Part I
Research on and Deployment of Chemical Weapons in World War I

The Scientist as Expert: Fritz Haber and German Chemical Warfare During the First World War and Beyond

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Abstract In the course of the First World War, scientists who would in peacetime generate new knowledge assumed the role of experts, i.e., professionals who made extant knowledge accessible to non-scientist clients. The deepest conviction of Fritz Haber, the 1918 Chemistry Nobel laureate, was that problems faced by mankind could be solved by means of science and technology. Herein, Haber is interpreted as a personification of an early German expert culture. Acting as both mediator and organizer, Haber coaxed politicians, generals, industrial leaders, and scientists to join forces in developing new processes for the mass-production of war-relevant chemicals and in establishing large-scale industries for their manufacture. Among the chemicals produced were poison gases—the first weapons of mass extermination. Haber's leadership resulted in a conglomerate of enterprises similar to what we now call "big science". In close contact with "big industry", traditional science was transformed into a new type of applied research. With borderlines between the military and civilian use blurred, Fritz Haber's activities also represent an early example of what we now call "dual use". He initiated modern pest control by toxic substances, whereby he made use of a military product for civilian purposes, but went also the other way around: During the Weimar era, he used pest control as a disguise for illegal military research. Having emerged under the stress of war, scientific expertise would remain ambivalent—a permanent legacy of the First World War.

The first major poison gas attack, at Ypres, on April 22, 1915 is irrevocably linked with Fritz Haber, the 1918 Nobel laureate in chemistry. The developments that connect the place, time, and person, are paradigmatic. They had their origins in the late nineteenth century and came to full fruition in the Great War. They shaped new trends that would leave a deep imprint on the twentieth century. Rather than

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describing at length Haber's life,[1] this contribution will focus on the impact of those trends on the ways in which the German physical chemist influenced future developments. More than any other person, Haber embodies the ambivalence of the modern scientist who has been praised as a benefactor of mankind and, at the same time, accused of being a war criminal. His scientific work transformed both food production and warfare. He was not just an eminent intellectual, but also belonged to the select group of experts who shaped in fundamental ways the functioning of modern societies in war.

With the outbreak of the First World War in 1914, the impact of Haber's research on warfare became increasingly apparent. We can differentiate two important strands of his activities, the first concerning the production of explosives. Cut off from its major supply of natural nitrates by the British blockade, Germany suffered a serious munitions crisis after only a few months of trench warfare. The Haber-Bosch process, for which Haber laid the scientific foundation, provided a large-scale supply of synthetic ammonia and thereby of nitric acid, its oxidation product. Haber was actively involved (technically, but also politically) in the development of the production facilities such as the huge chemical factory in Merseburg/Leuna (Szöllösi-Janze 2000a).

In the following, I will focus on the second strand of Haber's activities: as a physical chemist, Haber's main research focus was on the reactions of gases. This expertise had placed him at the centre of Germany's preparations for introducing an entirely new weapon—poison gas. I will condense my considerations into some major points.

1. The declarations of war in 1914 provided new spaces of warfare. Those spaces came about as a result of a massive use of science and technology which, in turn, were profoundly transformed by the war experience.

The battlefields of the First World War constitute a space extended into all three dimensions (Trischler 1996). Trench warfare created a new geometry of the battlefield that included new zones: no-man's-land in the crossfire of the artilleries, the widely branching system of trenches, wire fences, supply lines, the hinterland used for the necessary logistics. Extending warfare into the air and below the surface of the seas added the hitherto unknown experience of three-dimensional warfare, which developed its own dynamics. The experience of war was total: it took possession of all spatial dimensions.

Science and technology had a significant impact on these developments. In the three decades preceding the war's outbreak, railway systems had increased troop mobility. Telephone, telegraph, and radio improved communications. The military use of aircraft—not just balloons, but also the newly developed zeppelins and aeroplanes—as well as submarines added a new physical dimension to warfare.

[1]Some recent biographies on Haber are available in German and/or English: see Stoltzenberg (1994, 2004). Daniel Charles' more popular biography (Charles 2005) was published under different titles in the US and the UK with the same content. In what follows I will mainly refer to my own book (Szöllösi-Janze 1998, reprinted 2015).

None of these new weapons or technologies decided the course of the war. But they marked a turning point on the way to modern warfare. Not only did changes already underway speed up considerably but also completely new developments emerged because the total war forced the belligerents to find novel solutions to completely new challenges.

2. The integration of new spaces into warfare led to a formerly unknown convergence of the state, the military, the economy, and of science. In all belligerent nations, these developments were anything but visible at the beginning of the military confrontation.

As Jeffrey Allen Johnson underscored, in pre-war Germany, “the academic-industrial symbiosis still primarily consisted of its classical core”, meaning personal ties between industrial chemists and their colleagues in academe, mutual research support and the “educational link”, meaning the supply of trained manpower from the universities to a growing, science-based industry (Johnson 2000, 17–18). Johnson and MacLeod came to a similar assessment concerning the development of military technology. Areas such as munitions testing, military education, military medicine, and the technical disciplines within the military sector had long been established. However, as both authors also noted, “in no European country was there provision for the mobilization of scientific expertise, nor did anyone anticipate such mobilization to be necessary for a war that was expected to be short and fought with conventional military technologies” (Johnson and MacLeod 2002, 170).

Stagnation on the Western front meant that within a few months Germany faced multiple deepening crises, notably in areas such as access to raw materials and resources, munitions production, famine at the so-called “home front”, and, last but not least, politics. Under the pressure of having to win this war, no matter what the circumstances and no matter what the cost, economy turned into wartime economy based on regulation, rationing, and technology. “War is a technological forcing house”—that’s how Lutz Haber, an economic historian and Fritz Haber’s son, called his chapter on the history of the chemical industry in the First World War (Haber 1971, 184, 208). The progressive integration of external technical and scientific expertise into decision-making transformed the style and methods of government. Advisory committees, personal councils and consolidated advisory task forces proliferated in a very short time. Such processes affected all belligerents, if at different times and in different ways. The national “styles of scientific thought” (Harwood 1993), which reflected the characteristics of each country’s scientific cultures, went obviously hand in hand with national styles of scientific expertise.

3. In the course of the First World War, scientists and other academics adopted new roles as producers and re-producers of knowledge relevant to warfare.

Experts, and in particular their status, legitimacy, and control, have been the subject of heated sociological debates for decades (see Etzemüller 2009; Kohlrausch et al. 2010). Herein, I argue that the First World War contributed significantly to the emergence of the experts as a social stratum of intermediaries between the rulers and the ruled. In view of the rapidly evolving demands of modern warfare, only scientifically trained experts were able to maintain an overview over the extant knowledge in their fields. They were in a position to assess how science could contribute to the war effort by having the insights needed in industrial product design and manufacture. Through their advice, they placed themselves at the intersection between the military, the administration, and the industry. In this way, scientific experts started playing a highly significant intermediary role in society. They were anything but passive, but on the contrary actively helped to define possible solutions to all war-related military and social problems. Expert cultures mediating but also actively influencing government decision-making arose in all warring parties. This was particularly true for Germany. During the war, the traditional system of scientific research underwent rapid institutional change and functional differentiation. With state support, a whole system of highly centralized, closely linked research institutes, university seminars, and industrial laboratories had emerged.

4. Fritz Haber was among the first and most important scientists who offered their expert services to civil and military decision-makers.

Haber was by far not the only one to do so. Many scientists offered their help, and among those who did so, chemists played a prominent role. This demonstrates that the catchphrase about the reportedly "mandarin tradition" of autonomously researching German professors (Ringer 1969), originally coined in the humanities, is not appropriate for the sciences. Rather, it should make way for a more differentiated view of the transformation of the German academic community into a new type of scholarly self-understanding, which accelerated especially after 1914 (Johnson and MacLeod 2002, 176–177).

In hindsight, Haber's importance grew from his networking mind-set, which affected the ways in which he thought, communicated and acted. In support of modern warfare, he first had to establish the basic cooperation between the state, the military, the economy, and the scientific establishment. In April 1918, Haber quite consciously reflected on his role:

> Before the war, this relationship was incomplete. The general would live on the *bel étage* and would politely greet the scholar who lived in the same building, but there was no internal connection. For mediation, he would use the services of the industrialist who lived in that house as well (Haber 1918, 197).

Establishing this "internal connection" between the scholar, the general, and the industrialist was Haber's central aim during the war years.

5. Fritz Haber as a scientific expert had to simultaneously fulfil the triple role of mediator, organizer, and innovator.

The relative weight of the roles could vary depending on the task at hand (Szöllösi-Janze 2000b), but in the case of Haber's involvement in poison gas warfare, they played out as follows:

First, mediation[2]: Haber's research activities in physical chemistry led to the development of large-scale industrial solutions. From this long-term cooperation with BASF, he knew the different viewpoints and spoke the different jargons of both the industrialists and the scientists. During his time at the Kaiser-Wilhelm-Institute in Berlin, he also learned how to deal with political decision-makers. In wartime, Haber became something of a communications interface. He broke down communication barriers, translated the needs and aims of one party into the jargon of another, devised possible solutions drawn from his own scientific discipline, and applied these to large-scale crash programs. No institutions initially possessed such mediating abilities, which underscored the importance of individual experts.

Secondly, organization: as an organizer, the scientific expert goes beyond his role of just establishing communication. He aims to make communication and cooperation permanent, by establishing institutions and finding practical applications. In Germany, sharp borders between different academic fields existed. Haber succeeded in making the borders permeable: he would embody the interconnection among pure science, applied science, technical development, and a practical application. Although initially driven by wartime demands, such institutional cooperation was clearly intended to persist beyond the war's end.

Thirdly, innovation: this term describes Haber's contribution to the emergence of a modern type of scientific research. Later known as big science, it refers to a different way of organizing the research process. It grew out of the long-term cooperation among the state, the military, the economy, and the scientific establishment. However, politically networked, large-scale research had an immediate bearing on both the substance and the way of doing research.

6. The first use of poison gas at Ypres in April 1915 reflected Haber's early success as a mediator, organizer, and innovator.

As a simple volunteer advisor to the war ministry, Haber quickly understood the impact of the new spaces and dimensions of warfare. The layered system of trenches, dug outs, and command posts protected soldiers relatively well from conventional weapons. Chlorine gas, being heavier than air, would not just poison the surface of the battlefield but also sink into the structures built underground. Trenches and underground facilities would not be safe any longer. Haber also understood how to utilize the technological and scientific potential of large-scale chemical industry for military purposes and how to establish the necessary contacts. Of course he was aware that the German chemical industry produced and consumed toxic compounds for manufacturing intermediaries or for civilian goods. The chemical plants required only little adaptation to produce warfare agents: the carrier systems were common oxygen cylinders, distribution was well established, and budgeting was assured. The formerly export-oriented dye companies transformed themselves into producers of nitrates, explosives, and chemical weapons (see

[2]See Emil Fischer for another outstanding mediator among German chemists (Moy 1989).

Johnson 2000, 23). Haber was furthermore aware of the number of highly qualified German chemists. Their problem-solving skills easily translated from improving dyes to developing explosives or poison gas. An estimated 1,000 scientists supported Germany's poison gas efforts towards the end of the war, 150 of whom worked at Haber's own institute. The industrial laboratories employed most of them: Bayer alone had 200 chemists on its payrolls (Martinetz 1996, 30; MacLeod 1993).

Finally, Haber knew how to sell the potential contribution of science to warfare even to the mostly hesitant or dismissive military leaders. In doing so, he helped to permanently integrate science into warfare—even though its impact never reached the amplitude or acquired the strategic importance he had been hoping for. With warfare becoming more industrialized and technological, the officer corps underwent professionalization that resulted in growing numbers of officers with a technical education or scientific interest. Science and technology turned the German military, as Michael Geyer put it, into "a complex corporation for the highly efficient production of violence" (Geyer 1984, 99). Moreover, specialized military units began to emerge. Haber easily persuaded his military interlocutors that well-trained, specialized troops were needed to handle poison gas safely and reduce risk of its employment to their own troops. They were to become the so-called "Gas Pioneers". To this end, he enlisted physicists, chemists, biologists, engineers, and meteorologists who readily exchanged the boredom of the trenches for the excitement of becoming experts in a novel mode of warfare. They included future Nobel laureates and eminent scientists such as Otto Hahn, James Franck, Gustav Hertz, Hans Geiger, Wilhelm Westphal, and Erwin Madelung. Only future Nobel Prize winner Max Born refused all offers to take part in chemical warfare, instead preferring the less brilliant field of developing radio equipment for air planes (Born 1975, 235, 261).

7. The ways in which Fritz Haber organized his activities led him to adopt novel approaches to research: big science.

To use chemistry as a metaphor: Haber played the role of a catalyst in forcing the existing, at first rather reluctant elements—state authorities, military, industry, and science—to blend in a fierce chemical reaction that unleashed its own dynamics. This dynamics had an impact on research itself. Haber developed a complex, goal-oriented style of research that aimed for politically relevant results. Many well-resourced teams of scientists and technicians from different fields worked systematically and on long-term basis on a given project. Interdisciplinary research removed the formerly impermeable borders between different scientific fields in ways similar to how the erstwhile sacrosanct boundaries between pure science, applied science, technical development, and industrial mass production would disappear (see as an example Trischler 2001, 80–83). But we can put on our record that Haber's approach was in many respects a nucleus of modern big science. Its immediate impact was to lay to rest the idea of the Humboldtian German professor conducting autonomous research in utter freedom and splendid isolation. Whether this idea ever reflected a reality (see Paletschek 2001) does not matter here. In any case, the First World War pretty much buried the Humboldtian concept.

The poison gas project employed several interdisciplinary teams of scientists, engineers, lab technicians, and auxiliary employees. Each team bore responsibility for its specific sub-projects and, interestingly, enjoyed relative freedom of research within the overall program. In 1916, Haber's Kaiser-Wilhelm-Institute came under military command (for the following, see: Szöllösi-Janze 1998, 333, 438–439). By September 1917, its budget had increased 50-fold over peacetime levels. It comprised nine departments, six of which were researching offensive chemical warfare, including the projection of new warfare agents, the analysis of enemy agents, research in toxicology and pharmacology, and the generation of aerosols. Several teams specialized in the control of the risky large-scale production of warfare agents, gas munitions and gas mine launchers. The remaining three departments worked on gas defense and protection. Besides chemists, the teams included physicists, biochemists, pharmacologists, physicians, veterinarians, zoologists, botanists, and meteorologists, and were supported by engineers, explosives experts, medical officers, and technicians. Together with the auxiliary and temporary staff, the Kaiser-Wilhelm-Institute employed some 2,000 people.

The big science type structures of research in Haber's institute faced their share of criticism among colleagues: "I hope the lion does not lay its hand on our modest department", complained Lise Meitner who worked next door to Haber at the Kaiser-Wilhelm-Institute for Chemistry, "the Haber people treat us of course like conquered territory; they take whatever they want, not what they need" (in Charles 2005, 169).

8. Fritz Haber's commitment to the German war effort always implied plans to apply his wartime experiences to the future.

Haber always tried to transfer the results from poison gas research to future civilian uses. In a programmatic talk to officers of the War Ministry on November 11, 1918, he explicitly coined the phrase that his motivation was "to turn the means of extermination into sources of new prosperity". But he also realized that to apply his capacity for networked solutions to large-scale problems over a longer time, he had to maintain the all-important interaction between the state, military, economic and scientific communities (Haber 1924, 28–29). I will mention just one example.

Still during the war, Haber found immediate peacetime application of his poison-gas research in chemical pest control (for the following, see Szöllösi-Janze 2001). The German population suffered from famine as a consequence of the Allied blockade. Pests in countless mills and granaries aggravated the food situation further. With the help of his military personnel experienced in handling poisonous gases, Haber developed new methods for rooting out harmful pests. His teams organized systematic regional "gassing cycles" of mills and granaries and developed suitable operational techniques and systems to implement them all over the country. However, it was a typical ploy to consciously exploit the dual-use nature of the science and technology underlying gas warfare.

Already in the final phase of the war, Haber pursued the idea to continue military poison gas research under the pretence of civilian pest control. He was quite aware that the victorious Entente would prohibit any further military research, and he wanted to avoid anything that could be used as a pretext to close down his Institute as a whole. He pulled off an ingenious coup when he succeeded in transferring his institute's pharmacological department to the unsuspected Biological Reich Institute for Agriculture and Forestry (Biologische Reichsanstalt für Land- und Forstwirtschaft). There, it could hide under the cover of the laboratory for physiological zoology. Haber was able to raise generous anonymous funds to finance additional scientific and technical staff, new buildings, laboratory animals, and testing equipment. A deeper look into the sources reveals that he carried out a top-secret transfer of considerable funds from the German military, the Reichswehr, to the Biological Reichsanstalt. These funds covered the running costs of its physiological laboratory, which developed and tested poison gases not only for pest control, but also for military purposes. The long-term deal was initiated and arranged by Haber, whose role as mediator and organizer can hardly be overestimated (Szöllösi-Janze 1998, 452–467; 2001).

The dual use of poisonous gases for pest control, however, implied also an application which was absolutely beyond Haber's imagination. For it was within this far-reaching network of institutions, engaged covertly or overtly in research on toxic gases, that scientists developed processes to handle cyanides for pest control without the risk of harm to the technical staff. Among the substances they developed, there were Cyclon A and later the infamous Cyclon B, whose potential for dual use shows the tragic ambivalence of Haber's commitment. Cyclon B was a result of the conversion of military into civil poison gas research. Only some twenty years later, it was used against human beings as a means of mass extermination in the extermination camps. Haber was convinced that he could keep the interconversion of poison gas research under control, but in the Age of Extremes (Eric Hobsbawm), this was not possible.

9. "I was one of the mightiest men of Germany"—the technological imperative.

Many commentators have explained Haber's extensive involvement in the German war effort by pointing to his burning patriotism. He was indeed convinced that Germany had been pulled into the war against its will and was waging it for a just cause. Almost all other German scientists shared this view; they were, however, less intensely involved. It cannot have been mere patriotism, then, even though Haber also appeared to have felt a very "Prussian", state-oriented sense of duty and had a keen interest in the military. He also volunteered the services of his institute in support of the German cause, just like many other scientists. He showed initiative when approaching military leaders to offer his assistance. In line with his classical education, he saw a role model in Archimedes, who was said to have served "the progress of mankind in peace, but his home in wartime" (Haber 1920, 352).

In my view, his sense of power played a larger role for Haber than his patriotism. He was well aware of the power that the expert-scientist wielded as an intermediary between the ruling and the ruled. Especially during the first half of the war, the role of experts was informal—they connected with individuals rather than with institutions and stood outside formal bureaucratic structures. It was precisely this informality that they were able to use to their advantage. Scientific experts were flexible enough to take on tasks that cut across fields, including the early stages of policy advice (see Fisch and Rudloff 2004). Haber typified this transformation. As director of the Kaiser-Wilhelm-Institute for Physical Chemistry and Electrochemistry, he presented himself as a war volunteer who described his function simply as "adviser to the war ministry". He thus offered his scientific expertise and network of connections in an act of patriotic self-mobilization for the German war effort. Only later during the war, he became gradually integrated into the military-governmental apparatus. At the same time, he was perfectly aware of the fact that he was not only influential but also in control of a sector relevant to modern technological warfare. In hindsight, in August 1933, he reflected on his earlier power:

> I was one of the mightiest men in Germany. I was more than a great army commander, more than a captain of industry. I was the founder of industries; my work was essential for the economic and military expansion of Germany. All doors were open to me (Weizmann 1950, 437).

Haber's exercise of power went hand in hand with a technocratic mind-set— and a technocratic rhetoric. He was convinced that there was a scientific and technological solution to all societal problems. As a technocrat through and through, the demands of modern warfare challenged him intellectually. He was fascinated by the opportunities offered by modern science and technology to solve political, military, and economic problems. His notable ability for networking and strategic thinking served his remarkable creativity in addressing desperate situations. Typically, in one of his few remarks about his personal involvement in chemical warfare, Haber transpires as a gambler who had been provoked, with an almost physical sensation of risk, to play and win big in the game of high-tech warfare. In a letter to Carl Duisberg from February 1919, he wrote that he felt challenged to apply his own "scientific imagination" to future problems of warfare and find possible solutions at the forefront of scientific and technological progress. He portrayed conventional warfare dominated by artillery as a simple game of checkers that "turned into chess by poison gas warfare and the defence against it".[3]

So, is the scientific expert ultimately a mere technocrat fascinated by gambling at the large board of modern mass warfare?

10. As a key player in the high-tech combat of chemical warfare, Haber was aware of the underlying "human factor".

[3]Haber to Carl Duisberg, 26 February 1919. Abt. V, Rep. 13 (Haber Collection), no. 860, Archives of the Max Planck Society, Berlin.

It is no coincidence that the First World War accelerated the development towards the "scientification", the *Verwissenschaftlichung* that brought along with it the idea that the "human factor" is measurable. As a result, military leaders from all belligerent countries discovered the utility of the new discipline of psychology for their ways and means, such as intelligence tests in the US and the "psycho-technical" surveys of aircraft pilots in Germany (Raphael 1996, 174–176; Geuter 1984). Fritz Haber was highly conscious of the strong psychological dimension of chemical warfare. Like others, he used a specific gas warfare discourse. He rejected the suggestion that poison gas use was "unchivalrous" as initially argued by traditionally minded officers. On the contrary, he underlined that chemical weapons were more "humane" than conventional weapon technology, since their wide-spread use would shorten the war. This is, of course, a first-strike rhetoric. History did not bear out this argument, because weapon innovation set in motion an endless dynamics of increasingly lethal weapon technologies. It is well known that less than twenty-four hours after the German chlorine cloud attack at Ypres, the British commander in France and Belgium, Sir John French, sent a telegram to London:

> Urge that immediate steps be taken to supply similar means of most effective kind for use by our troops. Also essential that our troops should be immediately provided with means of counteracting effect of enemy gases which should be suitable for use when on the move (In Charles 2005, 164; Schmidt 2015, 26–28).

Haber's insight into the psychological dimension of chemical warfare went deeper yet. It was common knowledge—also among the Allied Forces—that poison gas war could unsettle the morale of the troops as well as on the home front (Schmidt 2015, 23). But Haber reflected on the impact of gas on the frontline soldier in a specific way. To him, the toxicity of chemical warfare agents was less relevant than the fact that the chemicals forced troops to wear respirators and use other protective devices. This demanded, as he wrote to Carl Duisberg, "better leadership and higher military ability".[4] The conviction that chemical warfare demanded a higher mind-set led to a curious expression of social Darwinism in Haber as well as in many other proponents of chemical warfare—just to mention Colonel Max Bauer, Haber's military protector, who used to ruminate on the "selection of the fittest" through poison gas warfare.[5] In this sense, Haber viewed chemical warfare primarily as a quest for psychological superiority. In modern scientific war, he wrote, the "psychological imponderables" are decisive.

> A strict selection divides the men capable of withstanding pressures thanks to this gas discipline and fulfilling their military duties from the inferior mass of soldiers who break up and leave their battle position (Haber 1924, 36, 39).

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[4]Haber to Carl Duisberg, 26 February 1919. Abt. V, Rep. 13 (Haber Collection), no. 860, Archives of the Max Planck Society, Berlin.

[5]See Max Bauer's Memorandum (1918) in Brauch and Müller (1985, 81).

"Gas discipline" as a means to select the fitter soldiers from inferior ones—this is twentieth-century social Darwinism at its best.[6]

Fritz Haber, however, was also the product of the nineteenth century. His personal duty was to remain loyal to the state and to commit himself unconditionally to the German cause. Even if his personal conviction had been different, Haber would not have questioned the German agenda, including chemical warfare. Just like millions of others, he never asked himself who exactly had set that agenda. For his personal morality, he relied on the presumed morality of the state, which he never doubted. His son, Lutz Haber, later described his father as "a Prussian, with an uncritical acceptance of the State's wisdom, as interpreted by bureaucrats" (Haber 1986, 2). The British physical chemist J. E. Coates discerned one of Haber's most important characteristics in his wish "to be a great soldier, to obey and be obeyed […] autocratic and ruthless in his will to victory" (Coates 1951, 146).

So Daniel Charles is quite right when he deems that Haber wasn't much preoccupied with the morality of his innovation because it arose from "a kind of technological imperative", which he viewed as "simply inevitable". Charles also correctly points out that Haber's vision was strictly limited to the battlefield. He never anticipated the possibility that future warlords would use poison gas or other weapons of mass destruction against civilian populations. "In this respect", Charles concludes, "Fritz Haber's imagination remained trapped in the nineteenth century" (Charles 2005, 174).

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[6]However, the phrase of gas warfare as "a higher form of killing," which has been repeatedly attributed to Haber since Harris and Paxman's study of 1982, cannot be found in the sources (see in detail Schmidt 2015, 484–485).

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From Berlin-Dahlem to the Fronts of World War I: The Role of Fritz Haber and His Kaiser Wilhelm Institute in German Chemical Warfare

Bretislav Friedrich and Jeremiah James

Abstract There is little doubt that Fritz Haber (1868–1934) was the driving force behind the centrally directed development of chemical warfare in Germany, whose use during World War I violated international law and elicited both immediate and enduring moral criticism. The chlorine cloud attack at Ypres on 22 April 1915 amounted to the first use of a weapon of mass destruction and as such marks a turning point in world history. Following the "success" at Ypres, Haber, eager to employ science in resolving the greatest strategic challenge of the war—the stalemate of trench warfare—promptly transformed his Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry in Berlin-Dahlem into a center for the development of chemical weapons and of protective measures against them. This article traces in some detail the path from Berlin-Dahlem to the fronts of World War I, lays out the indispensible role of Fritz Haber in German chemical warfare and provides a summary of his views on chemical weapons, which he never renounced.

1 The Run-up to Ypres

The lingering idea of using chemicals to incapacitate enemy troops had been rekindled by the belligerents in World War I once trench warfare produced a strategic stalemate on the war's Western front. On the German side, it was likely Max Bauer of the Supreme Army Command (*Oberste Heeresleitung,* OHL), see Fig. 1, who proposed to OHL's Chief, Erich von Falkenhayn, already in September 1914, to consider the use of chemical weapons in trench combat (Haber 1924, 85). In response to Bauer's proposal—and in the face of the shock of the Battle of the Marne[1]—von Falkenhayn promptly established a committee comprised of scien-

[1]Ending in Allied victory, this week-long battle (September 5–12, 1914) set the stage for the immovable trench warfare of the next four years of WWI.

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tists, industrialists and military officers, to assess the suitability and availability of various chemicals as weapons (Szöllösi-Janze 1998, 321–332 and references cited therein). Among the committee members was Fritz Haber's scientific rival, the physical chemist Walther Nernst, as well as the chemist and industrialist Carl Duisberg—but not Haber himself. The brainchild of the fledgling chemical warfare committee was the ineffective sneezing powder (*Ni-Stoff*) that was used amid the hostilities at Neuve-Chapelle already during the same month that the committee was formed. In response to the *Ni-Stoff* fiasco, Gerhard Tappen of the OHL, see Fig. 1, turned for help to his brother Hans Tappen, a chemist trained by Emil Fischer. Hans Tappen proposed to fill artillery shells with the lachrymator xylyl bromide, hence dubbed *T-Stoff*, that was first tested in January 1915. It was promptly used at the Eastern front, near Lodz, in cold weather with little or no effect due to its low vapor pressure at low ambient temperatures. At that point, von Falkenhayn decided to take his gloves off, abandon the "smelly stuff" and make use of lethal chemicals (substances that "incapacitate permanently," as he put it) in order to break the stalemate of trench warfare (Martinetz 1996, 18). To this end, Fritz Haber, who had meanwhile become, along with Emil Fischer, a member of Falkenhayn's chemical warfare committee and was privy to the failure of *T-Stoff*, proposed the use of chlorine as a chemical weapon. Heavier than air and thus suitable for striking enemy troops inside their trenches, chlorine held the promise of not only killing enemy combatants but also incapacitating their "conventional" weapons by corrosion. Although Haber would have preferred delivery via a barrage of artillery shells, he bowed to the need of the military to save ammunition and proposed to discharge the lethal gas from a great number of cylinders in the form of a cloud.

An attempt to test chlorine as a chemical weapon at the proving ground in Wahn near Köln in January 1915 was aborted due to the dangerousness of the gas and a decision was made by the OHL to test a chlorine cloud directly in battle on the Western front. Although viewed with skepticism and mistrust by most of the military, including von Falkenhayn himself, the idea of deploying a chlorine cloud found support from generals Berthold von Deimling and Emil Ilse, who were in charge of German operations in Flanders and who set their eye on the Ypres Salient, which, according to the Schliefen Plan, lay on the German Army's route into France. Von Deimling: "War is self-defense that knows no rules" (Deimling 1930, 201).

Much of the high-ranking German military took a more scrupulous—or chivalrous—approach to chemical weapons and at first openly detested them, thereby furnishing a curious substitute for the adherence to the spirit, if not letter, of the Hague conventions from 1899 and 1907 that limited the use of poisonous substances in warfare.

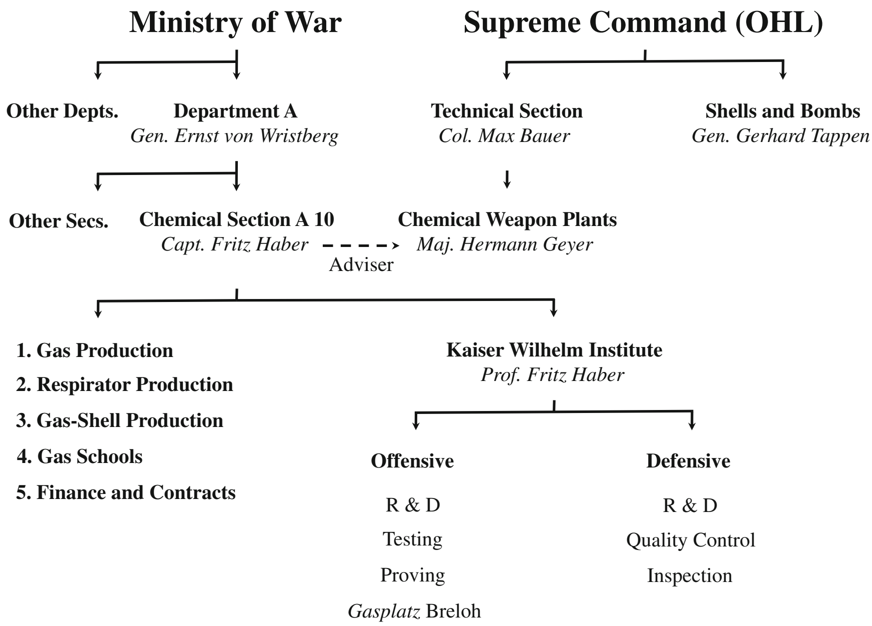

Fig. 1 Organization chart of the German chemical warfare from the end of 1916 on. After Haber 1986, 140

2 Ypres, 22 April, 1915, 1700 GMT

The commander of the gas units was Col. Peterson, with Fritz Haber co-opted as a member of his four-member staff.[2] The gas-warfare personnel, comprised of volunteers, was trained mainly in handling of gas cylinders, their transport, and protection. The steel cylinders were to be dug-in upright behind the battlements of the trenches and shielded with sand bags. Only the lead pipes were to peep out from the parapets, see Fig. 2. The training took place in Wahn during January 1915, but soon the chemical units, posing as “disinfection crews,” started moving to their positions on the Western front, reaching Ypres in February 1915. In the meantime, on Haber’s urging, many of the officer positions of the gas units were staffed with scientists—including meteorologists. These units would later become a part of the army corps of engineers (*Pionierregiment* or *-bataillon*). The movement of the chemical units and of their equipment to the front was accompanied by many mishaps, not least of them a serious injury suffered by Fritz Haber and Max Bauer on April 2 when they were caught in the midst of a small chlorine cloud released for testing purposes (Haber 1924, 88).

[2]The other members were adjutant Otto Lummitsch and Col. Ludwig Hermann (Szöllösi-Janze 1998, 327).

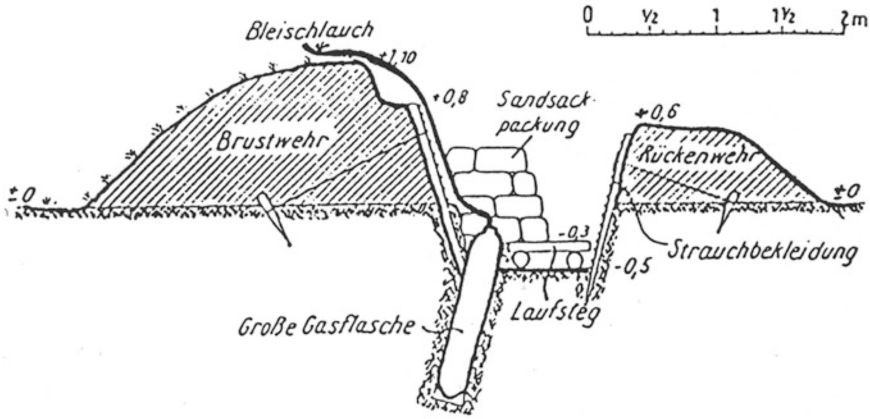

Fig. 2 Cross-sectional schematic view of a trench with a chlorine cylinder in position. After Martinetz 1996, VII

The first chlorine cloud attack on enemy positions (French and British) took place on April 22, 1915, at 1700 GMT (18:00 CET) in the perimeter of the Langemarck village near Ypres, when the prevalent wind finally turned in the northerly direction. Seven previous attempts had to be aborted because of unfavorable wind. The attack released 150 tons of chlorine gas from 1600 big and 4130 small cylinders placed at a distance of about 1 m from each other, covering about 6 km of the front. The chlorine gas concentration achieved was about 0.5% at a distance of 50–100 m from the cylinders, see Fig. 3. The first attack not only threw the Allied forces into a panic but reportedly injured about 5000 and killed about 1000. In addition, the Germans were able to capture 60 guns and a large swath of territory. To no avail, however, as the German military was unprepared to take advantage of the breakthrough:

> Unfortunately, the OHL had not prepared sufficient reserves because of doubts about the effectiveness of the new weapon. Otherwise it would have been possible to make a decisive advance (Lummitzsch 1955).

In spite of the "success" of the attack, it became clear that the predominant easterly winds made gas cloud attacks too unpredictable and unreliable a means upon which to base a new method of warfare. This led Haber to a renewed interest in poison gas grenades and shells, which were not so dependent upon rapidly changing meteorological conditions.

3 The Indispensable Fritz Haber

Fritz Haber, see Fig. 4, the founding director of the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry, took part in the widespread enthusiasm that accompanied German mobilization and entry into the First World War in the

Fig. 3 Aerial view of the chlorine cloud released by the German troops on April 22, 1915 at Ypres. Photo: Martinetz 1996, VIII

summer of 1914 (Hoffmann 2014, 7–31) and registered for voluntary military service at the beginning of August. He gave voice to his euphoria in a letter to Svante Arrhenius in Stockholm, writing:

> This is a war in which our entire people is taking part with full sympathy and its utmost abilities. Those who don't bear arms work for the war, and everyone scrambles forward voluntarily for the slightest accomplishment. You know Germany all too well not to know that such a unanimous commitment to a cause is only possible amongst us when all are conscious that the good of the nation must be defended through a just struggle. You should give no credence to the absurd fiction, according to which we are conducting a war out of military interests … but we now see it as our ethical duty to take down our enemies with the use of all our strength and bring them to a peace that will make the return of such a war impossible for generations and give a solid foundation for the peaceful development of western Europe (Zott 1997, 77).

When Adolf von Harnack, as president of the Kaiser Wilhelm Society (KWG), called together all of the institute directors on August 12, 1914 to discuss possible consequences of the war for the work of the KWG, Haber was already occupied by military concerns and sent his deputy Gerhard Just, see Fig. 4, in his stead. Haber worked first as a scientific consultant in the Ministry of War for the Artillery Command and the Production Department, where his expertise in applied chemistry and ammonia synthesis were particularly valued. Representatives of German political establishment and industry had quickly realized that a limit on raw materials made a long war unsustainable for Germany. Nitrates were of particular concern, as Germany relied upon Chilean saltpeter to supply both its fertilizer needs and its production of explosives and propellants, but the British sea blockade threatened to cut off this source. The war would also lead to shortages of myriad other raw materials and create related bottlenecks in industrial production. Hence, German chemists faced the challenge of rationalizing use and production of these scarce materials or finding substitutes for them.

Haber not only followed his maxim "In peace for mankind, in war for the fatherland"[3] personally, but applied it to his entire institute and promptly redirected its resources toward projects relevant to the war. The conversion to military research projects proceeded surprisingly smoothly and without noticeable resistance. This raises the question whether the war euphoria alone eased the transition or whether something inherent to the research policy of the Kaiser Wilhelm Society, especially its chemical institutes, enabled such a conversion. As Johnson has argued:

> True to his nature, Fischer stamped the scientific program of the Kaiser Wilhelm Society with a dual character. On the one hand, it was aimed at the most fundamental problems of natural science; but on the other, it was intended to produce solutions to technological problems of the highest national interest, particularly with regard to providing domestically available synthetic or artificial substitutes for imported materials (Johnson 1990, 133).

The development of the catalytic process for ammonia synthesis was already one realization of the desire to manufacture domestic substitutes for key imported goods. It is also amongst the common tenets of the history of WWI that without the Haber-Bosch process, the German military would have run out of munitions in 1915. Similar intentions led Haber to his wartime partnership with the Raw Materials Department of the War Ministry under Walther Rathenau, which eventually led him to research chemical means for waging war. As Johnson pointedly summed up the progression: "the logic of Ersatz [substitute] led to the problems of munitions, and eventually to poison gas" (Johnson 1990, 133).

In the first months of the war, the Institute searched for ways to economize or provide substitutes for so-called "war materials"—substances required for the operation of firearms, artillery and other war machines; examples include toluene, glycerin and saltpeter. Gerhard Just made rapid progress in this field, in collaboration with Otto Sackur, see Fig. 4. Together they were able to demonstrate, through careful freezing and boiling point measurements, that a combination of xylene and certain water-soluble fractions of crude oil could replace toluene as an anti-freeze in engines. Their discovery meant a savings of roughly 400 tons of toluene per month that could then be used in the production of TNT and other explosives and munitions. In the autumn and winter of 1914, Haber and his colleagues also took part in the development of respiratory irritants and tear gases in connection with the already mentioned conservation efforts.

[3]Usually quoted in this abbreviated form. For a full quote in German, see Haber (1920). Haber was referring to the attitude of Archimedes.

Fig. 4 Distinguished German scientists involved in chemical warfare. Clockwise from *top left*: Fritz Haber, James Franck, Richard Willstätter, Gustav Hertz, Hans Geiger, Otto Hahn, Otto Sackur, and Gerhard Just. Photos: Archiv der Max-Planck-Gesellschaft, Berlin-Dahlem, Jahresbericht der Schlesischen Gesellschaft für Vaterländische Kultur 1915, 1: 35–37, private collections of the authors

In connection with their efforts to develop new and more effective explosives and propellants, Haber, Just and Sackur attempted to replace the irritant in the T-shells[4] with a substance that would act as both irritant and propellant. Someone thought of using cacodyl chloride, which Robert Bunsen had first synthesized in 1837, but which chemists had scarcely researched since, because it was such a powerful irritant and explosive. On 17 December 1914, during an experiment intended to tame cacodyl chloride, there was an explosion in the laboratory. Sackur was fatally wounded, Just lost his right hand. Haber had left the room shortly before the blast and remained physically unharmed. Nevertheless, he was unsettled by the death of his highly-talented colleague and steadfastly honored his memory (James et al. 2011, 27).

After the accident, research on cacodyl chloride at the Institute was halted, but the explosion also marked a turning point not wholly ascribable to its tragic consequence: the end of significant research on explosives at the Institute and the beginnings of poison gas research. Sometime in the first half of 1915, Haber redirected research at his institute toward the needs of gas warfare. Unfortunately, the available sources do not provide precise answers as to when or how this occurred.

[4]Shells filled with T-*Stoff*.

The men of the gas brigades who carried out the chlorine cloud attack at Ypres, amongst whom numbered many Dahlem and Berlin scientists, including James Franck, Otto Hahn, Gustav Hertz, and Hans Geiger, see Fig. 4, experienced an immediate improvement in status. Haber was even promoted by the Kaiser from the rank of staff sergeant to captain,[5] a potent recognition of the value of his efforts. This advance in rank appears to have further motivated Haber to the self-assigned task of promoting chemical warfare, first as chemical advisor to the Ministry of War, then, beginning in November 1915, as head of the "Central Office for Chemical Concerns" in the Artillery Division. He essentially abandoned scholarly research and concentrated upon the problems of chemical warfare. In the words of his biographer Dietrich Stoltzenberg:

> everything else in his life [faded] into the background. Wife and family now had almost no influence on his life. In fact, for him, family, friends, and acquaintances were just further sources of aid for his cause (Stoltzenberg 1994, 256).

4 Haber's Kaiser Wilhelm Institute Under Military Command

Like most academic institutes, Haber's was essentially abandoned with even Haber spending much of his time near the front directing preparations for gas attacks. Then, at the end of April 1915, the Supreme Army Command assigned Haber the task of developing defensive measures against gas attacks. Haber systematically redirected his institute toward the pursuit of this goal and built it up into a German center for gas warfare research. Over half of the expenditures of the Institute in 1915 were for military purposes, above all for "experiments on the development of gas warfare methods." As of February 1916, the Institute worked "almost exclusively" for the military, which covered all related costs, including standard operating expense; the Institute even took on an army administrator, Lieut. Alfred Glücksmann, amongst whose duties was managing the Institute's budget (Szöllösi-Janze 1998, 344).

As noted, the first task of Haber's institute was the exploration of defensive measures and the development of gas masks. To this end, a special department for "Chemistry of Gas Defense" was established under Hans Pick. Among the duties of this department was the development and testing of gas mask prototypes, in collaboration with production firms. At the conclusion of these tests, the preferred design was one proposed by Leopold Koppel's Auergesellschaft, which would produce the masks in great numbers.[6] Still, mask design was only one part of

[5]Non-Jewish members of the German professoriate typically received the rank of a major, Szöllösi-Janze (1998, 63–64, 267); Schmaltz (2014, 206).

[6]Leopold Koppel, a banker and enterpreneur, funded Haber's KWI.

effective gas defense; yet more important was the development of effective filters. Early in 1915 filter designers had to reckon with chlorine and phosgene attacks, but as new and ever more malicious poisons were introduced, including mixtures of compounds consciously designed to penetrate the masks, the filters needed to be continuously updated and retested. Responsibility for filter development initially fell to the neighboring KWI for Chemistry, in the person of Haber's colleague and friend Richard Willstätter, see Fig. 4. The first complete new gas masks, body and filter, were delivered to the troops in September 1915, and by the end of January 1916, the entire Western Front was equipped with masks, an enormous technical as well as logistical accomplishment.[7]

The initial fabrication of gas masks also marked the beginning of an unprecedented expansion of the Institute, which took place between the autumn of 1915 and the end of 1917. The Institute grew to include 10 departments and employ 1500 scientists and support staff, the latter composed overwhelmingly of women, see Fig. 5, all employed in the research, development and testing of gas warfare equipment. This number would rise to 2000 at the end of the war (Szöllösi-Janze 1998, 348). The expansion began with the departments of Reginald Herzog and Hans Pick, see Fig. 6 and Table 1. Herzog and his coworkers took over the supervision and testing of gas mask production, while Pick dedicated himself to the chemical aspects of gas defense. Then, in November 1915, Friedrich Kerschbaum, see Fig. 6 and Table 1, previously technical adjutant to Haber, established a department devoted to the study of enemy poisons and defensive measures, as well as the development of new poisons. The founding of this department and the near simultaneous appointment of Haber to head the Central Office for Chemical Concerns were the final, decisive steps in the commissioning of the KWI for Physical Chemistry and Electrochemistry for poison gas research by the military. The subsequent unprecedented expansion of the Institute would make it a prototypical example of "big science," not only with respect to its sheer size but also, and above all, with respect to the complexity and interdisciplinarity of its organizational structure and research methods (cf. Szöllösi-Janze and Trischler 1990). The institute also served as an early example of how quickly and smoothly resources for the establishment of optimal research conditions can be secured in a military or security context whereas, under normal circumstances, their attainment frequently involves near-endless, often unsuccessful struggle. As Johnson put it, "the Dahlem complex gradually assumed the character of a research center for tactical military science and technology" (Johnson 1990, 189). Or, looking forward with the words of Fritz Stern, the Haber Institute during the First World War became "a kind of forerunner of the Manhattan Project" (Stern 1999, 119).[8]

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[7]We note that the testing of the gas masks was done, among others, by James Franck, Otto Hahn, and other scientists who let themselves be personally exposed to chemical warfare agents such as phosgen in the test chambers at Haber's KWI (Szöllösi-Janze 1998, 347–348).

[8]However, the Manhattan Project was by about two orders of magnitude larger in terms of human resources alone. See *Manhattan District History* Book I—General, Vol. 8—Personnel, dated 19 February 1946.

Similarly striking expansions of chemical warfare research occurred in the other warring nations, further encouraging German efforts. Although there was initially significant political debate in Britain as to whether German use of chemical weapons justified retaliation in kind, by May 1915 the British Ministry of Munitions had formed a chemical subcommittee, and in March 1916 the British opened a chemical weapons testing facility at Porton Down. France saw no similar political debate and had, in fact, already employed grenades filled with lethal chemicals early in the war, see below. In June 1915, France established a Directorship of Chemical War Materials under the Ministry of War and centralized chemical warfare research in laboratories near Paris (Lepick 1998). In so far as German efforts were exceptional, it was primarily in the degree to which research remained concentrated at the KWI for Physical Chemistry and Electrochemistry (Haber 1986; Martinetz 1996).

By October 1916, there were five departments dedicated to gas warfare research.[9] In addition to those already mentioned, Herbert Freundlich, see Fig. 6 and Table 1, headed a department dedicated to the supervision and testing of mask filters. That autumn, roughly one year into its expansion, the Institute employed a scientific staff of 77 chemists, pharmacists, and engineers, as well as a support staff numbering over 100. Up to that point, the Institute officially remained under the auspices of the Kaiser Wilhelm Society and the Koppel Foundation, which lodged muted complaints against the redirection of the Institute.

At the beginning of 1917, Haber's Office for Chemical Concerns was detached from the Artillery Division and refashioned into an independent department of the General Staff, Department A10, cf. Fig. 1. This department was then assigned control of Haber's institute, bringing the KWI for Physical Chemistry and Electrochemistry under military command. This reorganization was the result of a motion by the Ministry of War summarized by Haber in his letter to the minister of education that

> the whole operation of the institute be converted to a military one while keeping the name "KWI for Physical Chemistry and Electrochemistry" and that the staff currently working at the institute should be […] put on the staff of the military administration. The Ministry of War would […] as supervising authority still control the general direction of the institute on the condition that the position of Privy Counselor Capt. Haber […] as scientific director of the institute would remain unchanged, as would the positions of the others who had been members of the staff in peace time.[10]

This administrative move was accompanied by further enlargement of the Institute, primarily related to the intensification of efforts to develop new poisons. According to a report from Haber in September 1917, it was at this point that the Institute came to employ a staff of approximately 1500, with roughly 150 scientists and engineers, divided into 10 departments. Prominent scientific members included later Nobel laureate Heinrich Wieland, see Fig. 6 and Table 1, who worked on the production of new toxic gases, including the blistering agent mustard gas (LoSt,

[9]We draw on James (2011, 25–34).

[10]Fritz Haber, Letter to the Ministry of Education from 31 January 1916, Stoltzenberg (2004, 139).

Fig. 5 Out of the 1,500 employees of Haber's KWI after it became the German center of chemical warfare research and coordination, the majority were women. Photo: Archiv der Max-Planck-Gesellschaft, Berlin-Dahlem

named for Haber's coworkers Lommel and Steinkopf and also known as Yperite) and Ferdinand Flury, see Fig. 6 and Table 1, who tested newly-developed gases on live animals. Heinrich Wieland, who would receive the 1927 Chemistry Nobel Prize "for his investigations of the constitution of the bile acids and related substances," initiated his research into the relationship between steroids and the bile acids in 1912. During his 1917–1918 military service at Haber's Institute, for which he may have qualified due to his pre-war work on the fulminic acid, a primary explosive whose vapors are highly toxic, Wieland synthesized adamsite, in addition to his involvement in the synthesis of mustard gas. Wieland's penetration into the structure of the polymeric fulminic acids helped to lift the veil over what he called "an arid structural desert" under which he later discovered the constitution of bile acids as well (Karrer 1958, 342). To what extent Wieland was able to advance the line of research on steroids during his service at Haber's Institute remains unclear.

The two original Institute buildings could not contain all of the new departments and coworkers, and ever more barracks, kennels and other outbuildings sprang up on the Institute grounds, see Fig. 7. When even this space was consumed, rooms were requisitioned from the neighboring KWIs for Chemistry and for Biology, with the consent of their respective directors.[11] Toward the end of 1916, further growth

[11]And perhaps sometimes even without it. As Lise Meitner from the adjacent KWI for Chemistry noted: "Haber's people treated us like conquered territory; they didn't take what they needed but what they liked." (Stoltzenberg 1994, 255).

Fig. 6 Prominent heads of chemical warfare departments at Haber's KWI for Physical Chemistry and Electrochemistry when the institute was under military command. Clockwise from *top left*: Friedrich Kerschbaum, Ferdinand Flury, Heinrich Wieland, Reginald Oliver Herzog, Paul Friedländer, and Herbert Freundlich. Photos: Archiv der Max-Planck-Gesellschaft, Berlin-Dahlem and Martinetz 1996, II

Table 1 Departmental structure of Haber's KWI at the end of World War I, according to the 1921 "Hartley Report." The "defensive" departments are marked in red, the rest are the "offensive" departments (Haber 1986, 127)

Department	Assignment	Head
A	Development of respirators; Supervision of gas mask production	Reginald Oliver Herzog
B	Development of chemical weapons; Testing of enemy chemical weapons and protective gear	Friedrich Kerschbaum
C	Development of respirator drums and other protective appliances	Ludwig Hans Pick
D	Synthesis of new chemical warfare agents	Heinrich Wieland
E	Pharmacology and toxicology; Testing on animals	Ferdinand Flury
F	Supervision of the production of respirator drums	Herbert Freundlich
G	Supervision of the production of shells and fuses for gas munitions	Wilhelm Steinkopf
H	Trench mortars; Explosives	Otto Poppenberg
J	Supervision of the production of chemical warfare agents	Paul Friedländer
K	Particulate clouds – development of the "Gasbüchse"	Erich Regener

occasioned moves even further afield, and the Institute rented space in the Pharmaceutical Institute of the University, in a weaving school on Warschauer Platz, in the State Offices in Steglitz and on Königin-Luise-Straße in Dahlem (James et al. 2011, 32).

Compared to the extent of the research carried out on poison gases, the original documentation that remains is truly sparse. A single, relatively complete research report on chlorarsines remains from Johannes Jaenicke, at the time a member of Hans Pick's Department C, along with scattered reports from toxicity tests on animals and volunteers from the Institute staff (Haber 1986, 109). Extant correspondence between the main researchers is similarly sparse.

The post-war Allied forces reports on the Institute are somewhat more informative concerning the conduct of poison gas research, but even they are disappointingly superficial when it comes to questions of research procedures and practices, aside from quality testing protocols. Nevertheless, from these limited sources, the principal of them being the Hartley Report and its rendition in the book by Fritz Haber's son Ludwig (Lutz) Haber,[12] it is possible to sketch the following outline of chemical weapons research at Haber's institute.

The ongoing development of gas masks and filters, in increasingly close cooperation with industry, took place in Departments A (Herzog) and C (Pick). The work of these departments relied upon a steady exchange of knowledge between laboratory researchers and battlefield informants. Later in the war, prototypes from these departments would be tested against new poisons from Department B (Kerschbaum) (Hartley 1925, 39–42). Members of Kerschbaum's department strove to find and identify substances with potential for use in gas cloud and shell attacks. Their work consisted of a mixture of literature research to identify substances with an optimal combination of noxiousness, low boiling point and high vapor pressure, and experiments on animals and volunteers from the Institute staff to confirm the irritating or toxic effects of these substances (Hartley 1925, 45). Also, Kerschbaum along with Haber supervised the poison-gas production and filling facility ("*Gasplatz*") at Breloh, see Fig. 8. Department D (Wieland) focused specifically on deleterious arsenic and sulfur compounds, for instance mustard gas, and performed primarily laboratory research, including attempts to synthesize new substances with effects analogous to known poisons and irritants. Research on the physiological effects of various poisons, including careful study of their relative toxicity, occurred in Department E (Flury) and relied upon extensive animal experimentation. It was also Flury and his collaborators who promoted use of the so-called "Haber Constant," the product of the concentration and the exposure time required to cause death. This constant aided early efforts to define limits on

[12]Lutz Haber's personal interest in the topic of chemical warfare was fueled not just by his family lineage but also by his acquaintance and friendship with Harold Hartley, whose confidant—and in a sense heir of his extensive collection of materials connected with chemical warfare in WWI—Lutz Haber had become. Sir Harold Hartley was Fritz Haber's counterpart at the British War Office during WWI who, after the war, was in charge of inspecting German research and production facilities related to chemical warfare, and banned by the Versailles Treaty.

Fig. 7 Haber's KWI for Physical Chemistry and Electrochemistry with surrounding barracks, circa 1917. Photo: Archiv der Max Planck Gesellschaft

hazardous substances in the civilian sphere. Department J (Friedländer) was responsible for testing the quality of chemical weapons produced by industry, for which it employed predominantly classical analytical methods rather than measurements of physical constants (Hartley 1925, 50–52). Only in Department K, under Erich Regener, did techniques from physical chemistry play a central role. Regener's group used ultramicroscopes to study the small particles that constitute powders and smokes and their ability to penetrate existing gas mask filters.

Post-war assessments of the scientific value of this research by Allied representatives and later historians have been almost universally negative. In his own remarks on the subject during the 1920s, Haber emphasized the effectiveness and humaneness of chemical weapons, but, nonetheless, explained to Allied agents that all of the important toxic substances used in the war had already been synthesized and studied before 1914 and that "no systematic progress had been made" in their research. In the same vein, Richard Willstätter reported to the Allies that he did not consider the synthesis research pursued at Haber's institute particularly serious.

Apart from developing additional chemical agents at his Kaiser Wilhelm Institute (such as phosgene and mustard gas), Haber introduced the procedure of "Bunteschiessen" (variegated shelling), which consisted of first deploying "Maskenbrecher"—irritants based on organic arsenides (called Clark I and II) that penetrated all available filters and forced those under attack to remove their gas masks—and subsequently shelling with poisons such as phosgene or mustard gas (Haber 1986, 114–116).

Fig. 8 Inspection of the gas-testing and storage facility in Breloh near Münster on April 12, 1918. Head of the General War Department A (*Allgemeines Kriegsdepartment A*), Col. Ernst von Wrisberg (4th from *left*); Commander of the Breloh facility, Lieutenant-Colonel Ernst von Wangenheim (4th from *right*); Commander of the Field-Munitions Institute, Capt. Dr. Ludwig Hermann (3rd from *left*); Head of Department B at Haber's Institute, Dr. Friedrich Kerschbaum (1st from *left*). Capt. Fritz Haber (2nd from *left*). Photo: Archiv der Max Planck Gesellschaft

5 Haber's Views on Chemical Warfare

Haber advertised the first use of a chemical weapon as an important milestone in the "art of war"—and saw its psychological effect as key:

> All modern weapons, although seemingly aimed at causing the death of the adversary, in reality owe their success to the vigor with which they temporarily shatter the adversary's psychological strength (Haber 1924, 36):.

Haber also pointed out that key to success in chemical warfare are "intellectual imponderables" of the troops.

> A strict selection separates the troops that are capable of maintaining gas-discipline and who fulfill their combat task from the martially inferior mass of those who crumble and abandon their posts (ibid., 39).

He also emphasized that the variability of the effects of chemical weapons presents ever new demands on the "moral resistance" of the troops, as opposed to artillery shelling that is always the same and people get eventually used to it (ibid., 37).

Thus Haber viewed chemical weapons as a strategic means to break the stalemate of trench warfare by forcing the adversary to surrender, shorten the war, and thereby preclude the slaughter of millions by artillery and machine gun fire. In this sense he also referred to chemical weapons as "humane." He was not alone to do so, see below.

Haber's enthusiasm for chemical weapons had an important caveat, described by Haber's biographer Margit Szöllösi-Janze in this way:

> Was [Haber] a fanatic of gas-warfare? One must not overlook that he saw the significance of the gas weapon in its stupefying character and assessed the inherent dynamics of its use differently than the military. In his opinion chemical weapons could be effective and lead to a shortening of the war only if the war came to an end before the adversary would be able to develop suitable protective measures and even more dangerous chemical agents. For this reason, [Haber] voiced his opposition at a meeting in 1917 with [General Erich] Ludendorff [deputy of von Falkenhayn's successor as Chief of OHL, Paul von Hindenburg] to the use of mustard gas [that represented an escalation of the chemical war], which struck him sensible only if Germany could take advantage of its head start and win the war within a year (Szöllösi-Janze 1998, 332).

And indeed, the French began production of mustard gas in July 1918. Here's how Harold Hartley described the path of the Allies to mustard gas:

> [Hartley] was awakened early on that 13 July [1917] and was informed that the Germans had fired a new type of shell [at Ypres] that made a "plop"-like sound when it burst […] The next day [Hartley] had located some unexploded shells with yellow cross markings. They were defused, taken to [the General Headquarters], opened, the contents analyzed […] and the findings compared with the entry in *Beilstein*. By 16 July [the British] knew what the stuff was, and later analyses added little to this knowledge (Haber 1986, 192).

Haber's correspondence reveals his fascination with the new tactical possibilities opened by gas warfare and the room for "scientific imagination" that such technological means for conducting war had offered (Szöllösi-Janze 1998, 327). He used (and perhaps coined) the metaphor that conventional warfare was like playing checkers whereas warfare enhanced by chemical weapons was like playing chess. Haber never regretted his involvement in chemical warfare.

As for legal issues with chemical warfare, Haber put the blame for any transgressions against international law squarely on Erich von Falkenhayn. He did so in a testimony—which took the form of lectures—delivered to an investigative committee of the Reichstag in 1920–1923. However, in this testimony, Haber did not shy away from playing a legalistic shell game when he argued that German gas attacks were carried out either without the use of shells (like the chlorine cloud attacks) or with shells loaded, in addition to poison gas, with explosives (whereas the Hague conventions prohibited the use of shells or grenades filled solely with poisonous substances).

Haber also correctly claimed that chemical weapons were first used in WWI by the French—already in August 1914—when they fired rifle grenades filled with the highly toxic ethyl bromoacetate. Although ineffective because of the low concentrations achieved, the intended purpose was, according to Fritz Haber, the same as that of the German chlorine cloud: to force the enemy out of his trench positions by exposing him to an asphyxiating agent (Haber 1924, 87). This view was validated by the German parliamentary committee, which concluded:

> Neither the German nor the French governments, nor as far as is known, any other power participating in the war or a neutral one raised any objections against the modes of action in the gas war. From this it can be concluded that both sides viewed the Hague Conventions of 29 July 1899 and 18 October 1907 as obsolete and by silent agreement regarded them as annulled. Even when accepting this assumption, it remains a fact that the first obvious transgression of an international agreement was on the French side, whereas Germany only followed and thereby merely took a countermeasure as accepted in international law (Stoltzenberg 1994, 152).

6 The Legacy of Ypres

The universal abhorrence of chemical weapons as manifestly inhumane is surprisingly recent and so is their classification as weapons of mass destruction. While the latter is a concept of the nuclear age, the former is not... At the time of their use in the First World War, the perverse-sounding notion that chemical weapons were in fact humane had been a part of the vocabulary of munitions and war experts of the Central Powers and the Entente alike, including, for instance, that of the U.S. Assistant Secretary of War and Director of Munitions, Benedict Crowell:

> The methods of manufacturing toxic gases, the use of such gases, and the tactics connected with their use were new developments of this war; yet during the year 1918 from 20 to 30 per cent of all American battle casualties were due to gas, showing that toxic gas is one of the most powerful implements of war. The records show, however, that when armies were supplied with masks and other defensive appliances, only about 3 or 4 per cent of the gas casualties were fatal. This indicates that gas can be made not only one of the most effective implements of war, but one of the most humane (Crowell 1919, 396).

The few who forewarned Haber and the German military leadership that the German use of chemical weapons would lead to a quick retaliation by the Entente powers and a widespread use of chemical weapons were ignored. And indeed, the Entente introduced its own potent chemical arsenal within a few months of the first German chlorine cloud attack at Ypres, see also Table 2.

Table 2 Production of chemical weapons by country, in metric tons (Martinetz 1996, 120)

Country	Chlorine	Phosgen	Di-phosgen	Mustard gas	Chlor-picrin	HCN	Total
Germany	58,100	18,100	11,600	7,600	4,100	-	99,500
Britain	20,800	1,400	-	500	8,000	400	31,100
France	12,500	15,700	-	2,000	500	7,700	38,400
U.S.A.	2,400	1,400	-	900	2,500	-	7,200
Total	93,800	36,600	11,600	11,000	15,100	8,100	176,200

Artillery shells filled with chemical agents grew from a negligible proportion in 1915 to about 50% of the German, 35% of the French, 25% of the British, and 20% of the American ammunition expenditure by the Armistice (Spiers 2016). Providing little advantage to either of the equally equipped belligerents, chemical weapons greatly increased the already unspeakable suffering of the troops on both sides of both the Western and Eastern fronts. The British historian Edward Spiers recently characterized the WWI chemical weapons as "weapons of harassment" (ibid.). According to Augustin Prentiss's count (Prentiss 1937, 649), a total of about 90,000 soldiers were killed and 1.3 million injured by chemical weapons in WWI. What put finally an end to the war was the economic collapse of Germany (Mommsen 2011).

Albert Einstein's pacifist view contrasted sharply with that of his friend Haber. As he would put it later: "Warfare cannot be humanized. It can only be abolished" (Rowe and Schulmann 2007, 224). Strangely enough, there is no record of Einstein's criticism of Haber's WWI efforts, although Einstein occupied an office at Haber's institute at the time and must have been aware of what was going on. Gruesome as they were, chemical weapons have been banned only since 1997 (Organisation for the Prohibition of Chemical Weapons). Much of the military death toll in WWI (estimated to be at least 10 million troops) was, however, due to high explosives produced by the chemical industries of the warring nations. Hence the characterization of WWI as the "chemists' war," although chemical warfare surely added much weight to it. We note that the development and acquisition of the Haber-Bosch technology by Germany just in time for the Great War was key to sustaining her war effort: without it, the embargoed supplies of Chilean saltpeter would have run out within months and WWI would have indeed been as brief as anticipated by the German military planners, except that it would have ended not in Germany's speedy victory but rather her abrupt defeat.

Haber was without question the driving force behind the centrally-directed development of chemical warfare in Germany, whose use during WWI violated international law and elicited both immediate and enduring moral criticism, and has thereby inadvertently come to personify the moral flexibility of scientific research (Stern 2011; Dunikowska and Turko 2011). His efforts during WWI illustrate how quickly the fine line between the tolerable and the unacceptable can be crossed, in this case with fatal consequences.

As Haber's biographer Dietrich Stoltzenberg aptly noted: "It is easy to condemn [Haber]; it is much harder to make a sound judgment on him" (Stoltzenberg 1994, 153).

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Clara Immerwahr: A Life in the Shadow of Fritz Haber

Bretislav Friedrich and Dieter Hoffmann

Abstract We examine the life of Clara Haber, nee Immerwahr (1870–1915), including her tragic suicide and its possible relation to the involvement of her husband, Fritz Haber, in chemical warfare. Clara earned a doctorate in chemistry from the University of Breslau, in 1900, as the first woman ever, and married the physical chemist Fritz Haber within a year of her graduation. With no employment available for female scientists, Clara freelanced as an instructor in the continued education of women, mainly housewives, while struggling not to become a housewife herself. Her duties as the designated head of a posh household hardly brought fulfillment to her life. The outbreak of WWI further exacerbated the situation, as Fritz Haber applied himself in extraordinary ways to aid the German war effort, which included his initiative to develop chemical weapons. The night that he celebrated the "success" of the first chlorine cloud attack and his promotion to the rank of captain, Clara committed suicide. However, we found little evidence to support express claims that Clara was an outspoken pacifist who took her life because of her disapproval of her husband's engagement in chemical warfare. We examine the origin of this "myth of Clara Immerwahr" that took root in the 1990s from the perspective offered by the available scholarly sources, including those that have only recently come to light.

1 Prolog

On April 23, 1909, Clara Haber wrote to her PhD adviser and confidant, Richard Abegg, the following lines:

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> What Fritz [Haber] has gained during these last eight years, I have lost, and what's left of me, fills me with the deepest dissatisfaction (Haber 1909).

This sobering summary of an eight-year marriage with Fritz Haber may serve as a key document about Clara's life and fate, not least in regard to her suicide six years later. Over the last twenty five years, Clara's suicide has been widely regarded not only as a personal tragedy and a result of a marital drama but, especially after the publication of her biography by Gerit von Leitner (Leitner 1993), as a consequence of Fritz Haber's involvement in chemical warfare in general and the first chlorine cloud attack at Ypres on 22 April 1915 in particular. More than that, it has been seen as a signal of a "feminine, life-preserving science" that opposes a patriarchal science, keen on securing power and on the exploitation of natural resources. Herein, we show that, based on the available biographical materials about Clara Haber, nee Immerwahr, this interpretation of her suicide is lopsided, lacking proper consideration of the complexity of Clara's personality and the circumstances of her life and time.

2 Clara Immerwahr's Background

Clara Immerwahr[1] was born on 21 June 1870 at the estate of Polkendorf near Breslau, where her father, a PhD chemist, withdrew after the failure of his chemical start-up company. Apart from becoming a highly successful agronomist in Polkendorf and its surroundings, he co-owned a flourishing specialty store in Breslau dealing in luxury fabrics and carpets. The family maintained an apartment in Breslau where the Immerwahrs would stay during their frequent visits to the city. And Clara would live there during her studies in Breslau.

Breslau, characterized by Goethe as a "noisy, dirty and stinking" town (Goethe 1949, 378), transformed itself during the second half of the nineteenth century into a prosperous metropolis teeming with business and industrial enterprise. This was accompanied by an enormous increase in population, which doubled during the 30 years since 1875, reaching 471,000 in 1905 (Rahden 2008, 32). At the same time, Breslau developed into a major center of science and culture with a large educated middle class. There was the Schlesische Friedrich-Wilhelms-Universität, founded in 1811 (whose forerunner was the Leopoldina, founded in 1702), a number of colleges, as well as an opera house, several orchestras, and a city theater —all of them of national significance (Davies and Moorhouse 2002).

The era of economic and cultural prosperity that the city enjoyed coincided with the childhood and youth of Clara Immerwahr, whose family belonged to Breslau's well-to-do Jewish middle class. After Berlin and Frankfurt, the Jewish community of Breslau was the third largest, at over twenty thousand Jewish residents (Rahden

[1]Herein, we draw on the biography of Clara Immerwahr as detailed in Szöllösi-Janze (1998, 124–131).

2008, 32), and its synagogue, consecrated in 1872, even the second largest in Germany (Scheuermann 1994). Breslau's Jewish community was academically oriented and represented the city's "intellectual aristocracy," to which also the Immerwahrs belonged (Noack 1959). However, they were assimilated Jews, who participated in communal cultural life but would only rarely, if at all, go to the Synagogue. Jewish religion, customs and practices played essentially no role in the family life. The political attitudes of the Immerwahr family were liberal, which however entailed the cultivation and demonstration of a certain degree of Prussian-German national awareness and patriotism, especially after the German unification of 1871 (Clark 2007). Prussian was also the simple lifestyle of the family, which was frugal—not because of need but out of principle. So despite the family's wealth, Clara and her three siblings were brought up in modesty.

Apart from the virtues of simplicity, frugality and modesty, a great value was attached to education—not just for the son and heir, but also for the three daughters. This was typical for the German Jewish middle class, as 40% of female students at the higher schools in Breslau were Jewish. As opposed to Switzerland or the Anglo-Saxon countries, German high schools (*Gymnasium*) were out of limits for women until the beginning of the twentieth century. The Grand-Duchy of Baden was the first state in Germany to institute, in 1900, admission of female students to universities. Before then, it was only possible for women to attend university by a special permission or as guest auditors (Johnson 1998).

Clara's path to education was shaped by these constraints. She started her studies at a Höhere Töchterschule (sometime translated as "women's college") in Breslau, which was supplemented during the summer months spent at the Polkendorf estate by instruction provided by a private tutor. Clara graduated from the Töchterschule in 1892 at age 22. The school was supposed to provide a basic education for young women that was compatible with their social status and to prepare them for their "natural purpose," that is, as companions of their husbands, as housewives, and as mothers. Nevertheless, Clara was up for more and after graduating from the Töchterschule she entered a teachers' seminary, which was the only type of institution that offered a higher professional education to women (Szöllösi-Janze 1998, 124). However, the graduates of the teachers' seminary only qualified to teach at girls' schools and remained ineligible to enter university and study, for example, science, which is what Clara wanted to do. So in order to qualify for the university, Clara had to take intensive private lessons and pass an exam equivalent to the *Abitur*. This exam was administered by a special committee set up at a *Realgymnasium* in Breslau and Clara passed it successfully at Easter 1896, when she was 26 years old.

Subsequently, Clara began her studies at the University of Breslau, however only as a guest auditor, since in Prussia women would only become legally admissible as university students as late as 1908. Prior to this, starting in 1895, women were only allowed to attend lectures as guests, and even that was contingent upon the support of the professor and faculty and permission from the Ministry; the last required a certificate of good conduct, character references, and so on. It is difficult today to imagine what it meant to women to break into the male domain of higher learning and what kind of discrimination and humiliation was connected with it. Talk of "intellectual Amazons" was not uncommon.

The attitude of Max Planck, who accepted Lise Meitner as an assistant in 1912 and was helpful in promoting her career even earlier, declared in 1895, in response to a poll, that

> Nature herself prescribed a role for women as mothers and housewives (Planck 1897, 256).

Thus according to the spirit of the time, Clara Immerwahr, with her wish to become a chemist, violated a law of nature. After her successful *Abitur* exam, Clara applied to the university curator's office for permission to attend lectures in experimental physics as a guest. And she had to proceed in a similarly awkward manner with all the other lecture courses that she wished to take.

From early on, Clara developed a keen interest in the then new field of physical chemistry.[2] Richard Abegg, one of this new field's pioneers and a friend of Fritz Haber's, played a key role in fostering Clara's interest in physical chemistry while paying little heed to Clara's guest auditor status. It was also Abegg who supervised Clara's PhD thesis—a part of the graduation requirement in chemistry—and who wrote a joint paper with Clara in 1899. The joint paper, published in 1900 (see next section and references therein), must have been perceived by the young female chemist as proof of her success and as an accolade. The following year, Clara submitted her dissertation and applied to be admitted to the *Rigorosum* final, which entailed exams in chemistry, physics, mineralogy, and philosophy. She passed the exams during the Fall and defended her thesis at the university's main auditorium on December 22, 1900.

Clara graduated with *magna cum laude* and her graduation was mentioned in the daily press, as Clara was the first woman on whom the University of Breslau conferred a doctoral degree. The left panel of Fig. 1 shows her photo during her university studies.

Richard Abegg (Fig. 2) assumed in 1899 an academic position at the Chemistry Institute of the University of Breslau, which belonged to the most prestigious in Germany. In 1909 Abegg became Ordinarius at the newly founded Technical University in Breslau. However, he would not live long enough to see through the construction of the new laboratory for physical chemistry at the Technical University, which was slated to be his own (Nernst 1913). Abegg was an early fan of balloon flying—and founded and presided over the Breslau ballooning club. He died in a ballooning accident in 1910 at the age of 41. As Nernst colorfully narrated in his obituary notice (Nernst 1913), Abegg was extremely hard working,

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[2]Let us note that physical chemistry came about with a purpose, namely to save chemistry from taxonomy—from becoming a collection of little disconnected facts bred mainly by organic chemists. Its founders shared the view that chemistry should seek the general rather than cherish the particular and that the way to achieve it was to adopt the methods of mathematics and physics, Friedrich (2016). The success of physical chemistry in providing a common ground for chemistry was celebrated by Ostwald in his proclamation that "[p]hysical chemistry is not just a branch on but the blossom of the tree of knowledge" Ostwald (1887).

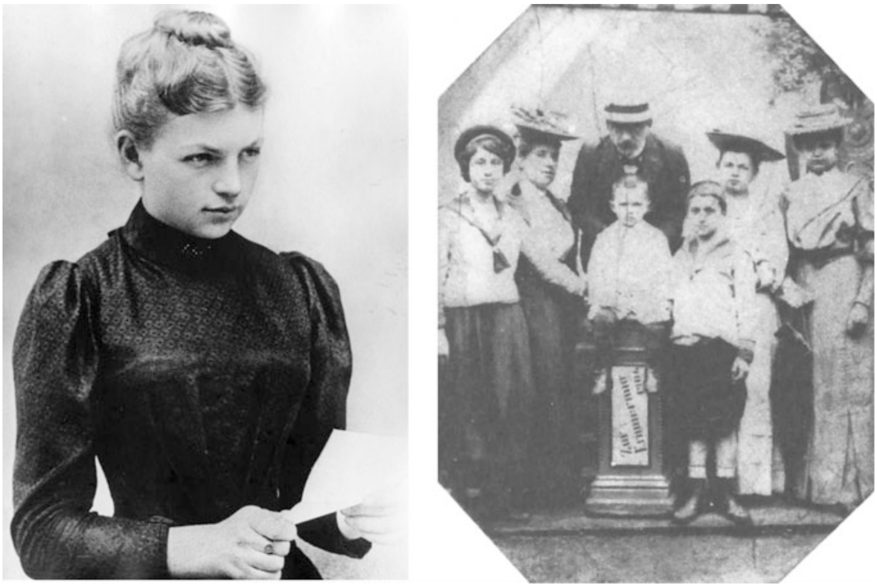

Fig. 1 *Left panel* Clara Immerwahr during her studies at the University of Breslau. *Right panel* Clara Haber, nee Immerwahr (2nd from *right*), on a family photo from 1906 with her son Hermann (seated in the center), her husband Fritz Haber (standing behind Hermann) and the landlady (2nd from *left*) of Habers' Karlsruhe apartment with her children; on the right is Habers' maid servant. Photos: Archiv der Max-Planck-Gesellschaft, Berlin-Dahlem

yet always had time for everybody. That must have surely made him an ideal academic teacher and adviser, particularly for Clara.

Otto Sackur (Fig. 2) was Clara's ten year junior *Kommilitone*, who studied chemistry at the University of Breslau, where, like Clara, he found an enlightened mentor in Richard Abegg. Sackur served on Clara's PhD committee as a referee.

As a *Privatdozent* at the University of Breslau, he was left after Abegg's death without an academic patron or a laboratory. It was during this period that Sackur launched his research at the intersection of thermodynamics and quantum theory. A reward in the form of a more senior appointment came at the end of 1913 when, thanks in part to mediation by Clara Haber, Sackur received a call to Haber's Kaiser-Wilhelm-Institut in Berlin. In 1914 he was promoted to the rank of a department head. After the outbreak of WWI he was enlisted in military research at Haber's institute, but continued on the side his experiments on the behavior of gases at low temperatures. In December of 1914, he was killed in a laboratory accident at his work bench, while trying to tame cacodyl chloride for use as an irritant and propellant (Badino and Friedrich 2013). He was just 34 years old.

While Abegg represented Clara's connection to science who, in addition, acted as her "cheerleader" and confidant in private matters, Otto Sackur was Clara's friend and *Kommilitone*. After Sackur's laboratory accident, Clara was among the first to attend to the injured. She proved capable of acting rationally in a situation

Fig. 2 *Left panel* Richard Abegg (*1869 Danzig; †1910 Tessin). Abegg graduated in chemistry from the Berlin University (1891) under August von Hofmann, received his *Habilitation* (1894) under Walther Nernst, was *Extraordinarius* at the University of Breslau (1899–1909), *Ordinarius* at the Technische Hochschule Breslau (1909), member of the Leopoldina (1900) and editor of the Zeitschrift für Elektrochemie (1901). Photo: Arrhenius, 1910. *Central panel* Otto Sackur (*1880 Breslau; †1914 Berlin). Sackur graduated in chemistry from the University of Breslau (1901) under Richard Abegg, received his *Habilitation* (1905) under Abegg, was department head at the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry (1914). Photo: Jahresbericht der Schlesischen Gesellschaft für Vaterländische Kultur 1915, 1: 35–37. *Right panel* Fritz Haber (*1868 Breslau; †1934 Basel). Haber graduated in chemistry from the Berlin University (1891) under August von Hofmann, received his Habilitation (1894) under Hans Bunte, was *Extraordinarius* (1898) and *Ordinarius* (1906) at the Technische Hochschule Karlsruhe, founding Director of the KWI für Physikalische Chemie und Elektrochemie (1911–1933), *Honorarprofessor* (1912–1920) and *Ordinarius* (1920–1933) at the Berlin University, Member of the Prussian Academy (1914). He was awarded the Nobel Prize in Chemistry for 1918. Photo: Archiv der Max-Planck-Gesellschaft, Berlin-Dahlem

drastic to the extreme and to coordinate attempts to help the injured. However, Sackur died on the spot, before her eyes; Clara was crushed by Sackur's death. At the site of accident, Fritz Haber was just gasping for air in the arms of a coworker. He was shattered to the point that he stopped for good explosives research at his institute (James et al. 2011, 27).

3 The Scientific Work of Clara Immerwahr

Clara’s scientific record consists of three research papers (Immerwahr and Abegg 1900; Immerwahr 1900a, 1901a), a supplement (Immerwahr 1900b) and an erratum (Immerwahr 1901b) to one of the research papers. Her first research paper is co-authored by her PhD adviser, Richard Abegg, the other two are solo. The second solo paper is an excerpt from Clara’s PhD thesis. Clara’s work concerned solution chemistry, one of the main preoccupations of physical chemistry at the time, and revolved about the connections among the conductivity, solubility, degree of dissociation, electrochemical potential and what was called electro-affinity.

The paper with Abegg, which expanded on the ideas of the 1899 Abegg-Bodländer paper that introduced the notion of electro-affinity as an organizing principle in chemistry (Abegg and Bodländer 1899), pretty much determined the topic and methodology of Clara's thesis paper. The thesis paper dealt in a more systematic way with the interplay between solubility of choice heavy metal salts and the electro-affinities of the constituent groups and atoms. Apart from providing tables of experimentally determined values of quantities such as equilibrium concentrations and relative electrode potentials, the paper aimed at assessing the issue of whether electro-affinities were additive quantities. The latter might be the reason for the relatively high number of citations (24) this paper has so far received.[3] However, one should keep in mind that quite a few of the publications citing Clara's paper are recent biographical articles about Clara rather than scientific papers.

Clara's second paper aimed to expand the solubility data base to include copper salts, using the ideas and methods developed by Walther Nernst, Wilhelm Ostwald and Friedrich Wilhelm Küster. The last was Clara's professor at the University of Breslau, who also deserves credit for arousing her interest in physical chemistry. He moved to the Bergakademie in Clausthal in 1899 and it was in Küster's Clausthal laboratory that Clara undertook the measurements reported in her second paper. As she noted, her data could be regarded as a corroboration of the Nernst-Ostwald-Küster theory.

Clara's PhD adviser Richard Abegg became well known for his work on valence that led to the octet rule. Clara's work on electro-affinity was somewhat related to this line of Abegg's research, but her contribution was not deemed significant enough to warrant Clara's inclusion in Svante Arrhenius's list of half a dozen or so of Abegg's former affiliates who had contributed to Abegg's research the most (Arrhenius 1910). To be sure, Sackur was not on that list either. However, Sackur made a name for himself in a research area that lay outside of Abegg's range of interests and published his key work only after Abegg's death (Badino and Friedrich 2013). It should also be noted that Clara's work, unlike Abegg's or Sackur's, did not seek to enrich the conceptual framework of physical chemistry in any way or to launch a new research direction.

Apart from her work as a researcher, Clara also gave public lectures, both in Breslau and later in Karlsruhe, on the broad topic of science in the household. Inspired by Lassar Cohn's popular book *Chemistry in daily life*,[4] Clara's lectures attracted audiences of up to one hundred women (Szöllösi-Janze 1998, 194).

[3] As of 7 September 2016.

[4] The book was translated into many European languages. Its author would become professor of chemistry at the University of Königsberg.

4 Clara's Husband: Fritz Haber

Apart from Abegg and Sackur, there was another pioneer of physical chemistry who entered Clara Immerwahr's life, namely Fritz Haber[5] (Fig. 2). Likewise a native of Breslau, Fritz likely met Clara at a dancing class (Szöllösi-Janze 1998, 124f). Little is known about this liaison, but Haber would later admit, at the occasion of his engagement with Clara in April 1901, that he was "in love with [his bride] as a [high school] student" and that during the intervening years he had "honestly but unsuccessfully" tried to forget her (Haber 1901). When the freshly minted Dr. Immerwahr appeared in April 1901 at the annual conference of the German Electrochemical Society in Freiburg—as the only female scientist—the affair between her and Haber was quickly rekindled.[6] As Haber would put it later in one of his letters (cf. Szöllösi-Janze 1998, 735, fn. 165), "we saw each other, we spoke and in the end Clara let herself be persuaded to give it a try with me." Clara would describe her motives for her acceptance of Fritz's advances in the already mentioned 1909 letter to her confidant Abegg:

> It has been my approach to life that it was only then worth living if one developed all one's abilities to the utmost and lived through everything that a human life can offer. And so I finally settled upon the idea of marriage […] under the impulse that if I did not marry a decisive page in the book of my life and a string of my soul would lie idle. But the boost that I got from it was very short (Haber 1909).

As Margit Szöllösi-Janze, the biographer of both Fritz and Clara Haber, pointed out, their wedding, which took place already on August 3, 1901, marked the end of "the chapter 'chemical science' in Clara's book of life" which "must have been clear to the chemist" even without "any effects on the string of her soul" (Szöllösi-Janze 1998, 129).

Upon looking at the last decade of Clara's life, one has to agree. Although at the beginning she may have harbored the hope that she would be able to resume her scientific work at some point, she must have increasingly let go of such hopes as time went on. During the first years of her marriage, Clara appeared at lectures as well as in the laboratories of the Technische Hochschule in Karlsruhe, where her husband would soon become the founding director of its institute for physical chemistry and electrochemistry.

Moreover, it seems that at the time Fritz Haber would involve his wife in his research and share with her his scientific ideas, as suggested by the dedication of his 1905 classic textbook *Thermodynamics of technical gas-reactions*:

> To my dear wife Clara Haber, Ph.D., in gratitude for her silent co-operation (Haber 1908).

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[5]Fritz Haber's authoritative biographies have been written by Szöllösi-Janze (1998) and Stoltzenberg (2004).

[6]In fact Haber asked Abegg to take Clara along to the Freiburg conference.

However, Clara was apparently not involved in doing any calculations for the book, as implied by the fact that this task fell to others (Haber 1908, x).

Nevertheless, that Clara's involvement in Haber's research entailed more than a silent co-operation transpires in her correspondence with Abegg, in which she reports about Haber's progress in writing the textbook, discusses academic appointments, and solicits advice about her own public talks. However, the dream of an equitable and reciprocal scientific marriage—such as that of Pierre and Marie Curie in Paris—did not come true.

The turning point likely occurred when their son Hermann was born in 1902[7] and/or when Haber became *Ordinarius* at Karlsruhe in 1906. Hermann was a sickly child, who claimed a lot of his mother's attention. Clara cared for the son lovingly while at the same time running a demanding household. At the beginning, the young family could not afford service staff and so Clara had to do a lot by herself. In a letter to Abegg written in 1901 from Karlsruhe, Clara declared that she would get back to the laboratory

> … once we become millionaires and will be able to afford servants. Because I cannot even think about giving up my [scientific work] (Haber 1901).

As we know, the Habers did get rich,[8] but nevertheless Clara would never return to the laboratory, despite Haber's positions as *Ordinarius* at Karlsruhe and later director of a Kaiser Wilhelm Institute. As the years went by, she would fall increasingly into the traditional role of a representative professorial wife, a housewife preoccupied with the well being of the family and a caring mother. This was aggravated by Haber's sharp-elbow mentality and his obsession with his work and career, which left little room for Clara's professional development and reduced her more and more to a mother/housewife. Clara broke down as a result and, as Szöllösi-Janze put it:

> the heyday that Haber had lived through in Karlsruhe was for his wife Clara her intellectual twilight (Szöllösi-Janze 1998, 353).

Clara saw it herself and committed her feelings to paper in her above mentioned letter to Abegg from 23 April 1909 where she said that

> [Fritz is a type of person] on the side of whom every other person who does not force his way even more recklessly at the other's expense than him, will perish. And that is the case with me (Haber 1909).

There were still six years left until Clara's voluntary exit from life on May 2, 1915. During this time Fritz Haber would enjoy further scientific and social ascent: in 1909, he laid the scientific foundations for the catalytic synthesis of ammonia from its elements ("bread from air") and in 1911 he became the founding director of the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry in Berlin.

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[7]This appears similar to the crisis of the marriage between Albert Einstein and Mileva Maric.

[8]Fritz Haber was awarded the patent rights for the ammonia synthesis in 1910, Szöllösi-Janze (1998).

Thereby Haber reached not only the Olympus of science in Germany but of science full stop. Clara could partake in the glory of it all—however not as a scientist but rather as a spouse of a scientist, a difference that the sensitive and earnest Clara surely must have reflected upon. The growing alienation of the couple was obvious to their contemporaries for whom

> the wearing down and the difficulties between the spouses were not of a petty kind but rather fundamental (Noack 1959, 301).

The strains and conflicts between Clara and Fritz further aggravated after the outbreak of WWI. In keeping with the maxim "In peace for mankind, in war for the fatherland,"[9] Fritz Haber applied himself in extraordinary ways to aid the German war effort (Stern 2011; Dunikowska and Turko 2011; Friedrich and James, this volume).

In part encouraged by the French use of tear gas (Haber 1924)—including its lethal variants—Haber took the initiative to employ chemistry in resolving the greatest strategic challenge of the war, namely the stalemate of trench warfare. Brought to glistening prominence by Germany's need to produce "gunpowder from air," Haber, backed by the profiteering chemical industry, was able to persuade his country's military leadership to stage a battlefield test of a chemical weapon—of "poison instead of air." This would earn him the epithet "father of chemical warfare."

The lethality of the April 22, 1915 chlorine cloud attack at Ypres lured the German military into adopting chemical warfare. Haber was promoted, by an imperial decree, to the rank of captain.

Haber celebrated the "success" at Ypres and his promotion at a gathering in his directorial mansion in Dahlem. The gathering took place in the evening of May 1, 1915. Afterwards, during the night from May 1 to May 2, Clara Haber committed suicide. She shot herself, with Haber's army pistol, in the garden of their mansion. Apparently, Haber, sedated by his daily allowance of sleeping pills, didn't hear the shots (there were two). Clara was found dying by their thirteen-year-old son Hermann.

5 Clara Haber's Suicide

Most of the materials related to Clara's suicide were generated nearly four decades later via interviews for the so-called Jaenicke Collection, named after Johannes Jaenicke (Hahn 1999), a Haber collaborator who planned to write Haber's biography and who headed the forerunner of the Archive of the Max Planck Society (Henning 1990). Mentions made in memoirs and personal correspondence of

[9] Usually quoted in this abbreviated form. For a full quote in German, cf. Haber (1920). Haber was referring to the attitude of Archimedes.

people who knew the Habers provide additional tidbits, albeit sometimes only between the lines. The coincidence of the suicide with the chlorine cloud attack at Ypres and Fritz Haber's key role in it gave rise to speculation and there were—as noted by Jaenicke—"numerous contradictory versions in circulation" (Jaenicke 1958). The Haber family treated the tragic event with utmost discretion, as a result of which there are no primary sources available, such as farewell letters, that would clarify the motive. Likewise, there are essentially no authentic contemporary testimonials available that shed light on the tragic event. Almost all of the extant testimonials are from the 1950s and 1960s, solicited and gathered by Johannes Jaenicke for his collection.[10] Twenty years earlier, in early 1940s America, Morris Goran, about whom little is known, except that he held a position at Roosevelt College in Chicago at some point, attempted to interview German émigré scientists about the German scientific establishment in general and about Fritz Haber in particular, however, with a mixed success. For instance James Franck, upon being contacted by Goran, characterized him as "the terrible guy in America [Goran], who wants to prove what a [great] man he is by writing about Fritz Haber" (Jaenicke 1958). In 1947, Goran published a rather hagiographic article about Fritz Haber (Goran 1947) and in 1967 a book *The Story of Fritz Haber* (Goran 1967), which contains a brief passage about Clara's suicide. In the passage, Goran stated that Clara was "vitally affected" (Goran 1967, 71) by her husband's involvement in WWI chemical warfare and committed suicide after a heated argument with Fritz about what she considered to be "a perversion of science" and "a sign of barbarism" (Goran 1967, 71). Goran gives no evidence or sources for either this scenario or these statements. Apparently, the much-quoted phrase about the perversion of science and barbarism, ascribed to Clara, is Goran's own. Apart from his political and moral categorization of Clara's suicide, Goran also points out for the first time that Clara was depressive and that

> chemical warfare was an avenue or excuse for the morbid worry she seemed to favor (Goran 1967, 71).

However, Goran doesn't give any references here either, which led Margit Szöllösi-Janze to the characterization of his book as one where "the line between a historically correct study and fiction is blurred" (Szöllösi-Janze 1998, 395).

In her Haber biography, Szöllösi-Janze has already critically evaluated the sources about Clara and her suicide that can be found in the Jaenicke Collection (Szöllösi-Janze 1998, 393–399), with the conclusion that the motives for Clara's suicide are as unclear as the available sources are ambiguous—and rare. However, the possible motives can be divided into two groups, listed on the left and right side of Table 1: on the left are sources suggesting that Clara's suicide had to do with Fritz Haber's engagement in the German war effort/chemical warfare and on the right with her unfulfilling personal (and absent professional) life and with depression.

[10]The individual items of the Jaenicke Collection have never been published.

Table 1 Possible motives for Clara Haber's suicide. Left: Sources suggesting that the motive had to do with disagreements about Haber's involvement in the German war effort. Right: Sources suggesting that Clara's suicide had to do with disagreements about personal matters and/or her depression

Disagreements about Fritz Haber's involvement in German war effort	Disagreements about personal matters; depression
Hans Krassa (1957); Archiv MPG[a]	Haber (1909); letter to Abegg[c]
Franck (1958); Archiv MPG[b]	Haber (1915); letter to Tamaru[d]
Goran (1967); source not given	Hahn (1915); letter to Otto Hahn[e]
Mendelssohn (1973); source not given	Meitner (1915); letter to Edith Hahn[e]
Von Leitner (1993); sources: either not given or Goran, Lütge, Lummitzsch tapped selectively	Lummitzsch (1955); Memoirs[f]
	Noack (1959); Archiv MPG[g]
	Goran (1967); source not given
	Lütge (1958); Archiv MPG[h]
	Haber (1970); Memoirs[i]
	Ebbinghaus (1993); review of von Leitner's book[j]

[a]Krassa (1957)
[b]Jaenicke (1958)
[c]Haber (1909)
[d]Clara (1915)
[e]Meitner (1915)
[f]Lummitzsch (1955)
[g]Noack (1959)
[h]Lütge (1958)
[i]Charlotte (1970)
[j]Ebbinghaus (1993)

Hermann Lütge, the former fine-mechanic at Haber's institute,[11] when asked by Jaenicke whether Clara committed suicide in response to "Haber's involvement in the abhorrent gas warfare" and whether Clara's "ethical asperity was a consequence of a hereditary depressive disposition," stated the following:

> No, this is not to be presumed. Frau Geheimrat [Clara] … was not in a state of mind to contemplate the abhorrence of chemical warfare … Yes, sometimes was Frau Haber gloomy, especially after being harshly rebuffed for mothering her husband too much (Lütge 1958, 260).

A similar answer was given to Jaenicke by Adelheid Noack, the niece of Clara's brother-in-law:

[11]Clara was the godmother of Hermann Lütge's son (private communication, Michael Lütge, 2016).

> There are various more or less pathetic accounts of her [Clara's] suicide, for instance that she had beseeched him [Fritz Haber] to abandon chemical warfare. These accounts are a nonsense (Noack 1959).

This is contrasted by James Franck's opinion, who stated in his conversation with Jaenicke that Clara was

> a good, talented person with distinct views, which often contradicted those of her husband … she wanted to reform the world. That her husband was involved in chemical warfare had surely an effect in her suicide (Jaenicke 1958, 1449).

However, Franck added that Fritz Haber

> expended an immense effort to reconcile his and [Clara's] political and human views.

Another proponent of the view expressed by James Franck was the physical chemist Kurt Mendelssohn, who had worked before his emigration in 1933 in both Berlin and Breslau.[12] In his book *The World of Walther Nernst* he stated:

> … there was a macabre sequel to his [Fritz Haber's] decision to develop poison gas. His wife, Dr. Clara Immerwahr, who was also a chemist, had pleaded with him [Fritz Haber] again and again not to work on gas warfare. His answer was that his first duty was to his country and that no argument, not even the entreaties of his wife, could shake his resolve. On the evening of Haber's departure for the front, Clara committed suicide (Mendelssohn 1973, 83).

An additional testimonial about a possible role of chemical warfare in Clara's suicide was delivered by her cousin Hans Krassa, according to which Clara visited Krassa's wife shortly before the suicide to confide to her about the "gruesome effects" of chemical warfare that she had witnessed, in particular the "testing on animals" (Krassa 1957, 1470). Krassa, however, added that other factors may had been at play as well. As far as Clara's disposition was concerned, Krassa stated that "the word gloom goes too far" and that "one certainly cannot speak of a hereditary depression."

That Clara was "exceedingly nervous," especially in the last years of her life, can be found in the testimonial by Otto Lummitzsch, the adjutant of the commander of the gas troops, who witnessed a visit by Fritz and Clara Haber at the proving ground in Wahn near Köln. He characterized Clara as

> a nervous lady, who was already then in sharp opposition to Geheimrat Haber's ventures to the Front along with the gas troops (Lummitzsch 1955).

This quote further attests to Clara's habit of "mothering" her husband.

Another aspect of Clara's personality transpires in the manner she behaved and dressed. According to James Franck,

> [Haber] liked to represent, whereas [Clara] exaggerated the simplicity of her manner and she dressed poorly – [perhaps] as a protest? (When I visited [the Habers] for the first time, the door was answered by a person whom I held for a cleaning woman. And I thought that it

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[12] It is conceivable that James Franck was in fact the source of Mendelsohn's account.

would have been fitting if in such a fine household [as Habers'] the cleaning woman had dressed a little more nicely – but it was Frau Geheimrat [Clara] herself) (Franck 1958).

Out of the rest of the testimonials on the right of Table 1 we would like to bring to the fore additional tidbits provided by Adelheid Noack and by Hermann Lütge. In her conversation with Jaenicke, Noack also mentioned that Clara was "horrified by anything sensual," in keeping with the fact that she had quit the marital bedroom in 1902, never to return to it (Noack 1959). This fact as well as Noack's testimonial was corroborated by Haber's second wife, Charlotte Nathan, who had access to such intimate information more than anybody else (Haber 1970, 83 and 89). A real bombshell was dropped by Hermann Lütge, who testified that during the fateful night of May 1–2, 1915, Clara caught her husband *in flagranti* with Charlotte Nathan (Lütge 1958, 260). Charlotte worked as a manager of the then incipient club "Deutsche Gesellschaft 1914," where she and Haber got to know each other and was invited to the grand celebration of the "success" at Ypres in Habers' mansion (although Charlotte later contradicted it). The sociologist Angelika Ebbinghaus (Ebbinghaus 1993) as well as the historian Margit Szöllösi-Janze (Szöllösi-Janze 1998, 398) indicated that they tend to the view that Clara's discovery of her husband's affair may have been the actual trigger for her suicide.

Although provided by contemporaries, the above testimonials had been delivered with a delay of about 50 years, which makes them historiographically problematic. However, there are two recently surfaced documents that had been written within days of Clara's suicide and that answer some of the questions posed in connection with it: they are the letters (dated May 5, 1915) by Edith Hahn, the wife of the chemist Otto Hahn, to her husband and the letters (dated May 6 and 9, 1915) by Lise Meitner, Otto Hahn's collaborator and colleague at the Kaiser Wilhelm Institute for Chemistry,[13] to Edith Hahn. These letters, recently published by Eckart Henning (Henning 2016), the former director of the Max Planck Archive, confirm that Clara was mentally unstable. So Edith Hahn wrote:

Of course was the woman [Clara] ill, she'd been always strange – everybody was mocking her (Hahn 1915).

And Lise Meitner reports that

as of late [Clara] had always made an impression of being agitated (Meitner 1915).

The letters also agree that the reasons for Clara's act of desperation were to be found in her private life. Edith Hahn wrote to her husband that

he [Fritz Haber] [was] guilty. I have the feeling that she was [strongly] attached to him and that he treated her badly – or at least quite indifferently, and that she suffered more than we can imagine. Recently, she complained [to me] that he would never write to her [from the front], this came out inadvertently and was so sad that I lied to her that you write to me only seldom [as well] and [pointed out to her] that her husband has had even less time [than you

[13]The KWI's for Chemistry and for Physical Chemistry and Electrochemistry were located next to each other—and the on-campus Haber mansion.

> did]. Poor, poor woman. I've had always the feeling that he was fed up with her, which I could understand to a certain extent (Hahn 1915).

In line with this, Lise Meitner wrote that

> she [Clara] has recently made remarks to the effect that she was unhappy in her marriage. And that he [Fritz Haber] is not exactly an affectionate person. Anyway, it's a very sad story (Meitner 1915).

That the likely reasons for Clara's suicide were personal is supported by yet another contemporary document. At the turn of 1914/1915, an exchange of letters took place between Setsuro Tamaru, Haber's former Japanese collaborator, who had to leave Germany after the outbreak of the war, and Clara Haber. In his lengthy letter, written on Christmas Eve 1914, Tamaru complains about his personal situation as a guest in Theodore Richard's laboratory at Harvard, characterized by personal and scientific isolation; about being forced to leave Germany; and about receiving "not a single line whatsoever, no reply from Herrn Geheimrat [Fritz Haber]" (Tamaru 1914). Furthermore, Tamaru's six-page letter is concerned with the political and military situation during the first year of WWI and contains Tamaru's stance regarding war and peace:

> I am a pacifist of sorts and am always against war. A war doesn't decide anything, just breeds the next war (Tamaru 1914).

In her equally lengthy reply, Clara in no way reacts to Tamaru's stance and describes the "melancholy of our separation" and "your [Tamaru] being missed at the Christmas table" instead (Haber 1915). The silence of Fritz Haber and of others at the institute Clara explains by pointing out that

> … my husband is working 18-hour days, almost always in Berlin, I'm taking care of 57 poor children[14] and Hermann [the son] has been ill since November … Apart from that we are all adversely affected by the outrage and the dull pressure [of the war] that disable any impulse to do anything else than to help the country in the few remaining hours [of the day] (Haber 1915).

Clara also provides a brief report about Otto Sackur's "terrible accident" and the shock she suffered as a result and concludes by stating:

> To your political contentions, which were very interesting for us [to read], I will not respond; I am too ignorant in the matters of foreign affairs to be able to properly answer [your points]. You are certainly right in many respects, but have somewhat one-sided views on some points (Haber 1915).

Even if one takes into account that at the time international correspondence was subject to censorship, what transpires in Clara's letter is a woman made heavy-hearted by human suffering and the burdens of the war rather than a political activist or indeed a pacifist. This makes quite questionable the image of Clara, created in the 1990s—see below—according to which she was an outspoken

[14]Clara ran a makeshift kindergarten that made use of the premises of Haber's KWI. The fathers of the "57 poor children" were on the front and their mothers had to work in order to make ends meet.

pacifist. Likewise questionable is Clara's opposition to her husband's involvement in chemical warfare and thus the subsumed motive of her suicide as having been connected with it. So Dr. Kremmer, the principal of Hermann Haber's school, described in his condolence letter to Hermann upon the death of Fritz Haber how Hermann's "Frau Mutter" came to him

> to report on the success of the first gas attack at Ypres right after receiving a telegram from the front about it (Kremmer 1934).

And Hermann Lütge, in his testimonial, stated that

> the boss [Clara] was proud of the services provided by her husband (Lütge 1958).

Another controversy connected with Clara's suicide concerns Fritz Haber's behavior during the aftermath of the harrowing event. Haber's departure for the eastern Front the same day (May 2) was often portrayed as a reckless abandonment of his thirteen-year-old son Hermann and a sign of callousness and egotism. Even Szöllösi-Janze argues that the visibly shaken Haber may have regarded the Front as a place to which he could escape from the tragic reality at home. However, the above-quoted letter by Lise Meitner sheds new light on this aspect as well:

> As you know, Haber was supposed to leave in the morning, but stayed until the evening, when he was [finally] forced to depart. I'm told that he inquired at the [military] headquarters whether, out of consideration for the unfortunate event, he could postpone his departure, but his request was denied (Meitner 1915).

Although Lise Meitner qualified her statement by adding "Whether it's true, I of course don't know," the passage nevertheless suggests that Haber was not as unfeeling a chemical warrior who left his son in the lurch without a reason as had been previously conjectured.

6 The "Myth of Clara Immerwahr"

The scarcity and ambiguity of the historical record notwithstanding, during the 1990s a narrative took root according to which Clara Haber was supposedly a pacifist and decisive opponent of chemical warfare, in contrast to her husband Fritz Haber, who was chemical warfare's main proponent and Clara's oppressor to boot. It appears that this narrative was catapulted into the public sphere in Germany and beyond by Gerit von Leitner's book *Der Fall Clara Immerwahr. Leben für eine humane Wissenschaft*, published in 1993 (second edition 1994) as well as various dramatizations derived from it. In it, Clara is presented as an outspoken pacifist (not unlike the Czech-Austrian 1905 Nobel Peace Prize laureate Bertha von Suttner) and a star scientist (not unlike Marie Curie) who was destroyed—as both a person and a scientist—by her oppressive and opportunistic husband. The sources in von Leitner's book are either not given or tapped selectively, so as to provide a spotless image of Clara while portraying Fritz Haber as a kind of Dr. Evil. Von Leitner's account ignores other sources that suggest that the reasons for Clara's suicide may have had to do with her private life. These testimonials or opinions are listed on the right in Table 1.

The emphasis on Clara's 1909 letter to Richard Abegg (Haber 1909) is a case in point. Written on funeral stationary and opening with a tirade about her inability to locate a fountain pen (described—in pencil—on two pages out of twelve), Clara denounces her husband and details her unfulfilling life with him. The letter may have been triggered by jealousy, after Abegg, during his visit to Karlsruhe, congratulated Fritz Haber on his discovery of the catalytic synthesis of ammonia without mentioning Clara (Ebbinghaus 1993). Clara, however, had not been involved in research—her own or Haber's—since about 1901, as she had acknowledged in the same letter. The letter is special in that it is the only one written by Clara to Abegg (or anybody else for that matter) where she had lost her nerve and complained about Haber and their marriage.

Von Leitner's book (Leitner 1993) apparently struck a chord with the *Zeitgeist*, as it had been well—in some cases even euphorically—received not only in feminist and pacifist circles but also by a majority of German literary critics writing for Germany's leading newspapers and magazines. So, for instance, Volker Ullrich published in *Die Zeit* a review where he paid tribute to von Leitner's book as

> one of the best examples of a new, woman-inspired form of writing history, … a fascinating historical portrait … that reveals what was covered up and concealed for decades (Ullrich 1993).

Ullrich's review became emblematic for the reception of the book by other critics and its tenor can be found in many additional, roughly thirty reviews that we could identify, published in leading supra-regional newspapers such as *Frankfurter Allgemeine Zeitung*, *Frankfurter Rundschau*, *Die Welt*, *Süddeutsche Zeitung*, *Die Tageszeitung*, in regional periodicals such as *Sächsische Zeitung*, *Tagesspiegel*, *Westfalen Blatt*, *Main Echo, Emsdettener Tageblatt*, as well as in journals like *Emma*, *1999*, *Zeitschrift für Sozialgeschichte*, or on ARD radio stations. And the *New York Review of Books* chipped in as well (Perutz 1996). Time and again, the reviews had made a connection to contemporary events in the 1990s, including misuse of scientific research by the military and the Gulf War 1990–1991. Another issue discussed in the reviews, one that touches upon the core of von Leitner's book, is that of equality in scientific/academic marriages such as that of the Habers and the fostering of academic careers of female scientists. All that lent relevance to von Leitner's book vis-à-vis the political trends and debates of the 1990s and made it into a vehicle for furthering the opinions, ideals and *Wunschbilder* of the peace movement, feminism and antimilitarism. Clara's attempt to have a self-determined life as a woman, mother and scientist as well as her tragic suicide are interpreted as a "[beacon of a] feminine, life-preserving science" and juxtaposed with the male, patriarchal power-oriented science concerned with the exploitation of resources.

Volker Ullrich's review is a prime example of such an interpretation of von Leitner's book that had over time acquired an almost paradigmatic character. As apodictic appear Ullrich's statements according to which von Leitner tore down "the veil of falsified legend built [around Fritz Haber]." However, what had been overlooked is that, through the back door, another legend was being ushered in: the myth of Clara Immerwahr. According to this myth, Clara committed suicide in opposition to the gas warfare and as a desperate protest against the development of weapons of mass destruction by her husband, whose effort was contemptuous of human life. This interpretation is not only too monocausal and simplistic, but is difficult to support by the available historical sources, as already outlined above; in the best case, it can be viewed as a catchy hypothesis lacking supporting evidence. Incidentally, a criticism of this sort had been already leveled against von Leitner's book by several reviewers during the 1990s. For instance, the historian of science Ernst Peter Fischer writing in *Die Tageszeitung* (and also *Weltwoche*) denounced not only the stylistic and substantive shortcomings of the book, characterizing it as a "total failure [*total misslungen*]," but he also pointed out that because of the missing references it is unclear whether the book is a "reliable rendition [of historical facts]" and how one-sided its interpretations are (Fischer 1993a, b). A similar argument was presented in the review by the historian Jakob Vogel in the *Frankfurter Allgemeine Zeitung*, who noted that

> a personal fate whose meaning comes about through a true-to-life contrariness [is sacrificed to] political correctness (Vogel 1993).

The main deficiency of von Leitner's book was also commented upon by the sociologist Angelika Ebbinghaus in *1999. Zeitschrift für Sozialgeschichte des 20 und 21. Jahrhunderts*, where she pointed out that the documented fragments of Clara's life

> could have provided the basis for a novel. Such a novel could have rendered the historical truth without necessarily being literally true. A biography, however, must fulfill other criteria, namely whether reality at least resembled that what has been presented.

Although von Leitner chose the scholarly genre of biography rather than novel—she ditched the standards of scholarship in the process of writing her account, such as documenting her statements by critically evaluated references. In her account she often puts statements/opinions in the heroine's mouth or describes situations involving the characters of her book for which no record or evidence exist. For instance, she states that "Clara admired the courageous Bertha von Suttner" and even describes a scene in which Clara discusses women's rights with her husband and takes the side of von Suttner. A partial list of statements and quotations appearing in von Leitner's and other accounts of Clara Haber's relation to chemical warfare that are of unknown origin have been listed elsewhere (Friedrich and Hoffmann 2016).

Since neither Clara nor Fritz Haber left behind diaries or correspondence from which such opinions, conversations or situations could be reconstructed, these and other passages in von Leitner's book can only be regarded as an unscholarly mixture of fiction and historical fact. Of particular significance is von Leitner's contextualization of Clara's suicide, as this is presented as a decisive protest against the development and use of chemical weapons, as a signal "against the chemical mass destruction" (Leitner 1993) and as (Kokula 1988).[15]

> a signal for a new definition of natural sciences that had not been heard.

The evidence provided by historical sources is too thin for such a strong hypothesis, not to speak about von Leitner's handling of the historical record. Therefore, we cannot but agree with an earlier assessment by Szöllösi-Janze that:

> As regards the viability and validity of the sources, the record about the last months of Clara Immerwahr's life during the First World War consists chiefly of gaps rather than proven knowledge (Szöllösi-Janze 1998, 395).

Despite all these defects and their explicit critique in the press as well as in Szöllösi-Janze's authoritative Haber biography, the image of Clara Haber, nee Immerwahr as an outspoken pacifist and opponent of chemical warfare prevails in the public awareness until this day.

Herein, we plead for a more differentiated view based on the available historical record, according to which Clara Haber's suicide appears to have likely been the result of a "catastrophic failure" (to borrow an engineering term as a metaphor) brought about by a most unfortunate confluence of a host of circumstances that included, apart from her unfulfilling life, Haber's philandering, the tragic deaths of her close friends, Richard Abegg and Otto Sackur, as well as the death and destruction of the war itself, amplified by the perversions of chemical warfare.

7 Epilog

Our intention has been to make the above points without belittling in the least Clara's achievements and courage. Honoring Clara, for instance through the Clara Immerwahr Award of the Nobel-Prize winning organization International Physicians for the Prevention of Nuclear War (IPPNW) or the Clara Immerwahr Prize of the Berlin Excellence Cluster UniCat, is highly to the point and should not be questioned in any way. Haber's institute, named after its founding director in 1952 and incorporated into the Max Planck Society in 1953, had a memorial built for Clara in the garden of the institute in 2006 (Fig. 3).

However, we should refrain from projecting our contemporary ideas about women's rights activists or peace activists on Clara Haber in an ahistorical way.

[15]Kokula is the maiden name of Gerit von Leitner.

Fig. 3 *Left panel* Gravestone of Fritz and Clara Haber at the Hörnli Cemetery in Basel. In his testament, Haber expressed his wish to be buried alongside his first wife Clara—in Dahlem if possible, or elsewhere "if impossible or disagreeable." Haber's son Hermann became the will's executor. In accordance with this will, Clara's ashes were reburied beside Fritz Haber's in Basel. Photo: Archiv der Max-Planck-Gesellschaft, Berlin-Dahlem. *Right panel* Memorial for Clara Haber in the garden of the Fritz Haber Institute, installed in 2006. The photo by one of the authors (BF) shows the memorial at the centenary of Clara's suicide, on May 2, 2015

What she achieved in her time does not need to be embellished with exaggerations or even wishful thinking fashioned by present-day aspirations. Her achievements speak for themselves and should not be degraded or even compromised by mixing them up with fabrications and *Wunschbilder*.

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Addition to Open Access Information

France's Political and Military Reaction in the Aftermath of the First German Chemical Offensive in April 1915: The Road to Retaliation in Kind

Olivier Lepick

Abstract Although France had been experimenting with chemical weapons when Germany launched its first lethal chemical offensive in spring 1915 in Langemark, the German initiative came as a huge tactical surprise to the country. Soon after the initial shock and the controversy that ensued on whether Germany had violated the laws of war that day, French authorities rapidly decided, without real political debate, to retaliate in kind. Although the country had to face heavy constraints, and due to a considerable scientific, industrial and financial effort, the French army was able to launch its first drifting cloud chemical attack on the battlefield only a few months after the German offensive. In the storm of the war and at this stage of conflict, when urgency was the only consideration and political influence far less than military, the French authorities did not realize that adopting chemical weapons in retaliation, ten months before Verdun, was one of the steps that would lead to the totalization of warfare and characterize the rest of the Great War.

1 Introduction

The sudden outburst of chemical warfare initiated by Germany in April 1915, which constituted a deliberate violation of the laws of war, dealt a real shock to French public opinion. Nevertheless, the decision was taken quite soon after to retaliate in kind. The French authorities launched a major industrial and scientific endeavor. And indeed, only a few months after the German surprise attack in Langemark, and despite many obstacles, the French army was ready to launch its first chemical offensive. The purpose of this paper is to describe the first days, weeks and months of the French response to the German chemical initiative, as well as the political and military context in which the decision to retaliate in kind was made by French authorities.

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The day after the German chemical attack on April 22 in the region of Ypres, a lively polemic broke out between France and Germany, the two protagonists, each blaming the other for unleashing chemical hostilities. German arguments rested in part on the existence of a French note dated February 21, 1915, which gave instructions about the use of suffocating grenades and cartridges. The existence of these materials was confirmed by Ulrich Trumpener in a brilliant article published in 1975 (Trumpener 1975). This article proved, for the first time, and beyond any doubt, that even if the Germans were the first to introduce a lethal form of chemical warfare during the First World War, France had already used non-lethal chemical agents on the battlefield before April 22 (Haber 1986, 32–33; Lepick 1998, 53–66), and, along with Great Britain, the country was already preparing and planning potential military chemical initiatives at the time of the Langemark chemical surprise.

2 Retaliation in Kind: A Purely Military Decision

Looking back at the first days following Langemark, the reaction of the French military authorities to the German initiative was tremendously quick.[1] As soon as April 23, a military pharmacist, Major Charles Didier, who was near Langemark the day of the German chemical initiative, informed the French General Headquarters (GHQ) that the toxin used by the Germans was chlorine.[2] The same day, Ferdinand Foch, commander of the Northern Army Group, organized a meeting at his headquarters with a renowned French chemist in Cassel, André Kling. The very same day Kling, who was Director of the Paris City Laboratory, started to investigate the issue by visiting hospitals, meeting with victims of chemical weapons, and ordering many post-mortem examinations. As Didier's conclusions about chlorine were rapidly confirmed, Kling immediately began working to develop protective devices for frontline soldiers. On April 24, the first crude orders were issued to field commanders. Foch also asked the Ministry of Industry to provide some input about possible protective devices that could be used by the army, while Paul Louis Weiss, head of the Mines Directorate of the Ministry for Public Works (*Travaux Publics*), proposed to use the know-how of the mining industry regarding respiratory devices to help the GHQ provide means of defense to the armed forces.[3]

[1]It is puzzling to consider that, contrary to the British historiography, there are only very few studies dealing with the French response to the German chemical initiative following April 22, 1915. The only serious study of the history of French chemical warfare during the First World War is the minutes of a lecture that was given in March 1920 by Professor Charles Moureu from the Collège de France, which was later published as: Moureu (1920).

[2]Letter from Charles Didier to the General Commander Army Group Belgium, April 23, 1915, Service historique de l'armée de terre, Vincennes, SHAT/16N826.

[3]Report on the organization of war chemical materials by House Representative Alain Albert d'Aubigny, August 25, 1915, p. 1, Service historique de l'armée de terre, Vincennes, SHAT/16N826.

On April 25 the French Ministry of War decided to begin the production of a crude respiratory protection that was mainly composed of a tissue containing a sort of bag filled with cotton. The device was to be soaked with thiosulfide just before the poisonous cloud reached the first lines, and secured over the mouth in order to neutralize the chlorine before it reached the soldier's lungs. Two days later, the first shipments were leaving for Flanders. By mid-May, more than 500,000 of these protective masks had been distributed to the field.

It is clear that, in contrast to what happened in Great Britain, there were no real political debates at the highest echelons of the French government about whether or not to retaliate. All political authorities were convinced that the decision to retaliate in kind was a military necessity, and proclaimed as one united voice that this kind of warfare was simply abhorrent. French military authorities found absolutely no opposition to their willingness to retaliate. Less than 48 hours after the German offensive in Langemark, military and political leaders had agreed on the fact that the country was to respond to the German initiative as soon as possible.[4] Nevertheless, how can we explain the absence of political input concerning such an important decision, especially since the use of new weapons that could lead to political consequences was strictly controlled by the civil political authorities? Initially, at this point in the conflict and up to the dismissal of Alexandre Millerand as Minister of War in October 1915, the French government's policy was not to interfere in the conduct of the war. At no other point during this conflict had the French GHQ enjoyed such great room for maneuver, such independence from political influence. Furthermore, the French government deemed that the German attack had liberated France from its obligations accruing through its signature to the Hague Convention. From a governmental perspective, the decision to retaliate in kind was purely technical and military and fully in within Foch's ambit. And Foch's decision was taken a few hours only after the April 22 attack. On April 25, General Maxime Weygand captured the general opinion in the country by stating:

> The Germans took the initiative to use inhuman means of warfare that had been banned by international treaties. But for us, it was not about procedures but about preparing as fast as we could the means to protect ourselves and retaliate in kind to these attacks […]. A new step toward total warfare has been taken by our enemies.[5]

On April 26, the Ministry of War asked all French chemical companies to report the amount of chemicals in their stocks which could be used to respond to the German initiative.[6]

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[4]On this subject, the following books are highly valuable: Joffre (1932); Poincaré (1930, 173, 350).

[5]Les Allemands avaient pris l'initiative d'un moyen de lutte inhumain et condamné par les accords internationaux. Mais il ne s'agissait pas pour nous de procédures, il fallait sans retard trouver à la fois contre ces attaques, la protection et la riposte […]. Un nouveau pas venait d'être fait pas nos adversaires dans la pratique de la guerre totale (Weygand 1953, 225). Translation by the author.

[6]Buat Archives, Service historique de l'armée de terre, Vincennes, SHAT/6N21; Dossier 18, Ministry of War, Notes on the measures adopted following the use of asphyxiating gases by the enemy on April 28, 1915.

Finally, on June 2, 1915 the French government published a press release for the attention of foreign countries. Starting with a vigorous denunciation of the awful techniques used by the German army, which violated all of the treaties signed by the Imperial government, the release closed with the statement that

> no government shall not respond to such barbarian initiatives without endangering its own troops. In this perspective, the French government intends, in the strict limits of its military needs, to use all necessary means that appear appropriate to stop the German military authorities from continuing to commit such horrible murders […]. (Le Temps, 1915)

3 Between Eagerness and Constraints: Organizing the Chemical Response

On April 26, a note from the GHQ was transmitted to all armies. The memorandum summarized the outcome of the interrogation of German prisoners captured near Bixschoote two days earlier. This short text described the defensive measures to be taken in case of gas attacks, and was intended to comfort the troops by stating that "a tissue soaked with the liquid that was distributed on the front lines or even one soaked with water could easily protect the soldiers against these toxic gases."[7]

Very rapidly, the French authorities built the organization charged with directing the national chemical retaliation program.[8] As soon as April 28, a committee composed of both military and scientific representatives was installed under the command of Paul Louis Weiss. Days later, three different organizations were created:

- One commission headed by Kling, tasked with identifying the chemical agents used by the enemy,
- a second headed by Weiss in charge of offensive aspects,
- and a third dedicated to the production of chemical agents, which was headed by the Engineer Corps.

On April 30, the first live experiments with non-toxic fumes took place at the proving ground in Satory (15 km southwest of Paris). On May 4, the first attempt to produce a chlorine cloud was conducted, with limited results. As liquid chlorine was difficult to obtain in the country, other products had to be considered. On June 2, 1915, Weiss, as head of the *Commission des Etudes Chimiques de Guerre* proposed a tentative organization for the military chemical services. He proposed the creation of a completely new directorate attached to the Ministry of War. This proposition was not backed by Albert Thomas, under-secretary for artillery and

[7]Note to the Armies by General Pelle, *Les Armées Françaises dans la Grande Guerre*, Ministère des Affaires Étrangères, Paris, 1922–1939, vol. 2, Annexe N°1451, p. 1017.

[8]The organization of the French chemical warfare services is described very precisely in: Vinet (1919, 1377–1415).

munitions, who wanted to extend his department's responsibilities to chemical warfare. Nevertheless, a consensus was found, and on June 18 a Directorate of Chemical Material (DCM) was installed under Weiss's command.[9] The scope of this DCM's duties was limited to research and development.

In July 1915 a group of representatives requested the creation of a new independent directorate under the Ministry of War. In accordance with the proposal from the GHQ, a colonel named Paul Ozil was promoted to head up this now fully independent DCM, placed in charge of all aspects of chemical warfare for the Ministry of War. Its internal structure remained unchanged until the end of the conflict, consisting of the three different commissions created a few days earlier: R&D, materials, and production.[10] Military camps and proving grounds were soon dedicated to chemical trials, in Satory for the protection of individuals and for small gas emissions, in Fontainebleau for artillery tests, and in Vincennes for explosives and structural tests. One of the first possibilities explored by French researchers was aerial chemical bombing. On June 10, the GHQ suggested to the Ministry of War that "airplanes could be an interesting means to deliver chemical weapons, especially in counter-artillery operations in hidden areas."[11] The initiative was given to General Fernand-Alexandre Curmer, yet rapidly led to the conclusion that, due to the limited amount of toxins that an airplane could carry, the use of airplanes to deliver chemical attacks bore little potential. During the same period, the GHQ was trying to develop measures to improve defenses against drifting chlorine clouds. On May 28, a first order was delivered to all armies, containing instructions for protective measures, but also describing methods to disseminate the clouds by artillery fire—thus exposing the lack of any real solution to respond to this new technology with military means.[12]

4 Chemical War: Scientific War, Industrial War

At the time Germany initiated chemical warfare, France was not in a position to fight and respond to the attack. The Germans were aware of this situation. The French chemical industry and its production were meager, and so were its capacities to produce chlorine, bromine and sulfuric acid. The French military chemical organization had to invest an immense amount of work and resources in order to

[9]Report on the organization of war chemical materials by House Representative Alain Albert d'Aubigny, August 25, 1915, p. 1, Service historique de l'armée de terre, Vincennes, SHAT/16N826.

[10]Letter from the Commander in Chief to the Defense Minister, July 21, 1915, Service historique de l'armée de terre, Vincennes, SHAT/16N832.

[11]"Chemical Shells, 18 septembre 1914–28 septembre 1915," Note from GHQ, June 10, 1915, Service historique de l'armée de l'air, Vincennes, Cartons A54, Dossier 1.

[12]Instructions established by the North Army Corps concerning defense against toxic gases, May 28, 1915, Service historique de l'armée de terre, Vincennes, SHAT/6N7.

provide the French Army with compounds that could be militarized. French chemists rapidly realized that domestic chlorine production capacity was so low that months, or even years, would be needed before a counterstrike could be launched. The possibility was investigated nevertheless, and live tests with chlorine were conducted in May, June and July. Because of the absence of a real chemical industry, French researchers were obliged to turn to other compounds, and delivery methods other than drifting clouds, rather soon reaching the conclusion that artillery was probably the best means of delivery to deploy chemical agents. The first agent available was carbon tetrachloride, which was easy to synthesize. The first promising trials were conducted on the Vincennes Proving Grounds in May and July 1915. As soon as August, Joffre approved production of a first batch of 50,000 shells containing carbon tetrachloride.[13] The shell received the code name "*Obus N°1*"; more than 420,000 were produced and then used in September during the French offensives in Champagne.[14] Nevertheless they were rapidly abandoned due to their lack of efficiency and low toxicity.

This apparent conclusion about the efficiency of artillery shells to deliver chemical agents by French military researchers can probably explain the ineffective performance by the first units, called "*Compagnie Z*," formed to prepare and execute drifting cloud chemical attacks. During summer 1915, two units of 800 non-combat troops were created, and three more in June 1916. These units were to conduct all 51 of the drifting chemical cloud operations that the French Army would launch during the war, the first of which took place in mid-February 1916, more than 10 months after the first German chemical attack (Lepick 1998, 133–174). Many other compounds were under close study by French researchers. The first agent the French researchers seriously planned to militarize was phosgene, one of the very rare toxic chemicals that was produced in large quantities in France. A limited production of shells containing hydrocyanic acid was ordered in June 1915, but surprisingly enough, the French government decided to postpone their immediate use. Because these shells were undoubtedly lethal due to the high toxicity of hydrocyanic acid, their deployment would have represented a clear and obvious violation of the 1899 Hague Convention, which prohibited the use of toxic shells. These shells, the first real lethal ones shot during the Great War, were used only during the battle of Verdun in February 1916.[15]

France, whose chemical industrial capacity was very limited, undertook a massive industrial effort. In 1915, only Germany had a real chemical industry in terms of not only size, but know-how, agility and resources. Before the war France was completely dependent on German imports of liquid chlorine and bromine. These imports came to sudden halt, of course, as soon as war broke out.

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[13]Memorandum on the use of poison gas in warfare by General Curmer, Service historique de l'armée de terre, October 1st, 1915, Vincennes, SHAT/16N839.

[14]Memorandum on the constitution of special units for the use of Z equipment, December 23, 1915, Service historique de l'armée de terre, Vincennes, SHAT/16N826.

[15]Secret message from the GHQ, February 18, 1916, Service historique de l'armée de terre, Vincennes, SHAT/16N707.

The challenge was for France to create adequate industrial capacity *ex nihilo*. The first demands for chlorine were covered by imports from Italy and mostly Great Britain. In early September, French authorities negotiated the acquisition of more than 50 tons of liquid chlorine per week from the Runcorn production facility,[16] the first batches of which arrived in France in October. The production capacities available for export in the UK were nevertheless far lower than those needed to supply a French military program. French authorities were forced to launch an ambitious industrial plan to build production facilities all over the country. As early as August 1915 a first industrial program was launched, planning the construction of six different chemical plants able to produce 30 tons of liquid chlorine a week. In early 1917, French liquid chlorine production capacity topped a level of 50 tons a day, a large share of which was produced in privately owned companies. For bromine, the problem was even worse, as Germany had a monopoly on bromine production in Europe. First supplies were imported from the United States as soon as June 1915. A solution emerged when a subterranean lake was discovered 600 km south of Tunis in Tunisia, at that time a French colonial possession, from which bromine could be extracted. A factory was built and began production in April 1916, yielding more than 900 tons of bromine during the war, plenty enough to fulfill the country's needs (Bloch 1926, 32).

Because of these industrial difficulties, the first French attack with drifting chlorine clouds did not take place until February 1916. The French conducted more than 50 such attacks, mostly during 1916. Some of them were massive, conducted on a front line more than 8 km long, and supported by more than 6,000 pressurized cylinders containing almost 300 tons of chlorine per operation.[17] The French rapidly abandoned this technique, for obvious reasons such as heavy meteorological constraints and early adoption of artillery as the main delivery system for chemical weapons, probably one of the most extraordinary offensive means of operation during World War I.

5 Retaliation in Kind: Towards Total War

The sudden outburst of chemical warfare initiated in April 1915 by Germany, which deliberately violated the laws of war, truly shocked the French public. Nevertheless, the decision was taken very rapidly by the French government to retaliate in kind, which entailed a huge industrial and scientific effort. And indeed, only a few months after Langemarck, the French army had surmounted many obstacles and was ready to launch their first chemical offensive. Great Britain was

[16]Letter from the 4th Directorate of the Ministry of Defence to the GHQ, October 17, 1915, Service historique de l'armée de terre, Vincennes, SHAT/16N827.

[17]General Curmer's archives. Service historique de l'armée de terre, Vincennes, SHAT/16N903.

able to launch the first allied chemical attack, on September 15, 1915 in Loos, followed by France in February 1916.

The scientific, industrial and financial effort was extraordinary for both countries, especially considering the starting point for France. But in the storm of the war, when urgency was the only law and political influence far less than military, the French authorities did not realize that by adopting chemical weapons in a mechanical way, as they did, they unconsciously took a first step leading to total war. Of course at that period of the conflict, gas was not yet a weapon of annihilation, but rather the weapon that promised local breakthroughs from the deadlock of trench warfare (Joffre 1932). This perspective was so crucial that political authorities stood aside. But, undoubtedly, ten long months before the battle of Verdun, the beginning of gas warfare was the first real step toward the totalization of the war.

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Preparing for Poison Warfare: The Ethics and Politics of Britain's Chemical Weapons Program, 1915–1945

Ulf Schmidt

Abstract Allied political and military leaders have frequently been credited both with considerable foresight and with strategic and moral leadership for avoiding chemical warfare during the Second World War. Scholars have not, however, fully acknowledged how close Allied forces came to launching a full-scale chemical onslaught in various theatres of war. The paper offers a thorough reconstruction of Allied chemical warfare planning which takes a close look at the development of Britain's chemical weapons program since the First World War. The findings suggest that no "lack of preparedness," as it existed in the initial stages of the conflict in 1939/1940, would have deterred the Allies from launching chemical warfare if the military situation had required it. Allied forces were planning to launch retaliatory chemical warfare ever since they had been attacked with chlorine gas in 1915. Just War theorists at first opposed the use of this new weapon and campaigned for an internationally enforced legal ban. The paper argues, however, that post-war military and political exigencies forced the advocates of the Just War tradition to construct new arguments and principles which would make this type of war morally and militarily acceptable. The paper explores the ways in which military strategists, scientists, and government officials attempted to justify the development, possession, and use of chemical weapons, and contextualizes Britain's delicate balancing act between deterrence and disarmament in the interwar period.

1 Introduction

Allied political and military leaders have frequently been credited both with considerable foresight and with strategic and moral leadership for avoiding chemical warfare during the Second World War. Scholars have not, however, fully acknowledged how very close Allied forces came to launching a full-scale chemical

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onslaught in the European and far eastern theaters of war.[1] Although Allied intelligence was aware of Japan's chemical warfare operations against China, which had commenced in 1937, the Allied military decided against retaliatory measures.[2] Chemical warfare would not only have violated international law and morality as it was known and understood at the time, but would have changed beyond recognition the image and conduct of modern warfare for generations to come. The fact that a potentially devastating event did not happen is seen as tangible evidence of the underlying morality and humanity of Western governments in defending modern civilization. A more thorough reconstruction of Allied chemical warfare planning, as is proposed here, one which incorporate and takes a close look at the development of Britain's chemical weapons program since the First World War, allows us to recognize that no "lack of preparedness," however serious it may have been in the initial stages of the conflict, would have deterred the Allies from launching chemical warfare if the military situation had required it. Allied forces were indeed planning for chemical warfare ever since they had been attacked with chlorine gas in 1915.[3]

From the moment chemical weapons appeared on the stage of armed conflict, Just War theorists opposed the use of this new weapon and campaigned for an internationally enforced legal ban. Chemical weapons, they argued, violated the requirement for non-combatant immunity because they indiscriminately killed and injured children, women, and the elderly. In the 1920s, however, military and political exigencies forced the advocates of the Just War tradition to construct new arguments and principles that would make this type of war morally and militarily acceptable. Responding to an international legal ban on poison gas, government experts began to condemn the inhumanity of armed conflict, while simultaneously accepting the need for this type of warfare in certain circumstances. There is therefore a need to examine the ways in which military strategists, scientists, diplomats, and government officials attempted to justify the development, possession, and use of chemical weapons through different means and methods of propaganda, and to contextualize Britain's delicate balancing act between deterrence and disarmament in the postwar period.

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[1]For some of the scholarship on the history of biological and chemical warfare since the First World War see SIPRI (1971); Harris and Paxman (1982); Haber (1986); Richter (1994); Evans (2000); Balmer (2001); Hammond and Carter (2002); Schmaltz (2005, 2006a, b, c); Wheelis et al. (2006); Tucker (2006); Schmidt (2006, 2007a, b, 2013); Schmidt and Frewer (2007); Spiers (2010); Avery (2013). For a comprehensive analysis of chemical warfare research and human experiments during the twentieth and twenty-first centuries, see also Schmidt (2015). Sections of this chapter have been reproduced with permission by Palgrave published in Schmidt (2012).

[2]See Van Moon and Ellis (1989, 1996).

[3]Spiers, for instance, suggests that "lack of preparedness was a principal reason for non-use of chemical or biological weapons between the major belligerents in the Second World War" (Spiers 2010, 57). For the use of chlorine in 1915 see Cowell et al. (2007).

2 Ypres 1915

By the time the first major chemical warfare attack in modern history came to an end, the Allies had lost hundreds, if not thousands, of soldiers. Allied propaganda estimated that 5000 soldiers had been killed and 10,000 had been wounded, though these numbers are generally accepted to have been exaggerated (Szöllösi-Janze 1998, 318).[4] Whatever the exact casualty figures, witness accounts confirmed that Allied troops had been exposed to one of the first weapons of mass destruction, which killed men slowly and painfully from within rather than wounding them on the outside. Total panic had gripped thousands of seasoned soldiers and civilians who fled from the toxic fumes; the modern battlefield had become a site of unimaginable horror and untold human suffering.

Despite a four-mile hole in the Western Front, and an enemy army in disarray, the German military, having failed to anticipate the effects of the "new infernal invention," as some called it, and lacking the necessary reserves to break through Allied defenses, was unable to exploit their sudden strategic advantage (Buffetaut 2008). Among those disappointed by the German lack of planning was the head of the Kaiser Wilhelm Institute in Berlin, Fritz Haber, who was instrumental in developing German chemical warfare agents. If only the military authorities had launched a full-scale offensive, he complained, "instead of the experiment at Ypres, the Germans would have won" (Harris and Paxman 1982, 10). Haber saw gas warfare as a more "humane" weapon of war:

> The gas weapons are surely not more horrible than flying metal fragments, on the contrary, the percentage of deadly gas injuries is comparably smaller, there are no mutilations and nothing is known […] in terms of follow-up injuries (Haber 1924, 35; see 25–41).

In 1919, much to the shock of the civilized world, Haber was awarded the Nobel Prize for Chemistry.[5]

Rejected as immoral and illegal by many, the new weaponry was greatly feared by the soldiers on the battlefield. Gas warfare became as much a psychological as a physical weapon. Often the experience of being gassed led to real and imagined clinical symptoms for years to come. The possibility of being killed by asphyxiating gases triggered deep-seated emotional responses and occasional nervous break-downs which psychiatrists classified as "gas neurosis"; in other cases, soldiers exposed to blistering agents were classed as suffering from "gas hysteria," since the substances could cause conjunctivitis and temporary blindness (Harrison 2010, 106–109). Eyewitnesses recalled that "gas shock was as frequent as shellshock" (Shephard 2000, 64).

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[4]Piet Chielens from the Flanders Fields Museum, Ypres, Belgium, has recently suggested that the number of "casualties" of the German gas attack near the Belgian town of Ypres in April 1915 was significantly lower than previously assumed (Chielens 2014; also Corrigan 2003, 164–165).

[5]For Haber's biography see Szöllösi-Janze (1998); Stolzenberg (2004); Charles (2005); see also the account by his son Lutz F. Haber in Haber (1986).

No one had been prepared for this kind and scale of warfare; few had ever imagined that poison gas would be used; almost all were shocked that the world would never be the same, that armed conflict would forever be tainted by what many perceived to be an unmanly, dirty form of warfare. As early as 22 April 1915, Michel Toudy, a soldier of the Belgian Grenadiers tasked with strengthening front-line defenses in the immediate aftermath of the first gas attack, noted in his war diary: "Throughout the entire night French territorials arrive in our trenches coughing and saying that it is not permitted to attack aged family fathers with asphyxiating gas."[6] Many Allied servicemen believed at this point that Germany had violated international conventions governing the conduct of war, which in many ways it had—if not the letter of the law, then certainly its spirit.

The German use of steel cylinders for the delivery of poison gas was meant to ensure that a large area would be cleared for a ground offensive once the gas had dissipated but it also had another, more profound rationale. Since the end of the nineteenth century, international law had prohibited the use of poison gas. Fearing that the ongoing arms race with Germany could weaken the fledgling Russian economy, and further destabilize the regime through strikes and revolutionary activities, Tsar Nicholas II had initiated the First Peace Conference in The Hague to revise and ratify the declarations about the laws and customs of war that had been negotiated in 1874 in Brussels. In 1899, representatives of twenty-six countries, including Britain, France, Russia, and Germany, had signed The Hague Convention Respecting the Laws and Customs of War, which not only regulated the treatment of prisoners of war and the care of sick and wounded, but also banned certain types of warfare and the use of modern technology, including aerial bombardment, chemical warfare, and hollow point bullets. Article 23(a) specifically prohibited the employment of "poison or poisoned arms."[7] In a separately signed document, The Hague Declaration Concerning Asphyxiating Gases, the contracting states also pledged to outlaw the use of poison gas as a means of future warfare by "abstaining from the use of projectiles, the sole object of which is the diffusion of asphyxiating or deleterious gases" (Tucker 2006, 10f.). Attempting to ban weapons which did not yet exist, The Hague Declaration contained three major loopholes which the belligerents exploited during the First World War: the use of irritants, the employment of gas through means other than by using projectiles, and the use of gas-filled, yet shrapnel-causing bombs, were not covered by The Hague Declaration. Faced with a war of attrition, the German army was less concerned about the inherent legality or morality of gas warfare but more about semantics. Whereas the use of gas-filled *projectiles* was against international law, the German military considered the use of poison gas released from cylinders to be lawful. Days after Germany's first gas attack, the *Kölnische Zeitung* claimed that "the letting loose of smoke clouds,

[6] In Flanders Fields Museum, Documentation Centre, Toudy papers. I am grateful to Dominiek Dendooven for sharing this source with me. See also Dendooven (2005).

[7] Convention (II) with Respect to the Laws and Custom of War on Land and its Annex: Regulations Concerning the Laws and Customs of War on Land. The Hague, 29 July 1899.

which, in a gentle wind, move quite slowly towards the enemy, is not only permissible by international law, but is an extraordinarily mild method of war" (Harris and Paxman 1982, 5). The Allied powers, however, described it as an act of inhumanity that violated "all codes of civilized behaviour" (SIPRI 1971, 231). It certainly did not bode well that the German military had given the poisonous cloud the code-name "Disinfection," a cover to confuse Allied intelligence, surely, but also one which portrayed enemy soldiers and civilians as vermin to be exterminated (Buffetaut 2008, 20).

Twenty-four hours after Germany's first gas attack, Sir John French, the Commander of the British Expeditionary Force, inquired about the existing supply of respirators and requested from London that "immediate steps be taken in retaliation to supply similar means of the most effective kind for the use of our own troops."[8] In his reply, Lord Kitchener, the War Minister, called for caution: "The use of asphyxiating gases is, as you are aware, contrary to the rules and usages of war. Before we fall to the level of the degraded Germans I must submit the matter to the government."[9] To investigate the matter, Kitchener called upon two civilian scientists: John S. Haldane (1860–1936), a former reader in physiology at Oxford University who, as director of a research laboratory in Doncaster, had worked with the mining industry in developing respirators against the toxic effects of mine gases;[10] and Herbert B. Baker (1862–1935), a professor of chemistry at Imperial College. Both were dispatched to France to find out what kind of gas had been used and inspect the site of the first gas attack. At St Omer, close to the general headquarters in France, they managed to identify the gas that had been used as chlorine through the use of a school laboratory (Thorpe 1936, 525; also Foulkes 1934, 37). For all concerned, it was clear that "immediate defensive measures were required."[11] On their return to Britain, Haldane submitted a full report to Prime Minister Herbert Asquith, while Baker briefed Lord Kitchener about the situation; the latter told him to "do his damnedest" to ensure that Britain could soon retaliate (ibid.).

Despite these bold declarations of intent there was considerable uncertainty among members of the British government as to whether Germany had actually contravened the terms of The Hague Declaration. On 26 April, Asquith told King George V: "As the gases are apparently stored in and drawn from cylinders, and not "projectiles," the employment of them is not perhaps an infraction of the literal terms of The Hague Convention."[12] Given that Germany was widely perceived as having violated the spirit of the Declaration, however, and with pressure mounting

[8]Foulkes 1934 (19); also Carter (2000, 2), who misquotes French in this instance.

[9]Foulkes (1934, 19f); Harris and Paxman (1982, 5); Hobbs et al. (2007, 260). See also TNA, WO142/241, correspondence between Sir John French and Lord Kitchener, 23–24 April 1915.

[10]For John S. Haldane see Douglas (1936); Sturdy (1987); Goodman (2008); Sturdy (2011); see also Haldane (1925, 63) who recounts how his father was sent to France to identify the gas which the Germans had used.

[11]TNA, WO188/802, p. 1.

[12]Hobbs et al. (2007, 260); TNA, CAB 37/127/40, Asquith to George V, 26 April 1915.

on the War Office to retaliate, the government knew that such legal sophistry would have little truck with the British public.

Within days, after graphic accounts of gas casualties had been published by *The Times* and other newspapers, anti-German sentiment reached fever pitch (SIPRI 1971, 231ff.). On 29 April, *The Times* commented:

> The willful and systematic attempt to choke and poison our soldiers can have but one effect upon the British people and upon all the non-German people of the earth. It will deepen our indignation and our resolution, and it will fill all races with a new horror of the German name.[13]

On the same day, the *Daily Mirror* reported that the German military had again used "asphyxiating gases" contrary to The Hague Declaration.[14] In Germany, meanwhile, gas warfare was portrayed as a modern weapon that was not only lawful but humane, one that produced a "rapid end" rather than the misery resulting from turning the German trenches "into a terrible hell."[15] A week later, on 7 May, the sinking of the *Lusitania* off the coast of Ireland by a German U-boat, killing 1198 civilians on board, including American citizens, caused further international outrage and turned public opinion firmly against Germany (see also Spiers 2010, 40). By portraying Germany as an "inhuman enemy," and German soldiers as barbaric criminals, hell-bent on committing atrocities against civilians by means of poison gas and submarine warfare, and in flagrant violation of the rules of war, Allied officials managed to bring the United States into the conflict and justify, in the eyes of the public, Britain's retaliatory measures.

Germany's premeditated gas attack initiated a Europe-wide chemical arms race on an unprecedented scale, one in which there was "no time to worry about ethics" (Harris and Paxman 1982, 21). Even neutral Netherlands got involved in the production of hundreds of tons of poison gas (Van Bergen 2012). The German gas attack "both inspired and provoked the British into retaliating with illegal weaponry, thereby opening the door to a virtually unlimited chemical warfare" (in Hobbs et al. 2007, 261). After recovering from the initial shock, Britain and France wasted little time in establishing large-scale programs for the testing of toxic substances, and in preparing their armies for all-out technological warfare to be fought irrespective of any moral or legal boundaries. At the end of September 1915, British forces attempted, but largely failed, to use poison gas in a major offensive at Loos in Belgium (see Lloyd 2006). Despite months of preparation, the training of special gas brigades, the employment of chemical experts, and the shipment and positioning of thousands of gas-filled cylinders along the front line, military planners began to appreciate the enormous problems associated with chemical warfare. Gas warfare was highly unpredictable, scientifically complex, and dependent on prevalent weather and environmental conditions, and it quickly turned into a nightmare for military strategists. Whereas the human cost of the Battle of Loos was

[13]*The Times*, 29 April 1915, p. 9; also UoK, Porton Archive, A201, WWI CW Media Articles.

[14]*Daily Mirror*, 29 April 1915.

[15]*Frankfurter Zeitung*, 26 April 1915; quoted from SIPRI (1971, 232).

substantial, strategic gains were almost negligible. The British had captured some 3000 German prisoners of war. Yet with over 50,000 British casualties, and hundreds of troops gassed by their own side—after the toxic cloud had changed direction—together with 3 miles of ground taken and then lost again, the military agreed that the machinery of war needed to be modernized if Britain and her Empire were to sustain a prolonged military campaign. Moreover, by using the newly developed Stokes mortar, the *sole* purpose of which was the delivery of chemical projectiles into and behind enemy lines, Britain had become the first nation to contravene the literal terms of The Hague Convention, and thus international law (Hobbs et al. 2007, 260f; also Spiers 1986, 24).

3 Porton Down

At the end of 1915, officials in the Ministry of Munitions concluded that the modern war machine needed nothing less than a fully equipped, large-scale testing ground to keep abreast of rapid developments in science, technology, and medicine.[16] In September, the Trench Warfare Department duly instructed the Scientific Advisory Committee to find and requisition a suitable "ground for experimental purposes."[17] A few months later, in early 1916, some 2886 acres of land near the villages of Idmiston, Idmiston Down, and Porton, on the southern edge of Salisbury Plain in Wiltshire, formed the basis of what came to be known as Porton Down.[18]

Porton rapidly expanded to take over 6200 acres of largely woodland and farmland, accessible through a complex network of roads and a light railway that interlinked the administrative headquarters, army huts, workshops, laboratories, munitions depot, open-air testing station, and animal farm, a place teeming with service personnel and civilian scientists working under the leadership of Porton's commandant, Lieutenant Colonel Arthur W. Crossley, a Mancunian, who had made his career as a chemist at King's College London. During the war, Porton was divided into four departments: the Commandant, the Division Officer Royal Engineers, the Works Department, and the Experimental Department. While the Division Officer Royal Engineers was responsible for the general upkeep of the facility, the Works Department, line-managed by the Superintendent of Experimental Grounds, carried out the construction work through civilian laborers. By 1918, the Experimental Department was divided into six sections: the Chemical Laboratory, the Anti-Gas Department, the Physiology Laboratory, the Meteorological Station, the Experimental Battery RA, and the Experimental

[16]TNA, WO188/802, p. 1.

[17]TNA, WO142/264, Lt Col A.W. Crossley RE, 'The Royal Engineers Experimental Station, Porton' (1919); also TNA, WO188/802, p. 1; Carter (2000, 3).

[18]TNA, WO142/264, Lt Col A.W. Crossley RE, "The Royal Engineers Experimental Station, Porton" (1919), pp. 3f. Work at the Station is believed to have commenced on 7 March 1916 when the first officer from the Royal Engineers reported for permanent duty.

Company RE.[19] As sign that Porton was there to stay, certainly for the duration of the war, the organization soon saw the creation of more permanent laboratories, photographic and meteorological units, barracks, and welfare facilities. By 1918, Porton had become a large-scale research facility with over 900 members of staff, many of them officers, thirty-three women from the Queen Mary Army Auxiliary Corps, who were employed as typists, and some 500 civilian workmen who maintained the workshops and laboratories.[20] At first, much of the work was directed towards developing new weapons of mass destruction.

In September 1916, the first use of the Livens Projector, an ad hoc device consisting of a steel tube, about 3 feet in length and 8 inches wide, dug into the ground at an angle of 45° in batteries of twenty, and detonated remotely through an electrical charge, opened a new chapter in gas warfare. It was no longer necessary to rely on the right meteorological conditions: bombs containing 30 lb (15 kg) of chemical agents, generally phosgene (CG), could be fired directly into enemy lines, resulting in high numbers of casualties and deaths. The power of the new weapon lay in the number of projectiles that could be fired simultaneously, sometimes more than 1000 at a time.[21] In April 1917, at the Battle of Arras, the British used the Livens Projector for a full-scale, deadly attack. Although inexpensive and inaccurate, with a range limited to one mile, it was an effective but also terrifying weapon that served as a technological precursor to "multiple rocket launchers and… aircraft cluster bombs" (Harris and Paxman 1982, 22). Gas shells, on the other hand, used by Germany and France from 1916, required less preparation, offered greater targeting precision, and were able to be fired over longer distances. In Germany, the symbols on the shell cases represented the different chemical agents: a white cross stood for tear gas, a green cross for phosgene, and a yellow cross for mustard gas (HS).[22] With an estimated total of 66 million gas shells fired during the war, chemical warfare had turned into an ever-present threat for Allied and German forces.

In December 1915, the German military used phosgene for the first time, an almost colorless and odorless gas, eighteen times more toxic than chlorine, which, when inhaled, caused serious lung damage from excessive fluid accumulation, and death within a few hours.[23] Toxicologists called it an "inner drowning" of the lungs Klee (1997, 269). Retaliating in June 1916, the Allies employed phosgene with devastating effect during the battles of the Somme; by firing 4000 gas-filled shells

[19]TNA, WO188/802, pp. 3, 10f; for Crossley see TNA, WO142/264, Lt Col A.W. Crossley RE, "The Royal Engineers Experimental Station, Porton" (1919).

[20]TNA, WO188/802, p. 10; McCamley (2006, 97).

[21]TNA, WO188/802, p. 20.

[22]Mustard gas, or dichlorodiethyl sulphide, was code-named 'H' or 'HS'. Lewisite, or chlorovinyl dichloroarsine, was code-named 'L'. For the exact chemical names of the code-named warfare agents see Historical Survey (2006, 209).

[23]For the properties of phosgene as a chemical warfare agent see Marrs et al. (1996, 185–202).

simultaneously, and thus releasing a total of 54 tons of gas over the target area, the Allies wiped out hundreds, if not thousands, of German soldiers, horses, and wild animals.

The close proximity of Porton's laboratories to one another allowed scientists and service officers to conduct integrated research across disciplinary boundaries. Except for a few scientists who wanted to protect their academic independence, most researchers were given military ranks.[24] Physiologists, chemists, pathologists, meteorologists, and a range of technical and military experts all collaborated in designing and executing experiments, both outdoors on the test range and indoors in the laboratory, sampling station, or gas chamber; by sharing their research data, they managed to improve protective clothing, diagnostic tools, and forms of treatment. Sometimes, relevant expertise had to be brought in from the outside. Porton's first respirator and gas tests, for instance, were conducted by civilian rescue workers from Derbyshire, where mining accidents from gas explosions were not uncommon (McCamley 2006, 97). Teamwork was an essential ingredient of Porton's developing research culture. It provided scientists and military personnel with an incentive to join the establishment and work long, exhausting hours, late at night, or during weekends. Porton's collaborative "spirit and unity of purpose," as Crossley put it, strengthened their belief that they belonged to an exclusive group of professionals who were tasked by the government to develop chemical weapon technologies.[25]

New challenges brought about by modern chemical warfare also led to advances at Porton in defensive technologies for both soldiers and civilians, for example in the design and development of more efficient respirators (Sturdy 1998). Realizing that Allied respirators offered improved protection against certain gases, chlorine and phosgene especially, German scientists developed ever more lethal and incapacitating agents that attacked the body from the outside. Dichlorethyl sulphide, or mustard gas as it became known in Britain because of its distinct garlicky, mustard-like smell, attacked the skin, causing severe burns and blisters within a couple of hours.[26] If inhaled, mustard gas could cause serious inflammation of the lungs, followed by a slow and painful death from asphyxiation. In Germany, the agent was called "Lost" in recognition of the two scientists (Lommel and Steinkopf) who synthesized it, and in France it was called "Ypérite" in reference to Germany's first mustard gas attack in July 1917, when the military employed the agent to deadly effect in the area around, yet again, the heavily embattled Ypres. The onset of symptoms was delayed, and thousands of soldiers were unaware of having been exposed to a toxic agent, yet developed severe blisters on their hands and neck, and in armpits, groin, and buttocks. The blisters often became infected, leaving soldiers

[24]TNA, WO188/802, p. 3; see also Roughton (1949, 320).

[25]TNA, WO188/802, p. 8.

[26]Sulphur mustard (mustard gas) was first synthesized in the mid nineteenth century and developed as a chemical warfare agent during the First World War. For the chemical properties of sulphur mustard see Marrs et al. (1996, 139–173).

totally incapacitated and in need of medical treatment. Impregnated leather gloves and suits drenched in linseed oil provided some degree of protection, yet these could be worn only temporarily. British scientists quickly came to realize that the complex scientific problems linked to mustard gas, and the means to protect the human skin from it, needed to be studied in great detail after the end of hostilities. As the "King" or "Queen" of war gases (Tucker 2006, 19; Klee 1997, 269; Groehler 1989, 72), contaminating Allied troops and their equipment for prolonged periods of time, mustard gas stood at the forefront of Porton's research until the end of the Second World War.

4 Servants of the Realm

The generation of civilian scientists and service officers associated with Porton during the Great War had grown up in Victorian and Edwardian Britain, came from middle-class or more modest social backgrounds, studied at elite universities such as Cambridge, Oxford, or University College London, and occasionally married into the British establishment. Porton's origin as a defense establishment during the Great War was intricately connected with a generation of male researchers who were driven by a deep-seated desire for advancement and social prestige, an emerging "intellectual aristocracy" with strong social and professional bonds, determined to unlock the secrets of the world through science and experiment and thus realize their visionary ideas of modern society (see also Sturdy 2011). Those who believed in the power of science were men such as Lieutenant Colonel Charles Lovatt Evans (1884–1968) who, according to a friend, "possessed the great qualities of some of the most zealous and distinguished of the Victorians, who accomplished their life's work by an immense capacity for hard work and a burning zeal for achievement."[27] At Porton, Lovatt Evans' colleagues included the Cambridge physiologist Joseph Barcroft. Despite his Quaker upbringing, Barcroft felt the need to contribute to the war effort after Germany's premeditated gas attack.

In January 1917, prompted by the devastating effects of Germany's mustard gas attack, Porton established a permanent laboratory for physiological tests on humans at nearby Boscombe Down Farm.[28] The department seems to have been limited at first to a single hut, measuring 30 feet by 15 feet, which was converted into an office and physiological laboratory. To ensure close liaison with the Royal Army Medical Corps (RAMC), medical officers were attached to Porton.[29] Conditions were

[27]*BMJ*, Obituary, Charles Lovatt Evans, 3 (1968), 5619, pp. 684–685.

[28]The decision was taken by the Chemical Advisory Committee under Barcroft's leadership: TNA, WO142/264, Lt Col A.W. Crossley RE, "The Royal Engineers Experimental Station, Porton" (1919), pp. 11ff; also TNA, WO188/802, p. 7; Sturdy (1998, 70).

[29]During the First World War, Rudolph Peters worked as the medical officer under A.E. Kent, who was in charge of offensive chemical warfare on sections of the front controlled by the British First Army; TNA, WO188/802, p. 7.

austere, to say the least, with Peters not only living in the hut but taking his bath in a round tin on the floor of the post-mortem room where the animals were dissected (Thompson and Ogston 1983, 499). Other accounts mention a better-equipped outfit: an old brick building, laboratories, offices, and even a gas chamber for various animal experiments (Garner 2003, 138). Whether staff deliberately played down the existing working conditions to highlight their scientific achievements is difficult to tell in retrospect, yet what seems to be certain is that facilities were relatively simple, even by the standards of the day. Under Barcroft's leadership, and in collaboration with British universities, for example with Cambridge's Chemistry Department, itself engaged in the preparation of toxic agents under the leadership of Sir William Jackson Pope (1870–1939), these men set out to investigate the effects of chlorine, phosgene, adamsite (DM), an arsenical irritant, and mustard gas in experimental gas chambers and to analyze the results in improvised laboratories.[30]

Research had at first concentrated on assessing toxic agents for their ability to kill within forty-eight hours, though experts soon discovered the "casualty producing effects" of certain gases. Chemical warfare, they realized, was not so much about killing people but about incapacitating them for the duration of combat activity. Toxicity trials had revealed that the length of exposure to certain substances, and their concentration, were key in determining the degree to which agents were harmless or dangerous. By the end of the war, Barcroft's team had examined the toxicity and the possible remedies for 160 substances, including mustard gas and lewisite, which became known among Allied propagandists as the "dew of death," a description that overemphasized its actual killing potential.[31]

Although Porton encountered difficulties in retaining some of the civilian scientists after the war, with men such as Barcroft, Lovatt Evans, and Starling returning to their university positions, often as FRS, almost all of them continued to conduct research which was informed by their work on chemical warfare.[32] In the interwar period, and thereafter, the "Old Portonians" formed a closely knit group of experimental scientists who continued to have close links to the British defense community at Porton Down.[33] This was the generation of military men and civilian researchers for whom the experience of the Great War, and of tens of thousands of gassed soldiers, marked a watershed in their determination to prepare the country

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[30]TNA, WO188/802, p. 15; see also Gibson (1941, 321f.); for Pope see also IWM, Photographic Collection, Portrait W. J. Pope (1870–1939).

[31]For a history of lewisite see Vilensky (2005).

[32]For Lovatt Evans' subsequent professional career see WL, PP/CLE/A.9, Jodrell Chair; PP/CLE/A.11, Service at Porton Experimental Station, Wiltshire, during the Second World War. Miscellaneous Correspondence re. Secondment and Service. For Barcroft's postwar career as a Reader in Physiology at Cambridge University see Roughton (1949). During the early 1920 s, Peters worked with F.G. Hopkins, Malcolm Dixon, and J.B.S. Haldane at the Balfour Laboratory at Cambridge University; see Peters (1959).

[33]Lt (later Maj) J.A. Sadd continued work as a senior civilian scientist at Porton until the 1950 s. Lt Col W.A. Salt, Lt Col A.E. Kent, Capt S.J. Steadman, and Lt A.C. Peacock all worked at Porton Down after the Great War.

for a future war, protect the army and civilians from the anticipated fallout, and supply the military with the means and methods to retaliate. On the eve of the Second World War, many of those who had fought in the previous war were ready to recommence research on chemical warfare to protect the United Kingdom and her allies.

5 Crisis of Legitimacy

Following the Armistice in November 1918, the victorious powers envisaged the creation of a demilitarized and largely peaceful world, free from violence and weapons of mass destruction. Undermined by feelings of revenge and demands for reparations, their vision got off to a difficult start. Under the Versailles Treaty, notorious for its humiliating terms, the Allies not only annexed territory, disarmed the German army, and extracted material resources from a traumatized, politically divided society that was barely coming to terms with military defeat, but also forced the government to admit sole responsibility for the war (Kershaw 1998, 136). To destroy any future chemical warfare capability, Germany was strictly prohibited, under Article 171, from using, producing, or importing chemical agents, including "asphyxiating, poisonous or other gases and all analogous liquids."[34]

Although far from homogenous, public opinion became a powerful force in shaping the international community's protracted disarmament negotiations.[35] In 1918, representatives of the British medical profession called for a ban on chemical warfare in *The Times*, describing it as an "unclean," uncontrollable, and malignant weapon of war which ought to be abolished.[36] Elsewhere, doctors and nurses employed by the armed forces protested against their involvement in this type of warfare. Some have argued that the interwar debate simply resulted from a "clash" between the wartime practicalities of using chemical weapons and the experienced or perceived horrors among "victims and observers alike," but this overlooks quite specific economic, political, and scientific factors as well as cultural traditions that shaped the discourse at a national level (see Van Bergen 2012). In the United States, where the chemical industries, like their British counterparts, launched a major publicity offensive, chemical warfare became a matter of domestic politics. Chemical warfare meant big business at a time of great economic uncertainty and guaranteed the employment of thousands of officers lecturing in US chemical

[34]"The use of asphyxiating, poisonous or other gases and all analogous liquids, materials or devices being prohibited, their manufacture and importation are strictly forbidden in Germany" (Treaty of Versailles, Article 171). Tucker (2006, 21); Hobbs et al. (2007, 278f.). Britain's proposal during the Versailles Treaty negotiations for full disclosure of Germany's wartime manufacturing processes was seen as an attempt at economic espionage, and rejected by the United States; see also SIPRI (1971, 235f.).

[35]See SIPRI (1971, 231–267), Chap. 3: "Popular Attitudes towards CBW", 1919–1939.

[36]*The Times*, 29 November 1918, p. 6.

warfare (CW) training facilities.[37] In a bid to improve chemical warfare preparedness and secure the postwar continuity of the Chemical Warfare Service (CWS), founded in mid 1918, stakeholders and major suppliers from the building, mining, and engineering trades, who advocated a more isolationist policy, became involved in a campaign to frustrate international disarmament negotiations. The proposed abolition of the CWS, in particular, threatened the existence of small, specialized companies supplying the US chemical warfare industry, which needed to adjust to peacetime conditions, for example through the sale of tear gas to law enforcement agencies. While Edgewood Arsenal highlighted the "relative humaneness" of toxic agents compared to high explosives in specially designed publications, engineering firms promoted their latest airtight steel tanks. Elsewhere, the producers of metal ores advertised their ability to deliver "gas by the ton."[38]

Yet the campaign also fuelled public anxieties against possible airborne attacks with toxic agents, and strengthened the resolve of organizations such as the British Association for the Advancement of Science and the International Committee of the Red Cross (ICRC) to protest against the use of poison gas in 1918 and call for an absolute ban on chemical warfare (SIPRI 1971, 239–242; Hobbs et al. 2007, 280; Van Bergen 2012). Having been criticized by the belligerents for abandoning its principle of impartiality, the ICRC subsequently took a more "neutral" position and "waged war on gas warfare" by campaigning for the improvement of defensive capabilities in the late 1920s in order to make the use of chemical warfare agents unworkable; there was even an ICRC-funded prize for innovative developments in the field of chemical defense. Anti-militarist groups and pacifists, however, became increasingly hostile towards the ICRC for viewing chemical weapons as an inevitable reality of future wars. In the aftermath of the Second World War, and in light of the Holocaust, the ICRC's stated policy of impartiality and non-interference became the subject of heated controversy, which has continued ever since.

Another major organization involved in shaping public opinion on the subject of chemical and biological warfare was the League of Nations. In the 1920s, it played a leading role in negotiating international agreements for the limitation and reduction of chemical weapons, and in prohibiting their use in future wars. Founded in 1920, the League of Nations was firmly committed to comprehensive disarmament, weapons control, and conflict resolution through international cooperation. Yet political setbacks during the League's formative years placed the United States in a powerful negotiating position. Held in Washington DC from November 1921 to February 1922, the Conference on the Limitation of Armament, organized by the United States to establish a new security framework in the Pacific area, sought, inter alia, a legally binding resolution for the prohibition of chemical weapons. During the negotiations, because of behind-the-scenes tensions between experts and

[37]CHF, Archive Collection, GB98.09, Williams—Miles Reprint Collection, William Williams, Notebook: US Gas School, 1918.

[38]CHF, The Edgewood Arsenal, Special Edition of *Chemical Warfare*, vol. 1, no. 5 (March 1919); for the origins of the CWS see Brophy and Fisher (1959); Ede (2011).

politicians about the real and imagined power of chemical agents and the ability to control them, careful management was required to preserve a united front (SIPRI 1971, 242ff.). Article 5 of the Washington Agreement prohibited the "use in war of asphyxiating, poisonous or other gases, and all analogous liquids, or materials, of devices," such use having been "justly condemned by the general opinion of the civilized world."[39] Despite reservations by Britain and France, which prevented the resolution from coming into force, the Washington Agreement marked an important milestone that galvanized public opinion and political power to work towards an international chemical weapons ban.[40]

Clearly affected by the international climate, Porton Down suffered a crisis of legitimacy after it transpired that Britain's chemical warfare program no longer enjoyed unconditional political and public support.[41] At first, almost all research activities ceased. Parliamentary questions were now being raised about Porton's annual cost to the taxpayer.[42] Reflecting public concerns about a substantially weakened economy, the MP Hugh Morrison queried in 1920 whether the government would not be well advised to "have it [Porton] closed down." In his cautious reply, which avoided revealing that the total cost of the establishment had been around £90,000 in 1919–1920,[43] Winston Churchill told the House of Commons that the government aimed to keep the experimental facility open "until the attitude of the League of Nations to chemical warfare is defined."[44] In March 1922, prompted by the Washington Agreement, the government came under renewed pressure, but insisted that it "would be failing in its duty if it failed to take all possible steps which might be necessary to protect the Forces of the Crown and the inhabitants of the country against gas attacks in time of war."[45]

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[39]Article 5 of the Washington Agreement stated: "The use in war of asphyxiating, poisonous or other gases, and all analogous liquids, or materials, of devices, having been justly condemned by the general opinion of the civilized world, and a prohibition of such use having been declared in treaties to which a majority of the civilized powers are parties; now to the end that this prohibition shall be universally accepted as a part of international law, binding alike the conscience and practice of nations, the signatory powers declare their assent to such prohibition, agree to be bound thereby between themselves, and invite all other civilized nations to adhere thereto." See https://ihl-databases.icrc.org/applic/ihl/ihl-search.nsf/content.xsp.

[40]Whereas the British representative pointed out that it is "impossible to prevent a nation bent upon Chemical Warfare from making preparations in peacetime, no matter what the rules of war may be," the French Government reserved the right "to act in accordance with the circumstances" if an enemy refused to give a guarantee not "to use poison gas"; TNA, WO188/802, p. 48; Tucker (2006, 21); Hobbs et al. (2007, 280).

[41]Subordinated to the Chemical Warfare Department, Porton shared responsibility for chemical warfare research with a number of supervisory committees and organizations, including the Chemical Warfare Committee and university research facilities.

[42]Hansard, HC Debate, vol. 122 c60 W, Experimental Ground, Porton, 1 December 1919.

[43]For the total cost of Porton Down between 1919 and 1924 see Hansard, HC Debate, vol. 181 c1108, Chemical Warfare Research Department, 10 March 1925.

[44]Hansard, HC Debate, vol. 130 c1063, Chemical Experimental Ground, 15 June 1920.

[45]Hansard, HC Debate, vol. 152 c984 W, Asphyxiating Gas (Washington Treaty), 27 March 1922.

Unbeknown to the public, the Cabinet had accepted the recommendations of the Holland Committee in May 1920 to expedite chemical warfare research and reorganize Porton Down. Made up of experienced military and civilian experts, the committee had concluded that the "safety of the Empire" could not be left to chance: "A nation which is unprepared for gas warfare lays itself open to sudden and irretrievable disaster."[46] Separating defensive from offensive research was seen to be impossible, because one could not be understood without the other. Recommended changes to the organization involved a reconstituted Chemical Warfare Committee, the attachment of experts to the Director of Military Intelligence, the consolidation of "research, design and supply" under the control of the Ministry of Supply, and improved liaison between Porton's scientists and the armed services, a subject which had caused some considerable controversy during the war.[47] It was recommended that Porton's staff should, in future, be composed "partly of soldiers and partly of men of science," the latter to be of "high standing" and "independent of outside inspection and criticism."[48] To attract scientists of the highest caliber, and because staff sacrificed parts of their careers and occasionally risked their own health in the pursuit of knowledge, the authorities were asked to offer substantial inducements in the form of salaries, security of tenure, pensions, and the right to publish.[49] Largely oblivious to stringent cuts to the military budget during a period of economic austerity, the committee weighed Porton's "considerable" running costs on the basis of national security considerations. It also believed that Porton's discoveries were likely to have scientific and commercial value that would transform the organization into a "very valuable national asset."

At the same time military interference with Porton's activities needed to be kept to a minimum, provided the General Staff could "indicate the general lines" which appeared to be the most promising. The tension between the ability to conduct independent research, free from external pressures, and the practical demands by the military to defend the country against potential chemical warfare attacks, together with the need for a credible retaliatory capability, have characterized Porton ever since.

Close liaison between Porton's scientists and expert networks elsewhere in Britain and overseas, essential in maintaining a first-class research facility, was to be assured through the Chemical Warfare Committee, which was broadly

[46]UoK, Porton Archive, A207, "Report of the Committee on Chemical Warfare Organization", 7 July 1919, p. 5; also TNA, WO188/802, p. 30.

[47]Subordinating field trials to the military requirements of war had, according to some, slowed down, if not inhibited, Britain's chemical warfare program during the Great War; UoK, Porton Archive, A207, 'Report of the Committee on Chemical Warfare Organization', 7 July 1919, pp. 3ff; TNA, WO188/802, pp. 13, 17.

[48]UoK, Porton Archive, A207, "Report of the Committee on Chemical Warfare Organization", 7 July 1919, p. 5.

[49]UoK, Porton Archive, A207, "Report of the Committee on Chemical Warfare Organization", 7 July 1919, p. 5; TNA, WO188/802, pp. 30f.

representative of the wider scientific, military, and business community.[50] To ensure the coordinated production of toxic agents, including those for testing purposes at Porton, the committee recommended the creation of a state-controlled factory for chemical warfare products at Sutton Oak, near St Helens in Lancashire, which later became the Chemical Defence Research Establishment (see Carter and Pearson 1996, 60f; Carter 2000, 52f.) A representative of Porton liaised with members of the committee about planned field trials. It was this coordinated approach to chemical warfare through an external body of experts and stakeholders that other nations, the United States and Canada especially, began to emulate.

6 Collaboration

On a bilateral level, Britain and the United States joined forces in developing offensive and defensive chemical warfare capabilities that required the sharing of information and resources. In 1918, after the American Expeditionary Force (AEF) sustained disproportionately high numbers of chemical warfare casualties due to an inadequate level of preparedness, the US Army attached liaison officers to Porton to keep abreast of Britain's advances in chemical warfare work, a tradition which continued thereafter.[51] Britain's scientists, on the other hand, developed close links with their counterparts at Edgewood Arsenal, near Baltimore, Maryland, which became the United States' headquarters for chemical warfare research and development (Chemical Corps Association 1948, 14ff.). Given the exclusivity of the field, together with the need to preserve the utmost secrecy, research networks which had been established during and after the First World War were central in creating a long-term system of bilateral, and later tripartite, cooperation on chemical warfare between the Allied powers.

Still unresolved questions about the legitimacy of chemical warfare, together with the widespread condemnation of toxic agents as a means of warfare, turned intelligence sharing between Britain and the United States into a sensitive issue requiring a clear understanding about confidentiality arrangements and levels of secrecy. By assigning the highest security classification to chemical and biological warfare matters, and by avoiding the publication of details that could inform other

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[50]In 1920, members of the Chemical Warfare Committee included: Joseph Barcroft (professor of physiology, Cambridge University), A.W. Crossley (former Commandant Porton and Director of the Cotton Industry Research Association), C.G. Douglas (physiologist, Oxford), Harold Hartley (chemist, Oxford), H. Levinstein (representative of Levinstein Limited, chemical manufacturers), Sir William Pope (professor of chemistry, Cambridge University), Jocelyn F. Thorpe (professor of organic chemistry at Imperial College and representative of the Department of Scientific and Industrial Research), A.M. Tyndall (professor of physics, Bristol University); see TNA, WO188/802, pp. 32ff.

[51]TNA, WO188/802, p. 11.

countries about the nature and extent of the work undertaken, Britain attempted to ensure that its expanding chemical warfare program would not become public knowledge.[52]

In addition, Britain was outsourcing certain types of research, some of it offensive in nature, to British-controlled laboratories overseas to deflect public attention from its expanding chemical warfare program.[53] Subsidiary research facilities in India and Australia, established in the 1920s, allowed British scientists to investigate the effect of chemical warfare agents under specific climatic conditions and among different population groups. Between 1921 and 1924, one of Porton's officers, Lieutenant Colonel W.A. Salt, ran the Military Chemical Laboratory in Dehra Dun in India, which conducted high-altitude and smoke trials to test different types of respirators suitable for bearded Sikhs.[54] Porton's service personnel and physiological staff also served as instructors to the Indian Chemical Warfare School in Begaum, a center of the armed forces for the British Raj. In 1929, the British authorities set up a Chemical Warfare Research Establishment in Rawalpindi, in the Punjab, staffed by scientists and officers from Porton, who engaged in smoke trials for the protection of bridges and other strategic sites.[55] To forge better relations, Indian representatives were invited to Britain for an appreciation of the power of chemical warfare. Around the same time, Britain established closer links with the Australian Chemical Warfare Board to study the effects of tropical and subtropical conditions on chemical warfare, attached Australian, Canadian, and South African representatives to Porton, and organized chemical warfare courses in the Dominions. In some cases, Porton helped Allied governments to deal with civil unrest by providing defensive technologies and chemical agents; in 1930, for example, Porton supplied South Africa with specially developed bombs filled with tear gas which the government employed against opposition groups. Most of Porton's activities overseas were strictly classified, not only to protect existing expertise but also to preserve Britain's political credibility in ongoing disarmament talks. At an international level, though, and in public, the subject of chemical warfare was openly discussed.[56]

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[52]UoK, Porton Archive, A205, Porton Experiments 1920 s, Atkisson to Chief of CWS, Washington, 15 July 1924.

[53]TNA, WO188/802, pp. 86–90.

[54]TNA, WO188/802, pp. 86ff.

[55]TNA, WO188/802, p. 88; see also Evans (2007).

[56]A pamphlet published by the League of Nations noted that "everywhere except Germany, experiments in Chemical Warfare openly proceed […]. It will not necessarily inflict more pain than high explosive, but will tend to aggravate the burden of war upon the civilian population"; TNA, WO188/802, p. 49.

7 The Geneva Protocol

The "Protocol for the Prohibition of the Use in War of Asphyxiating, Poisonous or other Gases and of Bacteriological Methods of Warfare," known as the Geneva Protocol, and modeled on Article 5 of the Washington Agreement, outlawed the employment of chemical and biological weapons. However, it failed to establish an international verification and enforcement system, and exposed deep-seated disagreements about disarmament. The United States was opposed to prohibiting the use of tear gas in war on the grounds that it was also used by police forces against civilians in peacetime, especially as a weapon for riot control, and they refused to ratify the Protocol until 1975. The French and the British were likewise reluctant to go ahead and ratify, and this further limited the scope of the Protocol to a "no-first-use" agreement (Hobbs et al. 2007, 286f.).[57]

Questions relating to chemical and bacteriological weapons routinely surfaced in the discussions of the Preparatory Commission for the World Disarmament Conference[58] that opened under the chairmanship of the former British Foreign Secretary and Labour politician Arthur Henderson (1863–1935) in Geneva in February 1932. Preliminary meetings had highlighted the relative ease with which a chemical industry could be adapted to the production of toxic agents, and their potential delivery from the air. Secret intelligence further suggested that almost all countries that had signed up to the Geneva Protocol were pursuing an offensive chemical weapons capability.[59] It therefore came as little surprise that the negotiations were beset by disagreements over what constituted "offensive" and "defensive" weapons and by Germany's belligerent posturing. Britain's high-profile role during the negotiations left senior officials back in London distinctly nervous about granting permission for human experiments involving chemical warfare agents. By the time Britain proposed a draft convention at the World Disarmament Conference in March 1933, two months after Hitler's accession as Reich Chancellor, it had become clear that Europe, if not the world, was faced with an extraordinarily brutal military dictatorship which had no intention of settling international disputes by peaceful means. The talks collapsed after Germany withdrew firstly from the Geneva World Disarmament Conference and then, in October 1933, from the League of Nations. Breathing tests with toxic substances remained prohibited until the outbreak of war in 1939 changed the ethics of human experimentation at Porton.

Whereas some have hailed the Geneva Protocol as "the high-water mark of the hostility of public opinion towards CW," others have stressed the role of the international community in reasserting its authority after the contravention of The

[57] See also Hobbs et al. (2007, 255–295). For the use of tear gas in dealing with civil disturbances in the United States see SIPRI (1971, 270).

[58] The title of the conference was "Conference for the Reduction and Limitation of Armaments."

[59] TNA, WO188/802, p. 49; see also the debate in parliament about Britain's "offensive" and "defensive" chemical warfare capability; Hansard, HC Debate, vol. 272 cc811–12, Chemical Warfare, 30 November 1932.

Hague Declaration during the First World War (SIPRI 1971, 247; Hobbs et al. 2007, 287ff.). Irrespective of whether chemical weapons had been "politicized" before, during, or after the war, whether politicians had responded to public opinion, or whether chemical weapons themselves were inhumane and immoral, the Geneva Protocol established a new international law which not only prohibited the use of chemical and biological weapons, but which, perhaps more importantly, most nations perceived to be obligatory.

8 Foreboding

Far from being a "sudden outburst" of idealism, the Geneva Protocol was the League's "attempt to meet a grave and increasing practical danger, viz., the insecurity of European peace and, resulting therefrom, the rise of a new competition in armaments" (Hobbs et al. 2007, 288f.).[60] In the context of emerging European dictatorships, this constituted a realistic assessment. Since the early 1920s, the German *Reichswehr* and the Soviet Red Army had been involved in clandestine military operations that included weapons development and arms trade. Although the manufacture of chemical weapons was banned under the Versailles Treaty, and outlawed by national legislation, Germany's chemical industry and the military were organizing shipments of poison gas from Soviet Russia. The accidental release of phosgene from a storage tank in Hamburg in 1928 alerted the international community to the fact that Germany was flouting the Versailles Treaty. By the early 1930s, Germany's rearmament program had reached such alarming proportions that another war in Europe seemed a realistic possibility, especially in the context of a Hitler-led regime.

In the context of the Europe-wide rearmament programs that preceded the outbreak of the Second World War, issues relating to chemical warfare became absorbed into debates about national security. Almost all European governments, including the Soviet Union and Britain, employed the threat of chemical weapons as a way of accelerating the introduction of comprehensive civil defense measures. Whereas Soviet citizens received anti-gas drills in simulated gas attacks on Leningrad and Kiev in 1928, the British public was exposed to exaggerated reports about the power of chemical weapons. One estimate predicted that all men, women, and children in Central London would be killed if a large poison gas bomb were dropped onto Piccadilly Circus; another estimated the death of all Londoners if 40 tons of newly developed toxic agents were released. Italy's widely reported, but at first vehemently denied, use of chemical weapons in Ethiopia in 1935 and 1936, which involved the alleged use of mustard gas bombs against civilians and hospital patients, led to demands for sanctions by the League of Nations and increased the

[60]See also TNA, PRO30/69/1273, "Some Questions on the Geneva Protocol" (1925).

value of chemical weapons as a propaganda tool among anti-fascist groups.[61] In the Middle East, the British government pursued a dual strategy of attempting to broker a political settlement in conjunction with providing practical support; Porton's experimental officer was dispatched to Egypt, Aden, the Sudan, and Palestine to advise military officials about defensive chemical warfare technologies.[62] The outbreak of the Spanish Civil War in 1936 led to a fierce propaganda war over chemical warfare, with insurgents and government forces each alleging the enemy's use of poison gas. In the context of Britain's appeasement policy, official support was limited to public condemnation and the supply of respirators to aid the Spanish government. Although the Spanish military had shown few moral qualms in employing chemical weapons against Moroccans in the mid 1920s, reports confirming the use of chemical agents during the Spanish Civil War never materialized, apart from one incident involving the alleged use of tear gas (SIPRI 1971, 258ff.; Balfour 2002, 123–156). At the same time, intelligence from Germany and the Soviet Union suggested increased chemical and biological warfare activities.[63]

Retaliatory preparations were likewise set in train. In 1936, in addition to existing facilities which produced 20 tons of mustard gas per week, the Committee of Imperial Defence ordered the development of a pilot plant with an estimated output of 50 tons per week for the production of a new chemical warfare agent, code-named HT, better known as Runcol.[64] Less than a year later, over 5 million respirators were reported to be in storage for a national emergency. Additional storage facilities for defensive equipment were set up in Canada and South Africa.[65] Following the notorious Munich Agreement of September 1938, and Hitler's invasion of what was left of Czechoslovakia in March 1939, the government distributed over 30 million respirators. Two years into the war, Britain had at its disposal a total of almost 4 million children's respirators and anti-gas helmets alone (Grayzel 2012, 250; Harris and Paxman 1982, 107f.).[66] Here was an aggressor who warranted the mobilization of all resources in preparation for a potential chemical warfare attack.

Shortly before the outbreak of war, research on chemical and biological warfare accelerated at all levels. Through liaison with the ARP Subcommittee, Porton became an integral part of Britain's civil defense planning with increased access to military intelligence and hardware.[67] In 1935, an RAF "Special Duty Flight" was put on permanent stand-by to allow scientists to study the effects of airborne gas

[61]TNA, WO188/802, p. 51; Grayzel (2012, 181f.).

[62]TNA, WO188/802, p. 89.

[63]TNA, WO188/802, p. 51; see also Balmer (2001).

[64]TNA, CAB4/24, Committee of Imperial Defence, "Policy with Regard to the Possible Use of Gas as a Retaliatory Measure in War", 8 July 1936; also Historical Survey (2006, 209).

[65]TNA, WO188/802, p. 89.

[66]Sources have recently come to light, however, which suggest that the majority of gas masks produced for civilians and service personnel contained significant amounts of asbestos; see Schmidt (2015, 69ff.).

[67]TNA, WO188/802, p. 44.

attacks on the Porton range (ibid.). Research and development at Porton included the design of respirators for humans and animals, detector and decontamination devices, filtration units for ships, buildings (including air raid shelters) and armored vehicles, methods to prevent toxic gas from infiltrating the London Underground and government buildings, impregnated garments to protect against specific agents, and the testing of anti-gas ointments. To assist the RAF in assessing wind conditions on the ground or the Royal Navy in battleship protection, Porton conducted research on smoke, including smoke curtain installations and assessments about the relation between screening effects and meteorological conditions.[68] Offensive work involved chemical shell and aircraft gas bombs, ground mustard gas bombs to contaminate whole areas, gas-filled rocket launchers, gas-spraying devices, toxic smoke (arsenical) weapons, or substitute agents ("pseudo gases") to mislead the enemy.[69] Hand in hand with the rapid expansion of Porton's areas of responsibilities in the interwar period came the expansion of its research staff, who forged closer links with subsidiary research facilities in India and later Canada.[70] The number of scientists affiliated with Porton during these years is testimony to the way in which the government managed to integrate research and development into the planning process for future military operations (McCamley 2006, 100).

By the late 1920s, the notion of gas warfare and its associated imagery had become a powerful part of the collective memory of the European public. This applied especially to First World War memorials. Built in 1929 on Belgian soil to commemorate the suffering of thousands of victims of asphyxiation in the first chemical attack in modern history, the Steenstraate gas memorial blamed the German military for this act of inhumanity, which is why the occupying German forces duly destroyed it in 1941 (Jacobs 1996, 46–48; see also Goebel and Connelly 2017, forthcoming).

9 Ethical Relativism

At the start of hostilities, Britain, France, and Germany pledged to abide by the Geneva Protocol, yet none of the parties trusted that the agreement would be observed "a moment longer than is necessary" (Harris and Paxman 1982, 83, 107). Britain anticipated the use of chemical weapons by one or more of the belligerents.

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[68]That smoke could be used as an effective weapon of war had been recognized as early as April 1915, days before Germany's first gas attack, when Winston Churchill as the First Lord of the Admiralty had commissioned a number of "wonderful smoke-making experiments"; Churchill (1923, 84f.); also Carter (2000, 53f.).

[69]TNA, WO188/802, pp. 53–66.

[70]Whereas the scientific staff had risen from 23 to 51 between 1922 and 1925, it had more than doubled to 120 by 1936/37. By 1938, Porton had a total of 152 researchers working on all aspects of defensive and offensive chemical warfare. The annual "Dominion Day" event, for example, organized by Porton between 1937 and 1942, offered visitors insight into Porton's research and development program; TNA, WO188/802, pp. 41, 89.

Millions of leaflets were distributed to all households and the BBC was on stand-by to broadcast pre-arranged gas warnings in the event of gas attacks. Following Hitler's *Blitzkrieg* campaign through the Low Countries and the surrender of France in May 1940, the threat of invasion by German forces loomed large in the minds of British officials in London.

By 1944, four years into an extraordinarily brutal and costly war, Allied military planners were growing increasingly concerned about the potential use of chemical agents by Axis forces, fearing the employment of these weapons in a desperate, last-ditch attempt to hold their positions. The large-scale decommissioning of scientific experts, who began to return to their prewar posts, added to a renewed crisis at military headquarters. Military planners warned about a lack of vigilance and the scaling down of chemical warfare preparedness which could cost Allied forces dearly in the closing stages of the war. At Porton, and elsewhere, researchers were likewise determined to finish the job at hand.[71]

At the same time, the authorities continued incessantly to prepare servicemen and civilians for the Allied invasion which might involve or trigger the use of gas warfare. In May, Porton carried out large-scale chemical warfare exercises in conjunction with beach-head operations by service and civilian authorities; at around the same time, scientists from Porton came to the conclusion that the use of mustard gas was likely to have a "big potential in the subjugation" of Japanese forces on the Pacific islands thousands of miles to the east.[72] With millions of soldiers and civilians killed and injured, families and children displaced, buildings burnt, and entire cities destroyed, there was little appetite among senior Allied officials to uphold standards of medical ethics and international morality if the end of combat operations would be delayed as a result. Mustard gas and phosgene were Churchill's chemical weapons of choice to attack deep within the German heartland and cause maximum casualties and mayhem, but also as weapons which could legitimately be deployed to defend Britain's beaches, ports and industry against an invading army. His retrospective assessment, made after the war, was that the Germans "would have used terror, and we were prepared to go all lengths" (Harris and Paxman 1982, 110; also Parker 1996, 49).

On 6 July 1944, one month after the D-Day landing of Allied forces in Normandy, Churchill returned once again to the subject by telling the House of Commons that the introduction of the German "flying bomb" raised some "grave questions" about the future conduct of the war. On the same day, dissatisfied by the negative assessment of the Joint Planning Staff (JPS) on the use of gas warfare as a retaliatory measure, he informed his Chiefs of Staff of his intention to employ chemical weapons if it were a matter of "life or death" for Britain or if it would shorten the war by a year:

> It may be several weeks or even months before I shall ask you to drench Germany with poison gas, and if we do it, let us do it one hundred per cent. In the meanwhile, I want the

[71]WL, PP/CLE/A.11, Lovatt Evans papers, Hill to Lovatt Evans, 24 April 1944; Lovatt Evans to Hill, 27 April 1944.

[72]TNA, WO188/802, p. 112.

> matter studied in cold blood by sensible people and not by that particular set of psalm-singing uniformed defeatists which one runs across now here now there. Pray address yourself to this. It is a big thing and can only be discarded for a big reason. I shall of course have to square Uncle Joe [Joseph Stalin] and the President [Franklin D. Roosevelt], but you need not bring this into your calculations at the present time. Just try to find out what it is like on its merits.[73]

Churchill considered it to be "absurd" to worry about the "morality on this topic" since all parties had used chemical weapons during the First World War. Whereas the bombing of large cities had formerly been regarded as a war crime, it was now done by the Axis and Allied forces on a day-to-day basis, he argued. Attempting to downplay any moral concerns of his senior military advisers, he noted: "It is simply a question of fashion changing as she [*sic*] does between long and short skirts for women" (ibid.). For the Prime Minister, the Geneva Protocol outlawing the use of poison gas was of no relevance if the existence of British realm were at stake.

Although Allied forces appeared to possess the capability, Churchill's senior military advisers stopped short of recommending the start of chemical warfare operations.[74] The Chiefs of Staff nonetheless expressed a high degree of confidence in respect of the state of Allied readiness to initiate chemical warfare operations. By 1944, British and American stocks located in Britain were deemed sufficient, they said, to produce a "formidable scale of gas attack on Germany during the early and most important phase after a decision has been taken to employ gas."[75] Britain alone had produced a total of 40,719 tons of mustard gas and 14,042 tons of phosgene and tear gases during the war (Carter 2000, 53). Instead of a prolonged use of some chemical agents by 20% of Bomber Command, the Chiefs of Staff recommended the concentration of all British and American long-range bombers in a "massive hammer blow," employing high explosives and phosgene and mustard gas bombs in quick succession on tactical and civilian targets. Phosgene would be dropped on 1000 tactical targets or twenty German cities, causing heavy casualties and deaths among civilians and civil defense personnel. Mustard gas, on the other hand, would be employed against 1500 tactical targets or, alternatively, against sixty specifically identified German cities covering the entire Reich that were "best calculated to bring about a collapse of German morale."[76] By causing death and destruction on a monumental scale, military commanders aimed to exercise intense pressure on the regime's leadership, but they were also acutely aware that the population was likely to lack the necessary "initiative required for active revolt" against the Nazi regime following gas attacks (ibid.).

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[73]TNA, PREM3/89, Personal Minute Churchill to Ismay, 6 July 1944; also Harris and Paxman (1982, 127ff.).

[74]TNA, PREM3/89, "Military Considerations Affecting the Initiation of Chemical and Other Special Forms of Warfare"; Harris and Paxman (1982, 130ff.).

[75]TNA, PREM3/89, "Military Considerations Affecting the Initiation of Chemical and Other Special Forms of Warfare."

[76]TNA, PREM3/89, "Military Considerations Affecting the Initiation of Chemical and Other Special Forms of Warfare."

In France, chemical weapons could aid the war effort by helping Allied forces to "break through the German defences," but they could also slow the military advance, affect communications, unsettle civilian labor, and negatively affect the relationship with the local population. The same was the case in the east, in southern France and in the Mediterranean, where chemical warfare was seen to be counterproductive in maintaining support from civilians and partisans. Existing chemical warfare stocks in the Far East were deemed to be insufficient to allow offensive chemical warfare to be conducted simultaneously in both theatres of war, and defensive measure were inadequate to protect the military from gas under tropical conditions.

Military officials were under no illusion that Germany would immediately retaliate against the United Kingdom, with London as the principal target, if the Allies started to use gas warfare. Although the possible effects of gas on the home front were difficult to judge, they felt that the general public, after five years of war, might be resentful of being exposed to toxic agents if it could be shown that this "could have been avoided."[77] The Chiefs of Staff were also concerned about the effects on public morale of potential retaliatory measures against Allied prisoners of war who might be forced to "work in contaminated areas."[78] All things considered, and irrespective of any political, legal, or moral considerations, Britain's military planners concluded that chemical and biological weapons were not an attractive military proposition. General Hastings Lionel Ismay, one of Churchill's closest military advisers, even suggested to the Prime Minister that the use of these types of weapons was likely to be detrimental to the Allied military campaign:

> It is true that we could drench the big German cities with an immeasurably greater weight of gas than the Germans could put down on this country. Other things being equal, this would lead to the conclusion that it would be to our advantage to use the gas weapons. But other things are not equal. There is no reason to believe that the German authorities would have any greater difficulty in holding down the cowed German population, if they were subjected to gas attack, than they have had during the past months of intensive high explosive and incendiary bombings. The same cannot be said for our own people, who are in no such inarticulate condition.[79]

However impressive the plans drawn up by the Chiefs of Staff in July 1944 may appear in retrospect, we still need to be careful not to jump to any conclusions, on the basis of the above outlined memorandum, in respect of the actual state of Allied readiness to start chemical warfare operations during the closing stages of the Second World War. Given what we now know about newly developed operational research methods which allowed experts to calculate more precisely the requirements for chemical weapons stockpiles needed for a major military attack, it seems far from certain whether the Allied military would actually have been capable of delivering the kind of "massive hammer blow" to the German enemy within the

[77]TNA, PREM3/89, "Military Considerations Affecting the Initiation of Chemical and Other Special Forms of Warfare"; Harris and Paxman (1982, 132).

[78]TNA, PREM3/89, "Military Considerations Affecting the Initiation of Chemical and Other Special Forms of Warfare."

[79]TNA, PREM3/89, Personal Minute, Ismay to Churchill, 28 July 1944.

operational realities of war conceived by the Chiefs of Staff, had the order to employ chemical and biological weapons actually been given. As plans were drawn up in the United States to employ chemical weapons as part of an invasion of the Japanese home islands, for example, it became apparent that the quantitative requirements far exceeded existing stockpiles of chemical munitions. Yet if we assume, for a moment, that the existing chemical weapons stockpiles were likely to be insufficient for the kind of attack the Chiefs of Staff had outlined to Churchill—who at this point seems to have been, by all accounts, keen to launch chemical warfare operations—then this raises a series of questions: whether the Chiefs of Staff were aware of the fact that their chemical warfare capability might not have been quite what it seemed, and if so, why they did not communicate this fact to the Prime Minister. The following scenario is certainly possible: under considerable pressure from Churchill to confirm the viability of employing such unorthodox weapons, which up to this point had not been used in the war, senior military officials—who were keen to keep it that way—might have overstated the Allied chemical warfare capability, thus preserving the impression that the current state of readiness was such that chemical weapons could be employed on a massive scale and at any time, if necessary, whilst simultaneously arguing against the immediate use of chemical weapons in the current conflict.

Although hardly convinced by the report, Churchill decided to accept the assessment of his senior officials, at least for the time being.[80] As it happened, Britain's Chiefs of Staff, and Churchill in particular, had no need to return to the subject of chemical warfare. In April 1945, after Allied forces had crossed the Lower Rhine, the Joint Intelligence Subcommittee concluded that Germany appeared unwilling and unprepared to initiate gas warfare to defend the territory of the Reich. However, it also counseled caution: "There remains the possibility that Hitler may recklessly order its use in the final stage of disintegration."[81] He never did. At the end of the month, Hitler ended his life in his bunker beneath the Reich Chancellery. Shortly thereafter, the unconditional surrender of the German army heralded the end of one of the most murderous regimes in modern history, and with it came the uncomfortable realization that Allied intelligence agencies had almost no knowledge of one of the greatest military and scientific secrets of the Second World War: nerve gas.

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[80]TNA, PREM3/89, Personal Minute, Churchill to Ismay, 29 July 1944.

[81]TNA, PREM3/89, War Cabinet, Joint Intelligence Subcommittee, "Use of Chemical Warfare by the Germans", 23 April 1945.

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Challenging the Laws of War by Technology, Blazing Nationalism and Militarism: Debating Chemical Warfare Before and After Ypres, 1899–1925

Miloš Vec

Abstract The German gas attack of April 22, 1915, took place immediately after intense efforts in international law to make war more civilized and to restrict poisonous weapons. Legal restrictions on war technologies reached a provisional peak at the Hague Conferences of 1899 and 1907. During World War I, the attitude of the German military became more radical, to the point of evading and denying international law. The silence in the face of the poison-gas attack was deafening, even among German scholars of international law. Older traditions from the history of ideas and collective mentalities played a crucial role in this, especially the idea of *raison de guerre* or military necessity, which were supposed to annul international law in case of military emergency. After the end of World War I, there was a lively international discourse on the legality of the German approach. Their debate was marked by a strong nationalist polarization of viewpoints. In subsequent agreements between states, the prohibition of poison gas was rewritten and strengthened.

1 Introduction: Chemical Weapons as the Subject of Juridification, Politicization, and Circumvention of Law

The story told in this essay has three phases and perhaps conceals a surprise. How much of a surprise it will be depends on the readers' expectations concerning historical international law around 1900 and the parties involved. Anyone who expects little will presumably not be disappointed; anyone who has high expectations of

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international law and the parties to it may find what happened—especially one central event and its consequences—sobering. This central event was the German chlorine gas attack in the Second Battle of Flanders near Ypres on April 22, 1915, which would become the subject of a highly controversial discourse on international law.[1]

The essay that follows is about the interaction of technology and law—more precisely, about the interaction of war technology and law of war. It will discuss the changing interdependencies between them, focusing on the creation and implementation of legal norms and especially on scholarship in international law at the time. The crucial turning points in the interaction were treaties on international law and declarations, technological innovations, the outbreak of the war in the summer of 1914, the aforementioned use of poison gas in April 1915, and finally the end of the war in 1918. The actual history of events of the German poison-gas attack of April 22, 1915, is, by contrast left out—in part because it is covered by the essay by Friedrich and James (in this volume).

The various phases of the international law approach to poison gas can perhaps be characterized by three terms: juridification, politicization, and circumvention of law. In my view, the discussion of international law around World War I followed this periodization, and for extended periods, at least, it held few surprises with unpredictable points. The years immediately following the use of poison gas in World War I were perhaps the exception—they bore surprises.

It is a contribution to the history of international law whose intention can by no means be judged ex post by the legality and illegality of the historical event (the legal arguments called on by the various parties will nevertheless be presented under 4.2). The goal instead is to reconstruct and analyze from the perspective of international law the events of that time, and especially the discussion of the parties involved and from scholars of international law.

The history of the German poison-gas attack is part of the history of international law, on the one hand, and of the general history of World War I, on the other. In the framework of the latter history, however, the aspects relating to international law have played an astonishingly minor role in numerous publications. One exception is Isabel V. Hull's book of 2014.

On the other hand, there exist strong lines of continuity, especially in legal studies, of historical regulations of international law to the applicable law of today. As a result, legal historians can, to an unusually large degree, fall back on detailed, high-quality historical accounts by scholars of international law (Bothe 1973; Jaschinski 1975; Marauhn 1994). The Saint Petersburg Declaration of 1868 as well as (at least) parts of the Geneva Protocol of 1925 are considered today to be customary international law (Marauhn 1994, 52; Stockholm International Peace Research Institute 1973, 99), the Gas Declaration of The Hague of 1899 is still a valid treaty law for the signatories and their successor states (Marauhn 1994, 47). They are therefore historical standards that are of enduring significance for international law today.

[1]See the contemporaneous bibliography in Kunz (1935, 85–88).

2 Codifying War Technologies in International Law Around 1900

Four sets of international regulations are particularly relevant to the discussion of the poison gas attacks near Ypres in 1915. Their historical genesis is characterized by comprehensive first steps to the transformation of the civilizing ambitions of the time into the legal regulation of war (Dülffer 1978). This process peaked in the Hague Conferences as forums of discourse and of multilateral agreements on limiting armaments and on the juridification of international conflicts by means of international arbitration and jurisdiction (Neff 2014, 323–28). They were intended as instruments for securing peace in the age of nationalism, internationalization, and imperialism (Dülffer 1978, 73–100).

The Hague Conferences were characterized by, among other things, political activism, which was supported by the pacifist movements together with some parts of the community of international law scholars. The public response was eminent, and it reflected the high expectations of international law at the time. This attitude was an expression of the optimism toward international law at the turn of the twentieth century. It was based on institutionalizations and a positivization of international law that was historically unprecedented. The nineteenth century produced more treaties than ever before. They were often multilateral; some of them even open for accession. Certain types of treaties functionally compensated for the lack of codification of international law, and they were therefore called "law-making treaties." This juridification of international relations culminated in a "treaty-making revolution of the 19th century" (Keene 2012). International law never had it as good as it did in the final years before World War I. It had taken on new tasks and new spheres of regulation, and their structures continue to shape international society even today: administration, technology, economy, public health, and time-keeping (Vec 2006, 1–164). International law was by no means merely a technocratic instrument in this process. Often one can even make out a decided "ethicizing" of international law: moral objectives become the focus of norm setting (Lovrić-Pernak 2013).

Simplifying considerably, this often reflected a juridification of international relations. This term is a thesis in legal sociology and political science that describes extension of law by means of increasingly dense and detailed regulations, by means of institutionalizations, and ultimately by means of legal resolution of conflicts. Some jurists around 1900 expressly articulated the hope for a global law in which the progress of international law of the nineteenth century would culminate.

Within this friendly sounding panorama, however, the law of war was a particularly touchy sphere. The use of violence was, on the one hand, restricted, but, on the other hand, legitimized, in that international law itself supplied a normative order to its employment (Simon 2016, 508). Different than economic and administrative regulation, the law of war concerned questions that were understood to be more delicate and more political. All of them addressed competencies of state sovereignty, but restrictions on the law of war were subject to clearer bounds than those of the other fields of regulation. The evolution typically took the form of transforming customary law into international treaty law (e.g., the prohibition of poison in the law of war). There was also the regulatory problem that these legal standardizations around 1900, just as much as those of the twentieth and twenty-first centuries, were often challenged by new technologies. Hence it represented the problem of regulating technology by law, in which the law always seems to hobble along after the technology (in accordance with the classical "legal lag" theory). Debates in international law over the legality of the use of poison gas in World War I will underscore this problem.

2.1 Restrictions on the Means and Methods of Warfare: The Regulations in International Law of 1868, 1899, and 1907

The legal bases for restrictions on chemical weapons, the validity of which was debated in the context of the use of poison gas at Ypres and beyond, can be identified precisely. In this section, they will first simply be presented, in their original wording. The heated debates over their validity and interpretation will be addressed later.

2.1.1 The Principle of Humanity: The Saint Petersburg Declaration of 1868

The first of these legal bases was the Saint Petersburg Declaration of 1868, in full title "Declaration Renouncing the Use, in Time of War, of Explosive Projectiles under 400 Grammes Weight" of November 29 (December 11), 1868. Its preamble reads:

> Considering:
>
> That the progress of civilization should have the effect of alleviating as much as possible the calamities of war;
> That the only legitimate object which States should endeavour to accomplish during war is to weaken the military forces of the enemy;
> That for this purpose it is sufficient to disable the greatest possible number of men;
> That this object would be exceeded by the employment of arms which uselessly aggravate the sufferings of disabled men, or render their death inevitable;
> That the employment of such arms would therefore be contrary to the laws of humanity.
> The contracting parties engage mutually to renounce, in case of war among themselves, the employment by their military or naval troops of any projectile of a weight below 400 grammes [about 13 1/2 oz], which is either explosive or charged with fulminating or inflammable substances (Declaration 1868).

The declaration thus regulated and formulated not only the special, explicit prohibition of certain weapons but also general principles of the law of war. According to Thilo Marauhn (1994, 46), it prohibited specific types of weapons (projectiles), on the one hand, and, on the other hand, established the "fundamental obligation to avoid unnecessary suffering and referred to the laws of humanity." In Marauhn's assessment (1994, 46), this was not a direct prohibition of chemical (poison) weapons. Rather, it stated the first general principles of humanitarian international law from which a prohibition of certain chemical weapons can be derived indirectly. The British scholar T. J. Lawrence, who was for many years a lecturer at the Royal Naval College in Greenwich and at the Royal Naval War College in Portsmouth, saw it as "the application of the true principle, which measures the illegality of weapons, not by their destructiveness, but by the amount of unnecessary suffering they inflict" (Lawrence 1923, 529).

2.1.2 The Impotent Model: The Brussels Declaration on Land Warfare of 1874

This same principle was applied again in the "Project of an International Declaration concerning the Laws and Customs of War, Brussels, 27 August 1874", which in Article 13 included the following provision: "According to this principle are especially 'forbidden': (a) Employment of poison or poisoned weapons."

The Brussels Declaration on Land Warfare of 1874 never came into effect. It did, however, lead to analogous resolutions by the Institut de Droit International in 1880 in the form of the "Manuel des lois de la guerre sur terre" (Kassapis 1986, 10; Kunz 1927, 13), unofficially known as the "Oxford Manual," which in turn was the model for the later positive-law regulations of 1899 and 1907 (Mérignhac 1900, 197).

2.1.3 The First Poison Prohibition in International Treaty Law: The Declaration on the Use of Projectiles with Asphyxiating or Deleterious Gases and the Hague Convention on Land Warfare of 1899

On July 29, 1899, the concluding act of the First Peace Conference in The Hague followed. It included the Hague Declaration (IV, 2) concerning asphyxiating gases. The preamble states that the declaration had been "inspired by the sentiments which found expression in the Declaration of St. Petersburg of 29th November (11th December) 1868." The declaration proper is as brief as possible: "The contracting powers agreed to abstain from the use of projectiles the sole object of which is the diffusion of asphyxiating or deleterious gases." (Carnegie Endowment for International Peace 1915b, V) It goes back to Article 13 of the draft declaration of the Brussels Conference of 1874. The wording of the Brussels Declaration on Land Warfare thus became part of the appendix to the Second Hague Convention of 1899 and of the Fourth Hague Convention. Although a prohibition of poison and poisoned weapons already existed under customary international law, the Hague Declaration of 1899 was the first time international treaty law expressly referred to "poison" weapons (Marauhn 1994, 46).

The formulation of the single objective or the single goal was often a point of reference for German interpretations, which argued that projectiles whose effects included not only gas but also fragmentation were permitted. It was also controversial whether gases that were not deadly also fell under the prohibition (Jaschinski 1975, 32–34). Later, other, non-German jurists also pointed to problems of the existing version. Lawrence (1923, 531–532) found the regulation dubious in comparison to other weapons and possible uses and believed that the horror of death by asphyxiating gases was no less than that of the fate of sailors drowning. Moreover, according to Lawrence, the adjective "deleterious" was "vague."

In 1899, the Second Convention, the "Convention with Respect to the Laws and Customs of War on Land", was passed (Kunz 1927, 13). Section 2, "On Hostilities," Chap. 1, "On Means of Injuring the Enemy, Sieges, and Bombardments," Article 22 reads as follows: "The right of belligerents to adopt means of injuring the enemy is not unlimited." Definitions and specifications of what was prohibited in Article 22 followed in Article 23, in which the parties were expressly denied unlimited rights in the choice of means to harm the enemy. It reads in part:

> Article 23.
>
> Besides the prohibitions provided by special conventions, it is especially prohibited: –
> (a) To employ poison or poisoned arms;
> (b) To kill or wound treacherously individuals belonging to the hostile nation or army;
> […]
> (e) To employ arms, projectiles, or material of a nature to cause superfluous injury;

Articles 22 and 23 established minimum standards for humanitarian warfare under existing international law. On the one hand, Article 23 provided definitions for and specifications of Article 22. On the other hand, a general principle prohibiting the use of poison in a certain sector was codified by treaty.

The final act of the Second Hague Conference of 1907 contained in Article 22 of the Fourth Convention (with identical wording) and in 23 a, b, e of the regulation the almost identical definitions of the Hague Convention on Land Warfare of 1899. The minor changes were (in *italics*)[2]:

> (a) To employ poison or poisoned weapons [instead of arms]
> (e) To employ arms, projectiles, or material calculated to cause unnecessary suffering [instead of of a nature to cause superfluous injury].

[2]Synopsis in: Carnegie Endowment for International Peace. Division of international law. 1915a. Pamphlet No. 5. The Hague Conventions of 1899 (II) and 1907 (IV) respecting the laws and customs of war on lands. Washington, D.C.: Carnegie Endowment, 17.

2.2 *No Notion of What Lay Ahead: The Intense Legal Discourse on the Hague Convention and Uncontroversial Interpretations of the Prohibition of Poison Prior to 1915*

The Hague Conventions included regulations on the law of warfare, and today it is contrasted with the Geneva Conventions, which concern the treatment and protection of people who are not or are no longer participants of the combat operations (Kassapis 1986, 1). The Hague Conferences marked a new era in the history of international law on warfare. Following the gas attacks at Ypres in 1915, the definitions established therein would become the central points of reference in the discussion of the legality or illegality of the German actions.

This led to the aforementioned problem of the relationship between legal regulations in their abstract form and the concrete events of real life to which they are supposed to be subsumed. In the period that followed, the regulations were often referred to, cited, and interpreted. But at the time of their enactment, no one could have foreseen how effective a weapon poison gas would become in just a few years and in which form it would be employed on the battlefields of the war to come (Bothe 1973, 8). For that reason, Bothe (1973, 88) argues that the intentions of the norm creators are interesting but not truly helpful when it comes to interpreting Article 23(a).

However, for the years between the passing of the norms quoted above and the beginning of World War I and even up to the German gas attack near Ypres, a lively, widespread juridical discourse on the law of war can be documented. The first and formal feature is that a considerable number of treatises appeared that addressed various subjects from the large field of regulating new warfare technologies. Their authors included jurists and specialists in international law or the military, and so did their readership.

If one considers only this thematic subset of the discussion of international law in this period, it is noticeable that the prohibition of poison is mentioned repeatedly. Nowhere, however, is this discussion focused on poisonous gas in the sense of the later events. The facts of the prohibition of poison are rather typically related to other, what could be called classical, historically experienced military strategies and given a pass (Zorn 1902, 7). In what follows, the accounts of several European scholars in international law will be laid out as examples.

The German international law specialist Hans Wehberg, who had a reputation as a pacifist, published the volume *Die Abkommen der Haager Friedenskonferenzen, der Londoner Seekriegskonferenz nebst Genfer Konvention* (The Treaties of the Hague Peace Conferences and of the London Naval War Conference and the Geneva Convention) in 1910. It only reproduces the original wording of the norm; there are no explanations of it (Wehberg 1910). The Swiss-German jurist and partisan of peace Otfried Nippold mentions poison but does not interpret or expose the problems of the term (Nippold 1911, 10). The same is true of Ernest Nys (1912, 144), professor and historian of international law in Brussels and member of the Permanent

Court of Arbitration. The German international law professor Karl Strupp wrote an account of the international law on land warfare that was published in 1914, already during World War I. In it the prohibition of poison is associated with the pollution of rivers, wells, and water pipes by infectious materials (Strupp 1914, 58).

Very similarly, Henry Bonfils, a French professor in international law teaching at the Université de Toulouse, wrote in 1908: "de contaminer les puits, les aliments, les armes, est absolument proscrit dans les guerres modernes" (poisoning wells, food, and arms is absolutely prohibited in modern wars) (Bonfils 1908, 660). A similarly limited interpretation is found in the book *Les lois de la guerre continentale*, by the French military judge Robert Jacomet, which was reprinted several times: he considers it to refer to poisoning wells and the spread of contagious diseases in the enemy's country (Jacomet 1913, 58). In the third volume of his textbook on the law of war, the French international law scholar Alexandre G. Mérignhac has an entry that again enumerates merely a classical historical arsenal of acts of poisoning, while gas as chemical weapon is not mentioned (Mérignhac 1912, 261). Mérignhac was even more monosyllabic with regard to Articles 22 and 23 in his earlier account of 1900 (Mérignhac 1900, 197). The account in the manual by J. E. Edmonds and Lassa Oppenheim, published around 1913, is also extremely terse: the prohibition is repeated word for word without any additional commentary.

To my knowledge, Albrecht Tettenborn deviates most from this widespread brevity in such accounts; in his analysis "Richtungen der einzelnen Kriegsmittelbeschränkungen" (Trends of the Individual Restrictions on Weapons), he interprets the term "Gift" (poison) (Tettenborn 1909, 22–24). In this case, his intense preoccupation with the wording of the norm that takes up the term "Gift" leads to a discussion of possible regulatory gaps. They are filled by the traditional historical practice of broad interpretation. The *ratio legis* of weapon prohibitions is extended to other fields, resulting in an expanded protection by the law of war. The discussion by Frantz Despagnet (1905, 645), professor of international law in Bordeaux and a member of the Institut de Droit International, of the possibility of poisoning air with gas also draws an analogy to the poisoning of water.

In the final years before World War I, this sort of treatment that exposes the problems of the subject was the exception, despite the codification of the prohibition of poison in treaties. The hesitant discussions that would follow in 1915 are even less evident. In the years since the prohibition of poison had been passed, modern technology had not yet posed a challenge to international law and its protective regulations. If one compares the tone and style of the comments of scholars of international law, something other than their brevity is striking as well: Scholarship on international law was not very politicized. There were no nationalistic undertones, no accusations or stereotypical discussions when it came to the establishment and application of norms of the law of war.

On the one hand, all of that is to be expected and not very surprising. On the other hand, academics working in the area of international law after 1915 will take another look at the positions previously taken by their colleagues and interpret them in light of recent events. It was not just that norms were read anew in the face of the ongoing or recently occurred gas warfare; previous positions were cited as well.

The old interpretations were reinterpreted. They took on a new weight and became in turn not only arguments, but potentially sources of international law as well (Vec 2017).

3 Militarization and Circumvention of Law: Debates on International Law During the Continental War with Gas, 1915–1918

This impression of the brevity, even inadequacy, of international-law scholars' interpretations of the prohibition of poison, combined with the not very politicizing tone of jurists' interpretations, would change after April 22, 1915, with a slight delay but a lasting effect.

As suggested in the introduction, whether this change appears surprising depends on the expectation one brings to historical international law and specifically during wartime. The lack of specific statements in the sources is also the subject of these expectations. Nevertheless, with all due caution it seems fair to conclude that there was an astonishingly weak or nonexistent response from European and American international law scholars to the gas attack of April 22, 1915.

3.1 International Law: Alive, but not Kicking

The international law of these years was often intensely preoccupied with the events of World War I. Many academics in international law adopted passionate stances on the legality or illegality of specific actions; others behaved more guardedly. This only makes all the more interesting the comparatively tepid discussion of the attack near Ypres that led me to the thesis condensed in the heading.

3.1.1 Scholarly Publications on International Law During World War I

It should be recognized first that the panorama of publications on international law during World War I is quite rich. The conflicts between states fueled the discourse on international law, opening up new themes and offering controversial issues to debate, taken up equally by scholars and nationalists (Toppe 2008, 103). Based on the type of publication, the following observations can be made: Books on international law continued to be published, especially anthologies of texts with the relevant regulations on the law of war (Carnegie Endowment for International Peace 1915a; Pohl 1915). These anthologies of texts did not, however, comment on or even mention the ongoing gas warfare (Pohl 1915). The legal journals and scholarly journals on international law that already existed during World War I published many essays and miscellanies on war and international law. The German *Zeitschrift für Völkerrecht*, for example, founded in 1906, reflected the new thematic trend in many ways (Hueck 1999). The changes in international law, the validity of specific norms, the subsumption of specific events to regulations under international law—all these issues now became the topic of intense debates among scholars of international law. It is interesting, however, that I was unable to find a single article in *Die Zeitschrift für Völkerrecht* concerning the subject of the gas attack. Monographs on international law also seem not to have mentioned gas warfare at all or at most very rarely. German scholars on international war seem to have been completely silent on the subject during World War I (Zecha 2000, 27). By contrast, poison gas was mentioned in A. A. Roberts, *The Poison War*, published in London in 1915 (Roberts 1915, 20). The statements of other international-law specialists from Allied countries will be addressed below (3.2).

3.1.2 Unclear Motives for and Few Scruples About the Use of Poison: Ex Post Justifications

The connection between the German decision in favor of the use of poison gas and international law also remained murky. According to Hull (2014, 232), the precise motive for the German employment of gas near Ypres is unclear. No documents can be found. Only subsequent justifications of the action with references to international law can be found. In these justifications the Germans argue that their use of poison gas was a reprisal for the French use. Modern scholars emphatically reject this justification as self-protection (Hull 2014, 233; Zecha 2000, 22). Instead, the Germans independently wished to employ poison gas. Nevertheless, the argument that the use of poison gas was supposedly a reprisal under international law shows that the Germans assessed its use based on the upstanding validity of the norm, since they asserted thereby that its use was a sanction for an injustice committed by the other side. That makes it clear that they assumed, at least ex post, that the use of poison gas violated international law. Other historical sources also suggest that the use on the part of the Germans had to overcome resistance that assumed it was illegal.[3] Fritz Haber (1924, 76), a chemist and the scientist responsible for the planning of German gas warfare, claimed in the 1920s that the military had conducted a legal review. Colonel General, head of the Generalstab (General Staff) and minister of war Erich von Falkenhayn had, according to Haber in a report to the investigating committee of the German Reichstag on October 1, 1923, “apparently personally reviewed the permissibility of gas weapons under international law.” Haber stated: “He was convinced beyond any doubt that his orders in the area of gas warfare did not violate international law” (Bell and Schücking 1927, 13; Haber 1924, 76–77).

[3] Otto Hahn reports a conversation with Haber in Martinetz (1996, 104).

3.1.3 Was the German Employment of Poison Gas a Symptom of General Disdain for International Law?

The striking absence of evaluations based on international law or any other normative considerations raises questions. What does this say about the German attitude to international law? To what can it be traced back? Hull is very emphatic here:

> the pattern of decision making seems clear. Civilian leadership, which was chiefly in charge of applying legal considerations, faced especially strong undertow from military institutions: from the junior, and then quickly from the senior naval officer corps regarding submarines; from the war ministry, which had already bought flamethrowers without advance discussion; and from OHL [Oberste Heeresleitung], which had already bombed civilian targets from the air." (Hull 2014, 238)

In this view, international law was disdained by the very parties who made the military decisions during World War I and bore responsibility for them. Hull's verdict is even more harsh from a comparative international perspective: Germany is said to have expressed particular disdain for international law (see also Partridge 1917, 6). With regard to the legal history, it is not easy to determine from the available sources whether this was in fact the case. There are several sources, at least, in which the attitude of other states to the poison gas attacks and international law is expressed.

3.2 The Law Comes Later: The Weak Normative Discourse on Gas Warfare After the German Attack

A first approach would be to ask how the other European powers reacted to the German poison gas attack and to what extent international law played a role in that discourse. But my thesis is that considerations of international law continue to be largely absent. Legal assessments of the German use of poison gas are found only here and there: The English international law professor Coleman Philippson noted in 1915, in an addendum to his account of the law of war during World War I, that "[the Germans] diffused asphyxiating gases among their enemy; such conduct being not only unlawful under the international declaration made in 1899, but contrary to humanity and civilization." (Philippson 1915, 217). A similar verdict is also found in Hall and Higgins (Hall 1917, 569 n. 2). French law professor at the Sorbonne Antoine Pillet (1918, 218) wrote in a book published toward the end of World War I that the prohibition of gas in Article 23(a) applied only to fluid or solid poison, since the prohibition of gas had been regulated elsewhere. And the rules therein date from another era of war technology, Pillet argued, so the prohibitions should not be applied to the new German gas attacks (1918, 244–245). Several other non-German authors addressed gas warfare (e.g., Clunet 1915).

Hence the surprise that international law played hardly any role in the German decision continues to some degree with Germany's enemies as well. As will be demonstrated in what follows, there was hardly any normative discourse on gas warfare, whether among politicians or in the general public.

3.2.1 The Lack of Protest: Political Voices and Official Reports

One first point concerns the question of the extent to which political voices and official reports articulated protest over the German poison gas attack. This question has also been examined frequently in the scholarly literature thus far, and the findings are quantitatively sparse. Zecha observed in 2000 "that neither the warring nor the neutral countries, for example, the United States until 1917, protested the use of poison gas or chemical weapons" (Zecha 2000, 26).

In the period immediately following World War I, not only Haber (Martinetz 1996, 114) but also the Germans Johannes Bell and Walther Schücking (with apologetic intent) asserted with satisfaction that no warring or neutral power had protested at all (1927, 9). Jaschinski, by contrast, asserted (without specifics) that the United Kingdom had accused Germany of violating "the laws of war of civilized countries" but other Allied countries had not protested the first large use of chemical weapons. Jaschinski condensed this into the memorable formulation "the silence of the Allied forces" (1975, 115).

By contrast, Garner (1920, 284–285) mentions a charge from the British War Office dated April 21, 1915, that "Germans had violated the laws of civilized warfare during their recapture of hill 60 east of Ypres, by employing shells which emitted asphyxiating gases." Moreover, "the Belgian commission of inquiry investigated the use of asphyxiating gases at Ypres" (Garner 1920, 272). Both Garner and Kunz report that the British field marshal Sir John French (later Earl of Ypres) denounced the gas attack in a battle report: "the enemy … by the use of an entirely new war method, one contrary to engagements entered into by them at the Hague Convention" (abridged quotation in Kunz 1927, 3, 14; Palazzo 2000, 43, Zecha 2000, 27; with different wording in Garner 1920, 276). In the House of Lords, Lord Kitchener would have protested this kind of warfare on May 18, 1915 (Palazzo 2000, 43). *The Times* of London reported a number of times (Garner 1920, 275–276). Hull (2014, 235) in turn quotes four statements by politicians that express outrage at the use of poison gas weapons. These four statements were not, however, official protests but only personal remarks, which Hull cites as evidence of the authenticity of the outrage of those who made them.

The picture in France is similar. In contrast to Britain, where official protest with underpinnings in international law was supposed to have been articulated, no one would ascribe that to France. Olivier Lepick, the scholar with the best knowledge of this material (1998), responded to a request by the present author by saying that no

French protest could be found.[4] Hull (2014, 237) notes that there were no discussions worth mentioning in France of the legality of poison gas weapons. Interest focused on France's own capacities: to catch up with Germany and to deploy gas weapons.

In the end, official protest did not follow until near the end of World War I—albeit not by the countries involved but by the International Committee of the Red Cross (ICRC). On February 6, 1918, it appealed to the warring powers to renounce poison gas weapons (Jaschinski 1975, 60; Overweg 1937, 64).[5] The use of chemical warfare agents was said to violate international law. The ICRC evoked the risk of the escalation of gas warfare and proposed a treaty on the renunciation as a return to the Hague Convention (Jaschinski 1975, 60). In their reply to this note of protest, the Allied countries first referred to their own use of poison gas as a "reprisal." By doing so they implicitly admitted (as the Germans had previously) that the use of this weapon was illegal but justified it with reference to earlier violations of international law by the enemy.

The warring powers thus demonstrated their awareness of the abstract legal standard; several of them (including the United States) nevertheless employed this weapon to obtain military advantage (Jaschinski 1975, 116). It is even more interesting, of course, that the first use did not produce an official outcry that mobilized international law as a normative basis for a complaint against the enemy in question. International law was almost inaudible in the discourse between countries with regard to the years of World War I—at least in the context relevant here of poison gas. Other violations, such as that of Belgian neutrality, were publicly denounced much more strongly. The only official objection in the case of poison gas, by contrast, came not from a state and not from one of the powers involved in World War I but from the International Committee of the Red Cross. It came late, in any case much later than the first use of poison gas. Nevertheless, as a complaint it set in motion justifications from the parties who had employed this weapon. These late justifications, like the ICRC's complaint, were presented in the language of international law.

3.2.2 The Daily Press: Restraint, Disinformation, and Loud Silence

Another surprise is the almost complete lack of discussion in the daily press. Here too astonishingly few traces of and references to the poison gas attack can be found. Even when they did occur, they occurred with strange distortions. The daily newspapers of various countries reported little about their own use; sometimes

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[4]Oral communication to the author on April 21, 2015 at Harnack-Haus in Berlin.

[5]Protest by the International Committee of the Red Cross, published in "Papers relating to the Foreign Relations of the United States. 1933." *1918, Supplement II: The World War*. Washington: US Gov. Print. Off., 779–781.

readers would first learn about it when the domestic press reacted to accusations from abroad or took positions justifying its own government.

Publication was subject to the conditions of wartime censorship. For that reason, it can be assumed that acts of the local government that seemed morally or legally dubious did not easily make it into the news. Those circumstances also explain why above all the possibly illegal actions in the form of the use of poison gas by one's own country were generally mirrored back via the detour of the enemy country's journalism. It remains surprising nevertheless that even the enemy's use of poison gas was not treated very prominently.

Several examples can be cited briefly for this assessment, and they are based on intense archival studies conducted by students in the summer semester of 2014–15 as part of a seminar on the history of international law in the Faculty of Law at the University of Vienna, held in Korneuburg in cooperation with the Österreichische Landesverteidigungsakademie ([Austrian] National Defense Academy) and the ABC-Abwehrschule "Lise Meitner" (Lise Meitner ABC Defense School) of the Austrian Federal Army.[6] According to these studies, the German use of gas weapons near Ypres was mentioned several times in the reporting on Ypres (Spitra 2015, 19). Often, however, the reader only learned about the use of gas from biased official reports from the Major Headquarters of the German Reich. It is even more curious that numerous reports refer first to French or English papers in order to reject their presentation of the facts or their legal views (Bischof 2015, 13–20). Moreover, such reports referred to official German announcements, according to which the enemies had been using such means for several months. In addition, there is a conspicuous silence where one would have expected reports. The first gas release by Austria-Hungary went unmentioned in the *Arbeiter-Zeitung*, the *Reichspost*, the *Neues Wiener Journal*, and the *Pester Lloyd* (Herzog 2015, 11). By contrast, there were lengthy reports on the attack on October 24, 1917, as part of the Twelfth Battle of the Isonzo; the victory was celebrated by the newspapers, but the gas that made it possible in the first place was not mentioned anywhere! The same was true of Austria-Hungary's last large gas attack as part of the Piave Offensive on June 15, 1918; no daily newspaper mentions gas.

But the poison gas attacks of the enemies also had a relatively weak journalistic response. The first English release of gas was not mentioned in any of the four Austrian-Hungarian newspapers studied. The same was true of the reporting one the first French release of gas on February 25, 1916, near Reims: the attack was not mentioned in any edition (February 21–28, 1916); nor was the attack using phosgene gas shells on February 21, 1915, near Verdun mentioned, even though this involved a new weapon (Herzog 2015, 11). In addition to the complaint of violations of international law, which by this time had become problematic, concerns about making one's own soldiers and nationals uncertain probably played the primary role in omitting such reports.

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[6] Seminar "Giftgas im Ersten Weltkrieg: Völkerrecht, Diplomatie und chemische Kampfstoffe," hold by Colonel Dr. Wolfgang Zecha, Lieutenant Colonel Erwin Richter, and Miloš Vec.

3.3 Possible Interpretations: Raison de Guerre as Its Own Form of Normativity?

If we sum up the observations thus far, we can conclude that international law played an astonishingly peripheral role not only in the Germans' decision whether to employ poison gas but also in the public discourse. Justifications often followed only in response to opponents' accusations of illegality. The justifications were repeatedly based on demonstrably false information, in the cases both of the German and Austrian-Hungarian armies and of the Allied forces. In what follows I will attempt to explain this attitude, in particular on the German side. Three possible factors seem to me worth mentioning.

3.3.1 Older Traditions of Disregard for International Law

First, the disdain for international law during World War I in general can be traced back to older traditions. For example, international law became established as a scholarly discipline in the nineteenth century, having ascended important steps of institutionalization at the universities and achieved a certain autonomy in the scholarly discourse. Considerable steps toward positivization with regard to the normative order between countries can also be observed. Part of this success story is institutionalization between countries and multilateral treaties with the possibility of accession (see Sect. 2 above).

At the same time, international law had always been subjected to academic, political, and practical criticism. The keyword here is the so-called deniers of international law. This collective name brings together heterogeneous doubts about international law as a genuine normative order. On the one hand, the publishing market in Germany for international law flourished, especially in the form of textbooks and monographs. That fed on older traditions of the history of scholarship in which natural law, political science, and imperial public law had prepared the ground well already by the end of the eighteenth century (Koskenniemi 2011). On the other hand, Germany in particular produced prominent deniers of international law. The flipside of such denial was often a complementary overemphasis on the sovereignty of the nation-state. In this view, the normative order between states could be subordinated to national law and national interests. This mixed explosively with the interests of certain military and political figures, and precisely in the situation of military conflict it was able to become acute that certain regulations of behavior between states would be regarded as nonbinding. Hull comes to the following clearly contoured and sharp conclusion regarding the German attitude toward international law:

> The legal discussions of autumn 1914 inside Imperial Germany reveal no identification with international law and no sense that law might be, intrinsically, a good worth upholding or in Germany's interest to strengthen. On the contrary, it mostly appears either as an impediment to necessary action, or at most as a tool one might instrumentalize." (Hull 2014, 239)

In this view, traditions of dismissing and denying international law were particularly strong in Germany.

3.3.2 Normative Plurality and Renouncing International Law: The Nature of the Laws of War

The second factor that can be identified is a particular dismissal of international law on war that took the form of the German military circumventing the law. For example, Hull (2005) suspects there was a specifically German mentality that easily thrived in the ideological soil described above. It found its classical expression in the notorious text *Kriegsbrauch im Landkriege* (translated as *The Usages of War on Land*), which was published by the German General Staff in 1902. It states that *raison de guerre* permits any warring state to employ all means that make it possible to achieve the aim of the war. This was restricted only by "*customs, traditions, or manner of war,*" but not by international law (Großer Generalstab 1902, 2–3). This rejection of all attempts to regulate the means of war by law is justified historically: "Immersion in the history of war will protect the officer from exaggerated humanitarian views; it will teach him that war cannot do without certain hardships, that rather the only true humanity often lies in its ruthless application" (Großer Generalstab 1902, 2–3). It is hardly surprising that such publicly expressed positions caused outrage from Germany's enemies in war and were exploited for propaganda. The text was quoted critically by international law scholars (Westlake 1907, 91; Garner 1920, 280) and was translated into several languages (German General Staff 1914; Grand État-Major Allemand 1916). The Italian edition of 1915 (Grande Stato Maggiore Germanico 1915) had an eloquent title page illustration showing German soldiers using a vise to crush civilians against the backdrop of a burning city.

Andreas Toppe came to a similar conclusion, identifying a lack of implementation in the German military and a "radicalization of military doctrine" (Toppe 2008, 28, 30, 105). The systematic location of this thinking is the idea that war has its own mechanisms. They are in a position to annul law and especially international law. It is condensed in the phrase "Necessity knows no law." This very formulation makes one think of the analogy to *raison d'état*, which also permits the violation of law and morality in time of need. That is why we speak by analogy to *raison d'état* of *raison de guerre*. This term also occurs in historical sources: in an extreme case, *raison de guerre* can overturn (international) law.

Evidence of this normative stance can also be found here and there in the late nineteenth century. The results of research of recent years and decades has shown that military figures—not only in Germany—often rejected the limitations on their means of warfare that were sought or agreed on at international conferences on international law (Messerschmidt 1983, 240). The argument was that while humanity may be a feasible principle for modern international law on war, it is alien to the true nature of war (Dülffer 1978, 150). Other military figures argued that one could better pursue humanity by creating new, more effective weapons than by prohibiting them (Dülffer 1978, 150). Finally, Fritz Haber's own dictum on the rapid poisoning effect of prussic acid (which was, of course, never a weapon of war) points in this direction: "One cannot die more pleasantly" (Cassar 2014, 31; Haber 1924, 81). That was formulated by comparison to ethyl bromoacetate, which had been employed by the French in August 1914 as the first (but not lethal) gas weapon, and according to Haber it caused a truly agonizing death. The legal assessment of various gases should therefore, in Haber's view, be considered in nuanced fashion. Some effective breathing poison could be breathed without a problem, while others were excruciating to breathe and were for that very reason were less likely to be effective as poison (Haber 1924, 81). Hence the limits should themselves be limited (Huber 1913, 359). Not international law but military utility should have the last word. Prohibitions in international law were therefore eyed with distrust because the military wanted to keep open the option of better weapons in the future (Dülffer 1978, 76). Interestingly, this attitude of criticizing or annulling international law is expressly shared by some experts in international law (Cybichowski 1912, 68–69; Lentner 1880, V). Even Hans Wehberg (1910, 14–15), who is regarded as a pacifist, writes: "In the extreme case […] every principle of the law of war can be breached."

Other, non-German scholar on international rights made comparable arguments (Rivier 1896, 241–242). Thus around 1900 there was an unholy alliance in which the military and international-law scholars placed the validity of the law for certain extreme cases under the proviso of necessity. It is hardly surprising that as the war continued, the aspect of the political utility of international law was emphasized more strongly (Koellreutter 1917/1918, 500).

3.3.3 Cruel, Unmanly, and Unchivalrous: The Military's Aversion to the Use of Poison

A third and last approach to explaining the absence of discourse on the use of gas as a weapon and its permissibility under international law is the discomfort in ethos of broad swaths of the military to poison gas. This argument focuses on the perception of this weapon and contrasts it with the disposition of military actors. Gas and poison were perceived as cruel, unmanly, and unchivalrous (Encke 2015, 2006, 197–218). All poison was considered a "womanish weapon," which is in keeping with the attribution of this way of killing to women in criminal law and criminology (Weiler 1998). Gas and poison were not used in man-to-man close combat; they did not cause bleeding wounds in physical battle. Rather, it was a weapon that only worked at a distance. This had already been an argument for considering medieval crossbows to be illegitimate or even illegal. All these elements underscore the asymmetry of the debate, in which they ran counter to a chivalrous ethos that preferred beating, stabbing, and shooting weapons (Encke 2015).

The depictions of poison gas in literature and art (see the essay by Kaufmann in this volume) underscore the problems that even parties of militaristic convictions had with this particular weapon. For example, pacifists and opponents of war produced many works that have since become famous in art history denouncing the effects of poison gas, including those by Otto Dix, among others. In *Die letzten Tage der Menschheit* (translated as *The Last Days of Mankind*), Karl Kraus (1922, 337) also left no doubt about the ethical doubtfulness of poison gas. In that work he coined the pun of the "chlorious" offensive:

> For the one thing that remains inconceivable is what possible connection exists between some chemist's inspiration, in itself a disgrace to science, and heroism. How fame in battle can be attributed to a 'chlorious' offensive without choking in shame on its own poison gas." (Kraus 2015, 262)

On the other hand, revealingly, there are no mentions or descriptions of poison gas in the art and literature that glorifies or affirms war.

All this shows that poison gas was a subject above all in nonaffirmative, antiwar, and critical accounts of war. The military, by contrast, had little sympathy for this weapon, and that can be seen as another reason for its silence on the subject.

4 The Continuing Politicization of International Law: The Legal Assessment of War Crimes, 1918–1925

After the war ended in 1918, there followed a third phase in the discourse on international law concerning the use of poison gas weapons. It was an intense, retrospective debate on the legality of their use under international law. The not very surprising form taken by this third and final phase is characterized by stark nationalization and an irreconcilable polarization of the political and legal standpoints.

4.1 Crime and Argument: The Intense Discourse After the End of World War I

The intense discourse on the use of poison gas that followed the end of World War I was embedded in the general public assessments of the events of the war years. From the prehistory of the war to its outbreak and over its course up to the end: All the events were evaluated in terms of domestic and international law. The parties sought the tribunal of the public and tried to win over public opinion. Between the wars, especially, the subject of gas warfare reached a climax in the public debate.

Perspectives of history and of international law thus went hand in hand politically, and they were also associated with narratives of proper conduct. For that reason it is right to speak of "war innocence research" (Große Kracht 2004, 8). Already in the July crisis and the first months of war, the so-called "colored books" were published by official authorities or at least by sources close to the government. In these texts the various national standpoints were presented with a suggestion of historical objectivity. The colored books of the enemy were in turn accused of distortions and omissions in their descriptions of historical events (Zala 2001, 27).

What had begun with the outbreak of the war continued over the course of the war with respect to events, with the intention of demonstrating the enemy's war crimes (Dampierre 1917; Niedner 1915). Because all sides were involved and making reciprocal accusations, it has rightly been called a "war of colored books" (Kuß 2010, 334). The public fight over the question of war guilt and the politically tinged legal discourse on war crimes followed the battle with weapons (Große Kracht 2004).

Gas warfare was also assessed in a number of publications after 1918. The major international scholarly works on international law published between the wars mention gas warfare frequently. Monographs, brochures, and essays devoted exclusively to poison gas were published (Ewing 1927; Eysinga 1928; Hanslian 1934, Kunz 1935, 85–88;). Some of these specialized monographs had a more scientific and technical tone (Endres 1928; Hanslian 1927, 2009; Meyer 1926; Woker 1925); other books focused on international law (Korovine 1929; Kunz 1927, Overweg 1937).

4.2 Self-justifications: The Nationalist Polarization of International Law

A number of such works were published in Germany, investigating the conduct of the war by Germany and other countries, some expressly discussing gas warfare. *Die deutsche Kriegführung und das Völkerrecht* (Deutsches Kriegsministerium und Oberste Heeresleitung 1919, 20–26) was published already in 1919; in the 1920s followed the five-volume *Werk des Untersuchungsausschusses* (Bell and Schücking 1927). The former work claims of the use of gas on April 22, 1915:

> *When updating the historical method of smoking out in a modern form with chlorine gas at Ypres, we neither used a more harmful material nor created a new means of combat.* The defining feature of our approach was simply that we brought to bear for the first time the *mass effect* of gas as a weapon, without which a military success in the field cannot be achieved with gas weapons. (Deutsches Kriegsministerium und Oberste Heeresleitung 1919, 23, italics original)

These lines contain the core of the German defense strategy in the debate on international law over the following years. The poison gas attack at Ypres was thus placed in historical and international contexts that were intended to relativize it. The specific claim of permissibility under international law resulted from additional arguments that the German authors presented to their readers with great care. Their conclusion defines the guilt and innocence of the parties to the war in a clear black-and-white schema:

> The factual and legal procedures in gas warfare are presented by applying the critical probe; they certainly justify the conduct of Germany, while to France falls the burden of having violated a global treaty. The reproaches made against us are thereby revealed to be part of the battle of lies by which the enemy league unceasingly strives to disparage us in the public opinion of the world. (Bell and Schücking 1927, 42)

Compared with that of the war years, this discourse on international law was intense and decidedly detailed. It is characterized by a nationalist polarization of standpoints. The attributions of guilt to the respective wartime enemy were expressed in the language of law and morality. The preferred politics of international law could often be derived simply from the nationality of the authors.

The Germans loudly and energetically defended themselves against what seemed to them a form of victor's justice and corresponding assessments of international law. They appealed to a number of counterarguments purporting to justify the use of poison gas. By contrast, the assertion that the use of poison gas was illegal could not be found in a single publication from Germany. The authors presented a whole arsenal of arguments for its legality under international law: The Hague Declaration of July 28, 1899, is said not to have applied (Kunz 1927, 20, 28; Meyer 1926, 296). The Hague Convention of 1907 was also said not to be applicable in World War I (Meyer 1926, 296–297). Alternatively, it was claimed that Article 23(a) was not relevant because gas is not a "poison" (Deutsches Kriegsministerium und Oberste Heeresleitung 1919, 24; Hanslian 1927, 5; Kunz 1927, 33; Meyer 1926, 298; Overweg 1937, 48–51). It was claimed that the Hague Declaration of 1899 did not apply to the "blue and yellow cross shells of the world war" or to artillery gas shells since "the spreading of poisonous gases is not their only purpose; rather, their main purpose was to render the enemy harmless" (Kunz 1927, 26; Strupp 1922, 201). Article 23(e) was also said not to be relevant because no "unnecessary suffering" was caused (Deutsches Kriegsministerium und Oberste Heeresleitung 1919, 24; Hanslian 1927, 5; Kunz 1927, 32; Meyer 1926, 298–299).

Furthermore, it was claimed in the alternative that the Hague Declaration of July 28, 1899, had been violated first by France; Germany merely followed suit and retaliated (Deutsches Kriegsministerium und Oberste Heeresleitung 1919, 23; Haber 1924, 83; Kunz 1927, 3–4; Meyer 1926, 301). It had been a case of a "state of emergency as recognized by international law" (Deutsches Kriegsministerium und Oberste Heeresleitung 1919). In general, it was claimed that the "Hague Accords had barely touched on the essence of gas warfare," since they had failed to recognize its humane essence (Meyer 1926, 302). The prohibitions of asphyxiating gas were said to have been annulled in the world war since both sides had made use of gas, claimed the international law scholar Josef Kohler in 1918; thus gas warfare had been legal (Kohler 1918, 212–213). The German international-law professors Julius Hatschek and Arthur von Kirchenheim claimed between the wars that the use of poison gas conformed to international law (Hatschek 1923, 316; Kirchenheim 1924, 405–406).

It is probably not oversimplifying too much to say that the standpoints of German jurists were primarily legitimizing, affirmative, defensive, and militaristic. One of the few exceptions was Mendelssohn-Bartholdy. He published a critical essay in 1927 with the revealing title "Kriegsnotwendigkeiten und Repressalien: Zwei Feinde des Völkerrechts" (The Necessities of War and Reprisals: Two Enemies of International Law) (Mendelssohn-Bartholdy 1927). In this text he expressed criticism of Haber and rejected the argument that the German use of poison gas had been a reprisal. He did, however, concede that the ambiguities of the rules had left many backdoors open.

The positions of academics in international law from Allied countries, by contrast, cannot be characterized so simply. There seems to have been a greater diversity of opinion and not so much thinking in camps. For example, there are French assessments in which poison gas as such is said to violate international law (but could be justified as a reprisal) (Rolin 1920, 326–327). The Allied use had been justified if and to the extent it had been reprisal (Hall 1924, 637, footnote 2; Garner 1920, 262, 271–292). The Archbishop of Canterbury and the Bishop of London (on May 16, 1915), by contrast, appealed to their government not to employ poison gas and descend to the level of the enemy (Garner 1920, 273, footnote 1). Articles 23(a) and 23(e) had been violated by the Germans to the extent that chlorine gas had been employed; by contrast, it was argued, other types of gas should be judged less harshly under international law (Lawrence 1923, 531).

Finally, there were positions not formulated by any of the countries that had been involved in the world war. It is presumably no coincidence that these positions tended to manifest principally antimilitary and pacifist features. In the polarized climate of politics and international law between the wars, it was all the more attractive for one side or the other to co-opt these to some extent neutral authors. Authors of such texts include Franz Carl Endres and Gertrud Woker. The latter published her book on behalf of the Women's International League for Peace and Freedom. Both authors emphasized not only that the German use of poison gas violated international law, but also the ongoing threat and the alarming role of a transnationally active armaments industry (Endres 1928, 38–39). Woker (1925, 16–19) frontally attacked Haber's argumentation, polemicizing against the "magnificent militaristic logic" she saw in the arguments that gas was effective and in conformity with international law.

4.3 Politicized Scholarship: No Mediation Possible

This controversy in scholarship on international law cannot be decided *ex post*, even if the arguments defending the German use of gas seem legally inconsistent and questionable to us today. To demonstrate this, a more detailed analysis would have to examine the arguments with an eye to contemporaneous theory about legal sources and about legal argumentation. Contrary to the later German objections that the Hague Treaty had not applied, for example, one need only point out the possibility that as positivizations of previous customary law they remained valid in the form of customary law as well; the fact that the Hague Treaty was reprinted in German World War I anthologies on military law also suggests it was believed to be valid (Kramer 2003, 281). Given the highly politicized climate and the intent to legitimize past actions, it was not to be expected the scholarly discourse would get closer to the subject matter, and in fact it did not. The camps remained hostile to each other, and there was no discernible mediation by third positions or even any softening of tone during the period between the wars. This thinking as part of a camp was particular stark in German scholarship on international law.

4.4 *Reforms as Affirmation of the Prohibition of Poison in International Law*

Thus the scholarly community in international law was not unified and did not come together on a view of past events. It was, however, better disposed to shaping such a view in the future. After the experiences of World War I, whether or not one judged certain past acts as in conformity with or as illegal under international law, all sides appeared agreed that poison gas should not be used in the future. Legal reforms and further standardization served to affirm the prohibition of poison under international law. Four stages should be identified here in conclusion.

4.4.1 Asymmetric New Paths: The Prohibitions of the Production and Possession of Weapons in the Paris Peace Treaties of 1919

First there were the Prohibitions of the Production and Possession of Weapons in the Treaties of Paris. The Treaty of Versailles set forth legal prohibition concerning the production and import for Germany:

> Article 171
> The use of asphyxiating, poisonous or other gases and all analogous liquids, materials or devices being prohibited, their manufacture and importation are strictly forbidden in Germany.
> The same applies to materials specially intended for the manufacture, storage and use of the said products or devices.
> The manufacture and the importation into Germany of armoured cars, tanks and all similar constructions suitable for use in war are also prohibited.
>
> Article 172
> Within a period of three months from the coming into force of the present Treaty, the German Government will disclose to the Governments of the Principal Allied and Associated Powers the nature and mode of manufacture of all explosives, toxic substances or other like chemical preparations used by them in the war or prepared by them for the purpose of being so used. (Jaschinski 1975, 61)

Largely identical rules were laid out in the four other Treaties of Paris for the other countries that had lost the war: Article 135 in the Treaty of St. Germain; Article 82 in the Treaty of Neuilly; Article 119 in the Treaty of Trianon; and Article 176 in the Treaty of Sèvres (Marauhn 1994, 61, notes 110–113).

On the one hand, this legal regulation presumed an existing prohibition of use (Jaschinski 1975, 61). On the other hand, it took new paths beyond the prohibition of use and created a preventative sphere for the first time (Marauhn 1994, 63). In relation to poison gas, therefore, it represented a legal norm for the prevention of war. Admittedly, it expressed an asymmetry of power: the prohibitions applied only to those countries that had lost World War I. There was no reciprocal application to the victorious powers.

4.4.2 Pacifist Efforts: Initiatives by the League of Nations

The League of Nations was also active in the context of its arms control efforts (Schücking and Wehberg 1924, 414–416; Overweg 1937, 77–81; Jaschinski 1975, 72). These efforts were an attempt in peacetime to make the use of chemical weapons de facto impossible or at least minimize the likelihood of their use in a future war (Marauhn 1994, 72). The bodies involved were the Council, the General Assembly, the Disarmament Commission, the Nonpermanent Arms Commission, the Commission on Intellectual Cooperation, and a subcommittee. The Red Cross also made a special submission to the General Assembly about preventive measures (Schücking and Wehberg 1924, 415). The various sides pursued the limitation or prohibition of manufacture and laboratory experiments. Issuing an "appel aux savants" to all countries to publish their pertinent inventions in order to make their use in war impossible (Freytagh-Loringhoven 1926, 118) was considered (but rejected). Expert opinions and reports were commissioned and committees established. It was decided to publish a report on the horrors of a future gas war; it was intended to be distributed to as broad an audience as possible (Freytagh-Loringhoven 1926, 118). These activities of the League of Nation overlapped with those of the Washington Conference of 1922. In the end the question was raised whether the members of League of Nations should be encouraged to join the Washington Treaty. Nothing more came of this (Meyer 1926, 304). For its part, the Washington Treaty never came into effect. Nevertheless, the Fifth Assembly of the League of Nations concluded a resolution in 1924 in which gas weapons were described as a threat to civilization in future wars (Overweg 1937, 80–81).

4.4.3 An Expression of the General Opinion of the Civilized World: The Washington Treaty of 1922

At the Conference on the Limitation of Armament in Washington, which had opened on November 12, 1921, a unanimous resolution was concluded on February 6, 1922:

> The use in war of asphyxiating, poisonous or other gases, and all analogous liquids, materials or devices, having been justly condemned by the general opinion of the civilised world and a prohibition of such use having been declared in Treaties to which a majority of the civilized Powers are parties, the Signatory Powers, to the end that this prohibition shall be universally accepted as a part of international law binding alike the conscience and practice of nations, declare their assent to such prohibition, agree to be bound thereby between themselves and invite all other civilized nations to adhere thereto. (Lawrence 1923, 532)

The signatories were the United States, the British Empire, France, Italy, and Japan.

It was not just the wording that was controversial (Jaschinski 1975, 65; Overweg 1937, 74–75). It was criticized for not distinguishing between asphyxiating and harmful agents. The Washington Treaty was not ratified by the participating countries, however, and therefore never came into effect.

4.4.4 Reassuring One's Principles: The Geneva Protocol on Poison Gas of 1925

Finally, the Geneva Protocol of 1925 on poison gas provided a new positivized norm. Once again it was assumed that a prohibition already existed (Jaschinski 1975, 67; Marauhn 1994, 49). This was now affirmed in the Geneva Protocol but its scope was not significantly changed (Marauhn 1994, 49). On June 17, 1925, the Protocol was concluded with the following wording, closely following that of the Washington Convention:

> The Undersigned Plenipotentiaries, in the name of their respective Governments:
> Whereas the use in war of asphyxiating, poisonous or other gases, and of all analogous liquids, materials or devices, has been justly condemned by the general opinion of the civilized world; and
> Whereas the prohibition of such use has been declared in Treaties to which the majority of Powers of the world are Parties; and
> To the end that this prohibition shall be universally accepted as a part of International Law, binding alike the conscience and the practice of nations;
>
> Declare:
> That the High Contracting Parties, so far as they are not already Parties to Treaties prohibiting such use, accept this prohibition, agree to extend this prohibition to the use of bacteriological methods of warfare and agree to be bound between themselves to the terms of this declaration. (Marauhn 1994, 49)

The general prohibition was in that sense a kind of self-reassurance and affirmation of the content of treaties and of customary law that had been valid prior to World War I but had often been breached in praxis between states during the war. Today the Geneva Protocol of 1925 is still valid and has been judged "probably the most significant special standard thus far prohibiting the use of chemical weapons" (Marauhn 1994, 47). In 1997, the "Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction" enhanced the prohibition of chemical and gas weapons and enforced the elimination of such weapons. Until today (February 2017), 192 states have signed the treaty.

5 Summary: Expectations Regarding International Law

The history of the struggle over international legal rules on the prohibition of the use of chemical weapons is thus far from over. On the contrary, countless violations of legal norms are etched into the history of the twentieth century. Time and again, new inventions have posed challenges to the prohibition as well. Nonetheless, the Geneva Protocol on Poison Gas seems a potential terminus for the narratives about the events of Ypres in 1915.

The prohibition of perfidious means and unnecessary suffering was violated many times in April 1915 and up until the end of the war in 1918, in the face of express agreements and despite the ongoing validity of customary international law. Even if one were to regard the detailed special prohibitions under international law as somehow inapplicable, there would remain the spirit of the norms as a further point of reference. After all, alongside the specific prohibitions there were also older general legal principles proscribing perfidious means and unnecessary suffering under international law deriving from the principle of humanity. That general principles of international law were disregarded to such an extent in the First World War relates to the particular moral values expressed in these principles. By this expression, legal principles can endow values with more vigor and prompt surprising decisions, but are also particularly fragile. It is no coincidence that certain legal disciplines in which the norm setting is not yet complete tend towards legal principles. The international law of the nineteenth century was one such area. Alongside the juridification of international relations, it relied heavily on general legal principles as well as on natural law (Vec 2012, 2017). The conflict surrounding poison gas in the law of war shows how fragile certain rules can become in practice. Under the conditions of the world war, under pressure from blazing nationalism and militarism, international law is drawn into the undertow of politicization, an undertow that weakened it so severely that one is inclined to speak of its almost total absence from certain areas of regulation in these years. Certain actors, including both military figures and international lawyers, practiced the circumvention or even denial of the law of war. Whether one is disappointed by this depends—as we have said—on the expectations of a contemporary reader contemplating the historical events of earlier epochs. The law of war in World War I was, especially when compared to other matters, a highly political area of regulation. In any event, the consideration of this time should always take into account the political circumstances and the larger context when it accentuates the *Realpolitik* and the relativism of this international law (Orakhelashvili 2011, 454–455).

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Military-Industrial Interactions in the Development of Chemical Warfare, 1914–1918: Comparing National Cases Within the Technological System of the Great War

Jeffrey Allan Johnson

Abstract This chapter examines the development of chemical warfare on the Western Front in the context of the large-scale technological systems developed by each of the major powers—Germany, France, Britain, and later the United States—in order to coordinate their industrial, academic, and military resources. As chemical warfare intensified from the tentative, small-scale experiments of 1914–1915 to the massive bombardments of 1918, it also changed qualitatively. Each side's innovations forced similar responses from their opponents, in an escalating arms race in which military exigencies increasingly overrode ethical concerns while tending to institutionalize chemical warfare. This process exemplified the war's increasingly "total" nature as a technological meta-system integrating the fighting fronts and home fronts on each side and across the lines. On the verge of permanently institutionalizing chemical warfare and militarizing its supporting industries, the process abruptly ended as the German system collapsed. But by then the war had transformed the image of chemical science and technology from a progressive force to one associated with the horrors of war.

1 Introduction

Although there is a great deal of literature on the role of scientists, especially Fritz Haber, in the development of chemical warfare during the First World War, relatively little has appeared on the role of the chemical industries and their collaboration with the military authorities. Chemical warfare was admittedly only a part, in some ways a relatively insignificant part, of the wartime activities of academic and industrial chemists. Yet in the popular mind it rightly looms much larger. For Germany's introduction of poisonous gas to the battlefield clearly violated the spirit

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of the 1899 and 1907 Hague Conventions, thereby introducing an era of literally unconventional warfare. Wilfred Owen's well-known poem "Dulce et Decorum Est" created an unforgettable image of the horrifying effect of gas on an unprotected soldier, which was also used to great effect in the commemorative ceremonial concert concluding the symposium at which the present chapter was presented. Images such as these highlight the role of chemical warfare in making the Great War increasing "total," in the process blackening the image of chemistry, especially the German variety. This chapter examines on this transformation after examining the development of interactions between the chemical industry and the military (as well as the interactions of both of these with academically-trained experts) in Germany, France, Britain, and later the United States, as a special case of the broader technological meta-system created by these opposing national systems on the Western Front from 1914 to 1918.

2 The Western Front as a Technological Meta-System

The Western Front can be viewed as a large technological system, or rather meta-system composed of several interacting national systems, within which military, industrial, and academic subsystems interacted in various ways. The idea of studying the chemical industry as a large technological system in a wartime setting goes back to Thomas Parke Hughes. Hughes conceptualized the development of high-pressure hydrogenation processes during and after the First World War as a case of "technological momentum," whereby a large-scale technological system tends to grow by maximizing existing productive capacities (when necessary, by adapting them to new uses) and by applying the experience of its scientists and engineers with previously successful approaches to the development of new products and productive capacities (Hughes 1969, 111–112). This pattern of growth is thus creative but also conservative, making fundamental changes in direction only when influenced by external forces. In a later full-length study of the electrical industry 1880–1930, Hughes developed valuable conceptual insights and a comparative regional approach, but with little attention to the First World War, whose impact on the electrical industry was far less than on the chemical industry. Hughes identified three sorts of technological systems: a purely technical, a technical-institutional, and a more "loosely structured system" whose components interconnect and interact, but which is "neither centrally-controlled nor directed toward a clearly defined goal" (Hughes 1983, 6). The present chapter examines this latter type as a meta-system and examines the development of chemical warfare as part of the larger meta-system of the Western Front—in which three and ultimately four large-scale systems operated and interacted in response to each other's initiatives: that of the Germans on the east side of No Man's Land, and those of the Allies to the west—the French, British, and finally the Americans—which cooperated increasingly well yet never grew into a seamlessly operating single system.

The growth and interactions of these systems thus shaped chemical warfare during the First World War.

From a military-economic perspective, the war was an extension of prewar competition among technological systems originating during the Second Industrial Revolution, in which since the 1860s large firms had utilized systematic innovation by teams of academically trained chemists, physicists, and engineers to carve out oligopolistic positions in the world market. With the advent of war, the opposing systems carried on—with apologies to Clausewitz—a kind of "economic competition by other means." That is, the war refashioned the process of systematic technological innovation, shifting it to military settings, whereby the oligopolistic opponents now stood on the other side of No Man's Land, and it was on the front rather in the marketplace that product testing took place. Depending upon results in the "battlefield marketplace," each side might expand its production, modify its product, or imitate or improve upon competing products of the opposition. Success could thus depend upon the ability of each system to function effectively as an innovative system, potentially on a very large scale, in a manner not very different from the process of peacetime competition, albeit without regard to questions of intellectual property at least for the duration of the war.

From a systems perspective, the war on the Western Front was actually two successive wars, which one could call the "Great War" and the "Total War" (Chickering and Förster 2000). Each of these involved a type of mobilization; the first, beginning on both sides in August 1914, was limited and based mainly on prewar structures and capacities, in proportion to the degree of technological momentum in the peacetime systems. New problems and constraints posed in particular by the advent of static trench warfare at the end of 1914 created growing pressures that led to a "second mobilization" in each nation, representing a much more "total" and more innovative utilization of their resources and marking the advent of a wartime system with its own technological momentum. The timing of these second mobilizations depended in part upon a variety of unanticipated developments such as the continuing German occupation of a significant part of the industrial region in northwest France, as well as the inadequacy of prewar tactics and equipment for achieving breakthroughs. Thus by the spring of 1915, pressures toward a second mobilization already existed on the Allied side, marked in the British case by the creation of the Ministry of Munitions in May 1915, which took over from the War Office the coordination of national production, began systematically to mobilize scientific and technical expertise, and notably departed from the British tradition of free enterprise by supervising the construction of a series of National Factories for munitions production, initially intended only to cover wartime needs (Simmonds 2012, 67–96). The French, reeling from the loss of industrial capacity to the German invasion, had already begun the task of remobilizing their economy for war in the fall of 1914, but a major transition also came in May 1915 with the appointment of Albert Thomas as Under-Secretary of State for Artillery and Munitions (Hardach 1992). It can hardly be coincidental that these major innovations as well as several others occurred shortly after the first German attacks with chlorine gas at Ypres on April 22, which represented a move toward total war in two senses, not only toward unconventional warfare but also a greater mobilization of the chemical industry, which was now beginning to discover the possibility of "dual-use" chemicals. Because this initially entailed only the adaptation of existing capacities and products to wartime uses, it did not yet represent a full second mobilization. That finally came with the Hindenburg Program of September 1916, in response to the British-French offensive on the Somme in summer 1916, which had been made possible by the Allied innovations since spring 1915 (Herwig 1997, 259–266).

The advent and development of chemical warfare could be said to constitute a special case of this broader systemic interaction and the "totalizing" process it produced, which began to have a major impact on the conduct of the war in 1916 and was still gaining momentum on the Allied side—especially with the addition of the American system and its thorough-going mobilization beginning in 1917 (Steen 2014, 75–112)—when the German system collapsed in November 1918, in part because its limited resources could not sustain a total mobilization (Herwig 1997, 440–450).

3 Chemical Weapons as an Illustrative Case

Chemistry in 1914 was already a highly industrialized science, marked by well-developed, institutionalized academic-industrial relations. Primarily because of the development of high explosives based on organic compounds during the late nineteenth century, there also existed elements of a prewar military-industrial symbiosis, albeit on a relatively small scale. All of the major countries had relatively small testing facilities in their arsenals, and all had contracts with civilian companies to produce munitions and other items that could not be produced in the arsenals themselves. Far more significant would be the prewar academic-industrial relationships that had emerged outside the military system. These relationships could to some extent be carried over, or at least serve as a model for the developing military-industrial and academic system during the war. Thus a potentially decisive military advantage for the Germans, albeit unrecognized before the war, was the highly innovative academic-industrial symbiosis developed by their coal-tar dye industry (Johnson 2000, 15–23). A half-dozen large, research-intensive firms, organized in two oligopolistic alliances, had obtained a quasi-monopoly amounting to almost ninety percent of world synthetic dye production. Nearly all of the dye factories or sales outlets in Britain, France, Russia, and the United States were actually German, using German chemists and mostly German-made chemicals for key processes. With the outbreak of war, the Germans would find themselves with a "chemical weapon"—thousands of research-trained, technically-experienced industrial chemists—which the Allied system would find it very difficult to match until the Americans began systematically mobilizing chemists for war work in 1918 (MacLeod 1998; Steen 2014, 96–97). Following the logic of technological momentum, most wartime innovations redirected known technologies in novel ways. This however gave a decided advantage to systems including large, well-established firms with longstanding traditions of technical expertise and good connections to academic institutions—precisely the characteristics of the German dye industry, which would thus find itself especially suited for the chemical war.

Moreover, by August 1914 the concept of "dual use," common today in discussions of chemical warfare, was already inherent in the nature of the chemical industry, especially in regard to synthetic organic chemicals. It was easy to modify chemical production processes so that with slight variations in raw materials, reagents, intermediates, and operating conditions, one could produce a wide variety of different final products for a wide variety of purposes, some of which could be military. At the outset of the war there were already three categories of products that included examples of what one might characterize, using a type of later American military jargon, as the "three D's" of *unplanned* dual use: disinfectants (chlorine), dyes (phosgene), and drugs (arsenicals) (cf. Haber 1986, 15–16, 21, 159). Chlorine had long been used for disinfecting municipal water supplies, among other things; phosgene (a deadly compound of carbon monoxide and chlorine) was an intermediate in the coal-tar dye industry, used for producing several different dyes; and most recently the dye corporation Farbwerke vorm. Meister Lucius and Brüning—Höchst (henceforth, Höchst) had begun to market organic arsenical compounds (developed in collaboration with the 1908 Nobel laureate for medicine Paul Ehrlich) as the first effective drugs for treating syphilis. Dual use in these cases was unplanned, because none of these products had originally been intended for military purposes. But the experience and expertise gained from systematic innovation in these fields—especially dyes and drugs, for which the largest firms together had about a thousand chemists in 1914, synthesizing and testing thousands of potential products—could easily be redirected. The Farbenfabriken vorm. Bayer-Leverkusen (henceforth: Bayer) and Höchst in particular had been working with synthetic drugs for decades, and in the process they had developed medical testing facilities and collaborative relationships with physicians to test the physiological effects of their compounds. In the pharmaceutical industry as such, there were also several larger firms such as Merck-Darmstadt that had developed similar combinations of chemical and medical expertise (Baumann 2011, 36–194). Thus the basic structure of the system was already in place in 1914, especially in the German context. The Allies' chemical industries, with less diverse product assortments (especially for organic chemicals) and less intensive processes of innovation, were less suitable for adaptation to chemical warfare; the Allies would thus require more fundamental changes in their prewar industrial systems. Nevertheless even on the Allied side there were possibilities for dual use; for example, both the British and French explosives industries produced picric acid as a high explosive; combined with chlorine, this would produce chloropicrin, which could be used as a chemical agent. Moreover, Allied producers of chlorine, for example for bleach, could also (in principle) fairly easily produce phosgene gas from chlorine and carbon monoxide, which required no organic-chemical expertise. In practice, however, inexperience and incompetence led to delays and inefficiencies, especially on the British side (Haber 1986, 83–86, 162–163).

4 Industrial Mobilization for Chemical Warfare: The Experimental Phase, 1914–15

At the outset of what was widely expected to be a short war, the German dye firms by and large did not expect to supply the military with much besides dyes for uniforms. They did produce some nitrates and nitrated products for dye manufacture, selling their surplus to the explosives industry (nitrotoluene and dinitrotoluene could be used to produce the high explosive TNT or trinitrotoluene), but they lacked the safeguards in their plants that were required by insurance regulations for producing the actual explosives. For this reason the leading German dye companies in August 1914 rejected appeals by the Prussian War Ministry to produce explosives, though they did however agree to produce nitrates as raw materials for explosives. As with the toluene products, these were not explosives as such but products for the explosives industry, however, and thus not fundamentally different from what the dye companies had already been doing before the war (Johnson 2006, 4–8).

Instead, chemical weapons became the bridge away from peacetime production patterns to the "weaponizing" of the dye chemical industry. This came about because of excess capacity in the dyeworks brought about first by the German embargo on the export of dyes imposed at the outbreak of the war, followed later by the tightening of the British blockade on the Central Powers, which cut the dye companies off from most of their global markets and forced them to consider other ways to use their idle facilities. Despite the induction of a large proportion of their staffs into the military, they wanted to use their remaining staff and facilities to produce something of value. Discovering the logic of dual use, as early as October 1914 both Carl Duisberg at Bayer (working with the physical chemist Walther Nernst as part of a secret military commission that followed up on unsuccessful secret prewar military experiments with ideas such as aerial phosgene bombs) and Albrecht Schmidt at Höchst (who had also tried to sell a chemical fog generator to the Imperial Navy before the war) began experimenting initially with non-lethal irritants that would not violate the Hague conventions, but when packed into artillery shrapnel shells could serve to drive enemy troops out of protected shelters such as cellars in buildings where the shrapnel alone could not reach them—at this point trenches were not yet the issue (Johnson 2003, 92–99; Baumann 2011, 195–271). It was relatively easy for the Germans to test these agents, as the process of synthesizing and testing such mainly organic compounds required no significant modification of their existing system. The Allies had greater difficulties, despite some prewar experimentation with chemical weapons. The French had actually entered the war with limited quantitates of non-lethal irritants packed in rifle grenades (Lepick 1998, 54–56). Although the early initiatives on each side had no significant impact on the early months of the war, the advent of trench warfare at the end of 1914 and the ensuing military stalemate fundamentally transformed the situation. The new German high commander Erich von Falkenhayn now demanded more lethal chemical agents, initiating the process of escalation that would lead to the emergence of the new system on both sides (Szöllösi-Janze 1998, 324; Johnson 2003, 94; Baumann 2011, 312–313, 738–739).

5 Scaling up, Innovation and Integration, 1915–17

The German introduction of chlorine cloud attacks at the Second Battle of Ypres in April 1915 was both the catalyst for the development of the new military-industrial-academic system on all sides, as well as—given the war's ultimate emphasis on delivery by artillery—a false start, albeit an inevitable one. After all, Fritz Haber (who had from the beginning of the war put his expertise and that of his Kaiser Wilhelm Institute (KWI) for Physical Chemistry and Electrochemistry at the service of the military) had originally proposed the chlorine cloud because of the shortage of shell casings and propellants—chlorine clouds would not require artillery shells—as well as the relative abundance of domestically-produced chlorine and not least the German efforts to remain at least technically within the Hague conventions (Haber 1924, 76–77, 87; Haber 1986, 27, 41–42). A decisive shift did not come until 1916, when they began using a toxic agent in artillery shells in response to a similar initiative by the French at Verdun. It is worth noting however that the Germans used diphosgene, somewhat less toxic than phosgene as such, apparently chosen because the chemical companies producing it found it easier and less dangerous to produce and load into shells (Haber 1986, 86). Thus although Haber's KWI became militarized in 1916 and substantially expanded its staff, the German chemical-warfare system in this period still largely depended upon the expertise, capabilities, and initiatives of its private industrial component, which had redirected its dye and pharmaceutical laboratories to systematically synthesize and test hundreds of potentially lethal compounds. And it was private industry that in 1916 established a loose "community of interests" (Interessen-Gemeinschaft, IG) encompassing all eight principal dye manufacturers in order to minimize internal competition while fostering the exchange of technical expertise and experience for war work and an expected "war after the war" with the rapidly growing and diversifying Allied systems (Abelshauser 2004, 171–173).

The British, whose domestic production of chlorine was about a tenth that of the Germans, initially chose to respond in kind to the German initiative, albeit after a characteristic delay of several months needed to produce just three-quarters of the amount their generals ordered for the unsuccessful chlorine cloud attacks at the Battle of Loos in September 1915. The British military authorities had been so unfamiliar with their own nation's chemical industry that it had taken them two months to find a suitable supplier (Haber 1986, 150, 162; Palazzo 2000, 62–63). Ultimately the British developed a considerable productive capacity for chemical agents, they established an effective testing range at Porton in 1916, and they produced an outstanding gas mask in the small box respirator of 1917; but they remained chiefly dependent on the French for phosgene, and their system too long remained decentralized and poorly integrated, with weak communication between its academic, business, national-factory, and military components (Haber 1986, 144–147, 162–170). These weaknesses resulted in such errors as developing cyanide compounds in 1916 to counter expected use by the Germans, who had already rejected them as ineffective (Girard 2008, 105–209). The British may here have been following the French, who relied heavily on cyanide products, but in general communication with the French was weak until the British sent a formal liaison officer to Paris in August 1916 (Lepick 1998, 118). Perhaps this was not surprising, as the British had consigned gas offensives to a peripheral, harassing role, mainly using clouds (and by 1917 drums of phosgene fired at close range from Livens projectors), whereas the French took a very different approach.

The French response had begun from an even weaker position than the British. Having lost a significant part of their chemical industry when the Germans occupied the northwestern part of the country, they were forced to commit massive resources toward reconstructing lost plants and establishing new ones, just to meet the requirements of the war economy in general. Moreover, for many critical substances (such as chlorine and bromine) they had been dependent on German imports. Responding to the German chemical warfare initiative would thus require fundamental changes to the French system, which they initiated immediately following the Ypres attacks. By July 1915 they had created a central Service du matériel chimique de guerre for the overall coordination of the key academic, industrial, and military functions, including a research and development section for gas offense (under the chemist Charles Moureu) and defense, a technical and industrial section to expand production and create new factories as needed, and a logistical section, all in Paris. The city's many laboratories allowed the French to effectively utilize their limited stock of technical expertise in chemical warfare work. The chemical service became part of the Under-Secretariat for Artillery under Albert Thomas, and from December 1916 of the new Ministry of Armaments (Lepick 1998, 109–110; also Lepick chapter, this volume). The connection to artillery reflected a tactical choice against cloud gas attacks, a logical choice because French domestic production of chlorine was insignificant. But because most chemical alternatives that the chemists initially tested (culminating in phosgene) also contained chlorine, and because they could obtain only limited amounts from the British, it was still necessary to construct a series of new chlorine plants beginning in August 1915, reaching a total of ten by 1917. Moreover, although the French could use gas shells in their rapid-firing 75-mm field gun, probably the best weapon of its kind in the war, in 1915 they still lacked heavy artillery with its higher-capacity shells. Thus to use gas effectively they first had to accumulate large quantities of 75-mm phosgene shells, which they did not begin firing until a critical situation arose with the German offensive against Verdun beginning in February 1916. In doing so they took the Germans by surprise, however, achieving the first effective Allied initiative of the chemical war (Lepick 1998, 113–119; Lepick, in this volume).

Because the ensuing German production of chemical shells was still only a tiny percentage of overall shell production in 1916, its impact on the war was still insignificant, and as yet the German chemical industry could meet demand by modifying existing plant (Johnson 2006, 12; Haber 1986, 157–159). Nevertheless, broader developments changed the balance between conventional explosives and chemical shell on the German side; in response to the Allied Somme campaign, the Hindenburg munitions program of September 1916 called for a massive increase in production of propellants and shells, but limited resources for high explosives production meant that the Germans would necessarily need to increase their dependence on chemical shells (Herwig 1997, 259–266; Johnson 2006, 13–14; Haber 1986, 260–261). Moreover, the increasing effectiveness of Allied gas defense would force the Germans to introduce new offensive weapons in 1917–1918, which would bring about the culmination of the chemical war—and help precipitate the German collapse (Haber 1986, 226–229, 275).

6 Culmination of the Chemical War, 1917–1918

The chemical war began to reach its culmination in mid-1917, when innovations on all sides, along with the addition of the United States to the Allied side, further magnified the "totalizing" tendencies that had begun to take effect in the previous year. These also produced significant institutional changes, further integration of the chemical war into the broader war effort, and the introduction of several new types of chemical agents with novel, increasingly insidious properties. These were products of the increasingly sophisticated research facilities and increasingly close academic-industrial-military collaboration that had begun to develop in the previous period. It now appeared that chemical warfare would be fully institutionalized on all sides.

In Germany Haber's KWI expanded into many of the other institutes in Dahlem, as well as several other institutions around Berlin, while mobilizing scientists from all over Germany to become a multifunctional center for all aspects of chemical warfare under Haber's department A10 in the War Ministry (see chapters of Bretisav Friedrich and Jeremiah James, and of Margit Szöllösi-Janze in this volume). By mid-1917 Haber saw arsenicals and sulfur compounds as the key to a new German chemical offensive, but he cautioned the High Command that Germany must win the war within a year. Once the Allies could produce the same weapons, Germany's situation would become "hopeless" (cited in Szöllösi-Janze 1998, 332). Elaborating on French approaches, the Germans had developed artillery tactics using a variety of chemical shell types, which they called *Buntschiessen*—varicolored shooting—after the spectrum of chemical shells designated by colored crosses. Blue Cross arsenicals, introduced in July 1917, were intended to penetrate the Allied mask filters and cause so much irritation that soldiers would be unable to keep on their masks, thus making them vulnerable to toxic Green Cross (diphosgene) that the masks could otherwise block. The artillerists welcomed this theoretically effective weapon, and the IG produced 8,000 tons in 1917–1918, but the KWI's scientists had not solved the practical problem of achieving fine enough