Ryan Johnson

Silent Casualty: Chemical Warfare and the Environment on the Western Front

Since the end of World War I, scholars have published numerous studies concerning chemical warfare during the First World War. Little research has been done, however, to examine the environmental consequences of chemical weaponry. This essay hopes to examine this overlooked topic. The changes to the environment caused by chemical weapons, and how humans adjusted to these alterations, is the focus of this paper. What were the environmental effects, including those of non-human species and the ecosystems of Western Europe, from the research, development, and deployment of poison gases? How did humans react to this new environment brought about by industrialized warfare? I argue that the use of chemical weapons was a form of total environmental warfare, where the use of weapons capable of killing all life were chosen and used for the purpose of military gain.

When compared to other conventional weaponry, chemical weapons are unique in terms of their relationship to the environment. As the British chemical warfare expert and Brigadier General Harold Hartley observed, "Gas is the only weapon which can produce continuous effects both in time and space."[1] Bullets or artillery rounds can be aimed, fired, and forgotten with a reasonable assurance that once the bullet or explosive shell leaves the barrel, it cannot come back to harm its sender. Poison gas and chemical shells, however, have this undesirable aspect. In addition, unlike the moving bullet or exploding charge, gas' ability to harm the enemy does not disappear after a few seconds. It can last for hours, weeks, or even years.

THE CHOKING AGENTS AND THE ENVIRONMENT

After the first German chlorine gas attack at Ypres in 1915, the Allies knew very little about what had hit them. However, by noting the biological changes endured by those who made contact

[1] Harold Hartley, "Chemical Weapons," lecture, 25 November 1926, Hartley Papers, Box 33 AI, Folder 4, Part I, p. 245, Churchill Archives Centre, Cambridge, United Kingdom.

with the cloud, and making observations regarding the environmental changes in the trenches, British scientists were quickly able to identify the contents of the first German poisonous cloud. For example, within fifteen minutes of exposure to chlorine, anything made of brass, aluminum, steel, silver, copper, or other metals corroded and turned a shade of green. Buttons, wrist watches, and weaponry were often checked for corrosion and discoloration. The corrosive effect can even cause weapons as large as artillery pieces to permanently jam. Field commanders stressed the constant cleaning of weapons and oiling metallic equipment. Ammunition was to be kept in boxes, and each round was to be inspected after an attack for any signs of deterioration.[2]

One of the initial clues British chemists had regarding the contents of the first poison cloud at Ypres were these corrosive attributes. Professor H. B. Parker, a chemist at the Imperial College in London, was sent to France to investigate the German gas attack. Soon after his arrival, Parker spoke with a Canadian gas victim on his death bed in a field hospital on April 29. Parker wrote in his diary that the soldier spoke of "how the cloud of gas came, how the French territorials ran away, and how the Canadians, he was one of them, had stuck it out. He was very bad, poor chap, before he had finished, but the doctor said it would do him no harm to talk. He said his buttons were all tarnished, and I cut them off to analyze the deposit."[3] Parker had suspected chlorine from the start, but his button analysis contributed to his conclusion that it was chlorine which killed the young man and his comrades. Other soldiers testified to the gas' corrosive characteristics. One soldier wrote after a German chlorine attack in December 1915 that "The gas was so strong that it turned all our buttons olive green, stopped our wrist watches and turned the rats out of their holes by the scores. The gas soon passed over and I was very relieved to get my helmet off."[4]

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[2] "Defence against Gas," WO 142-270, p. 86, The National Archives, London-Kew, UK.

[3] H. B. Parker, Diary, 29 April 1915, WO 142/281, The National Archives, London-Kew, UK.

[4] Captain E E Simeons, Diary, 19 December 1915, File 94/28/1, p. 11, Imperial War Museum, London, UK.

Yet far more striking than the gas' effect on equipment was its effect on the natural and organic environment. On living tissue, such as humans, insects or other animals, the war gasses had a variety of effects. On a broad level, however, tests during the war and in its usage in the field proved that the poison gasses killed almost all forms of organic life, including mammals, insects, reptiles, and even broad leaf plants and trees.[5]

Generally speaking, cloud gases such as chlorine and phosgene had an immediate and devastating effect on the environment, usually killing all life it came in contact with. However, the poisonous effect of the gas would largely disappear within a matter of hours. Gases deployed by chemical shells, notably mustard gas (also known as "yellow cross" or "Lost"), had the opposite effect: their deployment had little immediate environmental effect, but would prove harmful for a much greater period of time. This sort of inverted phenomenon was due to the chemical properties of the substances and the methods of deployment.

In terms of cloud attacks by chlorine and phosgene, the amount of gas used during these attacks was often enough to immediately kill all life on the battlefield. In a British after action report from a cloud attack on April 30, 1916, for example, the officer noted that "the grass and crops over which the gas-stream passed had been bleached and more or less destroyed. . . It is reported that several cows and pigs and a considerable number of rats were killed."[6] In June 1916, the British created a mixed chlorine and phosgene cloud during their offensive at the Somme. The cloud ran along a seventeen mile front, and drifted twelve miles into the German lines killing virtually everything in its path. Plants, humans, rodents, insects, and birds were wiped out. Trees lost all of their leaves, creating a barren, lifeless landscape. After the attack, a German reporter for the

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[5] James A. F. Compton, *Military Chemical and Biological Agents: Chemical and Toxicological Properties* (Caldwell: The Telford Press, 1987), 119-121.

[6] Andy Thomas, *Effects of Chemical Warfare: A Selective Review and Bibliography of British State Papers* (London: Taylor and Francis, 1985), 16.

Frankfurter Zeitung noted that dead mice and rats "are found in the trenches after gas attacks. Owls are greatly excited. Behind the front, fowls and ducks are said to become restless a quarter of an hour before the gas cloud approached; and the gas kills ants and caterpillars, beetles and butterflies."[7]

Not only were environmental effects noted in the field, but also in laboratories across Europe. To ascertain the physiological effects of experimental toxins, chemists and military scientists on both sides conducted numerous tests on humans and other species. British scientists conducted experiments and field tests at Porton, under the direction of Professor Major E. H. Starling. There, an entire breeding farm was established in 1917 to breed animals specifically for testing war gasses. Animals such as horses, cats, dogs, monkeys, goats, sheep, and guinea pigs were placed in simulated trench environments, complete with fences and sandbags, and exposed to chemical clouds.[8]

German scientists performed thousands of experiments in a number of locations. These experiments were largely done at the testing facilities at Breloh and Wahn, as well as the Kaiser Wilhelm Institute's Pharmacological, Electro- and Physical Chemistry Institutes in Berlin. Tests ranged from the individual dosing of an animal to the gassing of large groups of creatures. Cats and mice were the first species chosen. The animals were placed in air tight containers, ranging in size from one to forty cubic meters. Later, similar experiments were carried out on rabbits, dogs, and monkeys. For example, one experiment by the German scientist Dr. Emil Impends at Elberfeld looked at the lethal effects of a variety of gasses on cats. After Impends exposed cats to small amounts of chlorine, phosgene, K-Stoff, diphosgene, and dimethyl, he drew up tables showing the lethal dosage given and the time it took for the animal to expire. Additionally, animals were cut open to expose organs to gases or other toxins. Other times, mustard gas would be applied to open

[7] Robert Harris and Jeremy Paxton, *A Higher Form of Killing: The Secret History of Chemical and Biological Warfare* (New York: Random House, 2002), 21.

[8] Emil Impens "Giftigkeit verschiedenes Reizstoffe," 15 October 1915, 201-5.2, Bayer Corporate History and Archives, Leverkusen, Germany.

wounds. The incisions would then be stitched up and observations were made on the effects. [9] The quantities of gas used also varied greatly. Initial tests with mustard gas consisted of doses measuring in the milligrams. But by November 1916, the KWI were ordering yellow cross by the hundreds of tons in order to conduct larger tests.[10]

One of these large experiments took place during the summer of 1917, when scientists simulated a mustard gas bombardment on multiple targets. On a large field at Posen, scientists reconstructed an Allied position and placed one thousand (!) cats and dogs along the target firing area. After the animals had been secured, the scientists fired five hundred 7.5 cm mustard gas shells at the position. All of the animals were affected; some instantaneously, others suffered due to exposure after the shelling had long since ceased. So thrilled with the results of the experiment, on July 12 the German High Command authorized the use of saturation mustard gas shelling for the first time on humans at the front.[11]

The result of both human and animal research led to impressive anti-gas technologies. Reliable gas masks were available on both sides by 1916. As for non-human species, both Britain and Germany designed and produced reliable masks and respirators to protect their natural allies. At Porton, by July 1915 Professor Colonel Watson was conducting experiments with chlorine gas and new respirators for horses.[12] Horses served a number of functions at the front, including reconnaissance, transport, and communications. As a result, horses were often targeted with chemical barrages, as to impair the movement of troops and supplies. This was an effective strategy, and the

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[9] Harris and Paxton, *Higher Form of Killing,* 42.

[10] In preparation for a single "large experiment" (*Grossversuches*), a Dr. Kerschbaum at the KWI inquired about an order for around "6-800 kg of 'Lost.'" Letter from Dr. Kerschbaum to the management of Farbenfabriken vorm. Friedr. Bayer & Co., 11 November 1916, 201-6.3, Vol. 1, pt. 4, Bayer Corporate History and Archives, Leverkusen, Germany.

[11] Wachtel, *Chemical Warfare,* 106-107.

[12] Diary entry, 9 July 1915, Lt. Col. V.M. Fergusson, File PP/MCR/111, Imperial War Museum, London, UK.

slaughter of the enemy's horses could translate into tangible military gains. For example, on April 8 and April 9 1917, British batteries shelled German positions at Monchy-le-Pro with high concentrations of mustard gas, forcing the Germans to withdraw. The British killed forty transport horses the first night and another eighty the following night.[13]

The British first unveiled their horse respirator in 1916. It consisted of a flannelette bag impregnated with detoxifying chemicals. As horses breathe solely through their noses, the apparatus fit snuggly above the mouth, with a protective piece of canvas inside the mouth to prevent the animal from chewing through the device. The masks were not perfect, as the horses found them uncomfortable and their work efficiency and speed was reduced while they wore the respirator. Still, the masks were effective enough for the British Army to heavily invest in their production. The British produced and used some 700,000 units during the war.[14] Leg and hoof coverings were also developed and produced to protect horses from mustard gas contamination. The Germans built similar masks and protective gear for horses.[15]

Both sides developed not only gas protection for horses, but also for dogs and carrier pigeons. By the spring 1916, protective respirator boxes were already in use and afforded adequate protection for the valuable pigeons that relayed critical intelligence or messages across the front.[16] Due to their ability to fly, carrier pigeons had a better chance of survival than horses or dogs if no gas defense was available. British troops were ordered to simply release all the pigeons in the event of an

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[13] "Report on the effects produced by Gas Shells on the night of April 8/9 on the Third Army Front," April 1917, Hartley Papers, Box 33 AI, Folder 3A, Churchill Archives Centre, Churchill College, Cambridge, UK.

[14] H. S. Raper, "History of the Anti-Gas Department," 30 January 1919, WO 142-254, pp.7; 12, The National Archives, London-Kew, UK.

[15] See subsection 40, entitled "Protection of Animals" in "Defence Against Gas," WO 142-270, the National Archives, London-Kew, UK.

[16] One after action report from a German gas attack at the end of April 1916 noted that "Baskets were covered by respirators and birds were not affected." See "Notes on Gas Attacks by Enemy on First Army Front on 27th and 28th April, 1916," 8 May 1916, RG 9 III-C-3, 4115, File 1, Folder 15, p. 2. Library and Archives Canada, Ottawa, Canada.

attack to save them, as they could fly above the poisonous clouds. To protect the carrier pigeons, the British manufactured some 2,000 protective pigeon basket covers.[17]

MUSTARD GAS AND THE ENVIRONMENT

Up to this point, the negative effects of a chemical attack were relatively short term, albeit highly destructive. But in 1917, with the development of chemical shells and mustard gas, an unprecedented era of environmental contamination was born. Unlike a chlorine or phosgene cloud which evaporates within a couple hours, mustard gas' nagging consistency meant that territory contaminated with mustard gas created significant long-term effects. For those near the front, they could no longer trust the ground they walked on for fear of coming in contact with the new, liquid toxin. In addition, the deployment of gas via shells would prove to be an environmental catastrophe for future generations.

Unlike the chlorine based gases which attacked the respiratory system, mustard gas was a far more effective toxin because it attacked every part of the body. Exposure to mustard vapors can cause severe lung damage, loss of sight, and even death. The fumes destroy bronchial tubes, causing suffocation. Worse is exposure to the liquid itself. Immediate inflammation and tissue damage occur on contact to the skin, causing blisters and severe burns. Absorption of the liquid into the blood stream destroys white blood cells, which weakens the immune system. In high concentrations, exposure to the skin alone can cause death.[18] Oddly, mustard gas has no corrosive effect on metal objects, making it harder to detect the substance on objects or uniforms until it is too late.[19] Because the liquid is slow to evaporate, it can remain a danger for weeks if temperatures remain low.

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[17] Ibid, 12.

[18] Ibid, 13-14.

[19] "Procedure Recommended for Adoption in the Dockyards for Dealing with the Menace of Attack and Subsequent Contamination by Mustard Gas in all its Aspects," WO 188/67, The National Archives, London-Kew, UK.

The Germans chose gas shells as the means to introduce the toxin to the Allies. Gas shelling for the purposes of environmental destruction was nothing new to German chemical strategy. As early as 1915, the Germans shelled Allied trenches with experimental, chemical T-stoff and K-stoff shells in an effort to render the landscape uninhabitable. In a report dated 6 August, 1915, the German commanders specifically state that the T-stoff shelling is used "against a position or an area, the use of which is to be denied to the enemy for some time," but that the ground unfortunately cannot be occupied by friendly forces after the bombardment.[20] Yet unlike mustard gas, the time it takes for T- and K-stoff to degrade is far shorter.

In preparation for their 1918 spring offensive, the Germans produced hundreds of thousands of chemical shells. Yet the German chemical experts constantly struggled to control the danger of filling, or "charging," chemical shells. At first, chemical shells were produced at various depots at the front. Yet these shells were often unstable and prone to leaks or cracks. Multiple accidents compelled the Germans to centralize their chemical shell production into specialize areas suited to the risky task. In addition, the potential risk of experimental chemicals or poisonous clouds contaminating the urban landscape and poisoning the civilian populations in major cities like Berlin or Cologne was too great for Germany's military leaders. Major factories were therefore constructed outside the major city centers in Breloh, Adlershof, and Dormagen.

Unintended discharges and accidents were commonplace in both German and Allied chemical factories. On at least one occasion, a massive fire broke out in the Breloh filling plant, destroying the entire stock of ammunition. In the spring of 1917, another explosion, this time at the Adlershof plant near Berlin, destroyed the ammunition stockpiles and all the filling equipment. The explosion's shockwave tore the roofs off of the local inhabitant's homes a mile away.[21] Luckily, no

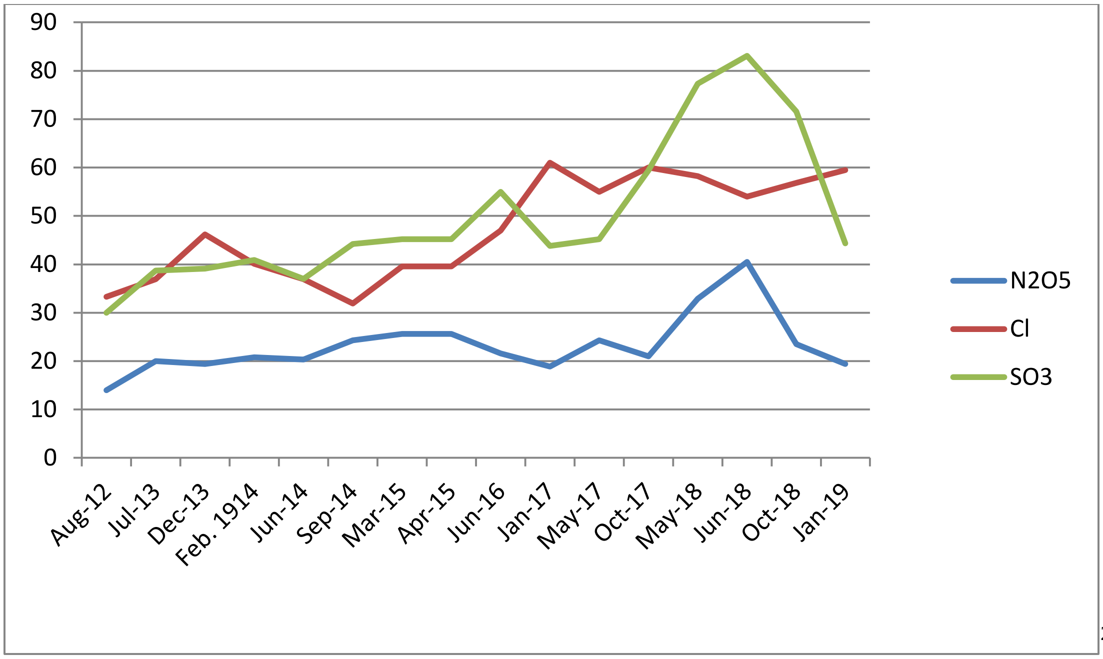
[20] Erich von Falkenhayn, "Memorandum Regarding the Employment of Gas Shells," 6 August 1915, Hartley Papers, Box 33 AI, Folder 3A, p. 1, Churchill Archives Centre, Churchill College, Cambridge, UK.

[21] Curt Wachtel, *Chemical Warfare* (Brooklyn: Chemical Publishing Co., Inc., 1941), 221.

one was killed by the blast or the gas. The British and French also endured their share of industrial accidents and spills. The majority of Allied mustard gas was produced in France, at Roussillon. Almost all of the civilian employees at the factory could be listed as casualties by any definition, as ninety percent of the workforce lost their voices and almost everyone developed conjunctivitis. Burns were also common.

Yet the environmental effects of these chemical weapons also negatively affected the average citizen living in the vicinity of the German chemical companies. This was perhaps most noticeable in the quality of their drinking water. For example, much of the drinking water in Leverkusen came from the Rhine, a river which had also been the primary waste disposal system used by Bayer, BASF, and other German chemical companies for decades. Already polluted by years of uncontrolled chemical dumping, the Rhine was by 1915 a suspicious source for quality drinking water. Still, water from the water works in Leverkusen was widely consumed. Data collected by Bayer scientists from the water works between 1912 and 1919 demonstrate a disturbing trend in water quality.

As Bayer produced more and more chemical agents for the war, levels of harmful chemicals directly associated with those agents – chemicals such as chlorine and sulfur trioxide – dramatically increased in the drinking water. For example, chlorine concentrations jumped from 31.9 milligrams per liter of water in September 1914 to 61 milligrams per liter by January 1917. Sulfur trioxide, a byproduct of mustard gas production and an ingredient in acid ran, jumped from 44.2 milligrams per liter in September 1914 to 83.1 milligrams per liter by June 1918. Below is a chart showing the increases in chemical concentrations in the Rhine. The scale on the y-axis is based on milligrams per liter:



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Notice that the concentrations of chlorine begin to rise considerably during the spring of 1915. This is not a random occurrence. Rather, the increase in chlorine contamination coincides with the first German chlorine attacks in April of that year. In addition, one can clearly see concentrations of sulfur trioxide escalate during the summer of 1917. Again, this trend seems to be directly correlated to the development and mass production of mustard gas at that same time. It is also important to point out that the levels of other potentially dangerous chemicals that did not increase until the end of the war, such as dinitrogen pentoxide (N2O5, a compound that breaks down into the toxic gas nitrogen dioxide as it decomposes) were nonetheless still in the water.

When compared to modern health standards, the toxicity of the water is quite shocking. For example, the United States' Environmental Protection Agency (EPA) declares that drinking water contaminated with chlorine at any level above four milligrams of chlorine per liter of water can be potentially hazardous to your health. Thus, the water was approximately fifteen times the safe level.

[22] "Hauptanalysenzahlen der sämtlichen Wasseranalysen von 1912-1920 vom Wasserwerk Leverkusen," 1920, 58-9.2, Bayer.

Safe nitrates levels are set by the EPA at one mg/liter. Therefore, the nitrogen-oxygen compounds contained in the Rhine were highly toxic and could cause serious illness or death.[23]

Meanwhile, the level of patience residents had along the Rhine regarding the level of chemical pollution in their waters was giving out. For example, the concentration of sulfur compounds in the river caused by BASF's dumping actually began to damage boats on the Rhine and poison the crews with toxic odors. The stench and damage led to public protests. To solve the problem, an effective, new water treatment facility was required. Yet one was not constructed until 1921. Even then, there would be no signs of desulfurization until the spring of 1926.[24]

Meanwhile, chemical barrages continued to change the landscapes into toxic moonscapes, as the German military used gas shell bombardment as a form of collective, environmental destruction. This was often done to the point of counter-productivity. The official German manual for gas shelling, entitled *Gas Bombardment by Artillery* (*Gasschiessen der Artillerie*), explained that the objective of gas shells was not necessarily to just kill the enemy's troops. The first line of the manual states that "the purpose of gas shelling is to annihilate or harm living targets and the disruption of the fighting ability of the enemy."[25] The manual goes on to recommend that "positions can be made unusable through contamination (*Verseuchung*) with gas."[26]

The decision to use chemical weapons relied almost entirely on environmental and meteorological conditions. By 1916, every front line German battalion on the Western Front

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[23] Environmental Protection Agency, "National Primary Drinking Water Regulations," 11 January 2011, http://water.epa.gov/drink/contaminants/index.cfm.

[24] Jeffrey A. Johnson, "The Power of Synthesis (1900-1925)," in Werner Abelshauser, et al. *German Industry and Global Enterprise, BASF: The History of a Company* (Cambridge: Cambridge University Press, 2004), 155.

[25] "Das Gasschiessen bezweckt die Vernichtung oder Schädigung lebender Ziele und die Störung der kampftätigkeit des Feindes." See "Gasschiessen der Artillerie," 1 December 1917, M 635/1, 990, p. 1, Landesarchiv Baden-Württemberg, Stuttgart, Germany.

[26] Ibid.

included a three-man *Frontwetterbeobachtungsstation*, (literally "front weather observation station") that monitored and recorded temperature, wind direction, and other meteorological data every hour.[27] These teams were highly skilled and amazed both the German and Allied High Commands with their accuracy. As one Allied official concluded, "It is perfectly clear that the German meteorologists have made very careful study of wind and weather before launching such gas attacks, and their success, in a large majority of cases, shows how well their weather forecasts were made."[28]

In addition to emphasizing meteorology, the manual also discussed the different types of bombardment, and how the topography played into which kind to use. For example, bombardments designed to surprise the enemy (*Der Gasüberfall*), cannot be conducted if the wind is still or moving less than three meters per second, if the sun is out, or if it is raining heavily.[29] Intense sunshine generates vertical air currents, pushing the gas into the atmosphere. Heavy rains not only dilute the toxin but can also push the clouds downward to the ground, rendering them "ineffective."[30] Muddy terrain also disrupts shell detonation on impact, as the soft terrain absorbs the higher velocity shells. In addition, the water-saturated ground can also act as a decontaminant if the shell's gas casing cracked or opened upon impact.

Perhaps the most devastating type of chemical shelling implemented by the Germans was the saturation of terrain with enough mustard gas as to render the environment uninhabitable. The gas manual suggests that these types of bombardments are especially effective if the area chosen still has enemy units in the target area, because they will feel the effects of both the incoming shells splashing

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[27] "Der Gaskampf," 1916, M 635/1, 1361, p. 5, Landesarchiv Baden-Württemberg, Stuttgart, Germany.

[28] Ibid, 29.

[29] "Gasschiessen der Artillerie," 1 December 1917, M 635/1, 990, p. 10, Landesarchiv Baden-Württemberg, Stuttgart, Germany.

[30] Ibid, 17.

on the ground (*Bodenwirkung*) and the subsequent vapors released from the mustard gas (*die Wirkung der Gelbkreutzschwaden*).[31]

In addition to weather, topography was also a significant concern among the German gas specialists. For example, areas of higher elevation tended to have stronger wind currents. Elevation also determined which gas to utilize for an attack. Chlorine cloud attacks were useless against positions of higher elevation, as the gas is heavier than air and will hug the ground upon discharge. It would, therefore, fail to climb up hill without the aid of a fortuitous wind. In addition, ground friction manipulated the dispersal of the cloud. Friction is, of course, highest on the ground, as vegetation, earth, buildings and other materials slow the progression of the gas and break up its concentration. As elevation increases, friction declines and becomes virtually non-existent. This, coupled with higher wind speeds at higher altitudes, meant that gas clouds moved faster at higher altitudes, rather than lower ones, creating a wave effect.[32] Depending on the permeability of the soil, temperature, and amount of gas deployed, surface run-off can also occur if the toxin is a liquid, such as mustard gas at a cold temperature. Geographical and human environmental conditions also played major roles. For example, forests, buildings, and corn fields would slow down the evaporation of chemicals, as the trees and buildings provided shade from the sun and cover from strong winds. As one German gas memorandum declared, "The firing procedure is applicable in every terrain. Forests, *Buschwerk*, and cornfields, the Reizstoffe remains effective for many hours."[33]

The soil on which the men fought also played role in determining the effectiveness of a chemical attack. Soil characteristics, such as their surface area, temperature, moisture content, and pH level influence the detoxification rates of chemical weapons. An example of soil effect can be

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[31] Ibid, 11-12.

[32] Taylor, *Lethal Mists*, 190-191.

[33] "Der Gaskampf," 1916, M 635/1 Bestellnummer 1361, p. 5, Landesarchiv Baden-Württemberg, Stuttgart, Germany.

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deduced from the first time Germans deployed mustard gas shell on July 12, 1917 in the Ypres salient. Along with high explosive rounds, the Germans fired a mixture of green and yellow cross shell in a punishing nine-hour barrage that finally ceased between 4:00 A.M. and 5:00 A.M. the following morning. The wind was all but still, moving only one to two miles per hour. Yet the temperature was warm and the ground moisture levels were perfect. The earth was unusually dry that day, as it had not rained for several days.[34]

The dry land created a hard surface for the toxic liquid to rest upon. This, coupled with the warm temperatures that facilitated evaporation of the toxin, created an awful scenario for those in the bombarded area. Additionally, subterranean organisms, including rodents, worms, or other burrowing creatures create tunnels and pockets within gassed areas that remain buried. The gas may then be released at a later time, so long as the environmental conditions maintained the integrity and toxicity level of the agent. Other, non-living organic materials such as humic acids enable soils to absorb higher levels of toxin.[35] Biological degradation can also occur if microorganisms use the chemical for sustenance. Although little data is available, some bacteria contain the exoenzymes necessary to transform mustard gas molecules, but the vast majority of microorganisms cannot survive the toxicity of mustard gas.[36]

Between July 1917 and June 1918, British chemical officials published a monthly pamphlet to update troops at the front regarding gas technologies and counter-gas tactics. British officials issued warnings regarding the persistence of mustard gas in the soils through these monthly newsletters. In September 1917, *Gas Warfare* warned that the "liquid from gas shell may remain on the ground and give off vapour, especially when the ground is warmed by the sun or is disturbed by

[34] Harold Hartley, "Report on the Gas Shell Bombardment of Ypres, Night of 12/13 July, 1917," 19 July 1917, RG 9 III-C-3, 4121, File 2, Folder 9, p. 1, Library and Archives Canada, Ottawa, Canada.

[35] Ralf Trapp, *The Detoxification and Natural Degradation of Chemical Warfare Agents* (London: Taylor & Francis, 1985), 25-26.

[36] Ibid, 34.

digging. . .when possible, men should be moved to areas which have not been shelled, but care must be taken that respirators are put on if men return to an infected place."[37]

Two months later, the pamphlets suggest troops should sprinkle chlorine of lime to neutralize areas contaminated with mustard gas. Yet British experts did not know for sure if chloride of lime would actually work. The pamphlet further recommended that if you were to try this method of neutralizing the toxins, do not use too much chloride on the contaminated area, as the smell of the chlorine would make detection of the mustard gas more difficult.[38] Oddly, the pamphlet seemed to contradict official decontamination procedures, as one British report recommended using thirty pounds of chlorine as the necessary amount to decontaminate *one* fifteen centimeter gas shell and that "treatment should only be attempted in exceptional circumstances. . . "[39]

In sum, decontamination was a constant labor at the front. Troops who came into contact with mustards were forced to conduct thorough decontamination procedures on their uniforms and equipment. German troops, for example, had detailed cleaning protocols for uniform decontamination. Uniforms had to be washed three times over in warm water, each time with a fresh tub of clean water. Contaminated water from pervious washes could not to be touched again. Boots had to be scraped clean of dirt and washed. The troops paid particular attention to the laces, which could absorb the mustard liquid like a sponge. [40] British troops experimented with a variety of methods, including treating the clothing with chloride and hot steam. Appearing to be fed up with the cleaning experiments, eventually British military officials seemed to simply give up as they declared, "As very heavily contaminated or directly splashed clothing cannot be effectively cleared without

[37] *Gas Warfare*, (September 1917): 7. Auld Papers, File 75/101/1, Imperial War Museum, London, UK.

[38] *Gas Warfare*, (November 1917): 8. Auld Papers, File 75/101/1, Imperial War Museum, London, UK.

[39] "Destruction of Mustard Gas in Dugouts," 1918?, WO 142-267, p. 1-2, The National Archives, London-Kew, UK.

[40] Erich Ludendorff, "Concerning Defence Against Yellow Cross," 6 June 1918, Box 44, p. 2-4. Churchill Archives Centre, Cambridge, UK.

damage to the cloth, it is advisable that no attempt should be made to clear such clothing, which should be buried."[41] Soldiers were also told not to use the water from shell craters for drinking, cooking or washing for fear of contamination.[42]

During the German offensive of March-May 1918, gas bombardments were on a scale unlike anything ever seen. This makes sense, as German and Allied officials noted after the attack began that weather was the primary reason the Germans timed the attack when they did. In an article published in July 1918, the noted Harvard climatologist Robert DeCourcy Ward stated that "From all evidence that has so far come to hand it is clear that the time must have been carefully chosen after consultation with the meteorological experts" and "all meteorological factors were in favor of the enemy."[43] On March 21, the Germans commenced their massive offensive with the firing of hundreds of thousands of gas and artillery rounds at Armentières, Bailleul, as well as other areas in the Ypres and Cambrai salients. Their targets were villages, Allied battery positions, and communication lines. During just the first four nights of the attack, the British estimated that the Germans fired some 150,000 yellow cross shells in the Cambrai salient alone. One British report stated towns as far back as "six or eight miles" from the front lines were shelled.[44] The report went on to warn that, "Roads passing through villages, woods or valleys are specially liable to be affected by [yellow cross] gas shelling."[45]

During the next three weeks, mustard gas shelling continued up and down the lines. On the nights of 7/8 April and 8/ 9 April, Armentières and Houplines were heavily bombarded again with

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[41] "Destruction of Mustard Gas in Clothing," 1918?, WO 142-267, p. 1, The National Archives, London-Kew, UK.

[42] "Precautions in Connection with Food and Water," Ibid, 10.

[43] Robert DeC. Ward, "Weather Controls Over the Fighting during the Spring of 1918," *The Scientific Monthly*, Vol. 7, No. 1 (July 1918): 24-25.

[44] *Gas Warfare* (March 1918): 7.

[45] Ibid, 9.

yellow cross; some 20,000 gas shells were fired into Armentières, which had already been heavily shelled the previous summer. The amount of mustard gas was such that the gutters of the town's structures were flowing with mustard gas liquid.[46] The town was so heavily contaminated, that on the 10th the German commanders ordered their troops to avoid entering the town "for a fortnight."[47] Meanwhile, those who survived the initial bombardment survived only to endure the agonies of mustard gas poisoning. Herbert Minchin, a machine gunner of the British 54th Battalion, recalled that on April 9, 1918, he woke up to discover the building his unit was sleeping had been completely saturated in yellow cross shell. The majority of the men were exposed with mixed effects. Some suffered simply loss of voice, while others were severely burned on their legs and bodies. "The Germans absolutely drenched the town for twelve hours with gas," Minchin recalled, "and men were being carried away wholesale. . ."[48]

In conclusion, whether in the factories, in the rivers, or on the battlefields, it can be said the environmental cost of chemical warfare was steep. Hundreds of different species were affected by the chemical war, and the human belligerents were forced to adapt to their new deadly surroundings. Environmental factors, such as meteorology and topography, played a significant role in shaping the gas war and with it the types of chemicals deployed. The chemical properties of the war gases generated different environmental effects, both in the short term and the long term.

As the guns fell silent on November 11, Europeans almost at once began to take note of the environmental destruction they had levied. Of particular notice was the natural destruction by their weaponry, and especially that of chemical shells and gasses. Germany had produced almost 100,000

[46] Harold Hartley, "A General Comparison of British and German Methods of Gas Warfare," 26 November 1919, Hartley Papers, Box 33 AI, Folder 6, p. 8, Churchill Archives Centre, Cambridge, UK.

[47] *Gas Warfare* (March 1918): 8.

[48] Herbert Minchin, "Recollections of the Great War," H I Minchin, File 06/54/1, p. 13, Imperial War Museum, London, UK.

tons of gas weapons during the war, more than Britain, France and the United States combined.[49] Over 66 million chemical shells were produced and fired during the war, but many never detonated. It is estimated that twelve million chemical shells remain in some 14 million acres of French soil, waiting to be uncovered. As one British soldier prophetically wrote in a letter over a year before the war ended, "There are many thousands of things [shells] lying about, and what will happen when the inhabitants return and commence to plough up their land and rebuild their homes, I do not care to think, for there will be many accidents, especially among the children I am thinking. . ."[50]

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[49] Haber, *Poisonous Cloud*, 170.

[50] H. J.C. Leland, "War Letters from France," 29 April 1917, File#96/51/1, p. 99, Imperial War Museum, London, UK.