Ethics of Chemical Weapons Research: Poison Gas in World War One

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Abstract: This paper first provides a brief narrative of the research, development, and deployment of poison gases in WWI as well as of the subsequent history of chemical warfare and international conventions to ban it. Because chemical weapons research is still allowed by national and international laws, and indeed widely conducted, it is a primary case for ethical investigation. The analysis shows that chemical weapons research is morally wrong by all major ethical theories, *i.e.* by both utilitarianism and deontology. That conclusion has frequently been blurred by confusions, such as between patriotism and ethics and between weapons research and deployment, which are clarified. The chemical communities who have honored the heroes of poison gas research seem to disregard ethics in their honoring system.

Keywords: *Ethics of chemical weapons research, poison gas, World War I, Fritz Haber*.

1. Introduction

In WWI thousands of academic and industrial chemists, including leading figures of all major belligerent countries, voluntarily and eagerly engaged in the research, development, large-scale production, or deployment of the first weapons of mass destruction, poison gases. That was the largest ever engagement of scientists in warfare until then, which left an enduring mark on the public image of the chemical profession (Schummer 2019).

It would seem that, after one hundred years, chemists would have drawn ethical lessons from that experience and openly condemn any involvement in weapons research. After all, the Chemical Weapons Convention (CWC) bans both the use and possession of these weapons, such that the issue appears to be only of historical importance. But this is not the case for several reasons.

First, the CWC explicitly allows chemical weapons research with amounts of poisons that could theoretically kill almost a billion people. In fact, at least eighty countries reportedly operate such research units (see below). Military

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research has long been the largest single area of governmental research funding in many countries. For example in the heyday of the Cold War about two thirds of the US R&D budget for science went into that area.[1] Chemical weapons, all prepared by chemists, still continue to be deployed, such as in Syria and in terrorist attacks or assassinations. Second, the CWC has a very narrow definition of chemical weapons that is focused on specific physiological effects and excludes, for instance, napalm, which was used in firebombs to intentionally kill hundreds of thousands of civilians by suffocation or burning during WWII, the Korean War, and the Vietnam War. The chemical arsenal of weapons is therefore much richer than poisons and includes all chemical preparations that are produced for the purpose of killing, harming, or threatening people.

Third, almost all ethical debates on chemical weapons have focused on deployment and ignored research. However, the one-time deployment of a weapon and the creation of an entirely new weapon to be used in the future and by any party are two fundamentally different actions that require different ethical assessment. The confusion has left an ethical vacuum on chemical weapons research that the professional societies of chemistry have hardly addressed, despite their efforts at writing codes of conduct.

This paper first provides a brief narrative of the research, development, and deployment of poison gases in WWI (Section 2.2) within the general setting of the war (Section 2.1). Then I take the best researched case of Fritz Haber in Germany to illustrate the complex interaction between academia, industry, military, and government in chemical warfare (Section 2.3). The next two sections survey the aftermath: first I summarizes the research and deployment of chemical weapons up to now, despite numerous international conventions (Section 2.4); then I look at how the scientific communities and their honoring systems have dealt with the protagonists of chemical weapon research (Section 2.5). After a brief introduction to ethics (Section 3.1), I assess chemical weapons research both from utilitarian and deontological theories (Section 3.2) and analyze various standard excuses by weapons researchers (Section 3.4), before drawing some general conclusions (Section 4).

2. Historical Narrative

2.1 The 'Great War'

After a 19-year old Bosnian-Serbian separatist assassinated the Archduke of Austria in Sarajevo on 28 June 1914, which triggered the First World War, almost 70 million soldiers worldwide were mobilized. A month after the assassination Austria-Hungary declared war on Serbia; Russia immediately sided with Serbia and asked France for help; Germany allied with Austria-Hungary and invaded on their path to Russia and France both Poland and neutral Belgium, which made the United Kingdom declare war on Germany; and so on. In the course of the war, which lasted from 28 July 1914 to 11 November 1918, about 40 countries, as well as their colonies and dependencies were involved. These included Japan, the Ottoman Empire (Turkey), Italy, Romania, Bulgaria, China, USA, Greece, Siam (Thailand), and Brazil, with major battlefields in Europe, the Middle East, Africa, and East Asia, as well as in the Atlantic, Pacific, and Indian Oceans. About 9 million soldiers died, several millions remained missing, and more than 21 million were injured, while the many millions of killed and wounded civilians worldwide have been left uncounted. In addition, the new colonial structures built during and immediately after the war turned into internal conflicts, from which particularly the Middle East, which was created by a secret British-French agreement from remains of the Ottoman Empire, has never recovered.

Like no prior war, WWI was an experimental battlefield for new weapons that drastically changed warfare, upending the received military knowledge. While war propaganda still upheld the face-to-face combat and particularly the cavalry – the heroic horsemen fighting each other with sabers – soldiers in muddy trenches faced machine gun fire and tanks that overran and buried them alive. Other novel weaponry included submarines attacking battleships and coastal cities unnoticed; airplanes that suddenly appeared and fired with cannons and machine-guns into the crowds from above; shells filled with high explosives that killed or injured anybody in the surroundings of its explosion and which were shot from several kilometers away and noticed too late to protect oneself; and poison gases.

2.2 Chemical warfare in WWI

Before WWI, a series of peace conferences initiated by Tsar Nicholas II of Russia had resulted in the first ever international treaties on the conduct of warfare, called the Hague Conventions of 1899 and 1907, after the city in the Netherlands where the treaties were signed and deposited. The articles defined by the conventions include rules of how to avoid, judge, and end wars; how to deal with civilians in combat zones, with merchant ships, neutral countries, and prisoners of war. They further specify which kind of weaponry and what kind of deployment should be considered a war crime. According to the Hague Convention of 1899 (IV.2) "the use of projectiles the object of which is the diffusion of asphyxiating or deleterious gases" was prohibited.[2] The second Hague Convention of 1907 more generally added the use of "poison or poisoned weapons" (IV, annex, 23).[3] Before the beginning of WWI all major belligerent countries ratified these parts of both Hague Conventions, except the USA that has never signed the first one.

In the course of the war, all major countries violated numerous clauses of the Hague Conventions, famous cases include the German air raids on Belgian, French, and English towns and the sinking of the ocean liner Lusitania. As to chemical weapons, perhaps the first violation of the Hague Conventions was the use of tear 'gas' grenades (ethyl bromoacetate) by the French military in August 1914 against the Germans. However, the French could have argued that ethyl bromoacetate is not a gas, as the convention required, but a liquid at room temperature that was dispersed by the explosion of the grenade. The Germans in turn developed grenades filled with the comparably toxic, and non-gaseous, tear 'gases' dianisidine chlorosulphonate, first used in October 1914 against the British in Northern France, and xylyl bromide, first shot on Russian troops in Poland in January 1915. The British likely used cloroacetone hand grenades since early April 1915. All these deployments had little to no of the desired military effects though. They were preliminary experiments in both chemical weapons development and in the transgressions of boundaries of international law, opening the door to an arms race.

Although the distinction between 'asphyxiating or deleterious' substances and 'poisons' is a matter of debate (and concentration, of course), the tear 'gas' grenades violated the first Hague Convention in that they employed projectiles to spread deleterious substances. The next transgression was a move to more toxic gases without the use of projectiles, a clear violation of the second Hague Convention, but not of the first one. On 22 April 1915 near Ypres in Belgian, the German military under the scientific supervision of the physical chemist Fritz Haber released about 168 tons of chlorine gas from a battery of more than 2,000 conventional gas cylinders making use of the wind that transported the toxic cloud to the lines of the unprepared British and French enemy, which caused hundreds of dead and probably thousands of wounded soldiers. Several chlorine gas attacks in the same manner followed during the next weeks in this Second Battle of Ypres, which brought only a small and temporary advantage for the Germans. After these first 'demonstrational experiments', and still in May 1915, Haber moved with now tens of thousands of chlorine gas cylinders to the eastern front at Bolimov, Poland, repeating the gas assaults on Russian soldiers on a much larger scale, causing thousands of deaths.

In response the British and French developed both effective gas masks and their own chemical weapons. In September 1915 the British launched their first gas attack with ethyl iodoacetate grenades and chlorine gas after Haber's model in Loos, France, but under wind conditions that caused many casualties to their own troops. The French, who also had a strong chemical weapons program under the guidance of Charles Moureu, filled grenades and shells with more toxic substances, introducing, among others, ethylsulfuryl chloride (June 1915), iodoacetone (August 1915), perchlormethylmercaptan (September 1915) benzyl iodide, chloroacetone (November 1915), and the very toxic hydrocyanic acid combined with arsenic trichloride (July 1916) into the chemical weaponry. Haber's team continued to switch between the western and eastern fronts and worked on various methods to deploy poisons. On one hand, they perfected the gas cloud approach by filling cylinders with the much more toxic but less volatile phosgene, propelled by admixtures of chlorine gas, probably first tried out in May 1915 on the eastern and then in December on the western front, which was soon copied by the British. On the other, they developed grenades and shells fired from mortars, filled with poisons, including methylsulfuryl chloride, chlormethylchloroformate, dimethyl sulfate, chloropicrin, diphosgene, thiophosgene and the notorious mustard gas (dichlorethylsulphide, first used in July 1917) as well as various arsenic compounds (phenyldichloro-, ethyldichloro-, phenyldibromo-, diphenylchloro-, and diphenylcyanoarsine). Although gas cloud releases from cylinders continued over the war, gas grenades and shell fillings became the dominant form of deployment, such that in the final years of the war most shells contained a poison. For instance, in the Battle of Messines (7-14 June 1917) the British bombarded the Germans with 75,000 chloropicrin shells; during the Third Battle of Ypres (31 July – 10 November 1917) the Germans fired about 50,000 mustard gas shells against the British, each shell filled with several kilograms of poison (Freemantle 2014, chap. 1).

In addition to Germany, France, and the UK, Austria-Hungary, Russia, Italy, and the US developed, produced, and deployed chemical weapons during WWI, although on a smaller scale (Freemantle 2014, p. 197). They thus all committed war crimes according to the Hague Conventions, which included no exemption for retaliation. In general, successful inventions by one party were soon copied by the others. However, detailed historical research on Austria, Italy, and Russia is still poor. Austria-Hungary employed various tear gases in grenades almost from the beginning of the war, released phosgene from cylinders since June 1916, and introduced new poisons such as the very toxic cyanogen bromide (September 1916) which is easily absorbed by the skin, making gas masks useless (Rauchensteiner 2014, pp. 542-545). Russia seems to have deployed chemical weapons early on too, and massively so since the Brusilov offensive in June 1916, whereas Italy seems to have embarked, despite rumors, on chemical warfare quite late (Zecha 2000). When the US entered the war in April 1917, they were well equipped with and used many of the aforementioned poisons and developed new ones, such as the highly toxic Lewisite (chlorvinyldichloroarsine), which they planned to spray from military aircraft on German cities, but shipped it to Europe only shortly before the armistice (Irwin 1921, pp. 37-42, Freemantle 2014, p. 197).

The chemical war induced a two-fold arms race of developing both more effective poisons and protective devices, of which the gas mask was the most important one. It was not only a defensive tool, as one might think, but also an important offensive one, particularly in trench warfare: while the enemy line was bombarded with poison grenades, shock or assault troops with gas masks advanced to conquer the poisoned territory. Thus the gas mask had to be effective against both the own poisons and those of the enemy, which were regularly analyzed by chemists at the frontline. As the number of chemical weapons increased, soldiers had to be equipped with a battery of filters, each effective only against a certain group of chemicals. The art of chemical weapons research consisted both in finding ways to circumvent the protective devices of the enemy and in being ahead in the development of new devices for the own troops. Initial efforts focused on chemicals that standard filters did not easily absorb, which multiplied the types of filters. A second approach employed some of the previously mentioned arsenic compounds (known as Clark I, Clark II, Clark III, and Adamsite) in the form of fine powders or aerosols that passed through all of the known filters. Because these substances are not lethal but only irritating, they forced soldiers to remove their gas mask and thereby made them vulnerable to phosgene and other lethal gases that were shot at the same time. A third approach, exemplified by mustard agent, consisted in liquids that penetrate cloth and poison the victims through skin contact, which made the gas mask useless.

Overall, about 150,000 tons of some 48 different poisons were produced during the war by chemical factories in Germany, France, UK, USA, Austria, Italy and Russia, in descending order.[4] It is estimated that about 300,000 soldiers were killed and about one million injured by chemical weapons, but these numbers are questionable for several reasons. First, shells, the most deadly weapons of WWI, likely killed more than 5 million soldiers, and it is difficult to distinguish if they actually died from shrapnel or from the poisons that many shells were filled with. Second, many poisons develop their lethal effects after days, weeks, months, or even years. For instance, phosgene ($COCl_2$), the most lethal chemical weapon of the war, recognized only by its hay odor, reacts with water in the respiratory tract to form hydrochloric acid, which dissolves the lung tissue over several days. The oily liquid mustard 'gas' ($(ClCH_2CH_2)_2S$) causes severe blisters about 24 hours after skin contact and was the most effective non-lethal agent, but could wield its damage many days after the attack via incidental contact with a contaminated surface. In addition, because of its strong carcinogenic effect, mustard gas can cause lethal cancer after years. Third, various endemics, including tuberculosis, typhus, syphilis, shigellosis, cholera, and malaria affected large numbers of troops and particularly killed those whose health conditions were previously weakened by injuries or poisoning. Fourth, it is difficult to imagine that military hospital personnel had sufficient time and know-how to determine if the poisons were the ultimate cause of death. Fifth, casualty statistics poorly cover battlefields in Eastern and Southern Europe and in the Middle East, where chemical weapons were deployed on victims who rarely had protective devices.

2.3 Haber's academic-industrial-military-governmental complex

To understand the role of scientists in chemical warfare, I focus on the best studied case, Fritz Haber's poison gas project in Germany. However, because chemical warfare was rather new, similar contexts for the involvement of chemists might be found in other countries.[5]

At the beginning of the 20th century the kind of state-funded scientific research institutes that exist today were largely unknown. One of the first was a private-public partnership between the wealthy banker and entrepreneur Leopold Koppel and the state of Prussia that led in 1911 to the foundation of the Kaiser-Wilhelm Society in Berlin, which later became the Max-Planck Society that nowadays runs 84 publicly funded research institutes. Initially there were only two in adjacent buildings: the KW Institute for Chemistry and the KW Institute for Physical Chemistry and Electrochemistry, of which Fritz Haber was the founding director.

Haber had already made himself a name by his considerable improvement of catalytic ammonia synthesis from hydrogen and nitrogen, in close collaboration with the chemical company BASF. Another collaboration, with the Berlin firm Auergesellschaft, which produced gas lantern mantles for street lights and which was owned by Koppel, was crucial to his appointment (Szöllösi-Janze 1998, 215f.). When Haber moved from the then still provincial Technical University of Karlsruhe to Berlin, he quickly connected with the political and academic establishment, including physical chemist Walther Nernst and organic chemist Emil Fischer at the University of Berlin.

At the beginning of the war these three chemists offered their scientific service to the government. Fischer, the leading German chemist of the time, had excellent connections to government and industry, and became the primary advisor in all war related chemistry matters. Nernst, together with Carl Duisberg (the CEO of the chemical company Bayer), was commissioned to research and develop tear gas grenades, which were first deployed in October 1914 (see above). The little military success of the tear gas grenades made the factual commander-in-chief of the German army, Erich von Falkenhayn, change his mind in favor of lethal poisons. Haber, who became scientific advisor in the war department, suggested the use of chlorine, a side-product from his ammonia synthesis, and elaborated a plan for its deployment to which Falkenhayn agreed. After the new weapon was, under Haber's supervision, successfully tested in the Battle of Ypres on 22 April 1915, his KW institute became a well-financed center for chemical warfare research (pp. 337 ff.).

From a small research institute with less than 20 employees in 1914, the KW institute turned into a 'Big Science' center that employed close to 2000 people in 1918 (pp. 263, 348 ff.). About 150 scientists – including many who would later became famous, such as Otto Hahn, Heinrich Wieland, James Franck, and Gustav Hertz – worked on the research, development, training, and scientific supervision of the deployment of chemical weapons on the battlefields, as well as on the further development of gas masks, for which Koppel's Auergesellschaft produced the filters. The largest part of the technical staff was responsible for the control of the gas mask production. Also the adjacent KW Institute for Chemistry, under the directorship of Richard Willstädter, was soon incorporated into the gas mask program. In addition, various other institutions were attached to Haber's institute, including soldiers training centers, weapons testing grounds, and shell filling stations with thousands of workers. Fischer and Nernst, who were both on the scientific board of the institute, served as advisors. In total, about 1,000 German scientists eventually worked for chemical warfare, most of them in industry.

New as it was, chemical warfare required building up new convictions, networks, and responsibilities within the established social structure. Haber's role was to fill that gap in any regard (pp. 332 ff.). First, in order to establish a link to the military, the professor of chemistry voluntarily enrolled in the army as a captain to supervise chemical attacks in the battlefields. Second, Haber could rely on his pre-established industrial connections and established many new ones with the chemical industry that produced the poisons. Third, he was appointed to a post in the war department that controlled the industrial support of all war relevant chemicals. Together with the directorship of his research institute, Haber was thus the crucial figure connecting academia, the military, industry, and government, and therefore, almost single-handedly, established for the first time what was only much later called the academic-industrial-military-governmental complex.

In the final years of the war Haber undertook various efforts to save his poison gas project, and his complex social network, for peacetime activities (pp. 419 ff.). He succeeded in transforming a portion of the project into a research facility for pest control (pp. 452 ff.). A particular irony of the history is that this facility in 1922 developed under the supervision of Haber, who was of Jewish descent, Zykon B, the main poison used in the gas chambers of the Holocaust two decades later (pp. 462 ff.).

After the war, Haber never denied that he was responsible for the German chemical weapons R&D program – although, of course, Erich von Falkenhayn and Kaiser Wilhelm II, commander-in-chief of the army by German constitution, were responsible for the weapon deployments. However, Haber's notion of ethical responsibility was limited in several regards. First, he argued that he had never cared about the Hague Convention and its interpretation because that had been Falkenhayn's responsibility (p. 326). Second, he was convinced that in times of war ethical standards are to be replaced by patriotism, such that warfare engagement becomes a moral duty for scientists (p. 428). Third, he was fully aware that his weapons program initiated an arms race among the enemies, a systemic force that, once put into action, all sides had to follow if they did not want to lose the war (p. 332). We will come back to these strategies of diminishing the responsibility of scientists in Section 3.3.

2.4 Aftermath I: Chemical weapons deployments and international treaties

Chemical weapons deployment did not stop after the official end of WWI. Many of the major hostile countries moved their forces to Russia to interfere in the Russian Civil War, where at the least the British (1919) and the Red Army (1921) reportedly used poison gas. Furthermore, several European countries used chemical weapons of mass destruction, dropped from air planes, in their efforts to control and extend their recently acquired colonies in the Middle East and North Africa. These likely include the British use of arsenic compounds against Arab and Kurdish rebellions (1920); Spanish massive air bombardment of Northern Morocco with mustard agent and other lethal chemicals (1923-26); and large scale deployment of mustard agent and other toxins in Libya (1928) and Ethiopia (1935-39) by the Italians. Moreover, during the Second Sino-Japanese War (1937-1945), which turned into WWII, the Japanese employed a battery of chemical weapons, including mustard agent and lewisite, as well as biological weapons (fleas infected with Bubonic plague) to kill Chinese civilians and troops.

In the late 1930s industrial chemists at IG Farben in Germany, while allegedly seeking insecticides, discovered the phosphate esters tabun and sarin, a new generations of extremely toxic nerve agents. Nobel Laureate Richard Kuhn soon started a chemical weapons research program and in 1944 discovered the even more toxic nerve agent soman. Nerve agents interact with the metabolism of neurotransmitters in the synaptic cleft, particularly by blocking the enzyme acetylcholinesterase that breaks down the neurotransmitter acetylcholine after successful neural signal transfer, resulting in permanent neural signals, muscle contraction, and a quick death. Although Germany produced large stockpiles of sarin and tabun for military purpose from 1940 onward, they did not deploy any chemical weapon in WWII, nor did the Allied Forces. However, after the Russian and US armies discovered the nerve agents in occupied Germany, a new chemical arms race began and numerous countries mass-produced and stockpiled nerve agents. In 1952 British scientists at ICI, again presumably searching for pesticides, discovered another new class of nerve agents among thiophosphonates, the so-called V-agents, of which particularly VX was soon manufactured for military purpose in the US and elsewhere. From approximately 1960 onwards the Russian chemical weapons program developed the Novichok nerve agents, which included a large number of organophosphate compounds, some of which are probably more toxic than VX.

Many countries replicated the chemical armament of the Cold War enemies, albeit on a much smaller scale, including those that had suffered chemical attacks by colonial powers during or after WWI. And some would use it. For instance, when Egypt interfered in the Yemeni Civil War (1962-67), they reportedly dropped phosgene and mustard aerial bombs and likely nerve agents (sarin). During much of the Iran-Iraq war (1980-1988) Iraq extensively used chemical weapons, particularly mustard agent and tabun, against Iranian and Kurdish soldiers and civilians, with tens of thousands of casualties. The latest confirmed deployments of chemical weapons have occurred during the still ongoing Syrian Civil War (since 2011) and included chlorine, mustard agent, and sarin.

Shortly after WWI international negotiations began about a more precise and efficient ban on chemical weapons, eventually resulting in the Geneva Protocol of 1925 that prohibited the “use in war of asphyxiating, poisonous or other gases, and of all analogous liquids, materials or devices”.[6] However, it is difficult to assess the actual effect of this treaty. By 1939 it was ratified by 40 parties, including almost all European countries, who indeed abided by the treaty during WWII. On the other hand, Italy and Egypt (who both had ratified it by 1928) have never been prosecuted for their war crimes. UN sanctions against Iraq and Syria, who ratified the treaty in 1931 and 1968, respectively, were either inefficient or blocked by members of the Security Council. Japan ratified the treaty only in 1970; and the US, who had still deployed tear gases during the Vietnam War, as late as 1975.

In 1992, following the Treaty on the Non-Proliferation of Nuclear Weapons from 1968 and the Biological Weapons Convention of 1972, the more ambitious Chemical Weapons Convention (CWC) was signed. Effective since 1997 this treaty prohibits, with unprecedented scientific and legal clarity, the use of chemical weapons, including tear gases and temporarily incapacitating chemicals. Moreover, it also prohibits the development, stockpiling, and transfer of chemical weapons, and requires that all member states declare and destroy by April 2012 their existing stocks and production facilities specific poisons. The CWC allows for the supervision and unannounced inspections by the Organization for the Prohibition of Chemical Weapons (OPCW) that was established for that purpose.[7] By 2017 all members of the UN have ratified the treaty, except Egypt, Israel, North Korea, Palestine, and South Sudan. Nine other countries have declared chemical weapons stocks and production facilities. Of those countries the US and Iraq were, in October 2017, still behind the schedule in the destruction of their stockpiles, and at least Syria appears to have originally made wrong declarations.[8]

Of course, the CWC had to consider numerous exceptions to their requirements for declaration and destruction, such as chlorine gas that is widely used in the manufacture of various civil chemicals. Therefore, the treaty includes both criteria and an explicit list of toxic chemicals divided up into three classes, according to their toxicity and the use in other areas, for which different declaration requirements apply.

Table 1. Selected toxicological data for some warfare poisons, based on rat experiments if not otherwise indicated; in approximate order of toxicity, but note the different values for different routes. Toxicological information is still very poor, not always comparable, or not available for many WWI poisons. Source: https://chem.nlm.nih.gov/chemidplus.

	boiling point (°C)	LD_{50}, skin (mg/kg)	LD_{50}, subcutaneous (mg/kg)	LC_{50}, inhalation (ppm)	LC_{Lo}, inhalation (ppm)
Chloroacetone	119	141^{b}		262 (1 h)	
Chlorine	-34.0			137^{3} (1 h)	800^{d} (30 min)
Arsenic trichloride	130	80			200^{e} (20 min)
Phosgene	8.2				190^{e} (15 min)
Hydrocyanic acid	26		3.0^{c}	160 (30 min)	
Chloropicrin	112			$111^{a,b}$ (20 min)	
Phenyldibromoarsine	265	15			
Mustard agent	216	5	1.5	$40.0^{a,b}$ (10 min)	
Lewisite	197	15	1.0		6.0^{f} (30 min)
Sarin	147	2.5	0.103	$0.81^{a,c}$ (30 min)	
Soman	198	7.8	0.071	$0.13^{a,c}$ (30 min)	
VX	300	0.25^{b}	0.012		

LD_{50} and LC_{50} are the lethal dose per kg body weight and the lethal air concentration, respectively, which kill 50% of a sample of test animals, differentiated by the species of the animal, the uptake route (skin absorption, subcutaneous, oral, inhalation, *etc.*), and exposure time in case of LC_{50}; LC_{Lo} is the lowest concentration reported to have caused the death of certain animals after a certain exposure time.

[a] converted from mg/m^{3}; [b] rabbit; [c] mouse; [d] dog; [e] cat; [f] human.

In the present context, the most important exemption is that the CWC does not prohibit chemical weapons research, but only requires annual reports on small scale production and research facilities. In 2015 eighty countries submitted such declarations, of which 23 referred to the highest toxicity class (OPCW 2016, p. 8). For research purposes ("medical, pharmaceutical, or protective") poisons, such as sarin and VX, can be produced and stockpiled up to an amount of one metric ton (Verification Annex, Part VI, A.1). Note that, based on the LD_{50} of Table 1, it is theoretically possible to kill almost one billion people with one ton of VX.

2.5 Aftermath II: Post-war honors for chemical warfare scientists

In August 1919, shortly after the formal peace Treaty of Versailles was signed, Fritz Haber escaped to neutral Switzerland, fearing the persecution by the Allies for war crimes. Two months later he received a message from Sweden that he would be awarded the Nobel Prize for chemistry, retrospectively for 1918, for his achievements in ammonia synthesis. However, by then Haber's invention had not much been used for the manufacture of fertilizers, which only became feasible and cheap by massive catalytic improvements that earned the former CEO of BASF, Carl Bosch, the Chemistry Nobel Prize as late as 1931. Instead, by 1918, ammonia by the Haber process was mostly used (via nitrogen dioxide and nitric acid to react with various aromatics) for the large scale production of high explosives for shells, such as trinitrotoluene (TNT), trinitroglycerin (TNG), and nitrocellulose. Moreover, in order to obtain hydrogen for ammonia synthesis (by electrolysis of aqueous NaCl solutions, the chloralkali process) equal amounts of chlorine were produced to be used as poison gas. Thus, immediately after the war, the Nobel committee honored the crucial chemical reaction that enabled the mass production of both high explosives and poison gas – a cynical prize for chemical warfare as contemporary critics called it.

By many other Nobel Prizes, which were already then considered the highest international awards in science, the Swedish Academy honored major figures in German chemical weapons research and development (Van Der Kloot 2004). Richard Willstätter, head of the national gas mask research unit, received the Nobel Prize for chemistry already in 1915. Walther Nernst, who like Haber escaped after the war out of fear first to Sweden and then to Switzerland after he had sold his estate in Germany, was awarded the same prize in 1920. Haber's most talented recruitments of his poison gas team, Gustav Hertz and James Franck, were the physics Nobel Laureates of 1925. Otto Wieland, the German co-father of mustard agent and Adamsite, won the chemistry prize in 1927. Otto Hahn did so only in 1947 after his co-discovery of nuclear fission had been developed into the 'atomic bomb'.

Despite notable exceptions, starting with Nobel Laureate Hermann Staudinger during and after WWI, the scientific community has never seriously questioned the reputation of these scientists because of their engagement in chemical weapons research. Instead, their names have been upheld as models for future generations. For instance, the KW institute that Haber once turned into the biggest weapons research unit worldwide, is now named the 'Fritz Haber Institute of the Max Planck Society'. The German Physical Chemical Society (Bunsen-Gesellschaft) calls its highest award the 'Walther Nernst Medallion' and its young scholars award the 'Nernst-Haber-Bodenstein Prize'. The top award of the German Chemical Society for organic chemistry is named after Emil Fischer.

The honoring of former 'heroes' of chemical weapons research is not confined to Germany (Freemantle 2014, pp. 44 ff., 219 ff.). For instance, the medical chemist Fritz Pregl, a leading figure in the Austrian chemical warfare project, received the chemistry Nobel Prize in 1923. When the International Union of Pure and Applied Chemistry (IUPAC) was founded in 1919, they elected as their first President Charles Moureu who had been head of the French offensive chemical warfare department during the war. Both Moreau and Nobel Laureate Victor Grignard, who was the major scientific innovator of French chemical warfare, are still honored by numerous monuments in France. In 1922 the British chemist Sir William Jackson Pope, who was knighted for his chemical warfare achievements, followed Moureu as President of IUPAC. Such as Pope had made for himself a name in the synthesis of mustard agent in Britain, so had James B. Conant in the US as a young scholar, whom historians of science mainly know from his mentoring of Thomas S. Kuhn. After the war, Conant rapidly advanced from chemistry professor to Harvard University President to one of the most influential science policy advisor in the US during and after WWII, particularly on nuclear weapons research and deployment. Before the rise of nuclear weapons physics, chemical weapons research appears to have been one of the most promising fields to make a career in science and science administration.

3. Ethical Analysis

3.1 A brief introduction to ethics

Ethics or moral philosophy, one of the oldest philosophical disciplines, serves various purposes. One is to justify or criticize new and existing national and international laws on the basis of accepted ethical principles. For instance, before a new law comes into force in democratic societies, ethical deliberations and debates are usually conducted to ensure that it is in accordance with the prevailing ethical standards. Equally important is the role of ethics in providing moral guidance in areas not covered by law. Because the law cannot – and for various reasons should better not – control all human behavior, this leaves ample room for ethics. For instance, chemical weapons research is not forbidden by any law. If you research a potential substance for chemical warfare, you could always argue that you are just studying the compound to understand its interesting chemical structure, or to find a new agent for pest control. No judge would be able to read your mind, although your colleagues might guess what you are after.

Ethical theories aim to make impartial judgments about what is morally right or wrong, regardless of any personal, corporate, or national interest, *i.e.* their first principle is impartiality. Like any theory, they do so by providing general principles and methods to derive judgments for particular cases. All ethical theories for the moral assessment of human actions fall into two main groups, utilitarianism and deontology, which both provide respectable moral positions. They differ to some extent in their moral judgments, but not, as we will see, about weapons research.

Utilitarian theories are based on a single principle, a normative rule for actions: act so that the consequences of your actions maximize the benefit of all people. Theories greatly differ in what they understand by 'benefit', how to calculate and balance it with harmful consequences, how to distribute it best, and to what extent 'all people' include future generations and nonhuman living beings. In the present context, these differences are unimportant. What matters is that utilitarian (and more generally consequentialist) theories judge actions in retrospect only according to their actually beneficial and harmful consequences, including the unintended adverse consequences, *i.e.* the naive good will that brings about harm is a major cause of moral failure.

Deontological theories (from Greek *deon*: duty, obligation) are based on two or more principles that are all general normative rules or duties. These duties are frequently organized by values (commandments of what one should strive for) and evils (prohibitions of what should be avoided). They all incorporate the utilitarian norm in the form of the commandment of benevolence and the prohibition of doing harm, which is typically of higher rank such that the prospective benefit rarely justifies doing harm. Unlike in utilitarianism, however, benefit and harm cannot simply balance each other out. On the one hand, there are additional absolute prohibitions, *e.g.* of harming human integrity or dignity. On the other, benefit and harm should each be fairly distributed according to values of justice. For specific contexts, such as biomedical ethics, core lists of further principles have been developed, albeit with vague priority rankings, which is one of the weaknesses of deontology.

The most famous deontological approach, by Immanuel Kant, provides a meta-rule for deriving normative rules in each kind of context, which is a sophisticated version of the Golden Rule: chose only those general rules of which you can reasonably want that it becomes a universal rule applicable to anyone. In deontology, actions are not judged on the basis of the actual consequences but according to whether one acts out of ethically justified duties or not, which of course includes the duties to foresee, based on the available knowledge, any possible harm and to avoid it. Here again, as in utilitarianism, naivety is a significant moral failure, not an excuse.

3.2 Ethical assessment of weapons research

Compared to ordinary life activities, science and engineering are special in that they potentially create entirely new entities that did not exist before, say a new chemical substance or a new weapon. Moreover they discover, and usually make public, the ways in which these new entities can be made. Research, development, and publication are the actions for which scientists and engineers are to be hold responsible and which are to be ethically assessed.

3.3.1. Utilitarianism

Let us begin with utilitarianism and ask what the likely consequences of successful weapons research are. They are of two kinds. First, those who get access to your knowledge will try to build the weapon and use it to threaten other people, some of whom will deploy it in order to kill or harm other people, if only to illustrate their power. That has been true throughout history, and includes the 'hydrogen bomb' that a growing number of countries have rebuilt. In general, despite all efforts to classify it as secret, scientific and engineering knowledge about powerful weapons quickly leaks, by espionage or the analysis of weapon tests, to the rest of the world, including your enemies, 'rogue states', and terrorists. It is difficult to find any exception to that historical law.

Therefore, according to utilitarianism every deployment of your weapon by anyone in the future belongs to the consequences of your research, according to which your action is morally judged. You might only have wanted your weapon used only as a means of deterrence, or for a certain one-time deployment by 'good guys' in a special situation, but that naivety is no excuse in ethics. Even if there are such special situations in which the possession or use of a weapon by one party has beneficial consequences, the overall consequences in the future, which includes any deployment by any party, are by all reasonable foresight harmful and outweigh any possible positive consequence. Thus from an utilitarian point of view weapons research is clearly morally wrong.

Moreover, as scientific research strictly builds on itself, which is an almost unique feature of science among all cultural activities, so does weapons research. The second type of consequences includes further research by others who modify and improve your weapon, making it more effective. If that is done by your enemy, it becomes a step in an arms race that develops ever more devastating weapons, of which poison gas research during WWI is a particularly instructive example because it quickly escalated once the international ban had been broken. In this case your original research does not literally cause the follow-up research, but it enables it, such that subsequent step(s) in an arms race are the consequences of your research activity for which you are co-responsible. You might desire to reach an immediate advantage for the good, but you actually contribute to an ever worsening development of weaponry. It is difficult to imagine another research situation where the utilitarian verdict, no matter what specific theory, is so clear as in weapons research.

3.3.2 Deontology

Much of what has been discussed above also applies to deontological ethics because the prohibition of doing or causing predictable harm is a major duty in all systems. Because all weapons research causes easily predictable harm in the future, it is forbidden.

And yet, the appeal to duty has frequently been abused for justifying weapons research and other crimes. For instance, Haber in the interwar period argued that he had performed his projects out of duty to his home country. Even Heinrich Himmler, leader of the Nazi SS, claimed in his notorious Posen speech (1944) that the extermination of Jews would be a “moral right”, a “duty to our people”. However, the alleged duties to one’s nation, corporation, or gang are not moral duties but only self-imposed rules by a group. They all violate the principle of impartiality that defines the scope of moral rules. In contrast a moral duty is a duty to anybody regardless of membership of a group, or to humanity as a whole. Hence, patriotism is not to be confounded with morality.

Kant’s meta-rule, which implements the principle of impartiality, is a useful test instrument for moral rules: chose only those general rules of which you can reasonably want that they become universal rules applicable to anyone. The rule to be examined is thus not ‘My chemical weapons research is permitted’, but instead ‘Chemical weapons research is generally permitted’. Can you reasonably want that anyone else follows this, now and forever? If you think that there are irresponsible people who should not be allowed to do that, then you consider the rule morally wrong. Moreover, if you think that such unrestricted weapons research leads to an arms race to make ever more poisonous substances that threaten the existence of humanity and all living beings, then you would even more strongly oppose the rule. Only a suicide candidate might want that, but that does not count as a 'reasonable' volition.

In sum, chemical weapons research and development is morally wrong according to all major ethical theories, all of which were well-known during WWI. This does not only include the synthesis of new poisons, but also the research and development of effective deployment methods in the form of actual weapons. All chemists who contributed to that during WWI and thereafter morally failed.

Note that you do not need to be a pacifist to accept the conclusion as some have argued (Kovac 2013). Even if you are willing to support the use of weapons under certain circumstances, you can strictly disagree with weapons research in general for ethical reasons.

3.3 Standard excuses by weapons researchers

After WWI chemical weapons researchers have expressed various excuses that, strangely enough, became popular vindications for moral wrong-doing in science. Because their ethical refutations are less known, it is worthwhile to point out the underlying misconceptions of the thirteen most common excuses.

My weapons research was a moral duty to my country

Surely most weapons researchers felt some obligation during their work, including patriotism and commitment to their research unit, and thus considered it only right to fulfill their duties. However, as has been shown above, 'moral duty to my nation' (or to any other group) is a contradiction in terms because morality implies impartiality, whereas patriotism includes a nationalistic bias. This position thus confounds patriotism with ethics. You cannot take holidays from ethics, not even in wartime.

I did only the research, others are responsible for deployment

That most common misunderstanding in science takes weapons research to be ethically neutral, only the deployment is to be blamed. However, this assumption is wrong by any ethical theory. Everybody is co-responsible for the consequences of one's action. Hence, also the creators of new weapons are co-responsible for any future deployments of their creations because those are the consequences of their action. There is no ethical theory that would allow for an exemption or excuse.

I did it to prevent greater harm

Even though there might be situations where the deployment of a weapon prevents greater harm than it causes, the arguments confuses research with deployment. It focuses on a specific deployment as the consequence of one's research, but neglects all future uses and misuses of the weapon that are to be considered in an ethical assessments too. This is the standard form of moral naivety that neglects the unintended but easy to foresee consequences.

Chemical weapons research is morally justified by Just War theories

This sophisticated form of the previous excuse refers to 'Just War' theories, according to which a particular war can be morally justified under certain conditions, which includes several elaborations of the Hague Conventions and the prohibition of weapons of mass destruction (*i.e.* nuclear, biological and chemical weapons), such that the argument is pointless. In general, 'Just War' theories are irrelevant for the moral assessment of weapons research, unless all possible hostile parties, including terrorists, will always comply to those rules, which is more than unlikely. 'Just War' theories can only be applied to very particular war situations, whereas weapons researchers increase the arsenal of weaponry for any party in any future war.

Chemical weapons are more humane than other weapons

After WWI many chemists, including Haber, argued that chemical weapons are more humane because of their lower death toll compared to other weapons.[9] On the one hand, it is impossible to calculate and compare the 'degree of humanity' of different weapons. For instance, is killing slowly over years more humane than killing fast? Moreover, during WWI and thereafter chemical weapons employed ever more toxic substances that were dropped or sprayed from airplanes to kill anyone living beneath. This indiscriminate or uncontrolled effect made them weapons of mass destruction, like biological and nuclear weapons. On the other hand, the argument again confuses weapons research with deployment. Research and development of any new weapons adds another tool for killing and harming people and is morally wrong as such, regardless of what other weapons already exist.

I did it only to have my people be prepared for retaliation

If chemists produce chemical weapons that existed before, they do no original research and development, but only production work. Then the arguments above do not apply. However as creators they are co-responsible for the use of the stockpile they produce, even if they have no control over the particular deployment. And they help their country to commit war crimes for which they are co-responsible. If, on the other hand, they develop new chemical weapons for 'retaliation', then they engage in morally wrong research and, even worse, contribute to an arms race that develops ever more devastating weapons.

We had to do it because the enemy forced us to do it

In times of war the enemy is usually made guilty by downplaying one's own activity as purely defensive and exaggerating that of the enemy as aggressive. This creates the dangerous constellation of an arms race in which each step further is justified as an allegedly defensive or responsive measure. Systemic forces seem to take over the responsibility of the individuals. However, systemic forces cannot assume ethical responsibility. Only individuals can be held ethically responsible, either alone or as members of a group who share the responsibility, such as a weapons research team or all chemists involved on either side. Pointing to systemic forces is therefore no moral excuse, but a way to shift responsibility to an abstract entity. Moreover, using this argument to justify ad hoc research in an arms race once again confuses the different responsibilities of weapons research and deployment.

If I had not done it, somebody else would have done it

A frequent excuse tries to downplay one's own role by arguing that one was a replaceable actor: my refusal would have made no difference, others would have worked in my position such that the consequences were unavoidable. What at first glance looks like a moral argument is actually not. Imagine a man is lying unconscious on the street with money in his hand. You steal his money thinking, 'If I don't do it, somebody else will do it'. If you are tried for your crime, your excuse would make no impression because it is morally irrelevant for the judgment of your culpability in committing a robbery. Pointing to other possible criminals does not diminish one's responsibility, nor does it excuse wrong-doing, be it robbery or weapons research.

I was ordered/forced to do it

Many weapons researchers have tried to diminish their responsibility in retrospect, arguing that they had no other choice, were forced or ordered to do so. However, there is no single reported modern case of forced research; it is even questionable if creative research is possible under force. The social pressure on weapons researchers is usually not different from that of any other employee. Leaving a weapons program might bring some disadvantage, for example, in one's personal research career or earnings. But that does not count as a moral excuse, such as the need of money does not excuse a thief. The question is: why does somebody get involved in such a research program in the first place?

My research is only for protective purposes

The Chemical Weapons Convention permits the small-scale production of highly toxic substances for medical, pharmaceutical and protective research (see above). However, that permission can easily be abused. First, as we have seen above, protective devices such as special gas mask filters are part of offensive equipment. They allow offenders to use poisons while being themselves protected. Second, any new highly toxic substance that might be researched for some pharmaceutical effect is at the same time, by its toxicity, a new potential chemical weapon. Thus, if you first synthesized it, you are co-responsible for its possible military or terrorist abuse by anyone in the future.

I did not intend terrorists to use my weapon

As a weapons researcher you are supposed to know at least what anybody else knows, that knowledge about powerful weapons readily leaks out to the rest of the world, including terrorists. You might not have intended terrorists to use your weapon, but that is an unintended consequence of your research that is easy to foresee and for which you are co-responsible.

My research serves the purpose of keeping peace by way of mutual deterrence

According to Cold War standard rhetoric, a war between two enemies becomes unlikely if both are equally equipped with weapons of mass destruction that are ready to be deployed as retaliation for any possible first strike by the other. Apart from the general deficits of the argument, it can hardly be applied to weapons research. The argument presupposes a weapons balance. However, research on either side to create more sophisticated or disastrous weapons is an attempt to destroy exactly that balance, which triggers an arms race rather than enabling stable conditions for peace.

I didn't know what my research was used for

The development of complex weapons systems requires a division of labor. Various individuals or research groups each work on a small element of the entire system. If the project is secretly coordinated, it might be possible that some researchers, particular young scientists, are not aware of the overall goal of their individual work. However, such conditions hardly apply to chemical weapons research aimed at poisons or explosives, where military purposes are likely intended. If, nonetheless, senior researchers trick young scientists into weapon research projects without their knowledge and consent, they commit a major ethical offence.

3.4 Ethical analysis of honoring warfare chemists

As we have seen in Section 2.5, many leading figures of chemical warfare research in WWI had excellent careers afterwards. Moreover, they received numerous Nobel Prizes and have been honored by the scientific community in the names of educational buildings, scientific institutes, and awards till the present day. No doubt they all made other important contributions to science that are worth commemorating. However, they also morally failed according to all major ethical theories. And many were honored, not despite, but because of their warfare engagement.

Using someone's name for a scientific institution or an award honors the person's integrity as a whole rather than a particular achievement. For instance, Germany's biggest research institute for physical chemistry is called Fritz Haber Institute, not Nitrogen Fixation Institute, because it honors and commemorates Haber entire lifetime work beyond his contribution to nitrogen fixation. It singles out the person as an outstanding role model for a younger generation, to be admired and copied. How can this still be justified in today's world?

One could argue that Haber's scientific achievements and his unquestionable personal engagement for his employees outweigh his moral failure. But how does one balance these factors? Does not such a compromise deliver a dangerous message: your scientific achievements can outweigh your moral failure? In the same vein one could honor the Nazi physiologists who, by brutal or lethal experiments on concentration camps prisoners, produced valuable physiological knowledge.

It seems more likely that many chemists take moral failures to be marginal and ignore them. For instance, biographies of WWI warfare chemists, except for Haber, written by fellow chemists typically omit their war engagement or mention it only in passing, as if nobody should not know about that. They thereby miss the chance of engaging young chemists in historical and ethical issues of their discipline and the chance to draw valuable lessons. Moreover, they further isolate chemistry from a civil society that learn about such topics from public media. Keeping moral failure as an open secret leaves the impression as if the chemical community has not come to terms with ethics since WWI.

4. Conclusion

The story of poison gas in WWI is an instructive example of the academic-industrial-military-governmental complex. Actors from different fields collaborated in a network with the aim of committing a war crime. Such complexes invite confusion about who is responsible for what. Thus the first task of an ethical analysis is to disentangle the network and define the primary responsibilities according to the different kinds of actions and decisions that occurred: The scientists and engineers research and develop the new weapon; industry produces it; the government has the ultimate decision on its deployment; and the military decides when and how it will exactly be deployed. In the case of Haber, parsing the responsibilities is particularly difficult because he had positions in virtually all fields of the academic-industrial-military-governmental complex. The next step consists in eliminating all non-ethical duties and commitments, such as by patriotism, public pressure, business contracts, and local law. Based on an ethical theory you can then perform an ethical assessment of the individual contributions and, on a more advanced level, of the interactions of the actors.

In the case of weapons research conceptual confusion abounds, particularly between ethics and patriotism and between research and deployment. Based on patriotism weapons researchers have constructed a pseudo-moral legitimation for their work. And moral debates on weapons research have either made researchers responsible only for certain deployments or rejected any responsibility for deployment. However, ethically the creators of a new weapon are co-responsible for all subsequent uses and misuses of their creation, which they enable and of which they are supposed to know the overall harmful consequences. There is no excuse of not-knowing or not-intending.

Since WWI governments have employed or contracted scientists on a large scale for researching new weapons that would soon spread worldwide. While politicians might feel responsible only for their own use of these weapons, they tempted scientists into becoming ethically responsible for all possible uses and misuses of their creations in the future. By upholding conceptual confusions about responsibilities, or by having a blind spot towards weapons research, scientific societies have never adequately responded to that large-scale abuse of science (*e.g.* by condemning it in their codes of conduct).[10] This has made science, and chemistry in particular, suspicious to the public, and rightly so according all major ethical theories. Obviously there are still important lessons to learn from WWI.

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Further Reading

There are numerous books on poison gas in WWI. Freemantle 2014 provides a broad and up-to-date view; Friedrich *et al.* 2017 is the latest anthology. Still worth reading is the classic Haber 1986, written by the son of Fritz Haber. For a comprehensive history of chemical warfare, see Tucker 2006. The best researched Haber biography, with numerous valuable insights, is Szöllösi-Janze 1998, for a very short English essay, see Szöllösi-Janze 2017. Papers on ethics of chemical weapons research typically confuse research with deployment. For an introduction see Kovacs 2016 and Schummer 2001. Some of the standard excuses are dealt with in Ryberg 2003.

Notes

[1] For data, see the OECD database (http://stats.oecd.org).

[2] See http://avalon.law.yale.edu/19th_century/dec99-02.asp.

[3] See http://avalon.law.yale.edu/20th_century/hague04.asp#art23.

[4] Freemantle 2014, p. 197, on the industrial production see Johnson 2017.

[5] This section mainly draws on Szöllösi-Janze 1998 to which the following page references refer if not otherwise indicated.

[6] For the text and the dates of signatures and ratifications, see http://disarmament.un.org/treaties/t/1925.

[7] See https://www.opcw.org/chemical-weapons-convention/.

[8] The nine countries are Albania, India, Iraq, Japan, Libya, Russia, (presumably) South Korea, Syria, United States. Japan, which declared abandoned chemical weapons from WWII located in China, is also behind schedule. Syria declared fulfillment of the destruction in August 2014 after which numerous chemical weapons deployment have been confirmed.

[9] Note that during the war, Haber argued that chemical weapons are more humane because they would save lives by ending the war faster, meaning that they would bring a soon German victory by their devastating effect (Szöllösi-Janze 1998, p. 327).

[10] The only code that mentions chemical weapons at all is the one by the German Chemical Society, but it condemns only their production and not their research.

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