Colin Mesuda

Mustard Gas: World War I, World War II, and Today

I. The Origins of Chemical Warfare Agents and the Implementation of Mustard Gas

The Second Battle of Ypres in 1915 hosted the first use of poisonous gas in international warfare. The German Army deployed the gas chlorine (Cl_2), a potent irritant, against French Algerian troops with hopes to redefine the slow, unpredictable nature of the prevailing, often stalemated trench warfare. During the battle, German soldiers released the chlorine by hand from heavy cylindrical tanks onto the battlefields of the Western Front. This method, although effective in terms of agent dispersal, proved dangerous, as shifting, unpredictable winds blew some of the gas back at the German soldiers. Consequently, the German military considered future applications of chlorine with mixed feelings. Chlorine initially effectively scattered, injured, and sometimes, in high concentrations, killed enemy troops, but enemy knowledge of the gas overtime limited its utility as a chemical warfare agent, as it was easy to both detect and defend against. Therefore, the German military chose to invest heavily in chemical warfare research because they realized not only the potential for improved chemical and delivery mechanism engineering, but also the psychological terror gaseous weapons could induce in the enemy on the battlefield.

Such ambitions to either synthesize or produce more effective chemical warfare agents first led to the implementation of phosgene, and later mustard gas in 1917. Both German and Allied forces chose to adopt the gas as a chemical warfare agent at this time due to its efficient, relatively safe method of delivery through artillery shells and the observed difficulty of enemy forces to adequately counter gas attacks. However, Mustard gas was neither a new nor revolutionary compound. Indeed, scientists began synthesizing and describing the properties of Mustard gas and other, similar compounds in the early 19th century. The chemical and physical properties of Mustard gas are important to grasp if one wishes to understand why military forces selected it, rather than chlorine or phosgene, as their weapon of choice amidst the proliferation of gaseous warfare agents in 1917 and 1918.

II. The Chemistry of Sulfur Mustards: How and Why They Work

Mustard Gas is a member of the family known as the sulfur mustards, a group of sulfur-based compounds. Sulfur Mustards consist of a central sulfur atom, surrounded by two short hydrocarbon (carbon and hydrogen) chains that each terminate with a chlorine atom, as shown in Figure 1. The chlorine atom ends of the sulfur mustard molecule are perhaps its most significant aspect, as the chlorine atom readily eliminates, or leaves the molecule, to form an unstable, reactive intermediate. This intermediate harms biological systems because it tends to bond to, or alkylate, DNA, a process that compromises cellular health (cytotoxic) and can lead to cancer (carcinogenic). Mustard Gas and similar sulfur mustards are also vesicants, or chemical compounds that act as blistering agents and thus cause rather severe skin irritation and chemical burns.

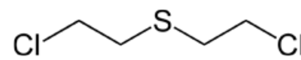

Figure 1. Structure of Mustard Gas

At room temperature as well as at battle conditions, Mustard Gas is a colorless, viscous liquid that coexists with its vapor phase. This may surprise those who have heard of Mustard Gas before, as most records refer to it as a yellow-brown gas. Interestingly, impurities rather than Mustard Gas itself give the compound, in application, its characteristic color. Although both the liquid and vapor phases are harmful, only the vapor phase penetrates clothing. Additionally, Mustard Gas is fat-soluble, and therefore easily penetrates skin, where it can then engage in the detrimental reaction detailed above.

Several formulations of Mustard Gas exist; all have relatively high melting points and low vapor pressures. The former property limits utility in cold conditions, and the latter gives Mustard Gas its deadliest property, persistence, or the ability to remain effective, often undetected, in a given area for an extended period of time. The term Mustard Gas typically refers to the HD variety, a formulation of distilled sulfur mustard obtained from the reaction of thiodiglycol with hydrochloric acid. Scientists synthesized other formulations to reduce the few disadvantageous properties of Mustard Gas. For example, the HL formulation consisted of a mixture of sulfur mustard and Lewisite, a similar vesicant. Because Lewisite has a lower melting point than Mustard Gas, its incorporation increased the utility of Mustard gas in cold, winter conditions. This ability to engineer new formulations of existing gases, and sometimes new gases entirely, encouraged research efforts, and reveals why chemical warfare could reach such great prevalence even when temporarily rendered ineffective.

III. Mustard Gas in World War 1: "The Chemist's War"

World War 1 brought chemical warfare agents to the forefronts of military research, engineering, and tactics. German and Allied forces frequently employed Mustard Gas to disable advantageous positions held by the enemy. Indeed, Mustard Gas functioned more as a dispersant than a lethal agent, as it is typically only fatal, especially relative to chlorine and phosgene, in high concentrations. Moreover, even victims subjected to such high concentrations often survived for months after exposure. This highlights why the German and Allied forces considered chemical warfare agents as viable supplements to existing strategies, rather than as outright replacements. It was precisely Mustard Gas' nature as a strategic supplement that enabled it to change the face of warfare not only in World War 1, but also in future wars.

On the battlefields of the Western Front, Mustard Gas instilled fear both in those subjected to it, and those who employed it. Mustard gas enabled military forces to surprise even the most seasoned forces, as it was unlike any other battlefield strategy implemented before. It was dense, and therefore settled near the ground, where any soldier injured or merely taking cover would be overwhelmed by its strong presence. It was also, over time, difficult to detect and, as mentioned previously, notoriously persistent. Therefore, attackers usually could not occupy recently cleared regions or positions. Careless advances, even if by an individual, sometimes led to "contagious" Mustard Gas attacks, as one soldier poisoned could poison other soldiers around him.

By the end of World War I, nearly 89,000 had died due to Mustard Gas attacks, with well over one million injured. Those injured often died after the war. Mustard Gas tended to take one down a slow and grueling path of death. Although the number above is not small, counter measures and research significantly reduced it. During the war, researchers developed gas masks and protective clothing to prevent, or at least lessen, direct exposure to Mustard Gas. The clothing and masks accomplished this goal, rendering Mustard Gas a less effective agent with each advancement. Soldiers also developed more efficient procedures, thus becoming more organized in the face of Mustard Gas attacks. Nations still chose to invest heavily in Mustard Gas and other chemical warfare agents, however. This investment, coupled with a growing, general hatred towards the substance, created a tense environment where Mustard Gas would be produced, but rarely utilized.

IV. Mustard Gas in World War 2: "The Unfought Chemical War"

The general sense of disgust that lingered within all participants of World War I encouraged discussion regarding the ban of chemical and biological warfare agents. Many believed that chemical warfare could not coexist with the civilized world; the two were mutually exclusive. German and Allied diplomats began such discussions shortly after the armistice in 1918, but did not achieve significant negotiations until the Geneva Protocol of 1925, that prohibited the use but not the storage or development of chemical warfare agents. Therefore, although the protocol successfully banished mustard gas and similar agents from the battlefield on paper, it failed to relieve the paranoia instilled in so many that deadly gases could return, perhaps in more refined or aggressive forms. Indeed, as demonstrated in World War I, Mustard Gas only proves ineffective in the face of sufficient preparations. The ban on chemical weapons could then, ironically, rid the battlefield of gas masks and protective clothing rather than the dangerous chemical warfare agents themselves. These two former safeguards often hindered the performance of soldiers in standard procedures, so armed forces were reluctant to distribute them unless the possibility of gas attack was inevitable or very likely.

Fortunately, although some nations including the United States did not ratify the protocol before World War II, nearly all nations abided by it. This is not to say that mustard gas attacks ended entirely, however. Gas attacks persisted on a global scale, often to quell rebellion or assist military campaigns. For example, Italy betrayed its commitment to the protocol by employing mustard gas during its invasion of Ethiopia in 1935. Likewise, Japan used mustard gas as well as other chemical warfare agents against Chinese troops in 1939 and throughout the Second Sino-Japanese War. The former examples illustrate global difficulties in regulation, but do not address how Mustard gas could, even when dormant, continue to inspire research and above all, persist not only in the minds and bodies of the soldiers exposed to it, but also in the people unfortunate to coexist with it.

V. Mustard Gas Today: Personal, Medical, and Ecological Concerns

Personal accounts and investigation of World War II records indicate that the research methods scientists practiced in World War II and the interim years were just as, or perhaps more so, inhumane as the deployment of the chemical warfare agents themselves. Researchers used human test subjects to note how effectively Mustard Gas could, in varying concentrations, disable or scar an individual with, and sometimes without, experimental protective clothing and ointments. Those chosen for testing were often lied to, sworn to secrecy, and not documented properly. Consequently, the first veterans to reveal the nature of the Mustard Gas research experiments were generally denied compensation.

Unfortunately, given the aforementioned research conditions, it was difficult to prove, without additional information regarding the nature of Mustard Gas, that there was any causal relationship between one’s exposure to Mustard Gas and existing, reported health conditions. To solve this problem in the United States, the Department of Veterans Affairs revised the compensation process, making it less strict and more specific. For example, the VA asked the Institute of Medicine to write a report detailing the extent that certain health problems were associated with Mustard Gas exposure. The effect of the report was successful, and alleviated many of the veteran’s concerns. The report could not, however, cure the health conditions caused by crude methods of research that would ultimately be fruitless, as chemical weapons were scarcely implemented after World War I.

Mustard Gas also put a burden on the environment that, still today, proves difficult to resolve. Although deployment methods advanced with research and development, such delivery mechanisms remained imperfect. Post-war battlefields around the world, and particularly those in France, Belgium, and Germany, contain unexploded ammunition still capable of detonating today. Cleanup efforts are continuous, but complex, as the two methods of disposal, disarmament and detonation, can harm both the individual and the environment. The stockpiles of Mustard Gas produced after World War I continue to pose problems as well. Initially, some nations elected to dump a portion of their stockpile into available seas, but this behavior was quickly condemned and outlawed. Nations such as France have chosen to build chemical disarmament plants that enable safer, more controlled, methods of Mustard Gas disposal. Such factories are not always regulated carefully, however. Mustard gas leaks can harm factory workers and are, not surprisingly, nearly impossible to cleanup immediately.

Perhaps the most intriguing aspect of Mustard Gases, or more generally, the mustards, is their flexibility. Nearly all mustards can act as chemical warfare agents, but one family of substances, known as the nitrogen mustards, can also act as chemotherapy agents. The nitrogen mustards helped spark the chemotherapy industry, which continues to grow and prosper today. Here, two chemical structures coexist, different by little more than one atom, one helping to save lives, and the other to take them away.

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