had used tear gas in March 1915 in the Argonne,[12] but there is no confirmation and I am inclined to think that if such gas was used on that occasion, it was only on a small scale. Nevertheless the available information points to a clear French intent to introduce tear gas in Spring 1915. Their attitude reflected the growing belief that chemical substances, in addition to high explosive were needed to drive the enemy from casemates, dug-outs, and trenches and so weaken his defences.

The Germans reached the same conclusion by a different route, but instead of restricting themselves to tear gas they extended the concept to chlorine and so transformed the nature of chemical warfare. There are different versions of how it all began. The most plausible is that Gen. Falkenhayn, at the time Chief of the General Staff, instructed Bauer to call a meeting at the Wahn range (south east of Cologne, later the site of the airport) early in October 1914 to discuss methods for generating smoke or fire and also materials having lachrymatory and other irritating effects which would cause the enemy to break cover. Nernst and Duisberg attended. The former, an eminent physical chemist, was well known at OHL as a volunteer driver and a man of original ideas.[13] The latter, the leading figure in the German chemical industry, also knew Bauer and his office was not far away at the Bayer company in Leverkusen. Someone (it may have been Duisberg) suggested dianisidine chlorosulphonate, which causes violent sneezing, but is otherwise inoffensive. It was readily obtainable from Leverkusen, being derived from an important azo dye intermediate. Several hundred kilos were ordered, filled into shells and used at the capture of Neuve Chapelle on 27 October.[14] The Germans quickly and ingeniously modified the

105 mm howitzer shell so that the shrapnel, instead of being embedded in black powder, was surrounded by the chemical. It was expected that the explosion would grind and disperse the material. But in their hurry they failed to make tests, so that they did not discover until too late that the dispersal was small and the irritant action short.[15] This non-event was the more galling because the enemy were unaware of the first use of chemical shell! Production was stopped.

OHL had no chemist, but Col. Gerhard Tappen, the chief of the operations branch, had a brother, then working in the Heavy Artillery Department of the War Ministry. Hans Tappen was a chemist and had written a dissertation on benzyl bromides; he thus knew something of tear gas and recommended it to his brother. The moment was right, the connection influential, and Hans was assigned in November 1914 to Spandau where the ordnance works supplied him with shell cases lined with lead to resist the corrosive action of xylyl bromide. Bauer did not think much of the idea, but Gerhard Tappen pulled rank and insisted on trials which showed that a liquid shell-filling was practicable. Further tests, near Berlin in December 1914 and at Wahn on 9 January 1915 (the latter attended by Falkenhayn himself) showed that T-*Stoff*, the code name for both xylyl- and benzyl bromide, was a satisfactory filling. Orders were given for production to be increased and permission obtained to fill T-*Stoff* into 150 mm howitzer shell for field use.[16] Hans Tappen had meanwhile gone to Leverkusen where he developed other lachrymatory substances. The production of the different active agents which were given code names presented no particular technical problems, and as the scale of shell filling was initially small, the suppliers were instructed to deal with this too. Table 3.1 shows that by Spring 1915 three firms were involved.[17]

The Germans having adopted tear gas now faced an unexpected difficulty. Range tests indicated that the 150 mm howitzer shell was the best mode of delivery, but at the turn of the year there were not enough howitzers of this calibre.[18] That restricted the use of tear gas, and the first T-shell firing was delayed until 31 January 1915 when it took place against the Russians at Bolimów. As the ambient temperature was extremely low the liquid failed to vaporize, and so, once again, the Germans made a false start. To prevent this, bromacetone (B-*Stoff*) was added and the French were shelled with a mixture of T and B at Nieuport in March.[19] Though these beginnings were hardly impressive, the Allies were aware of something unusual going on, but uncertain how to react.[20] The howitzer problem had eased and during spring and early summer, the Germans used T-shells on about half a dozen occasions, in particular on 22 April in association with the chlorine cloud. Various attempts were made between February and April 1915 to add toxicity to the tear gas by mixing it with phosgene, but the modified filling was not apparently used in the field. The Germans (probably at Nernst's suggestion) also experimented with trench mortar bombs filled with phosgene or with a mixture of phosgene and chlorine. Haber gave a demonstration of these bombs at Wahn on 25 March

Table 3.1. *German Tear-Gas Materials, Manufacturers, and Start of Operations*

Chemical compound	*Code**	*Manufacturer and Location*	*Production started*	*Shell-filling began*
Xylyl bromide and benzyl bromide	T	Kahlbaum, Berlin	Dec. 1914	Jan. 1915
		Bayer, Leverkusen	Jan. 1915	Jan. 1915
		Hoechst, Höchst	Apr. 1915	Apr. 1915
Bromacetone	B	Bayer, Leverkusen	Dec. 1914	Jan. 1915
Bromomethyl-ethyl-ketone	BN	Hoechst, Höchst	Apr. 1915	n.a.
Methyl chlorosulphonate	—	Bayer, Leverkusen	Jan. (?) 1915	n.a.
Dichloromethyl chloroformate	K†	Bayer, Leverkusen	Jan. 1915	Jan. 1915

* Suffix *-Stoff* (= substance) omitted.
† When filled into trench mortar bombs the code letter was C.

1915. Once again Duisberg was present, and had cause to remember the occasion for he inhaled some of the gas and was lucky to get away with a slight case of pneumonia and a few days in bed.[21] An even earlier instance of a toxic material in shells occurred in December 1914 at Haber's institute: the object was to find a poisonous tear gas that could be carried and dispersed by cast iron shell, which despite its poor fragmentation was being pressed into service. Dr. O. Sackur, possibly inspired by Stenhouse's work sixty years before, was studying the action of dichloromethylamine on cacodyl chloride, a very unstable compound. There was an explosion, Sackur was killed instantly, and all work on the compound ceased.[22]

The story so far is nothing more than a listing of incidents. Each of them was small and, taken separately, unimportant, but as a whole they illustrate the piecemeal approach to chemical warfare and important differences between the belligerents. The British confined themselves to experiments. The French relied on their pre-war work on tear gases, extended it, and had every intention of using these materials in the first half of 1915. The Germans spasmodically investigated various proposals and such was the potential of their chemical industry, that whatever was suggested could be implemented at short notice. The scientific and technological ability of the German manufacturers was unquestioned. But the users, the artillery, remained half-hearted. There was considerable reluctance to integrate the novel chemical fillings in artillery procedures. How else to explain the intermittent use of tear gas in summer 1915 and the gap between filling shell with K-*Stoff* in January and issuing it in August? Vinet's statement[23] that during 1914–15, Bayer, Hoechst, and Kahlbaum filled

'about 1 mln projectiles' with various chemical warfare materials is unsupported by statistics and, in my opinion, grossly exaggerated. Given the reports of individual actions, a more likely figure would be a fifth to a quarter of Vinet's total.

But the main reason for the lack of interest and the absence of any urgency among the belligerents was the shortage of shell cases, propellants, and explosives; the Germans also temporarily lacked heavy howitzers. In conditions of scarcity the military opted for the familiar: they argued that this was not time for experiments even if the novel materials were worthwhile substitutes, and furthermore they had sufficient evidence to show that large quantities had to be used in order to be effective. Nevertheless if the stalemate of trench warfare was to be broken in 1915, a novel solution was required. It was found by Haber, and to the extent that he originated and developed the concept of the gas cloud, the Karlsruhe militants were right to call him the father of chemical warfare.

How did he become involved and make his contribution? He had been chiefly concerned with nitrogen supplies, though the institute was, as we have seen, carrying out some military scientific investigations. The trigger apparently was the testing of T-shell in mid December 1914: Haber was present and came away convinced that tear gas was useless on a small scale. He made his views known and suggested firing xylyl bromide bombs from trench mortars arranged in groups. He was thus anticipating Livens's projectors of 1916–17. Haber was told his idea was impracticable because the equipment could not be quickly supplied. We may digress here to note that in Britain Livens got a similar answer from the War Office, but went ahead regardless. Haber did not, instead—with his practical turn of mind—he suggested the next best thing, the discharge of gas from cylinders.[24] This time OHL was receptive, not least because the cylinders existed (or it was believed that they did) and chlorine was available. Haber declared that the gas would form a cloud which would drive the enemy out of the trenches into the open. The idea appealed. Before the year was out he was put in charge and, at the age of forty-six, to everyone's surprise, was raised from NCO in the Reserve to Captain. The promotion was as unconventional as the weapon.[25]

Was he a good choice? In Haber the OHL found a brilliant mind and an extremely energetic organizer, determined, and possibly also unscrupulous. Was chlorine a good choice? It was certainly Haber's choice, and given his prestige and position it was accepted. He was aware of its limitations and, personally brave, paid little attention to the risks. In a hurry to get chlorine to the front he underrated the drawbacks and gambled that the German infantry could do without protection. This was a miscalculation and it was aggravated by an even more serious mistake in the selection of the material. Phosgene, though not so readily available in the same quantity, would have achieved the hoped-for results much more effectively. But its use would have imposed some delay while masks and supplies were got ready. Hindsight helps of course: we have seen how

the German interest in chemical warfare was becoming increasingly diversified, and as they were prepared to ignore the moral issue posed by the Hague Conventions they would have done better to damn the consequences and rely for their initial surprise on the more powerful weapon.

The German preparations took about two and a half months. The first hurdle was the formal acceptance, and Falkenhayn had to take the decision. OHL while considering gas 'unchivalrous' nevertheless hoped it would lead to a decisive solution in the West. The experts assured Falkenhayn that chlorine from cylinders was not a breach of Hague II and that there was no risk of early retaliation. Haber was not consulted by Falkenhayn about the legal aspect and subsequently wrote: 'Although he never asked for my opinion on the state of the law, he left me in no doubt that he accepted the limitations of international law which he intended fully to adhere to.'[26] The inconsistency between the attitude ascribed to the leadership and the actual policy suggests confusion and an attempt by Haber to cover up. He was invariably consulted on technical aspects, and is reported to have urged that gas should only be employed if the generals were sure of victory. Thus the unfolding of events allowed military optimism to overrule scientific common sense. In retrospect one can consider this an early instance of having an expert 'on tap, but not on top'. It was also the first of many instances of mutual incomprehension between chemists and regular officers. In the end Falkenhayn gave the go-ahead around the middle of January.[27]

Next, the site had to be chosen. The Army commanders were asked and with the exception of Duke Albrecht of Württemberg, commanding the 4th Army, all refused. His men faced Ypres. The refusals and the single acceptance were odd, because Ypres was not the best location. There were better sites in Artois north of Lens, and in Champagne east of Reims. More time and trouble at this stage would have saved disappointments later. But the chief of staff of the 4th Army, Ilse, together with Gen. Deimling, a middle-aged Württemberger who commanded the XV Corps in position between Hoge and Hill 60 were summoned to OHL on 25 January and told by Falkenhayn that gas would be used in the south-eastern sector.[28] They were optimistic at OHL and had convinced themselves that the capture of Ypres would be a major success; staff officers even justified trying out the new weapon against the British, on the ground that they were the most resolute and dangerous opponents.[29]

It is time to take a closer look at Ypres where in February 1915 the gas troops began their work. The town, though often shelled, still had its recognizable landmarks in the winter of 1914–15. The civilian population had remained and even in April 1915 farmers were working their fields.[30] The fighting of the previous November had halted the Germans north and east of the Yser canal at Bikschote and Langemark, say 8 km from the centre of the town. The line curved in a big semi-circle; the configuration was like a giant saucer of which