Chapter 3

HISTORICAL ASPECTS OF MEDICAL DEFENSE AGAINST CHEMICAL WARFARE

ROBERT J. T. JOY, M.D., FACP*

**Colonel, Medical Corps, U.S. Army (Ret); Professor Emeritus, Department of Medical History, Uniformed Services University of the Health Sciences, 4301 Jones Bridge Road, Bethesda, Maryland 20814-4799*

INTRODUCTION

In discussing the history of the use of any new weapon and the medical response to it, one must also describe the context of the weapon: its scientific, social, and political aspects. For chemical warfare, there is the particular idea that chemical weapons are inhumane and immoral. Medical people, who treat the wounded, may well believe that *all* weapons are inhumane. Nevertheless, even the terms are relative—consider Pope Innocent II, who, in 1139, forbade the use of the relatively new crossbow as "Hateful to God and unfit for Christian Use."[1(pp35–36)] His prohibition was cheerfully ignored; the crossbow was used for over 300 years. In this essay, I will return to the issue of the moral use of the chemical weapon, but let us begin with the early history of chemical warfare itself.

EARLY HISTORY

In Thucydides's *History of the Peloponnesian War,* the 4th-century BC war between Athens and Sparta, we find the earliest description of chemical warfare. Thucydides describes how the Athenians were defending a fort at Delium in 423 BC, when the allies of Sparta attacked:

> The Boethians took the fort by an engine of the following description. They sawed in two and scooped out a great beam from end to end and fitted [it] together again like a pipe. They hung by chains a cauldron at one extremity, with which communicated an iron tube projecting from the beam, and this they brought up on carts to the part of the wall composed of vines and timber and inserted huge bellows into their end of the beam and blew with them. The blast passing closely confined into the cauldron, filled with lighted coals, sulfur and pitch made a great blaze and set fire to the wall. The smoke made it untenable for the defenders who left and fled, and the fort was taken.[2(p262)]

In AD 660, some thousand years later, a man named Kalinkos, who was either a Greek architect or a Syrian alchemist, invented Greek fire. The actual formula is lost, but it probably consisted of resin, pitch, sulfur, naphtha, lime, and saltpeter. Greek fire was an excellent naval weapon because it would float on water and set fire to the wooden ships of the era.[3]

In the 9th century, Leo IX of Byzantium, writing on warfare, described "vases filled with quicklime which were thrown by hand. When broken, the vase would let loose an overpowering odor which suffocates those who are near."[4(pp45–46)] Historically, then, the chemical weapons were fire and gas.

NINETEENTH CENTURY

In 1812, Admiral Thomas Cochrane of the Royal Navy of Great Britain proposed packing ships with sulfur, setting them afire, and having them sail into the French ports during the Napoleonic wars. Cochrane argued that the resultant sulfur dioxide would be carried by prevailing winds into the forts and thus incapacitate the enemy.[5–7] The Admiralty turned down his idea as impractical and further stated, "It is against the rules of warfare."[7(p22–23)]

Some 30 years later, during the Crimean War of 1854, Sir Lyon Playfair, a noted British chemist, proposed the use of cyanide-filled shells against the Russian fort at Sebastapol. The War Office rejected the idea, stating that it was "as bad as poisoning the enemy's water supply."[8(p23)] Playfair was appalled by that decision and made an interesting prophecy:

> There is no sense to this objection. It is considered a legitimate mode of warfare to fill shells with molten metal, which, scattering among the enemy, produced the most frightful modes of death. Why is a poisonous vapor which would kill men without suffering to be considered illegitimate? This is incomprehensible to me. But no doubt in time chemistry will be used to lessen the suffering of combatants.[8(p23)]

When the American Civil War started in 1861, the use of Greek fire was threatened but, in fact, never used. Edwin Stanton, President Lincoln's secretary of war, received an interesting letter from Mr. John Doughty of New York in 1862. Enclosing a sketch of an artillery shell (Figure 3-1), Mr. Doughty wrote:

> Above is the projectile I have devised for routing an entrenched enemy. Chlorine is so irritating in its effects upon the respiratory organs that a small

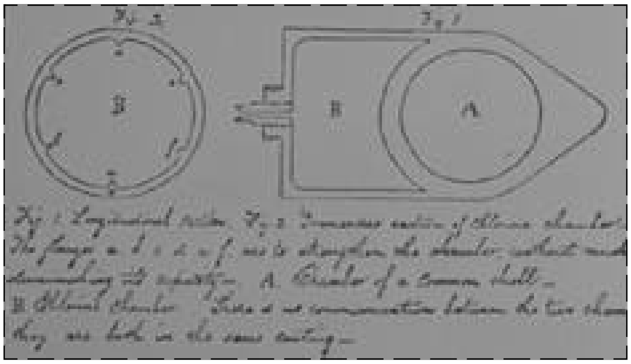

Fig. 3-1. John W. Doughty's original drawing of the artillery chlorine shell he proposed in a letter to Edwin M. Stanton, Secretary of War, in 1862. Original drawing held at Record Group 94, Records of the Adjutant General's office, entry 286, special file 62B (TR3), National Archives Building, Washington, DC.

> quantity produces incessant and uncontrollable violent coughing. A shell holding two or three quarts of liquid chlorine contains many cubic feet of the gas.[9(p9)]

He went on at great length in his letter to describe the potential of this shell against ships, trenches, "casemates, and bomb-proofs." He concluded by stating:

> As to the moral question involved, I have arrived at the somewhat paradoxical conclusion that its introduction would very much lessen the sanguine character of the battlefield and render conflicts more decisive in their results.[9(p9)]

Historians have been unable to find a written response to that letter. Of course, the gas shell was not used.[10]

After the American Civil War, chemistry advanced rapidly as a science. As early as the 1830s, Frederick Woehler had synthesized urea, and organic chemistry began. In Germany in the 1840s, Justus von Liebig had introduced isomer chemistry and chemical fertilizers. In Sweden in the 1860s, Adolph Nobel produced trinitrotoluene (TNT) and dynamite. In 1912, a German chemist, Fritz Haber (Figure 3-2), developed the ammonia process for making nitrates. By the turn of the century, Germany had become the center of world chemistry. The six largest German firms held 950 chemical patents, whereas the six largest British firms held only 86 patents. Ninety percent of the

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Fig. 3-2. Fritz Haber (1867–1934) received the 1918 Nobel prize for solving the heretofore intractable problem of making atmospheric nitrogen available for use in myriad industrial chemical processes, including making fertilizer and explosives. He became interested in toxic gas as a weapon of war early in World War I. Along with Walther Nernst, Haber was responsible for the German chemical warfare program and directed the initial German attack on Ypres. He was also a strong advocate of chemical warfare after World War I. Reprinted with permission from Goran M. *The Story of Fritz Haber.* Norman, Okla: University of Oklahoma Press; 1957.

dyes used around the world were produced in Germany.[11,12]

As is usual with human advances, consideration was given to the use of chemicals (or, in the vernacular of the time, poison gases) in war. The moral question that Mr. Doughty had raised in 1862 during the American Civil War became an issue at the Hague Convention of 1899, an international meeting aimed at limiting the horrors of war. Among the issues raised was that of poison gas. The American military representative at that meeting was Rear Admiral Alfred Thayer Mahan of the U.S. Navy, who stated the official military position very well:

> It seems to me that it cannot be proved that shells

> with asphyxiating gases are inhumane or unnecessarily cruel or that they could not produce decisive results. I represent a people, animated by a lively desire to make warfare more humane, but which nevertheless may find itself forced to wage war, and therefore it is a question of not depriving ourselves through hastily adopted resolutions of means which we could later use with good results.[13(p46)]

The Hague Convention did outlaw chemical warfare, but the agreement had so many loopholes that it made no real difference when it came to the testing ground of World War I.

WORLD WAR I

During World War I, chemical warfare began with the German introduction of portable flamethrowers, which were not terribly effective after the initial shock wore off. There were a number of problems with flamethrowers: the flames lasted only a minute or two; the devices had a tendency to blow up and kill the operator; and they were easy to counter by shooting the operator.

Chemical warfare began in a tentative way with the French use of tear gas grenades in 1914 and early 1915. They were not particularly useful. The Germans began experimental work on chemical agents in late 1914 and produced a tear gas artillery shell. These were used against the Russians in January 1915 but were not particularly effective, owing to the cold weather. Fritz Haber, Director of the Kaiser Wilhelm Institute of Physical Chemistry in Berlin, proposed the use of chlorine gas, to be released from cylinders.[14,15]

By 1915, the trench line between the French and British forces and the Germans was established from the English Channel to the Swiss border, and a stalemate set in. At the junction of the British Expeditionary Force and a French territorial division near the old Belgian city of Ypres, an event occurred on 22 April 1915 that marked a new kind of warfare (Figure 3-3):

> Suddenly at about 4 p.m., there rose from the German trenches opposite the lines occupied by the French Colonial troops, a strange opaque cloud of greenish-yellow fumes. A light breeze from the northwest wafted this cloud toward the French who fell gasping for breath in terrible agony. Terror spread through the ranks, and a panic followed which quickly spread from front to rear lines.
>
> We saw figures running wildly in confusion over the fields. Greenish-gray clouds swept down upon them, turning yellow as they traveled over the country blasting everything they touched and shriveling up the vegetation. No human courage could face such a peril. Then there staggered into our midst French soldiers, blinded, coughing, chests heaving, faces an ugly purple color, lips speechless with agony, and behind them in the gas-soaked trenches, we learned that they had left hundreds of dead and dying comrades. It was the most fiendish, wicked thing I have ever seen.[16(p13)]

Intelligence warnings had been available for some 2 weeks about the Germans putting gas cylinders in the trenches, but the British and the French failed to heed them. The Germans released 150 tons of chlorine from 6,000 cylinders (50 lb of liquid per cylinder), and their tactical success was immediate. They punched a hole through 15,000 troops, leaving perhaps 800 dead and maybe another 2,500 to 3,000 incapacitated.

However, the German High Command was not ready for follow-up, in part because they did not trust the weapon. In part, they saw it as a civilian

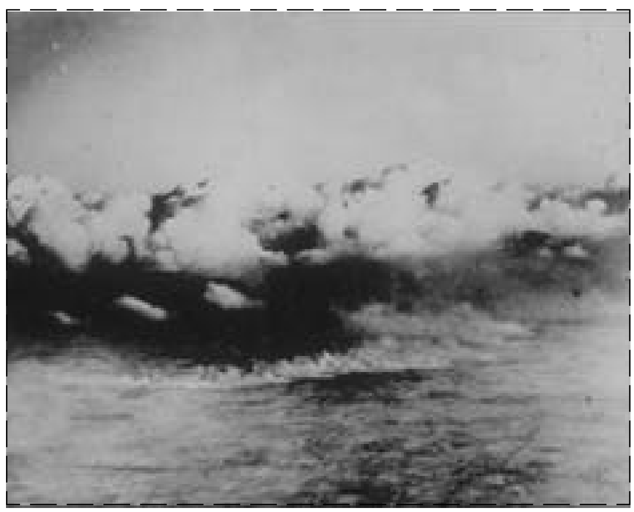

Fig. 3-3. This photograph is reputed to show the historical German chlorine gas cloud attack at Ypres, Belgium, on 22 April 1915. Although there is little evidence to support this claim, the photograph does show a visible cloud, probably created by a cylinder attack. Photograph: Courtesy of Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

a

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b

Fig. 3-4. Warfare in the chemical age. (**a**) British soldiers at the Battle of the Somme appear to be wearing PH helmets in this photograph dated July 1916. (**b**) The PH helmet was an improved version of the earlier hypo and P helmets in which air was inhaled and exhaled through the fabric. The PH helmet incorporated an expiratory valve, and the cloth was impregnated with chemicals designed to destroy phosgene (the active agent was hexamethylenetetramine). This protective mask was stiflingly hot, and prolonged wear resulted in carbon dioxide retention. Source for figure legend: Prentiss AM. *Chemicals in War: A Treatise on Chemical Warfare.* New York, NY: McGraw-Hill; 1937: 536. Photograph a: Reprinted with permission from Imperial War Museum, London, England. Photograph b: Courtesy of Pictorial History, Gas Defense Division, Chemical Warfare Service, Vol 5, Edgewood Historical Files. Held at Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

idea that had been pushed on them by professors Walther Nernst of the University of Berlin and Fritz Haber of the Kaiser Wilhelm Institute. (Haber had developed the ammonia process and Nernst formulated the third law of thermodynamics. After the war, both men won Nobel prizes for their work in chemistry.) More importantly, reserve troops had been diverted to the Russian front while the Germans had been waiting for the right weather for their gas attack.[17–20]

Now began the race between weapon protection and weapon development. Medical involvement in chemical warfare began with the development of protective systems as well as with the treatment of patients. The Germans were the first to develop a mask. It had pads soaked in bicarbonate and sodium thiosulfate,[21(p538)] with some charcoal between the layers. The British began using “veil” respirators: the soldier put a soaked gauze pad over his nose and mouth and then wrapped millinery veiling around his head to hold the gauze in place. The British rapidly developed a flannel hood, in which a flannel bag with eyepieces was soaked in glycerin and sodium thiosulfate and then pulled over the head (Figure 3-4). The French M2 mask was similar to the British mask, in which air was breathed through multiple layers of cloth impregnated with neutralizing chemicals (Figure 3-5). In early 1916, the Germans introduced a far more sophisticated mask, which featured a canister containing the neutralizing chemicals attached to the front of the mask. Air was breathed through the canister (Figure 3-6). Horses were the prime movers in World War I and had to be protected from chemicals by gas masks that looked like nose bags. Artillerymen, quartermasters, and transport personnel were directed to mask their horses before masking themselves (you can’t teach a horse to hold its breath).[17,19,22–26] But until a gas-warning system was implemented and soldiers routinely carried gas masks, casualty rates approached 5%, with a 25% death rate (Table 3-1).[18(App D)]

By September 1915, the British were moving chlorine cylinders to the front. Major Liven of the British army developed the Livens projector, a mortar that could throw shells holding 1.5 gal of either chlorine or phosgene. The Germans continued to use gas cloud attacks; by December 1915, the standard mixture consisted of chlorine and phosgene[21(pp154–155)] (Figure 3-7). In 1916, the British developed a “box respirator” (Figure 3-8), in which the mask was connected by a hose to a canister filled with protective chemicals and filters and carried in

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Fig. 3-5. The French M2 protective mask was similar to the British cloth helmets and the earliest German masks in the sense that the nose and mouth were covered with cloth impregnated with neutralizing chemicals. Even though somewhat ineffective, the M2 protective mask was used throughout World War I and was even used by members of the American Expeditionary Force early in its deployment. By 1916, the French had the makings of a vastly superior mask, designed by the respiratory physiologist Tissot. This mask incorporated inlet and outlet valves and contained a design feature still found in today's masks: the inhaled air passes over the lenses, thereby preventing their fogging. Practical problems prevented its widespread adoption by the French army. Reprinted with permission from Hartcup G. *The War of Invention, 1914–18.* London, England: Brassey; 1988.

a canvas pouch. This was later copied by the Americans. Like the British protective mask, the early American mask had a nose clip and an internal mouthpiece. Dennis Winter quoted a British officer's view:

> We gaze at one another like goggle-eyed, imbecile frogs. The mask makes you feel only half a man. The air you breathe has been filtered of all save a few chemical substances. A man doesn't live on what passes through the filter—he merely exists. He gets the mentality of a wide-awake vegetable.[27(p124)]

TABLE 3-1

SIX CHLORINE–PHOSGENE CLOUD ATTACKS: BRITISH CASUALTIES DECEMBER 1915–AUGUST 1916

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Adapted with permission from Moore W. *Gas Attack.* London, England: Leo Cooper; 1987: Appendix D.

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Fig. 3-6. The most widely used German mask was introduced in early 1916; this painting was made in 1917. The neutralizing chemicals were placed in a canister attached directly to the facepiece of the mask. The wearer both inhaled and exhaled through the canister. Protection depended on a tight seal between the mask and the wearer's face so that only air that had passed through the canister entered the respiratory tract. In addition, note the World War I–vintage truncal armor worn by these storm troopers. Reprinted with permission from Smith B. *France: A History in Art.* New York, NY: Doubleday; 1984.

Fig. 3-7. The Germans continued to use gas cloud attacks throughout 1916, usually mixing chlorine with phosgene. Colonel H. L. Gilchrist, medical director of the American Expeditionary Force for gas warfare, prepared this illustration for chemical warfare training purposes. The drawing is based on an actual German gas cloud in 1916 but an American division is substituted for the British division that was actually attacked. The gas cloud is seen as totally interrupting the division's medical evacuation system, as well as making inoperative its two "degassing stations" (see Figure 3-20). Reprinted from Gilchrist HL. *A Comparative Study of World War Casualties From Gas and Other Weapons*. Edgewood Arsenal, Md: Chemical Warfare School; 1928: illustration 1.

Fig. 3-8. The British small-box respirator, introduced in 1916 and seen in 1918 in this photograph, was vastly more satisfactory than the earlier British helmets. The wearer breathed through a mouthpiece (like that worn by a scuba diver). Since a spring clip was applied to the nose, only air that had passed through the mouthpiece could enter the lungs. An absolute seal between the face and mask was unnecessary. The mouthpiece was connected by a tube to the canister containing neutralizing chemicals, which was worn around the trunk. Although the small-box respirator was much more protective than its predecessors, it was probably even less user-friendly. Photograph: Courtesy of Pictorial History, Gas Defense Division, Chemical Warfare Service, Vol 5, Edgewood Historical Files. Held at Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

A new weapon had come to the battlefield. It was not decisive in a strategic sense, and it did not break the stalemate of trench warfare. At the tactical level and to the soldier, however, it had a significant and frightening impact (Figure 3-9). Frederic Brown summarized it well:

> Gas is insidious. It often causes casualties without any warning. It exerts a tremendous effect on morale, especially in untrained troops. Uncertainty as to when and where gas is present and how it will act is demoralizing even to troops with high discipline. Nothing breaks a soldier's will to fight so quickly as being gassed, even slightly. His imagination magnifies his real injury 100-fold.[20(p153)]

In April 1917, the United States entered the war, unprepared for chemical warfare. We had no organization, no equipment, and no personnel trained for chemical warfare. The U.S. Bureau of Mines was given the task of researching and developing chemical agents, primarily through contracts with universities. The Signal Corps was tasked with making the gas alarms, the Ordnance Corps with making the weapons and ammunition, and the Engineers with providing troops with chemical weapons and training them in their use. The Army Medical Department was directed to manufacture protective equipment and provide troops with training in its use. The Medical Department performed physiological studies on the energy costs and pulmonary function of individuals wearing masks. It also conducted controlled gas-exposure studies by exposing volunteers to low doses of gas to test the efficacy of various protective masks (Figure 3-10). In October 1917, at Edgewood Arsenal, Maryland, the United States began to build a huge industrial complex for making chemical warfare agents; this facility poured out

Fig. 3-9. In this posed instructional picture of a gas attack, the soldier on the right has removed his small-box respirator and is inhaling poison gas. What message is this training photograph illustrating? That the mask is defective and is letting in the chemical agent? That the soldier thought he smelled gas, and, fearing that the mask was defective, ripped it off? Or perhaps that the soldier could not see (the lenses of the small-box respirator were notoriously subject to fogging), removed his mask, and is now suffocating? Whatever its intended purpose, this photograph reminds us that removal of the mask in the presence of chemical agents was a major cause of chemical injury in World War I. Gilchrist pointed this out in 1928:

> Investigation showed that these casualties were caused by general lack of gas discipline. It was found that the standing order that "Men will not remove the mask until ordered to do so by an officer" was absolutely disregarded by practically all units affected, and that fully 75 per cent of the casualties were due to the disobedience of this order, casualties which efficient training and discipline would have prevented.

Gas mask discipline was the key to low chemical casualty rates in the face of this insidious weapon. Quotation: Gilchrist HL. *A Comparative Study of World War Casualties From Gas and Other Weapons.* Edgewood Arsenal, Md: Chemical Warfare School; 1928: 16. Photograph: Reprinted from Moore WE, Crussell J. *US Official Pictures of the World War.* Washington, DC: Pictorial Bureau; 1920.

Fig. 3-10. The men are testing experimental canisters, probably performing a primitive form of quality assurance for equipment to protect against chemical warfare agents. Photograph: Courtesy of Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 3-11. This poster from World War I was designed to encourage enthusiasm for quality assurance among women who worked manufacturing protective masks. Photograph: Courtesy of Pictorial History, Gas Defense Division, Chemical Warfare Service, Vol 5, Edgewood Historical Files. Held at Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

chemical munitions by the ton for shipment overseas.[28–30] (Chemical warfare research done at The American University, Washington, DC, during World War I had a long-delayed fallout. In 1993, during construction of new homes in Spring Valley, a neighborhood located near the university, chemical warfare munitions from World War I were uncovered. It seems that the then-vacant wooded area was used as a testing range. The material has

Fig. 3-12. Harry L. Gilchrist (1870–1943), shown here as a major general and head of the Chemical Corps, was the preeminent figure in the history of the U.S. Army's medical defense against chemical agents. As a Medical Corps colonel, he was medical director of the Gas Service, American Expeditionary Force 1917–1918, and was responsible for all important aspects of chemical casualty care. He was chief of the medical division of the Chemical Warfare Service at Edgewood Arsenal from 1922 to 1929 and head of the Chemical Corps from 1929 to 1934. Following his retirement from the army in 1934 and until 1940, he was editor of *The Military Surgeon*, the predecessor journal of today's *Military Medicine*. Photograph: Courtesy of Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

been removed by the U.S. Army Chemical Corps, with assistance from other agencies.[31])

Unfortunately, the first masks sent overseas with the AEF were defective (Figure 3-11), and the new AEF arrivals were fitted with French masks. General Pershing, the commanding general of the AEF, was very familiar with the divided responsibilities for chemical warfare in the United States. To prevent this from occurring in the AEF in France, he put an infantry colonel, Amos Fries, in charge of a unified Gas Warfare Service, which later became the Chemical Warfare Service (CWS, the forerunner of today's Chemical Corps). In turn, Colonel Fries chose an army physician, Colonel Harry Gilchrist (Figure 3-12), to head the medical section of his service. Gilchrist was very well known for his work in infectious diseases and was highly regarded as a researcher. (In 1929, Gilchrist gave up his medical commission, transferred to the Chemical Corps, and became a major general and the head of the corps.)

Treatment regimens were directed toward the lung irritants that produced pulmonary edema, alveolar disruption, vascular stasis, and thrombosis. Therapy consisted of good nursing, rest, oxygen, and venesection. Death from exposure to chlorine or phosgene usually occurred within 48 hours after cardiopulmonary collapse.

With the effects of the respiratory agents largely defeated by masks, the Germans changed the rules. In July 1917, they introduced dichlorethyl sulfide (mustard) against British troops at Ypres, Belgium. Delivered by artillery shells, mustard caused 20,000 casualties (Figure 3-13). To quote Gilchrist:

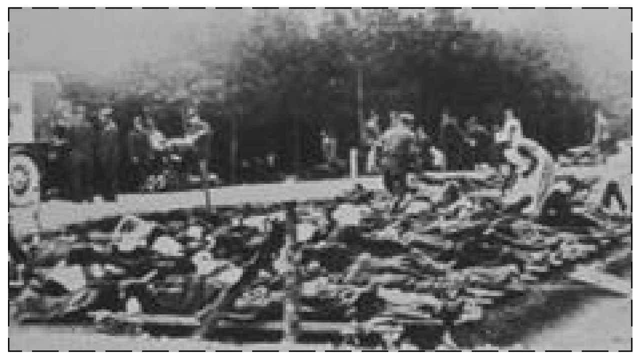

Fig. 3-13. This photograph from Gilchrist's study of World War I gas casualties has the following figure legend: "War photograph—Showing a small proportion of many mustard gas casualties in the United States forces resulting from a severe gas attack." Note that none of the healthcare providers are wearing protective equipment. Casualties are being unloaded from an ambulance in preparation to being triaged. Effective triage of chemical casualties was very difficult, as is apparent from this excerpt from an operational report:

> Gas cases were the most difficult of all to handle. It is impossible for the surgeon to properly diagnose his cases. One has no means of knowing whether he is dealing with delayed gas poisoning or with a simple case of Gas Fright … (but) all palpable cases of poisoning were immediately evacuated, taking precedence over other cases.

Quotation: Cochrane RC. The 3rd Division at Chateau Thierry July 1918. In: *US Army Chemical Corps Historical Studies: Gas Warfare in World War I*. Washington, DC: Office of the Chief Chemical Officer, US Army Chemical Corps Historical Office; 1959: 90. Study 14. Photograph: Reprinted from Gilchrist HL. *A Comparative Study of World War Casualties From Gas and Other Weapons*. Edgewood Arsenal, Md: Chemical Warfare School; 1928: facing page 20.

Fig. 3-14. Although this photograph is frequently held to show the inhumanity of chemical warfare, the unequivocal fact is that very few mustard casualties developed permanent eye injuries—let alone blindness. Reprinted from Marshall SLA. *American Heritage History of World War I.* New York: NY: Simon and Schuster; 1964: 167.

> At first the troops didn't notice the gas and were not uncomfortable, but in the course of an hour or so, there was marked inflammation of their eyes. They vomited, and there was erythema of the skin. Actually the first cases were diagnosed as scarlet fever. Later there was severe blistering of the skin, especially where the uniform had been contaminated, and by the time the gassed cases reached the casualty clearing stations, the men were virtually blind and had to be led about, each man holding on to the man in front with an orderly in the lead [Figure 3-14].[32(p44)]

Armies were now faced with a persistent agent. In fact, mustard has remained active (in concrete) for up to 25 to 30 years. It has a low-dose effect, does not have a strong odor, and, in addition to being a lung agent, is also a skin agent. Brown put it well:

> To the soldier, grave problems were presented by the requirements for individual and collective protection. The very air the soldier breathed and the objects he touched became potential weapons. How would the soldier eat, drink, sleep, perform bodily functions, use his weapon, or give and receive commands? How would he know his area was contaminated?[20(pp34–35)]

The presence of mustard gas meant that everyday living became a real problem. Areas previously safe from the lung gases were no longer safe from

Fig. 3-15. This photograph from Gilchrist's study of World War I gas casualties has the following figure legend: "War photograph—An old ruin heavily contaminated with mustard. Warning sign on ruin; place guarded by troops to prevent entrance." More often than not, contaminated sites were not so clearly identified. Photograph reprinted from Gilchrist HL. *A Comparative Study of World War Casualties From Gas and Other Weapons*. Edgewood Arsenal, Md: Chemical Warfare School; 1928: facing page 27.

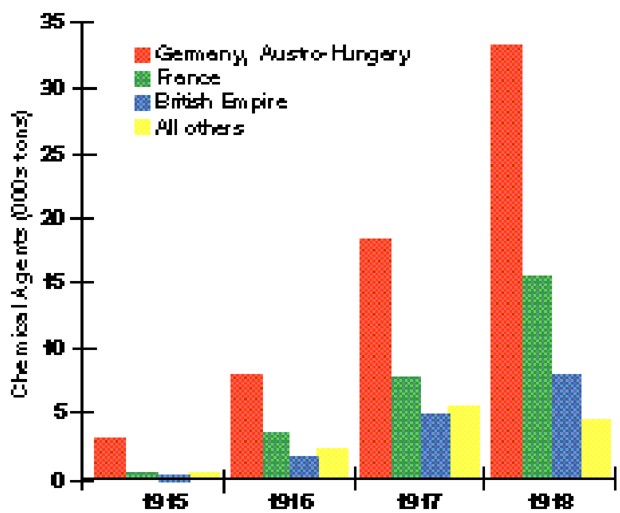

Fig. 3-16. Chemical agents used per year by major belligerents in World War I, in thousands of tons. Data source: Stockholm International Peace Research Institute (SIPRI). *The Rise of CB Weapons*. Vol 1. In: *The Problem of Chemical and Biological Warfare*. New York, NY: SIPRI; 1971: 128. Cited by: King CR. *A Review of Chemical and Biological Warfare During World War I.* Aberdeen Proving Ground, Md: US Army Materiel Systems Analysis Activity; 1979: Table 17, page 45. AMSAA-Tactical Operations Analysis Office Interim Note T-18.

mustard (Figure 3-15). It is heavier than air and thus settles. Because of its persistence, huge areas of ground remained dangerous for days and weeks, just as if they had been mined. Effective as mustard was, chemists continued to produce new agents and combinations of agents. By the end of the war, 11 single agents and at least 7 combinations had been developed. Thousands of tons of these new weapons were produced by both sides (Figure 3-16). By 1918, approximately 25% of all artillery fire was chemical rounds. Whether for good or ill, this new weapon had come to stay.[17,33–39]

MEDICAL PROBLEMS CAUSED BY MUSTARD

I will discuss in detail the medical problems with mustard gas during World War I. I have chosen mustard because the issues of diagnosis, evacuation, treatment, and contamination are similar to those with nerve agents, and because mustard is still used as a weapon today. During World War I, patients and stretcher-bearers alike had to don masks, limiting their vision and activity and making head-wounded patients difficult to mask and treat. In the U.S. forces, gassed patients were identified by a crayon cross on their foreheads because patients could appear well when evacuated but suffer from symptoms hours after exposure to mustard.

In addition to the problem of triage of patients by type of exposure, there were the problems of hysteria and malingering. New troops often confused the smell of high explosives with that of gas and, as a result, made honest errors of self-diagnosis or suffered from "gas mania." [A graphic example of the problem of triage and diagnosis is apparent in the following U.S. Army afteraction report, describing an event that took place in 1918:

> One form of psychoneurosis, "Gas Fright," was very common but most cases could be restored to the lines after a few hours' rest. One instance occurred where an entire platoon of machine gunners developed this form of psychosis. These men were eating their meal just before dark when a shell fell and burst at a distance of about 100 meters. They continued eating and many of them had finished when someone yelled Gas! and said their food had been gassed. All the men were seized with gas fright and a few minutes later made their way to the Aid Station. To an inexperienced eye they could have easily been diagnosed as gassed patients. They came in in a stooping posture, holding their abdomens and complaining of pains in the stomach, while their faces bore anxious, frightened expressions and some had even vomited. After reassurance, treatment with tablets of sodium bicarbonate, and a night's rest, they were quite well again.[40(p91)]—RFB, ed.]

Gilchrist studied 281 cases consecutively admitted to a field hospital and found that only 90 of them were true gas casualties. Some were malingerers, some were misdiagnosed by battalion surgeons, and some had made honest errors of self-reporting.[13]

The mass casualties that were generated by mustard gas demanded a medical capability for quick mass decontamination of those attacked (Figure 3-17). Colonel Gilchrist organized a mobile degassing unit, a medical unit that provided showers and uniform changes for 5% of division strength. The unit (12 men and 1 officer) had the capability to decontaminate 24 men every 3

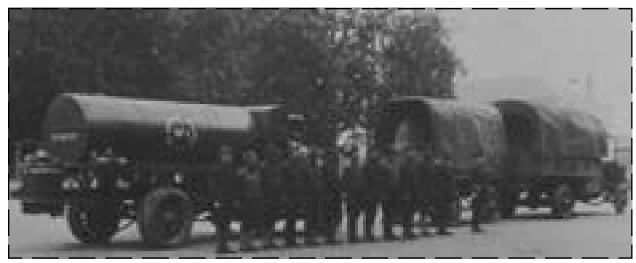

Fig. 3-17. The mobile decontamination facility was the essential part of the degassing station, two of which were to be added to each division. As events transpired, only one experimental mobile decontamination facility was actually constructed, but it was never used in combat. Its objective was "to give hot baths and clean clothing to those subjected to the fumes of mustard gas at the nearest possible points to where gas bombardments take place." Given what is now known about the speed with which mustard injury develops, attempting to slow the progression of mustard injury by this regimen was most likely an exercise in futility. Nevertheless, by providing a shower and clean clothing, the degassing station would have played an important role in improving the general sanitation and morale of combat troops. Quotation: Gilchrist HL. Field arrangements for gas defense and the care of gas casualties. In: Weed FM, ed. *Medical Aspects of Gas Warfare*. Vol 14. In: Ireland MW, ed. *The Medical Department of the United States Army in the World War.* Washington, DC: Government Printing Office; 1926: Chap 4: 61. Photograph: Courtesy of Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 3-18. This photograph from Gilchrist's study of World War I gas casualties has the following figure legend: "War photograph—Special ambulances used for transporting mustard gas casualties rendered necessary due to insidiousness of mustard." Note that the ambulance crews appear not to be protected against mustard. Reprinted from Gilchrist HL. *A Comparative Study of World War Casualties From Gas and Other Weapons*. Edgewood Arsenal, Md: Chemical Warfare School; 1928: facing page 30.

Fig. 3-19. This photograph from Gilchrist's study of World War I gas casualties has the following figure legend: "War photograph—Special gas aid station for administering to gas casualties. Here cases suffering from different gases were, when possible, segregated." Note the lack of protective equipment; the casualty being loaded into the ambulance was apparently not deemed a threat, possibly because he was a victim of a respiratory agent. Reprinted from Gilchrist HL. *A Comparative Study of World War Casualties From Gas and Other Weapons*. Edgewood Arsenal, Md: Chemical Warfare School; 1928: facing page 31.

minutes. This unit was not for treating patients but for decontaminating troops who had been exposed to mustard but were not yet casualties. A water tank truck carried enough water for 700 showers of 2 minutes' duration; the water was heated by a gasoline heater at the rear of the truck. A long tent was erected, with the showers at the back of the tent. At the front of the tent, the men discarded their contaminated clothing and then stepped under the showers. The men in the medical unit who handled the contaminated clothing were protected by rubber-and-oilcloth uniforms and gas masks.[29,32]

The low volatility of mustard and its ability to cause injuries at very low doses required medics to segregate the patients and to establish specialized evacuation systems and equipment, because mustard contaminated everything it came in contact with. Indeed, a single man with mustard on his uniform could easily contaminate an entire ambulance or dugout (Figures 3-18 and 3-19).

The acute conjunctivitis induced by mustard (Figures 3-20 and 3-21) required immediate eye irrigation. Most of the eye cleared up in several weeks. Nevertheless, during the resolution stage of mustard-related acute conjunctivitis, patients were photophobic for a considerable period.

Skin burns were treated in a variety of ways (Figure 3-22). First, the patients were washed down by corpsmen who wore protective clothing. Early in

Fig. 3-20. A nurse is irrigating the eyes of soldier who has a probable mustard injury. Given the rapidity with which mustard damages tissue, however, we know now that eye irrigation would have provided only symptomatic relief. Reprinted from Moore WE, Crussell J. *US Official Pictures of the World War.* Washington, DC: Pictorial Bureau; 1920.

Fig. 3-21. In 1918, the British prepared for the American Expeditionary Force a series of color drawings and descriptions of injuries caused by chemical warfare agents. This drawing depicts a severely burned eye in the acute stage after exposure to mustard vapor. A portion of the original description follows:

[Severely burned eyes] may be recognized by certain characteristic features that are depicted in the drawing [right]. Whenever a dead white band crosses the exposed area of the conjunctiva, while the parts of this membrane covered by the upper and lower lids are red and oedematous, serious injury from the burning is likely to have occurred.

In the case illustrated, the caustic effect of the vapour is seen chiefly in the interpalpebral aperture. On each side of the cornea there is a dead white band due to coagulative oedema, which compresses the vessels, impairs the circulation, and thus acts as a menace to the nutrition of the cornea. The swelling in the region of this white band is slight, while the protected conjunctiva above and below it is greatly swollen and injected and may even bulge between the lids.

The exposed portion of the cornea is grey and hazy; it has lost its lustre, and when viewed with a bright light and a magnifying glass it shows a blurred "window reflex" and a typical "orange-skinned" surface. The haze gradually fades off above in the region of the protected part of the cornea where the surface is usually bright and smooth. The pupil is at first contracted as the result of irritation and congestion. In this drawing it is shown as artificially dilated by atropine ointment, which should always be used early in severe cases or where there is much pain and blepharospasm.

Reprinted from *An Atlas of Gas Poisoning*. 1918: Plate 11A. Handout provided by the American Red Cross to the American Expeditionary Force.

Fig. 3-22. An extensive mustard burn of the buttocks. This degree of mustard injury, analogous to a second- or third-degree thermal burn, was unusual. The original description that accompanied this drawing, provided to the American Expeditionary Force by the British (also see Figure 3-21), follows:

The man sat down on ground that was contaminated by the poison and the vapour passed through his clothing, causing inflammation of the buttocks and of the scrotum. A diffuse reddening appeared twenty-four hours after exposure, and this was followed by an outcrop of superficial blisters. On the eighth day the erythema began to be replaced by a brown staining, and the drawing was made on the eleventh day during this change of tints. Infection of the raw surface was avoided, and the healing was complete in three weeks.

The blisters in this case were probably aggravated by pressure, for the inflamed skin becomes very fragile, so that the surface layer is readily loosened by pressure or careless rubbing. The blisters may be very tiny bullae, as on the eyelids, or they may coalesce into areas many inches across, covering a collection of serous fluid which perhaps itself contains enough of the irritant substance to injure other skin if it is allowed to flow over it.

The blisters are usually quite superficial and almost painless in their development. But the raw surface that is left after the blister has burst becomes most acutely sensitive to all forms of mechanical irritation. Deeper destruction of the dermis may be caused by spreading necrosis where the substance attacks the skin locally in high concentration, or when secondary infections are implanted on the raw surface. Chronic and painful sores then result, and in this event the skin does not regenerate completely, so that thinly covered scars for a long time will mark the site of the burn.

Reprinted from *An Atlas of Gas Poisoning*. 1918: Plate 6. Handout provided by the American Red Cross to the American Expeditionary Force.

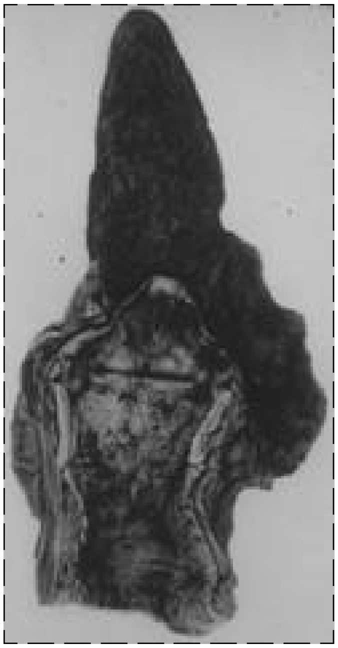

Fig. 3-23. The figure legend that was published with this photograph in the official history of the U.S. Army Medical Department in World War I reads: "Gross changes in larynx and trachea of a soldier who died four days after inhalation of mustard gas." Purulent secretions in the smaller bronchi rather than at the glottis caused the respiratory failure that lead to the death of this soldier. The efficacy of tracheal suction in clearing the airway appears not to have been widely known during World War I. Reprinted from Weed FM, ed. *Medical Aspects of Gas Warfare*. Vol 14. In: Ireland MW, ed. *The Medical Department of the United States Army in the World War*. Washington, DC: Government Printing Office; 1926: Plate 10.

the conflict, burns were initially treated with grease, which only enhanced infection. Later, sodium hypochlorite was used as a constantly running solution, soaking the skin.[25]

Patients who died from mustard inhalation had gross destruction of the tracheobronchial tree (Figure 3-23). In contrast to the pulmonary agents, mustard produced hemorrhage and alveolar edema. Mustard-induced lesions were more difficult to treat than those induced by phosgene or chlorine.

How dangerous were these chemical weapons as killers? Gas was a major cause of casualties: it accounted for up to 30% of hospitalized patients (Figure 3-24). Although gas was a significant

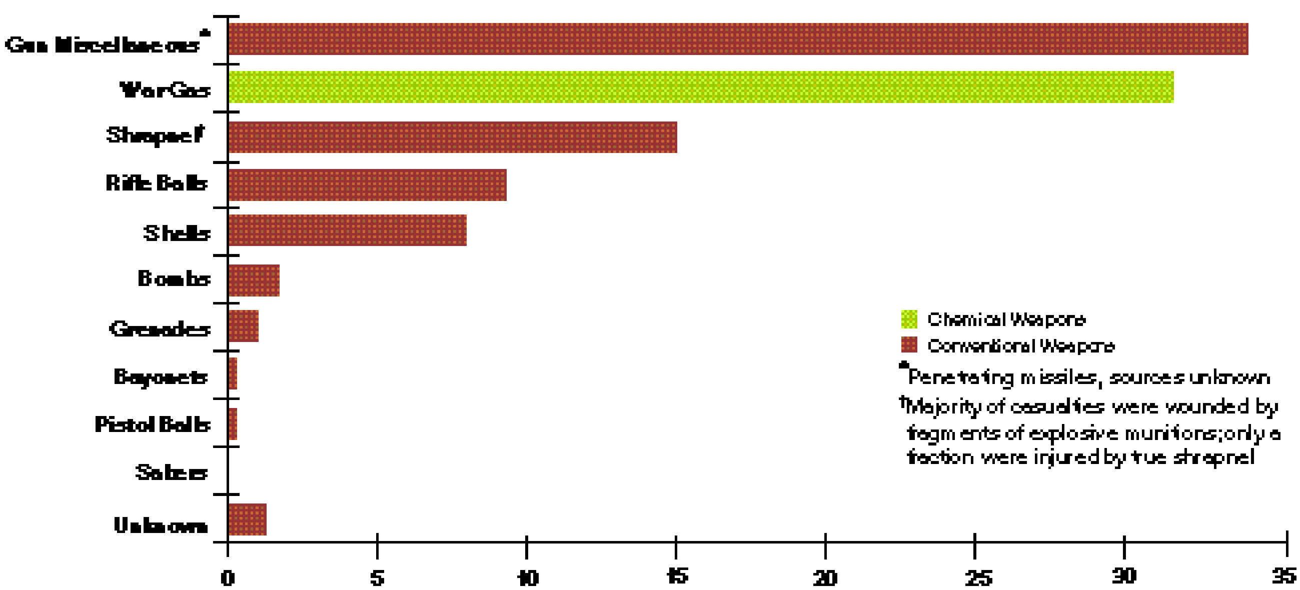

Fig. 3-24. Hospitalized casualties in World War I, in percentages by causative weapon (database: 224,089 casualties). Adapted from Gilchrist HL. *A Comparative Study of World War Casualties From Gas and Other Weapons*. Edgewood Arsenal, Md: Chemical Warfare School; 1928: Chart 7, page 19.

TABLE 3-2

CHEMICAL CASUALTIES IN WORLD WAR I

Country	Nonfatal Chemical Casualties	Chemical Fatalities	Percentage Fatal
Germany	191,000	9,000	4.5
France	182,000	8,000	4.2
British Empire	180,597	8,109	4.3
United States	71,345	1,462	2.0
Russia*	419,340	56,000	11.8

*[The data from which Prentiss (and before him, Gilchrist) derived these figures have apparently been lost to history. However, the Russians themselves analyzed their casualty statistics from World War I. The Narkomzdrav Commission found the figures for nonfatal and fatal gas casualties to be only about one tenth as great as Prentiss's values, which are the ones commonly accepted in the West (total gassed casualties: 40,000–65,000; died of gas: 6,340). Source for these data: Kohn S. *The Cost of the War to Russia*. New York, NY: Howard Fertig: 1973: Table 75; page 136; Table 76. Originally published in 1932.—RFB, ed.]
Adapted from Prentiss AM. *Chemicals in War: A Treatise on Chemical Warfare.* New York, NY: McGraw-Hill; 1937: Table 11, page 653.

factor in casualty production, it was not especially lethal. [The AEF incurred 52,842 fatal battle injuries, but only about 1,500 were due to gas[21(p652)]—RFB, ed.] (Table 3-2).

The Russians suffered out of proportion to the rest of the belligerents because they were late in deploying an effective mask. For the United States, the chemical agents were minor contributors to the number of soldiers killed in action: only about 200 of the total of more than 70,000 wounded by gas.[13] The real problem was the imposition of a major medical and logistical burden on the army. In the AEF, for example, gas patients had significant hospitalization periods (Table 3-3), although the great majority returned to duty. The generally low lethality and high morbidity rate led a great many people to see the chemical weapon as holding much promise for the future of war.

TABLE 3-3

AMERICAN EXPEDITIONARY FORCE: HOSPITAL DAYS DUE TO CHEMICAL WARFARE

Agent	Chemical Casualties	Average Days Hospitalized
Unknown	33,587	37.3
Chlorine	1,843	60.0
Phosgene	6,834	45.5
Mustard	27,711	46.0

Adapted from Gilchrist HL. *A Comparative Study of World War Casualties From Gas and Other Weapons.* Edgewood Arsenal, Md: Chemical Warfare School; 1928: Table 7, page 21.

THE INTERWAR YEARS

After World War I ended, work at the Edgewood medical research laboratories continued. New gas masks were developed, such as those with high-eyepoint lenses for use with binoculars, and masks with speaker diaphragms. As those who have worn mission-oriented protective posture (MOPP) gear know, one cannot really be heard through a mask. Initially, scientists at Edgewood worked on oilcloth-and-rubber uniforms for mustard protection and then developed the resin-and-chloramide uniform. Smoke and gas delivery systems were added to weapons such as tanks and airplanes. The U.S. military paid attention to gas; troops were trained, in the interwar years, in both simulated and real chemical environments.[21,41,42] In short, we took the threat of chemical warfare very seriously: research and training received considerable attention during the interwar years.[5,9,26,30]

The Army Medical Department made a big investment in research. In fact, it put more money into research on the chemical weapon than into anything else in the interwar period. Colonel Edward Vedder, Medical Corps, U.S. Army (Figure 3-25), was in charge of the medical laboratory at Edgewood that produced new mask canisters that could filter smoke in addition to the standard respiratory agents. This development made possible the protection of American soldiers against respiratory tract effects of arsenic-based compounds—the most potent chemical agents of that period. Clinical cases were studied and animal research was performed with the agents, as well as experimentation in humans and attempts at new treatment.

In 1925, Vedder published *Medical Aspects of Chemical Warfare*, a superb book that contains excellent data on the pathology and physiology of various chemical agents (particularly mustard). Much of the text is still germane. On the inside front cover of the book is a picture of a soldier horribly wounded by shrapnel, yet alive. Vedder argued that if this is the result of a humane weapon, then the chemical weapon, by comparison, must be much more humane.[26] Vedder was not alone in this view of the relative humanity of chemical warfare. It was a predominant view of many writers who analyzed the subject.[5,9,17,21,30,33,41–45] The development of the lethal nerve gases by the Germans in World War II, however, has vitiated these arguments.

In the interwar years, a number of medically important spin-offs came from the chemical warfare program. The Americans developed Lewisite, an arsenical, at the end of World War I. It did not turn out to be a particularly effective agent, although it did lead to the development of British anti-Lewisite (BAL), which is useful as a chelating agent in metal poisoning. It was noticed in soldiers who had been exposed to mustard during the war that the white blood count fell. This was verified in 1919. Dougherty, Goodman, and Gilman showed in 1942 that the nitrogen mustards could be useful in the treatment of leukemia and lymphoma. This was the beginning of specific chemotherapy for cancer.[46–48]

Between World War I and World War II, disarmament conferences included discussions of the prohibition of gas warfare.[49] Nevertheless, the chemical weapon continued to be used but only against colonial native peoples. For example, in 1920, the British dropped mustard gas bombs on Afghan tribesmen north of the Khyber Pass. In 1925, the Spaniards used mustard bombs and mustard artillery shells against Riff tribes in Morocco. In 1935, when Mussolini moved from the Italian colony in Libya to conquer Ethiopia, the Italian troops were ambushed. Although equipped with modern arms they were heavily outnumbered, so Marshall Badoglio, the Italian commander, used aerial delivery of mustard bombs against Egyptian troop concentrations and saturated the ground on his road flanks to interdict the movement of barefoot Ethiopian troops.[50,51] (A complete list of proven or alleged use of chemical weapons between 1919 and 1970 can be found in *A Review of Chemical/Biological Warfare During World War I*.[25(pp13–14)])

Fig. 3-25. Edward B. Vedder (1878–1952) was director of pathology at the Army Medical School (now Walter Reed Army Institute of Research) from 1904 to 1913. It was during this period that he wrote his seminal book on beriberi. After serving in the Philippines during World War I, Colonel Vedder returned to the Army Medical School in 1919. It was there that he wrote this still-useful book on chemical casualties. From 1925 to 1929 he was chief of medical research for the Chemical Warfare Service. He had an illustrious civilian academic career following his retirement from the army. Photograph: Courtesy of National Library of Medicine. Bethesda, Md.

WORLD WAR II

When World War II broke out, there was a general expectation and apprehension that the chemical weapon would be used. The Japanese practiced civilian operations while wearing masks. British troops trained with masks in the North African desert. In London, during the height of the blitz, schoolchildren were issued masks. German mothers and children had special capes and masks available. Americans came out with a whole series of tactical and training masks. Walt Disney designed a mask with a Mickey Mouse face for American children, so they would not be frightened by wearing the mask (Figure 3-26). Fortunately, American children never had to use these masks. By 1942, after the United States had entered the war, all U.S. troops trained in masks. Full discussions of the United States efforts in World War II are found in the U.S. Army in World War II series published by the Center of Military History.[52–54]

The United States developed a new generation of protective uniforms, which soldiers carried, along with their gas masks, on every D day in Europe. Chemical weapons were indeed used in World War II, in the form of smoke and flame. Smoke was used for screening troops and movement, especially in Europe. Americans in the Pacific used the flame weapon against Japanese caves and bunkers.

Fig. 3-26. Walt Disney helped design this Mickey Mouse gas mask for American children. The intention was that children would not be frightened of the cartoon character and would therefore be more willing to wear the mask. Photograph: Courtesy of Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

For reasons that historians are still debating, gas itself was not used. One reason the Germans did not use it was that they thought the Americans had developed new, secret nerve gases—comparable to tabun, sarin, and soman—which the Germans had developed between 1936 and 1944. The Germans may have been led to believe this because of the alleged paucity of reports on insecticide research published in the open literature in the United States, and they wrongly deduced that the Americans were now manufacturing nerve gas. In reality, however, there was no industrial base in place ready to produce nerve agents in large quantities[20]—because neither the British nor the Americans had discovered nerve agents.

Other historians have argued that because Adolph Hitler had been a gas casualty in World War I, he was personally opposed to the use of gas weapons in World War II. Similarly, many senior officers on the Allied side in World War II had faced gas as junior officers in World War I and were highly resistant to its use in World War II. It was official U.S. policy that the United States would not use chemical warfare first but would retaliate if it were used against us or our allies. Thus, the United States was prepared to retaliate. It was in part because of this preparation that American and British troops had the only military gas casualties in World War II.

In 1943, Bari, a city on the Achilles tendon of Italy, was a major supply port for the British Eighth Army fighting in Italy. The SS *John Harvey*, an American ship in harbor, carried a highly classified load of 2,000 100-lb mustard bombs. When the Germans hit Bari harbor in a surprise raid they got 17 ships (Figure 3-27); among them was the *John Harvey*. Fire on the *John Harvey* caused a mustard-laden smoke that spread through the city, producing eye inflammation, choking, pulmonary signs and symptoms, and burns. No one really knows the extent of the civilian casualties; however, by the 9th day after the bombing, 59 military deaths had been recorded. Shortly after the bombing, Lieutenant Colonel Stewart Alexander of the U.S. Army Medical Corps,

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Fig. 3-27. The Bari mustard disaster, caused by a German air attack the night of 2 December 1943, resulted from the need to have chemical munitions deployed in the combat zone. The presence of those weapons was necessary to make possible an immediate retaliation should the enemy choose to initiate a chemical attack. However, the deployment of those munitions was kept secret so as not to give the enemy any justification for launching a preemptive chemical attack. Although the merchant ship carrying the mustard bombs, the SS *John Harvey,* had been docked at Bari for several days, the ship was not unloaded because the appropriate authorities did not know of the highly dangerous nature of its cargo. No photograph exists showing the *John Harvey* after the German attack; the ship was completely destroyed by the explosion of the conventional munitions that it was also carrying. Instead, this photograph shows the Bari harbor some hours after the attack. Reprinted with permission from Popperfoto. Northampton, England.

the chemical warfare consultant on General Eisenhower's staff, was sent to Bari, where he made the diagnosis of mustard poisoning. He reported 6l7 cases in troops and merchant marine seamen, with a 14% fatality rate. This fatality rate, 3-fold higher that of World War I, was largely because the merchant marine seamen had been thrown into the sea, where they either got badly burned or swallowed mustard in the water.[55,56]

Lethal gases—pesticides, prussic acid, and cyanide, as well as carbon monoxide—were used as killing agents in gas chambers in the Nazi death camps.[57] This is obviously not a military use of the chemical weapon.

THE POSTWAR YEARS: 1945 TO THE PRESENT

Chemical agents have been used in warfare since World War II. There is a suggestion that they were considered for employment in Korea in 1950.[58] In 1963, the Egyptians used mustard bombs against the Yemen royalists in the Arabian peninsula. The United States used chemical defoliants in Vietnam for canopy clearing and crop destruction, and used tear gas for clearing tunnels and bunkers (Figure 3-28).[59] The Soviets used chemical warfare agents in Afghanistan, probably mustard and a nerve agent.[25] However, the discovery that Iraq had used chemical agents (mustard and perhaps nerve gas) in its war with Iran shocked the public in the western democracies in the 1980s.[60] Iraqi use of hydrogen cyanide and possibly a nerve gas against its own Kurdish population in 1988 was universally condemned.[61,62]

In the United States, the congress has debated the chemical agent issue over several years, with much of the debate focused on the morality of the weapon.[63–65] Congress decided in 1988 to approve the production of the binary nerve gas weapon, influenced then by increasing evidence that chemical weapons were in hand and appeared to be increasing in the arsenals of nonfriendly nations (see Exhibit 4-1 in Chapter 4, Medical Implications of the Chemical Warfare Threat).[66] The accuracy of such information can clearly be challenged, and the lists themselves vary from publication to publication.[66–68] Nonetheless, interest began to increase in a new United Nations treaty to ban chemical weapons.[69,70] In September 1996, the U.S. Senate considered the new treaty, which called for banning production of chemical weapons and for an inspection program. General John M. Shalikashvilli, Chairman of the Joint Chiefs of Staff, urged ratification. Public debate varied widely.[71–73] The U.S. Senate initially rejected the

Fig. 3-28. Tear gas was used extensively by U.S. forces in the Vietnam War, especially in clearing enemy tunnel complexes. The U.S. government, however, did not consider tear gas to be a chemical weapon and therefore did not consider its use to be banned by international law. Many others outside of government disagreed, using as evidence the fact that those who used tear gas wore protective masks. The soldiers shown here are wearing the little-known M28 protective mask. This lightweight (and perhaps more comfortable) mask was designed to be worn in situations in which the threat was not from nerve agents, and the heavy-duty protection offered by the standard masks was not necessary. Photograph: Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

treaty,[74] but it has since been approved, not only by the U.S. Senate (24 April 1997), but also by the 65 member nations of the United Nations required for its enactment and enforcement.[75]

While it is true that there are residual effects—physical, physiological, and psychological—after every American war,[76] the chemical weapon has aroused persistent public interest, veterans complaints, and charges of medical indifference, cover-up, and incompetence. After World War I, the issue was tuberculosis caused by pulmonary agents.[77] After World War II, there was the delayed discovery of cancer and cataracts in enlisted men who had been test subjects for chemical exposures.[78] After the Vietnam War, the herbicide Agent Orange (specifically its dioxin component) had been the assigned cause for a number of compensable diseases.[79] And, as of this writing (January 1997), some veterans of the Persian Gulf War have an unexplained Gulf War "syndrome," with low-dose exposure to chemical agents being suggested as a possible cause.[80]

It is obvious that use of the chemical weapon remains possible. This textbook documents this concern on the part of the U.S. Army Medical Department. I therefore believe that it is the responsibility of the U.S. military medical community to prepare to operate in a chemical environment. Fighting a chemical war will markedly hinder our medical, tactical, and operational capacity (problems well discussed in this textbook), and cause long-term postexposure residual effects. Thus, students of this topic may still find relevance in the words that Sir Charles Bell (who was a surgeon at Waterloo in 1815) wrote in 1812:

> When the drum beats to quarters there is now a time of fearful expectation, and it is now the surgeon feels how much the nature of the wounds of those who may be brought to him ought to have occupied his mind in previous study.[81]

It is that "previous study" that is the purpose of this book: to educate our military and civilian medical communities about chemical warfare and their consequent medical responsibilities.

SUMMARY

The chemical weapon has a long and ancient history, especially in its presentation as flame and smoke. Modern chemistry made possible the use of chemical agents in a logistically and tactically feasible way in World War I. Most of what was known—and is still understood by the public—is based on the gas warfare of 1915–1918. Since then, "poison gas" has usually aroused public repugnance at its use as a weapon. Modest use in the 1930s against tribes and its lack of employment in World War II suggested that "gas warfare" had ended. The discovery of the German nerve gases after World War II, the Cold War, and the utility of tear gas in Vietnam maintained a military interest in the chemical weapon.

The use of gas by Iraq against Iranian troops and the threat of Iraqi use in the Persian Gulf War clearly document that chemical warfare remains possible.

(This chapter was based on Dr. Joy's lecture, "Historical Aspects of Medical Defense Against Chemical Warfare." The figure legends were provided by the textbook editors.)

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