Introduction

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Taking the horrific events that took place at Ypres in 1915 as its point of departure, this volume traces the development of chemical weapons from their first use as weapons of mass destruction by German troops in Belgium to their deployment in Syria in the summer of 2013. The book has emerged from a conference commemorating the centenary of the events at Ypres, held at the Fritz Haber Institute of the Max Planck Society in Berlin. The contributions focus on the preconditions and immediate consequences of this war crime, but also cover, by way of examples, the subsequent history of chemical weapons, including their role in World War II, their global spread, and their recent deployment. The volume ends with a documentation of the commemoration ceremony closing the conference, comprising speeches of the Green Cross director Paul Walker, the Belgian ambassador Ghislain D'hoop, and the Nobel laureate Gerhard Ertl.

The first part of the volume deals with "Research on and Deployment of Chemical Weapons in World War I," as well as with the roles of the key actors involved. The dual-use characteristics of chemistry are, first and foremost, emblematically represented by the figure of Fritz Haber. In the history of science, he has played a double role. On the one hand, he is one of the most outstanding chemists of the twentieth century and even a benefactor of mankind. Through his development of ammonia synthesis, he is the most influential chemist as regards the history of humanity as a whole. Haber played a key role in negotiating the conditions and contracts for the large-scale industrial synthesis of ammonia required by the German Army for the production of munition to continue the war. His commitment to these negotiations led to the establishment of industrial capacities based on the industrial process that had been brought to maturity in 1912 by Carl Bosch and Alwin Mittasch, based on the scientific work of Haber. This dual-use process is still the present-day basis for the production of fertilizers, without which modern agriculture would not be able to feed the current world population that has grown

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from around 1 billion in 1900 to over 7 billion today. On the other hand, Fritz Haber was also the pioneer of the deployment of science-based weapons of mass destruction.

Margit Szöllösi-Janze, author of the authoritative biography of Haber, investigates this dual role. In her contribution, she describes how the "expert culture" that gave rise to "big science" and "big industry" came about in Germany during World War I and also Fritz Haber's key role in this historic change. In particular, she reconstructs the conditions that led, on April 22, 1915, to the use of chlorine gas in Ypres following the initiative of Fritz Haber, who also provided the scientific guidance for its deployment. Motivating this action were the concerns of the German military about a possible "explosives shortage" that could ensue should the war drag on and access to supplies of natural nitrates be blocked by the allies. Given this concern, Haber's ammonia synthesis would prove to be very opportune.

In September of 1914, the military had already suggested that by-products from the manufacture of explosives could be used as chemical weapons. This solution also served industrial interests. The chief of staff, Erich von Falkenhayn, took up these suggestions and installed a commission that later included Haber. He was among those scientists and experts who offered their services to the military when the war broke out. Not only was Haber driven by the ambition to solve the problems of war in a technocratic way, that is, by means of science and technology, but he also sought to create a network connecting industry, academia, the military, and the politicians, thereby promoting the societal role of scientists. At the end of the war, around 1000 scientists were involved in the development of gas warfare in Germany, 150 alone from Haber's rapidly expanding Kaiser Wilhelm Institute. This represented a striking success that would have lasting consequences for the relation between science and the military.

The above history of the inception and implementation of chemical warfare in World War I Germany is described in the contribution by Bretislav Friedrich and Jeremiah James, who follow Haber's pathway from science to chemical warfare in greater detail and show how the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry in Berlin-Dahlem became a center for the development of chemical weapons and of protective measures against them. They analyze, in particular, the role of Fritz Haber and his Kaiser Wilhelm Institute in the acceptance and use by the German military of chemical weapons as a means of resolving the greatest strategic challenge of World War I, namely the stalemate of trench warfare. The paper details the path from the Ni-Stoff and T-Stoff to the chlorine cloud and beyond, the transformation of Haber's Kaiser Wilhelm Institute after it fell under military command, as well as Haber's views on chemical warfare. The implications of this transformation of science into a military resource are investigated in further contributions to this volume.

But also the personal contexts of Haber's involvement in the war are illuminated. The contribution by Bretislav Friedrich and Dieter Hoffmann examines, on the basis of the available scholarly sources, the life of Fritz Haber's first wife, Clara, nee Immerwahr, including her suicide and its possible relation to her husband's involvement in chemical warfare. They also critically re-examine the origin of the

"myth of Clara Immerwahr," according to which she was a top scientist, not unlike Marie Curie, and an outspoken pacifist, not unlike Bertha von Suttner.

The German deployment of chemical weapons of mass destruction had far-reaching repercussions for warfare. Olivier Lepick investigates the French reaction to the German poison gas attack and shows how this attack initiated a political and moral chain reaction in the course of which any reservations concerning the use of chemical weapons were abandoned by all sides involved. In France, the relevant decisions were taken by the military, largely independently of the politicians. In this way, chemical warfare led to one of the first arms races, with massive involvement of science and industry. Great efforts were undertaken, for instance, to rapidly overcome the French deficit with respect to the German chemical industry. The sites and structures of chemical industry still reflect this race even today.

Ulf Schmidt has reconstructed the pertinent developments on the British side. British scientists shared with their German colleagues the ambition to support the military with the development of an arsenal of chemical weapons. As in Germany, ethical concerns and the norms of international law were overruled in response to the perceived German radicalization of war and its disregard for any formerly established restrictions (*Entgrenzung*). Even Churchill strongly argued for the use of chemical weapons of mass destruction.

This situation is all the more surprising because during the nineteenth century, international law seemed to be taking huge steps forward and German international law was highly regarded throughout Europe. As the historian of law Miloš Vec argues in his contribution, the possibility of gas warfare was anticipated long before war broke out, but neither this nor the Haag Convention of 1907 had any impact on legal efforts to contain it. In any case, the Haag Convention left open loopholes that the contemporary actors used after the war to justify their decisions. It was argued, for instance, that the Haag Convention does not cover gas attacks originating from rigidly installed batteries rather than movable artillery or that "military necessity" could be used to justify violations of international laws.

Remarkably, the ethical and legal evaluation of gas warfare was severely hindered by several mechanisms. Among these mechanisms was not only the disregard for international law and the argument that war has its own logic, but also the military's aversion to overtly assume responsibility for the use of chemical weapons which clashed with the pretense to chivalry. Another mechanism was the relativization of chemical warfare in terms of its comparative assessment from a "sober" scientific perspective, as may be illustrated by Haber's infamous remark in a talk at the Reichstag: "Cyanide—there is no nicer way to die."[1]

Rather than simply documenting his inhumanity, as is often portrayed, it shows an attempt to shed responsibility by focusing on the scientific aspects, comparing

[1]"Die Einatmung der Blausäure belästigt in keiner Weise. Man kann nicht angenehmer sterben." Fritz Haber. 1924. *Zur Geschichte des Gaskrieges: Vortrag, gehalten vor dem parlamentarischen Untersuchungsausschuß des Deutschen Reichstages am 1. Oktober 1923*, p. 81. In Fritz Haber. *Fünf Vorträge aus den Jahren 1920–1923*. Berlin: Springer, 1924, p. 75–92.

the gruesome effects of ethyl bromo-acetate deployed by the French (already in August 1914) against German troops with those of hydrogen cyanide: While the toxicity of both gases was about the same, Haber argued, the effects of ethyl bromo-acetate caused torturous inhalation injuries in addition to death by asphyxiation. All of these maneuvers contributed to the repression of critical reflections and certainly played a role in the further expansion of chemical weapon capacities, which took place largely unnoticed by the public.

Another prominent theme in several contributions to this volume is how the junctions, networks, and structures resulting from World War I continued to shape the relation between science and war until World War II and far beyond. This path-dependency of economic, military, and scientific events is also at the center of the contribution by Jeffrey Johnson, which emphasizes the systemic character and institutionalization of the symbiosis between academic science and industry in the service of the military—in the course of and as a consequence of World War I. This symbiosis was also a consequence of feedback effects between German and Allied developments that led to what might be characterized as a veritable globalization of the "Haber complex" of science and the military.

Experimentation with the new warfare technology was followed by upgrades and successive improvements through ever more innovations and ever more widespread deployment of chemical weapons. Globalization and the dual-use character of chemical fertilizers, disinfectants, and drugs are mostly responsible for the persistent spread of chemical weapons of mass destruction in spite of the various attempts to ban them. These farther-reaching implications are more deeply explored in the second part of this book, dedicated to the "Contexts and Consequences of Chemical Weapons."

The sustained influence of the Haber complex was by no means obvious from the outset. The military historian Edward Spiers has argued that the "success" of the German gas attack and the use of chemical weapons in general were both highly controversial after the end of World War I. Certainly, chemical weapons were not decisive for the outcome of the war, partly because the integration of the new weapons into existing tactics and strategies was unclear. But as Spiers points out, the introduction of mustard gas in 1917 not only increased the number of gas casualties, but also promoted the use of chemical weapons during the later stages of the war. In any case, investments into the further development of chemical weapons seemed to be a worthwhile endeavor.

One thing was clear and is shown by several of the contributions to this volume: the horrific psychological effects of these weapons and their terrifying character. These effects are impressively illustrated and discussed in Doris Kaufmann's contribution on the gas war in European literature and art during the interwar period. Remarkably, there were no images that glorified gas warfare, while many images and literary accounts preserved the experience of the horror instilled by these weapons. They show the impersonality of war, the feeling of helplessness in gas attacks, and the shock of seeing one's comrades suffer. Doris Kauffmann also addresses the public battle over the interpretation and collective remembrance in the war's aftermath.

The immediate postwar period is also at the center of the contribution by Roy MacLeod, which analyzes the debate about chemical weapons in the USA and the questions of its willingness to deploy them as well as the means it had for protection against them. The paper traces, in particular, the sordid history of the refusal of the US political establishment to become party to the 1925 Geneva Protocol. The contribution also shows the extent to which this debate was part of a public discourse that in some respects resembles the later discussions about the protection—often naïve and futile—against nuclear weapons.

The discussion of the wider political and historical contexts should not let us forget the immense suffering induced by chemical weapons, even long after the end of World War I. In his contribution, Wolfgang Eckart has, on the basis of numerous historical documents, brought to light the misery that the war caused for the one thousand gas casualties and the one million wounded. Ultimately, there was no shelter from gas attacks and the injuries were unspeakable: blindness, suffocation, blistering of the skin, pulmonary edema, and, ultimately, an excruciatingly painful death. Many victims also suffered harrowing psychic damage that was treated by using electroshock therapy. If the victims managed to survive this, they were then sent back to the front. Those who remained were socially stigmatized. During the era of the Weimar Republic, the pensions of such victims were cut, and during the Nazi period, some soldiers involved in the gas war who had certifiable psychic damage became victims of "euthanasia" killings. Even in the early Federal Republic, the victims continued to be humiliated by Nazi doctors. Scientists and military personnel described their suffering in a sober and factual language—despite the fact that scientists like Haber, in particular due to work undertaken in the toxicological department of his institute, were intimately familiar with the suffering caused by gas.

The indifference of scientists to the suffering of gas victims turned into their outright instrumentalization by scientists under the Nazi regime, as is shown in the contribution by Florian Schmaltz that addresses the research on chemical weapons undertaken during this period. Schmaltz describes how soldiers and concentration camp inmates were forced to take part in inhumane experiments. His analysis makes it strikingly clear that these criminal experiments did not take place in a covert space but in the midst of a network of communications in which these experiments and their results were requested and evaluated by the military and other officials. To a large extent, the scientists who ran these experiments were able to continue their careers unhindered and suffered no consequences after World War II.

Two contributions are dedicated to the role of chemical warfare on the Pacific front during World War II. The paper by Walter Grunden is dedicated to a discussion of the remarkable phenomenon that the war between Japan and the allies did not lead to a mutual acceleration of gas attacks, as happened between Germany and France during World War I. This is all the more surprising because between 1937 and 1945, the Japanese military used chemical weapons on more than 2000 occasions, mainly in the war against China. The reason for the reluctance of the Japanese to deploy chemical weapon was fear of retaliation in kind, a counter-attack

with the same weapons. The Japanese were very aware that the Americans were capable of retaliation, unlike the technologically inferior Chinese military.

As Jeanne Guillemin shows, even months before the end of the Pacific War on September 2, 1945, a commission on war crimes from the United Nations and the Chinese government had begun to take stock of Japanese war crimes. These included several instances of the use of chemical and biological weapons. Between 1945 and 1946, US officials also pursued an investigation into these war crimes with the participation of the United States Chemical Warfare Services, but with the aim of keeping this information secret for reasons of national security. One of the reasons for this secrecy was the fear that once the Americans publically accused the Japanese, they would themselves be liable to accusations of having used such weapons, as when they dropped atomic bombs on Japan. The Geneva Protocol of 1925 that unequivocally prohibits the use of chemical weapons was ratified by the USA only in 1972. A comprehensive consensus regarding the Geneva Protocol and the passing of the convention on chemical weapons emerged even later, after the end of the Cold War. This was also due to the fact that chemical weapons had in the meantime spread across many new states as, metaphorically speaking "the poor man's nuclear weapon."

The final part of the book is dedicated to current issues of "Dual Use, Storage and Disposal of Chemical Weapons Today." One of the key challenges is how to control the existence of chemical weapons under difficult conditions. The proliferation of chemical weapons continues due to global trade relations and the lack of export regulations from many national legislatures. More detailed inspections are necessary in order to guarantee compliance with international agreements, such as the convention on chemical weapons, which has been signed by 191 nations. Such inspections also require ever-larger scientific and technical efforts.

The production plants and storage spaces of chemical weapons from both world wars still profoundly shape Europe today, as the contribution by Johannes Preuss makes evident. The frontlines of World War I have not been cleared and only superficially buried. While there were no secret production plants for chemical weapons during World War I because they were produced by the traditional chemical industry, such plants were built and hidden in forests and at remote sites during the Nazi regime. A company founded by the Armament Office (Heereswaffenamt) under the camouflage name Verwertungsgesellschaft für Montanindustrie GmbH (collecting society for the coal and steel industry), founded in 1935, constructed more than 114 factories in which tens of thousands of tons of mustard gas, tabun, and other poisonous substances were produced that have sustained damage to and continue to impact on even today's environment. In Ammendorf, south of Halle an der Saale, for instance, more than 25,000 tons of mustard gas were produced. During the GDR period, the buildings on the site were demolished and simply covered by three meters of earth. Therefore, it can be expected that the territory is still very highly contaminated. In Falkenhagen, east of Berlin, chlorine trifluoride was produced using a technique developed by a collaborator from the Kaiser Wilhelm Institute for Physical Chemistry and Electrochemistry. After the war, many of these poisonous substances were only

superficially removed. Large quantities of mustard gas have been filled and either brought to a mine in Italy or disposed of in the Baltic Sea. The decontamination of the production sites is feasible but would require considerable investment.

In his contribution, the biologist Matthew Meselson draws on his experience as advisor in the 1960s to the United States Arms Control and Disarmament Agency in Washington. He addresses the use of chemical weapons to destroy vegetation and in particular for deforestation and the destruction of crops during the Vietnam War, and also the debates surrounding these issues. The military ineffectiveness of this deployment soon became apparent, as enemy provision and supply lines were not seriously affected. It nevertheless took a considerable amount of time before a decision was taken to renounce their use. The circumstances under which President Nixon was presented with the relevant information turned out to be decisive. Despite the obvious uselessness and absurdity of the operation, the deployment of chemical weapons could only be stopped at the presidential level. Overcoming the compartmentalization of information in large institutions is evidently a crucial measure in increasing rational decision-making.

The account by Karin Mlodoch of the suffering of the Kurdish victims of the 1988 poison gas attack by the Bath Regime in Halabja confronts the reader with another aspect of the drama that still persists to this day. It traces the "indelible smell of apples" that has left indelible traces in the minds of the survivors of this attack. The persecution of around 6 million Kurdish people in Iraq began after 1978 and reached an apex during the Iraq–Iran war between 1980 and 1988 with around one million casualties. In 1987, Saddam Hussein's cousin Ali Hassan led a campaign against the rural areas inhabited by the Kurds and destroyed around one thousand villages. During this military campaign, chemical weapons such as cyanide, sarin, and VX were used, and not only in Halabja. German enterprises had delivered the expertise and technology for the production of these weapons; whether they had done this consciously or inadvertently remains controversial because of the dual-use issue. There was virtually no international aid for the thousands of victims. Many fled to Iran as the only location where medical help could be sought. Many survivors died in the following years, handicapped children were born, and orphans sought their identity. Today these victims struggle to have this poison gas attack recognized as genocide, rather than have it trivialized as the "collateral damage" of war.

In his contribution, the expert for disarmament Ralf Trapp reports on his experiences in the context of United Nations inspections dealing with the removal of Syrian poison gas stocks in the sequel of the deployment of sarin in 2013. This deployment differed from other uses because only small quantities were deployed with local effects. Nevertheless, an estimated 600 to 1300 people were killed. A further peculiarity of this case is that the removal of chemical weapons had to take place in the midst of a civil war. Contrary to the rules of the Organization for the Prohibition of Chemical Weapons (OPCW), the stocks were not destroyed on site but rather taken out of the country. For this purpose, a complex plant for the destruction of chemical weapons had to be installed on a ship where the highly toxic substances were decomposed into less toxic ones, which were then brought to Germany and Finland for final disposal. This case illustrates what some years ago

was still inconceivable: A multilateral operation can work together to dispose of chemical weapons despite tensions and disagreements on essential questions of politics and security.

This hopeful view is confirmed by Paul Walker's magisterial review of a century of chemical warfare. Looking back at one hundred years of chemical warfare, the significance of a worldwide agreement on chemical weapons can hardly be overestimated. The 1993 Chemical Weapons Convention (CWC) is undoubtedly a key achievement, which in 2016 included 192 countries with 98% of the world's population. That this is more than a political framework becomes clear when considering that of the 72,525 metric tons of chemical agents declared to date in eight possessor states, over 66,000 metric tons—92%—have been destroyed in the last 25 years.

The volume closes with two authoritative statements. The ambassador of the Kingdom of Belgium, Ghislain D'hoop, points to the special role of diplomats and scientists "in making sure that the world fully understands the horrors of chemical warfare and unites in condemning its manufacturing, stockpiling, and use." Nobel Prize Winner Gerhard Ertl from the Fritz Haber Institute reminds us that the glory of Germany's rise after World War II is "tarnished by dark stains that have imbued later generations with sorrow and shame." These statements constitute a legacy to be taken to heart whenever we confront the challenges of the powerful potential of science, obliging us to take responsibility, also with a view to future generations, for its conscientious use.

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