Chapter 16

CHEMICAL DEFENSE EQUIPMENT

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INTRODUCTION

A number of countries around the world have the capability to use chemical weapons. In fact, within the past decade, several events have been well documented where chemical weapons were used in armed conflict, most notably during the Iran–Iraq War. The most recent threat of such use was during the Persian Gulf War, where U.S. forces might have been exposed to the effects of both chemical and biological agents. An essential part of preparedness to continue operations in a chemical environment is adequate equipment.[1,2] Such equipment must encompass all areas of concern: detection and warning, personal protective equipment, decontamination and medical prophylaxis, and treatment. Only an integrated approach to the problem of protection can allow individuals to provide an effective response in a chemical warfare environment with a minimum degradation in human performance.

The primary item of protection is the personal respirator, designed to protect individuals against volatile agents and aerosols. The respirator must be carefully fitted on the face to ensure minimal leakage, and individuals must be well trained in the donning of masks (a maximum of ≤ 9 sec being desirable). In addition to the respiratory hazard, many chemical agents are dermally active. This requires that a proper overgarment, usually containing an activated charcoal layer to adsorb chemical agent, be donned, along with protective gloves and boots. The complete ensemble can seriously degrade individual performance; 50% reduction of mission-related task performance has routinely been measured in tests. (The physiological effects of wearing chemical and biological protective gear are discussed in detail in *Environmental Hazards of the Battlefield*, a forthcoming volume in the *Textbook of Military Medicine* series.) In addition to physical performance degradation, there are reports of psychological problems with some individuals while wearing the complete ensemble, owing to the claustrophobic effects.[3] This subject is discussed separately at the end of this chapter, in a section titled *Psychological Problems Associated With Wearing Mission-Oriented Protective Posture Gear*.

The rapid detection and warning of an opponent's use of chemical agents is critical to the protection of forces.[4,5] Usually, the chemical agent will be delivered via an aerial or missile attack, or an upwind release where the cloud of agent passes over a troop concentration. Timely detection is required to permit all potentially exposed forces to adopt an adequate posture, since the effects of agents can sometimes occur in less than a minute. Vesicant agents and some nerve agents (eg, VX and some of the G series), which can remain active for long periods of time, can affect individuals via the dermal route, thus requiring that a proper overgarment be part of the protective ensemble. Likewise, detection equipment is also used to confirm agent hazard reduction and facilitates reducing the mission-oriented protective posture (MOPP) level and the removal of protection equipment: the "all clear" signal.

Decontamination of equipment, facilities, and personnel is also required after an attack if effective military operations are to be maintained. Some of this decontamination burden can be mitigated by the use of effective collective protection equipment, which can allow continuing operations such as communications and medical care within protected facilities.

One criterion for the selection and use of protective equipment items is the need for joint service use, although there are some differences between the missions of air and ground crews that must be accommodated. This chapter is not intended to be all-encompassing in chemical defense equipment; rather, it is intended to describe the items and operations that are of greatest interest to the medical community.

The following sections address each of the protection areas described above in detail, with the current equipment items featured and items in development that are designed to overcome the deficiencies of present equipment briefly described. Sufficient technical data are included to allow the healthcare professional to become familiar with the operation, components, and the limitations of the present chemical defense equipment. Should the interested reader desire more detail on chemical defense equipment, several sources are available. First, the written references and expert consultants to this chapter are sources of vast amounts of information. Possibly of more value to the healthcare professional is the nuclear, biological, and chemical (NBC) officer who is an integral part of each combat element and who is available to provide detailed advice as well as hands-on assistance.

Several tangential issues must be noted that impact on the area of chemical defense equipment, especially in the future. First, a continuing intelligence need exists to identify new agents that may be used against combat forces and ensure that the defense equipment meets the new threats. Second, it cannot be overemphasized that a viable, active, training program be maintained. And third, medical input into operations while participants are wearing protective equipment is vital to maintenance of a combat operation. Rest periods consonant with work loads and MOPP gear will allow continuing operations even in a contaminated environment. The development program will provide continuing improvements in the chemical defense equipment available to the forces, and updates will be required as new and better equipment comes on line.

INDIVIDUAL PROTECTION EQUIPMENT

The chemical–biological warfare threat can come in three possible physical forms: gas, liquid, and aerosol (ie, a suspension in air of liquid or solid particles). Protection against chemical agents disseminated as aerosols is especially difficult because the individual particles deliver a large amount of agent at a tiny site, thereby overwhelming the local capacity of the adsorbent.

Chemical agents can gain entry into the body through two broad anatomical routes: (1) the mucosa of the oral and respiratory tracts and (2) the skin. The icon of chemical warfare—the gas mask—protects the oral and nasal passages (as well as the eyes), while the skin is protected by the overgarment.

As noted earlier, total individual protection requires an integrated approach with the primary mechanism being respiratory protection which, when combined with an overgarment, gloves, and boots all properly fitted and used correctly, can provide excellent protection against chemical agents of all known types.

Respiratory Protection

Much of the basis of our understanding of the general principles of respiratory protection is contained in four source documents:

- *Chemical Warfare Respiratory Protection: Where We Were and Where We Are Going*, an unpublished report prepared for the U.S. Army Chemical Research, Development, and Engineering Center[6];
- *Jane's NBC Protection Equipment* (the most recent edition available), particularly the chapter titled "Choice of Materials for Use With NBC Protection Equipment"[7];
- *Basic Personal Equipment*, volume 5 of NATO's *NAIG Prefeasibility Study on a Soldier Modernisation Program*, published in 1994[8]; and
- *Worldwide NBC Mask Handbook*, published in 1992.[9]

Readers interested in greater detail can consult these sources and the authors of this chapter.

The fundamental question of protective mask design was first addressed in World War I: should the mask completely isolate the soldier from the poisonous environment or should the mask simply remove the specific threat substance from the ambient air before it can reach the respiratory mucosa? The first approach requires that a self-contained oxygen supply be provided. Because of a multitude of practical logistical constraints (eg, weight, size, expense), this approach is not used except for specialty applications in which the entire body must be enclosed.

The more common practice has been to follow the second approach: to prevent the agent from reaching the respiratory mucosa by chemically destroying it, removing it in a nonspecific manner by physically adsorbing it, or both. Destruction by chemical reaction was adopted in some of the earliest protective equipment such as the "hypo helmet" of 1915 (chlorine was removed by reaction with sodium thiosulfate) and in the British and German masks of 1916 (phosgene was removed by reaction with hexamethyltetramine).[6] More commonly, the removal of the agent was brought about by its physical adsorption onto activated charcoal. (Due to its mode of formation, this substance has an extraordinarily large surface area, some 300–2,000 m^2/g,[10] with a corresponding plethora of binding sites.) It was soon recognized that impregnation of the charcoal with substances such as copper oxide, which reacted chemically with certain threat agents, further increased protection.[6]

The effectiveness of modern masks depends on both physical adsorption and chemical inactivation of the threat agent. For example, in the M17 protective mask the adsorbent, known as ASC Whetlerite charcoal, is charcoal impregnated with copper oxide and salts of silver and chromium.[6] The M40 protective mask uses an ASZ impregnated charcoal, which substitutes zinc for the hexavalent chromium (CrVI). The Centers for Disease Control and Prevention and the National Institute for Occupation

Safety and Health have identified CrVI as a potential human carcinogen.[11] A filter layer to remove particles and aerosols greater than 3 µm in diameter is also a component of all protective masks.

The location of the filters and adsorbent vis-à-vis the respiratory tract was also one of the questions that mask designers addressed in World War I. In the standard British mask (the small box respirator of 1916), the filter and the adsorbent were contained in a separate container worn around the soldier's trunk and connected to the mask by a hose. By way of contrast, in the standard German mask introduced in late 1915, the filter and adsorbent, contained in a small can (canister), were attached directly to the mask. The advantages of the canister arrangement were lighter weight and reduced work of breathing. But these advantages were gained at the expense of a smaller protective capacity and a degree of clumsiness associated with motion of the head. The canister is attached directly to the mask in the majority of modern protective masks. The contents of a modern canister are shown in Figure 16-1.

Several of the essential features of modern protective mask design—features that might be thought to be more recent—also originated during World War I. For example, designing the inside of the mask so that inhaled air is first deflected over the lenses (which prevents exhaled air, saturated with water vapor, from fogging the lenses) and the use of separate one-way inlet and outlet valves (to minimize the work of breathing) were World War I–era inventions. The need of masked soldiers to be able to talk to one another was also recognized then. Interestingly, in the period after World War I, the U.S. Navy introduced the first useful solution to this problem: a moveable diaphragm held in place by perforated metal plates in the front of the mask. This device ultimately became the voicemitter found in today's protective masks.[6]

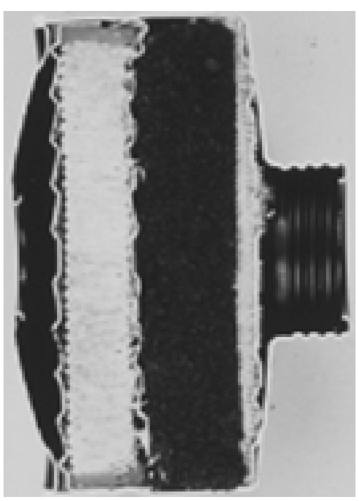


Fig. 16-1. The C2A1 canister is used with the M40 protective mask. After ambient air enters through the orifice on the left side, it passes first through the pleated white filter (where aerosols are removed), then through the layer of ASZ charcoal, then through a second filter (to remove charcoal dust), and finally exits the canister through the orifice on the right side. Photograph: Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

An important question of mask design is the composition of the elastic material used to cover the face: the faceblank. The first masks introduced in World War I were made of rubberized cloth or leather. Subsequent masks used natural rubber, but recently, sophisticated synthetic polymers using silicone, butyl, and perfluorocarbon rubbers have been used.[6] Silicone rubber has the advantage of making possible a tight fit or seal between the mask and skin, with a correspondingly decreased potential for leaking (a factor said to be responsible for about 5% of mask failures).[12]

Unfortunately, silicone rubber offers rather low resistance to the penetration of common chemical agents. Perfluorocarbon rubber is very impermeable but is expensive and tears easily. Butyl rubber offers both good protection and seal and has therefore become the material of choice.[7] Even this description of materials used to construct the faceblank underestimates the complexity of actual mask design. In today's standard U.S. military masks, the faceblank consists of two separate layers: an inner later made of silicone rubber (for maximum seal) and an outer layer made of butyl rubber for maximum protection (Figure 16-2).

The design of the modern protective mask is a sophisticated process. This is nowhere more apparent than in the designers' recognition of the dictates of respiratory physiology: specifically, the importance of dead space. The greater the space between the back of the mask and the face of the wearer in relation to the tidal volume, the smaller the proportion of inhaled air that will reach the alveoli. To minimize dead-space ventilation, modern protective masks have what is equivalent to a second mask—the nosecup—which is fitted separately from the mask proper and inserted between the main mask and the wearer's midface (Figure 16-3). The smaller volume encompassed by the nosecup, rather than the total volume enclosed by the entire mask, is responsible for most of the dead space added by the mask. Furthermore, the nosecup provides an extra seal against entry of threat agents.[6]

Fig. 16-2. The M45 protective mask facepiece has two skins. The inner skin is composed of silicone rubber, and the outer skin is composed of butyl rubber. This arrangement maximizes both mask-to-skin seal and chemical agent impermeability. A similar design is used in the M40 protective mask. Photograph: Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

Fig. 16-3. The nosecup of the M45 protective mask has a single, large hole in the center through which exhaled air is expelled on its way to the exit valve in the main mask. Inhaled air, which has passed through the canister, passes up and around the side of the nosecup, preventing fogging of the mask's lenses, after which it passes through the valve (seen on the reader's left) on its way to the soldier's respiratory tract. Photograph: Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

The work of breathing added by the mask is an important factor; it determines not only soldiers' acceptance of a given mask, but more importantly, the degree that a soldier's exercise tolerance is degraded. Since the pressure gradient that is required to move a given mass of air is flow-rate dependent, to make a quantitative comparison between the work of respiration of different masks, it is necessary to specify a specific flow rate. For example, at a flow rate of 85 L/min, a pressure gradient of about 8 cm H_2O is observed in World War II–vintage masks. At the same flow rate, the gradient for the M17 is 4.5 cm H_2O, and for the M40, 5 cm H_2O.[6] By way of contrast, breathing at a rate of 85 L/min without a mask requires a pressure gradient of 1.5 cm H_2O.[13] Some mask wearers perceive the 3-fold increase in the work of breathing as "shortness of breath."

Developmental objectives in personal respiratory protection equipment generally encompass factors such as personal comfort, breathing resistance, mask weight, and the ability to provide protection from new agents. Present equipment has met a number of these objectives but much remains to be done, especially in the area of new and improved chemical-resistant materials, manufacturing methods, and scratch-resistant lenses. All of these items must be integrated into a new, reliable, less cumbersome, and less degrading system.

Ground Crew Personal Protective Equipment

The equipment described below is generally suitable for use by all services, although oceanic environments may require that other construction materials be developed for the navy and marine corps. The masks protect against all known chemical and biological agents, whether in droplet, aerosol, or vapor form. However, a protective mask is only as good as its fit. In the past, the degree of fit was assessed by field-expedient qualitative indices (eg, the degree to which the mask collapsed with its inlet valve obstructed). The modern technology incorporated into the M41 Protection Assessment Test System allows the degree of fit to be quantitated.

M41 Protection Assessment Test System

The protective masks issued to members of the U.S. armed forces protect the individual's face, eyes, and respiratory tract from field concentrations of chemical–biological agents, toxins, and radioactive fallout particles. Several critical steps must be taken to ensure that an assigned mask will function properly in a toxic chemical environment:

- select the correct mask size,
- properly fit the selected mask,
- validate the mask protection,
- train the user in the proper wear and use of the mask, and
- perform preventive maintenance checks on the mask as required.

The M41 Protection Assessment Test System (PATS) was fielded to validate the protection afforded by the M40, M42, and M17 series masks (Figure 16-4). The PATS is a miniature, continuous flow, condensation nuclei counter. It samples particles from ambient air and compares them with particles in the air contained inside the wearer's mask. The resulting numerical values are then used to determine the protection factor (PF) of the mask. The result of the pass/fail test is determined by the mask's ability to provide a PF of 1,667 or greater, which is the minimum army requirement. The PATS ensures that the mask is the proper size for the individual wearer, and that there are no critical leaks in the mask system due to missing or defective parts or improper maintenance.

Two PATS are fielded for each battalion-sized unit, and are located at the headquarters company. One PATS is fielded for each separate company-sized unit. To date, the PATS is used by the army and has been ordered for the marines and air force.

Mask, Chemical–Biological: Field, M17A2

The blended natural rubber faceblank of the M17A2 Chemical–Biological Field Mask protects the wearer's face, eyes, and respiratory tract, while the attached M6A2 hood protects the exposed portions of the head and neck (Figure 16-5). The M17A2 protects the face, eyes, and respiratory tract from field concentrations of chemical and biological agents. When used together, the natural rubber facepiece and the M6A2 hood resist liquid chemical and biological agents. In fact, the hood was designed to completely cover not only the rubber components of the mask but also the head and neck so as to augment protection against liquid agents.

The M17A2 protective mask provides respiratory protection through the use of two M13A2 filter elements. Each filter element is "pork chop" shaped and is internally mounted within the cheek pouches of the mask. Each also consists of an activated charcoal gas filter paper and a particulate filter laminated together.

This mask can be used in any climatic condition, but the M4 winterization kit must be installed when used in temperatures of –20°F or below. A voicemitter outlet valve, provided on the front of the facepiece, transmits the user's voice outside the mask. A drinking tube assembly is attached just below the voicemitter and allows the user to drink while wearing the protective mask. The drink system couples with the M1 canteen cap (Figure 16-6).

The forehead straps, temple straps, and cheek straps come together at a head pad for ease of fitting. The M17A2 mask is manufactured in four sizes to accommodate all personnel: extra small, small, medium, and large. For personnel requiring vision correction, optical inserts are provided. The optical inserts are both prong-type and wire frame–types; the wire frame–type is easier to mount inside the mask.

The mask is compatible with shoulder-fired weapons, night-vision devices, and sighting devices. A variety of accessory items is available, including the M1 waterproof bag, the M4 winterization kit, the M6A2 hood, the M15A1 carrier, and optical inserts and outserts. This series of mask is currently being replaced by the M40 protective mask.[14,15]

Mask, Chemical–Biological: Field, M40

The M40 Chemical–Biological Field Mask series represents the latest generation of protective mask to be issued to the U.S. military. The inner layer of the facepiece is composed of molded silicone rubber that fits tightly against the face, and has an inturned peripheral seal, which increases comfort and fit. The mask's two ridged eyelenses are approximately 35% larger than the type used in the M17A2, thus providing a better field of view (Figure 16-7).

Filtration is provided in the M40 mask by one C2A1 filter canister, which, at the user's con-

Fig. 16-4. The M41 Protection Assessment Test System (PATS). Ambient air is assessed through the green hose. Air inside the mask is assessed through the colorless hose, which couples with the protective mask by means of the drinking tube extension. For further information, see Department of the Army. *Protection Assessment Test System (PATS)*. Washington, DC: DA; 14 January 1995. Training Circular 3-41.

a b c

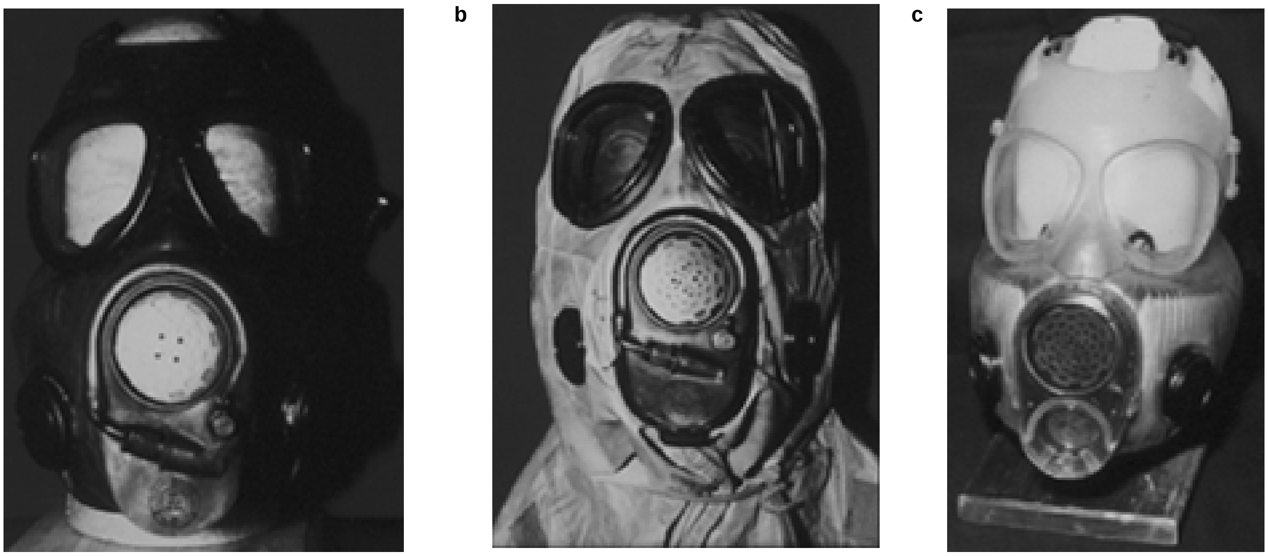


Fig. 16-5. (**a**) The M17A2 Chemical–Biological Field Mask. (**b**) The M17A2 protective mask with hood. (**c**) This transparent version of the M17A2 protective mask was prepared in the hope that wearers could recognize each other. Now this unique design, which was never fielded, serves only to show where the two pork chop–shaped M13A2 filter elements are located. Photographs (a) and (b): Reprinted from Brletich NR, Tracy MF, Dashiell TR. *Worldwide NBC Mask Handbook*. Edgewood, Md: Chemical Warfare / Chemical and Biological Defense Information Center; September 1992: 371. Photograph (c): Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

Fig. 16-6. The M17A2 Chemical–Biological Field Mask with drinking tube assembly allows the soldier to drink without unmasking. Soldiers wearing mission-oriented protective posture (MOPP) gear must drink water to prevent heat stress. The drinking tube, essentially a flexible straw, couples with the canteen cap. The soldier holds the canteen upright and inverted, then sips water through the tube. After a few sips, the soldier needs to puff his own exhaled air back into the canteen to equalize the atmospheric pressure without introducing contaminated air. Then he can take a few more sips of water before he needs to equalize the pressure again. Photograph: Courtesy of Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 16-7. The M40 Chemical–Biological Field Mask. Reprinted from Brletich NR, Tracy MF, Dashiell TR. *Worldwide NBC Mask Handbook*. Edgewood, Md: Chemical Warfare / Chemical and Biological Defense Information Center; September 1992: 385.

Fig. 16-8. The M42 Chemical–Biological Field Mask. Reprinted from Brletich NR, Tracy MF, Dashiell TR. *Worldwide NBC Mask Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Center; September 1992: 383.

venience, can be mounted on either cheek. Two canisters may be mounted on both cheeks for special-purpose activities such as explosive ordnance disposal or technical escort. The standard C2A1 canister will protect against 16 attacks of nerve and vesicant agents. For each exposure, the C*t* can be as great as 20,000 C*t* mg•min/m^3 (C*t* represents the product of concentration [in milligrams per cubic meter of air] and time [in minutes] of exposure to a gas or aerosol, and is discussed in other chapters in this textbook, in particular Chapter 5, Nerve Agents). Any other standard-thread canister issued by North Atlantic Treaty Organization (NATO) countries will fit the M40 mask.

Communication is provided by two voicemitters. One is mounted in the front to allow face-to-face communication; the second is located in the cheek to permit the use of a radio telephone handset. A drinking system consists of internal and external drink tubes; the external tube has a quick-disconnect coupling that connects with the M1 canteen cap. A six-point, adjustable harness with elastic straps located at the forehead, temples, and cheeks comes together at a rectangular head pad.

The M40 mask comes in three sizes: small, medium, and large. Optical inserts are provided for vision correction and outserts are available to reduce fogging and sun glare and to protect against scratching. A check valve on the nosecup prevents exhaled air from fogging the lenses inside, and an air deflector directs inhaled air over the lenses, which also helps prevent fogging. Accessory items available include a carrier, a hood to protect the neck areas, and a waterproof bag.[16–18]

Mask, Chemical–Biological: Field, M42

The M42 Chemical–Biological Field Mask is the same series as the M40. The materials of construction and the basic features are identical, but the M42 protective mask is used by combat vehicle crews (Figure 16-8).

Filtration is provided by a C2A1 canister attached to the mask by a corrugated hose; the canister is housed in a specially designed canister carrier. The M42 integrates with the combat vehicle filtration protection system. The M42 also has a dynamic microphone that integrates with the combat vehicle via a microphone cable.[19,20]

Mask, Chemical–Biological: MCU-2/P

The MCU-2/P Chemical–Biological Mask is used by U.S. Air Force ground crews and aircrews when not in flight. This protective mask is constructed of molded silicone rubber facepiece material, and an integral, molded, polyurethane, one-piece panoramic lens is bonded to it (Figure 16-9).

Filtration is provided by one C2A1 canister mounted on either side of the facepiece. The primary voicemitter is located over the mouth area with a secondary voicemitter in the cheek area to utilize telephone handsets. The mask incorporates a drinking tube, which connects to the M1 canteen cap. The mask has a six-point, adjustable head harness suspension made of elastic, which comes together in the center head back into a rectangular patch of woven material. The mask comes in three sizes: small, medium, and large. Accessories include a carrier bag, a butyl-coated nylon cloth hood, outserts to protect the lens in storage, and a waterproof bag.

Aircrew Personal Protective Equipment

Each protective mask in current use is described in detail. There are some differences between the masks designed for helicopter use and high-performance aircraft, owing notably to the operational

Fig. 16-9. The MCU-2/P Chemical–Biological Mask. Reprinted from Brletich NR, Tracy MF, Dashiell TR. *Worldwide NBC Mask Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Center; September 1992: 401.

envelope. All masks protect against all known chemical and biological agents whether in droplet, aerosol, or vapor form.

Mask, Chemical–Biological: Aircraft, M43

The facepiece of the M43 Chemical–Biological Aircraft Mask is fabricated of bromo butyl and natural rubber with an integral butyl hood and skull-type suspension system (Figure 16-10). The M43 has two models, designated Type I and Type II. The two models are identical with the following exceptions: Type I has a notch in the right eyepiece that accommodates a special sighting device used by Apache helicopter pilots, and uses a different microphone for communication; Type II has two spherical lenses and uses a dynamic microphone. Both microphones interface with the helicopter communications systems.

The mask is connected to two C2A1 canisters, which lower breathing resistance. A hose assembly that attaches to the two C2A1 canisters is located on the left cheek. The canisters are attached to a motor blower unit (capacity: 4 cu ft/min), which is powered either by aircraft electrical power or a battery. A constant overpressure is maintained within the mask by the motor blower unit.

The mask has an inhalation air-distribution assembly for regulating the flow of air to the mouth and nose, eyelenses, and hood assembly. The M43 mask has a drink capability which couples with the canteen cap. The mask is produced in four sizes from small to extra-large. Accessories include a mask carrier, vision correction outserts, winterization kit, nuclear hood, facepiece carrier, eyelens cushions, and a blower and harness assembly.

This new design effort was based on the need for little-to-no visual impairment. The requirement was met by placing the protective mask's eyelens 14 mm from the eye, which kept the spherical curvature equidistant from the corneal surface to eliminate parallax. This lens configuration increased visual capability to within 4% of nonmasked vision in the same individual. Each mask is fitted to an individual crewman and remains with that crewman while he remains on flight status.[21,22]

Mask, Chemical–Biological: Aircrew MBU-I9/P

The MBU-19/P Chemical–Biological Aircrew Mask is the newest generation to be fielded by the U.S. Air Force exclusively for aircrews. This mask, dubbed the Aircrew Eye/Respiratory Protection (AERP) system,

Fig. 16-10. The M43 Chemical–Biological Aircraft Mask. Photograph: Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

Fig. 16-11. The MBU-19/P Chemical–Biological Aircrew Mask. Reprinted from Brletich NR, Tracy MF, Dashiell TR. *Worldwide NBC Mask Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Center; September 1992: 395.

is issued in a helmeted version for fighter pilots and in a nonhelmeted version for aircrew and pilots of other types of aircraft (Figure 16-11).

The AERP mask-hood subsystem has a hood composed of bromo butyl coated fabric that incorporates standard MBU-19/P oxygen mask, clear plastic lens, neckdam, drinking facility, and communications systems. The MBU-19/P breathing subsystem consists of a chemical-resistant delivery hose, a chemical–biological canister, in-line filter, and manifold assembly including an emergency oxygen filter. The breathing system will operate whether or not supplemental oxygen is present.

The blower system incorporates a variable-speed motor, battery, external power-supply cable, housing assembly, control switch, chemical–biological canister, and a means of securing the blower while the crew member is mobile. The mask receives filtered air from the blower unit, which also allows overpressure within the hood which defogs the lens and is vented through an exhaust valve.

The communication system consists of the intercommunication unit, battery, electrical branch assembly, microphone, and bracket.

Developmental Respiratory Protection Equipment

The objective of development systems is to provide the next generation of respiratory protection equipment that will minimize mission degradation and assure compatibility with future weapons systems and equipment while maintaining protection levels. RESPO 21 is the latest generation wherein new materials and manufacturing technology are being investigated and evaluated.[23] New and improved filtration systems designed to remove or degrade new classes of agents are under evaluation. Systems designed to meet all service needs in one equipment item are in the design phases. It is hoped that these systems will overcome the deficiencies found in current equipment (eg, excessive weight and performance degradation).

Protective Clothing

An overgarment can be made to protect skin from chemical agents by either physical or chemical means:

1. The overgarment can be made of fabric that is impermeable to most molecules, even to air and water vapor.
2. The overgarment can be made of fabric that is permeable to most molecules, but that also chemically alters or physically removes chemical agents before they reach the skin.

In the first method, the chemical agent is totally excluded because the agent is physically prevented from penetrating the substance of the overgarment. In the second method, the agent enters into the fabric of the overgarment but is absorbed before it can reach the skin. An overgarment made of an impermeable material such as Saran wrap or butyl rubber can offer complete protection against threat agents but at the unacceptable cost of causing heat injury. Cooling by sweating is not possible if water vapor cannot pass through to the ambient environment. Most fielded overgarments, therefore, depend on the fabric's ability to adsorb the threat agent. Activated charcoal is used for this purpose in U.S. military designs.

Placing a soldier into full chemical protective equipment—mask, overgarment, gloves, and boots—is a decision that appropriately considers not only the protection aspect but also the added heat stress and potential for dehydration. The heat stress problem must be recognized from the start.

Fig. 16-12. From left to right, the soldiers' gear is for mission-oriented protective posture (MOPP) levels 2, 3, and 4. Photograph: Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

Personnel must begin a drinking regimen prior to encapsulation to ensure that they do not become dehydrated quickly. The physical burden of a full ensemble can add 9 to 14 lb to a normal load; this added weight combined with heat stress, dehydration, and physical exertion can cause significant impairment to any mission.

Because of these factors, the completeness of protection is stratified by the anticipated magnitude of the threat from chemical–biological agents: that is, *the mission-oriented protective posture* (Figure 16-12). Five MOPP levels have been recognized previously, but with Change 2 to Field Manual 3-4, *NBC Protection*, the number was updated to seven in 1996 (Exhibit 16-1).[5] The two new MOPP levels are MOPP Ready and Mask-Only Command, but readers should be aware that MOPP levels are revised frequently to meet newly defined needs.

The MOPP level must be coordinated with the work load if troops are to remain effective. The overgarments in present use must be redesigned to reduce heat stress, reduce weight and bulk, and provide increased comfort as well as reduce the logistical burden. The present clothing will be described in detail except for the special-purpose equipment used by demilitarization personnel or special-purpose forces.

The sources for the following discussion are *Items of Combat Clothing and Equipment*,[24] and experts at the U.S. Army Natick Research, Development, and Engineering Center, Natick, Massachusetts,[25] whom interested readers can consult for greater detail.

Protective Ensembles

Like various other armies of the world, the U.S. Army has chemical protective clothing available for individual protection. Several types are available, depending on the protection required to perform a specific mission and whether the protective clothing needs to be permeable or impermeable. Most troops use permeable protective clothing, which allows for air and moisture to pass through the fabric without hindering the chemical protection capabilities of the clothing. This type of permeable protective clothing is described in the following section.

Battledress Overgarment

The current standard A protective overgarment is the battledress overgarment (BDO). The BDO protects the wearer from all chemical agent vapors, liquid droplets, biological agents, toxins, and radioactive alpha and beta particles; however, the BDO does not stop either X or gamma radiation. For weartime and protective capabilities of the BDO following removal from the protective bag, refer to Field Manual 3-4/Fleet Marine Force Manual 11-9, *NBC Protection*.[5] The BDO protects the wearer for 24 hours after contamination from chemical agent vapors, liquids, and droplets; and biological agents and toxins.

The effectiveness of the BDO is in its serviceability. Weartime of the BDO begins when it is removed from the sealed vapor-barrier bag and stops when it is returned to the vapor-barrier bag. *Wearing the BDO for any part of a day constitutes a day's wear*. The BDO becomes unserviceable if it is torn, ripped, a fastener is missing or broken, or petroleum, oils, or lubricants are splashed or spilled on the overgarment. This unserviceableness necessitates replacement.

The BDO is manufactured in two layers: a tightly woven outer layer and a charcoal-impregnated inner layer to adsorb agent liquid or vapor (Figure 16-13). The garment consists of a hip-length coat and trousers with appropriate fasteners and multiple pockets. It is manufactured in eight sizes ranging from XXX Small through XX Large. The BDO is not designed to be decontaminated or reimpregnated for reuse.

EXHIBIT 16-1

LEVELS OF MISSION-ORIENTED PROTECTIVE POSTURE (MOPP)

MOPP Ready	Soldiers carry their protective masks with their load-carrying equipment. The soldier's MOPP gear is labeled and stored no further back than the battalion support area and is ready to be brought forward to the soldier when needed. The time necessary to bring the MOPP gear forward should not exceed 2 hours. A second set of MOPP gear is available within 6 hours. Units at MOPP Ready are highly vulnerable to attacks with persistent agents and will automatically upgrade to MOPP Zero when they determine, or are notified, that chemical weapons have been used or that the threat for use of chemical weapons has risen. When a unit is at MOPP Ready, soldiers will have field-expedient items identified for use.
MOPP Zero	Soldiers carry their protective masks with their load-carrying equipment. The standard battledress overgarment and other individual protective equipment that make up the soldier's MOPP gear are readily available. "Readily available" means that equipment must either be carried by each soldier or be stored within the soldier's arms' reach (eg, within the work area, vehicle, or fighting position). Units at MOPP Zero are highly vulnerable to attacks with persistent agents and will automatically upgrade to MOPP 1 when they determine, or are notified, that persistent chemical weapons have been used or that the threat for use of chemical weapons has risen.
MOPP 1	When directed to MOPP 1, soldiers immediately don the battledress overgarment. In hot weather, the overgarment jacket may be unbuttoned and the battledress overgarment may be worn directly over the underwear. M9 or M8 chemical detection paper is attached to the overgarment. MOPP 1 provides a great deal of protection against persistent agents. The level is automatically assumed when chemical weapons have been employed in an area of operations or when directed by higher commands.
MOPP 2	Soldiers put on their chemical protective footwear covers, green vinyl overboots, or a field-expedient item (eg, vapor-barrier boots), and the protective helmet cover is worn. As with MOPP 1, the overgarment jacket may be left unbuttoned but the trousers remain closed.
MOPP 3	Soldiers wear the protective mask and hood. Again, flexibility is built into the system to allow the soldier relief at MOPP 3. Particularly in hot weather, soldiers may open the overgarment jacket and roll the protective mask hood for ventilation but the trousers remain closed.
MOPP 4	Soldiers will completely encapsulate themselves by closing their overgarments, rolling down and adjusting the mask hood, and putting on the NBC rubber gloves with cotton liners. MOPP 4 provides the highest degree of chemical protection, but it also has the most negative impact on an individual's performance.
Mask-Only Command	Only the protective mask is worn. The mask-only command is given in these situations: 1. When riot control agents are being employed and no chemical or biological threat exists. 2. In a downwind vapor hazard of a nonpersistent chemical agent. The mask-only command is not appropriate when blister agents or persistent nerve agents are present.

Adapted from Avery M. Major, Chemical Corps, US Army; US Army Chemical School, Doctrine Development Division, Fort McClellan, Ala. *New MOPP Levels and Peacetime Filter Changeout Criteria*. (Summary of Change 2 to Field Manual 3-4, 21 Feb 1996.) Internet Chemical-Doctrine discussion site, 24 Jul 1996.

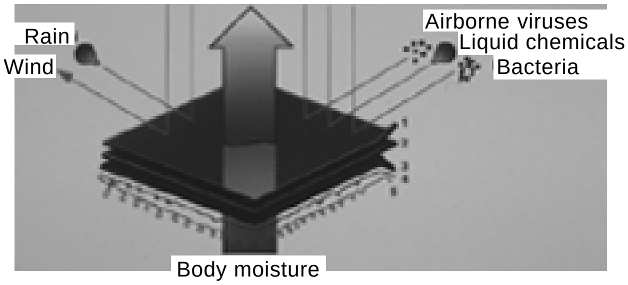


Fig. 16-13. A soldier wearing the battledress overgarment (BDO) and battledress uniform (BDU) is afforded five layers of protection. Although allowing body moisture to evaporate, the garments repel rain, wind, airborne viruses, liquid chemicals, and bacteria. (1) The BDO consists of two layers. The outer layer is a 50% nylon–50% cotton, twill weave, Quarpel-treated fabric in woodland camouflage pattern. (2) The inner layer of the BDO is made of 90-mil polyurethane foam impregnated with activated carbon and laminated on the inner side with nylon-tricotton knit. (3) The BDU for temperate-zone wear is made of 50% cotton–49% nylon–1% static dissipative fiber, twill weave fabric. (4) The drawers and undershirt are made of 100% cotton. (5) Human skin surface. Drawing: Courtesy of US Army Research Institute of Environmental Medicine, Biophysics and Biomedical Modeling Division, Natick, Mass.

Aircrew Uniform, Integrated Battlefield

The aircrew uniform, integrated battlefield (AUIB) is designed to replace the BDO, the chemical protective overgarment (CPOG), and the Nomex (a synthetic aramid polymer, manufactured by Du Pont Advanced Fiber Systems, Wilmington, Del.) flight suit for aircrews operating in a contaminated environment (Figure 16-14). It is also designed to protect against petroleum and oils. It provides flame resistance as well as NBC protection. The outer shell is a laminate of 95% Nomex/5% Kevlar (polyparaphenyleneterephthalamide, manufactured by Du Pont Advanced Fiber Systems, Wilmington, Del.), while the inner layer is a 90-mil, carbon-impregnated, flame-resistant foam/nylon laminate. The AUIB is designed as a two-piece garment with a coat and trousers with appropriate fasteners and is available in woodland or desert camouflage. The heat stress burden of the AUIB is similar to that of the BDO.[5]

Chemical Defense Aircrew Ensemble

The chemical defense aircrew ensemble (CDAE) is the newest generation of aircrew protective clothing to be fielded by the U.S. Air Force. It is a one-piece garment consisting of the Nomex flight suit, a charcoal undergarment, and long cotton underwear. The CDAE incorporates carbon-sphere technology to adsorb chemical agent. It is basically two suits differing in color: the CWU-66/P is green and the CWU-77/P is brown. It may be laundered as many as 10 times prior to chemical agent exposure without destroying the protective capabilities of the coverall.[26]

Protective Boots and Gloves

A soldier wearing the chemical protective boots and gloves discussed here will soon realize that mobility is compromised by the boots and that tactile ability is degraded by the gloves. The present boots provide good protection against chemical warfare agents but are only an interim solution to the need for combined chemical protection, ease of decontamination, and safety. Wearers are at serious risk of falls due to the lack of adequate traction, and the weight of the boot contributes to the increased fatigue from complete protection ensemble wear.

Fig. 16-14. The aircrew uniform, integrated battlefield (AUIB).

Fig. 16-15. The black vinyl overboot (BVO).

The boots do not protect the wearer from heat or cold and in some cases may contribute to medical problems such as trench foot, frost bite, or other cold weather injuries. The protective gloves degrade tactility and again will not protect against heat or cold and may increase the chance of cold weather injuries if the work glove is not worn over the protective glove. The following descriptions of protective boots and gloves are based on information from *NBC Protection*.[5]

Green and Black Vinyl Overboots

The green vinyl overboot (GVO) and the black vinyl overboot (BVO) (Figure 16-15) are used to protect the individual's combat boots against all known chemical and biological agents, vectors, and radioactive (alpha and beta) particles. The overboots also provide protection from the environmental effects of snow, rain, and mud. (However, GVOs and BVOs issued and worn for environmental protection should not be used for NBC protection. A new pair should be issued with NBC protective gear.)[27] Following contamination by liquid agent, the boots will provide protection for a limited time. Following exposure to liquid agents, the boots should be decontaminated with a 5% household bleach–and-water or a 5% high-test hypochlorite (HTH)–and-water solution. This allows the overboots to be worn additional days before replacement. Should DS2 (Decontaminating Solution 2; diethylenetriamine, ethylene glycol monomethyl ether, sodium hydroxide; manufactured by Dalden Corp., Anaheim, Calif.) come into contact with the overboots during decontamination operations, they must be washed as soon as possible since it will soften and discolor the overboots. For additional information about weartimes and protective capabilities, refer to *NBC Protection*.[5]

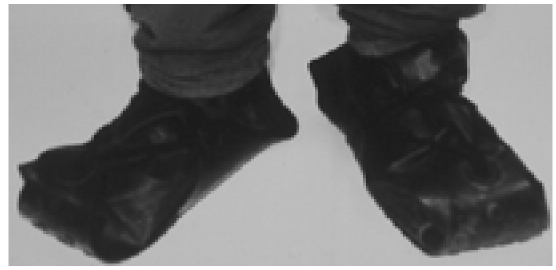


Fig. 16-16. The chemical protective footwear cover (CPFC).

Chemical Protective Footwear Cover

The chemical protective footwear cover (CPFC) is an impermeable black butyl rubber footwear cover that protects the combat boot from all agents (Figure 16-16). The CPFC has an unsupported butyl rubber sole and butyl rubber uppers with long laces, which fasten a front eyelet with side and rear eyelets. The CPFC can be decontaminated with 5% chlorine solution, then inspected and reused. If exposed to DS2, the CPFC should be washed since DS2 causes the rubber to deteriorate. The CPFC offers poor traction and the laces can cause a tripping hazard when the wearer is moving. Again, the CPFC offers no protection against cold; therefore, suitable precautions must be taken. Refer to *NBC Protection*[5] for protective capabilities.

Chemical Protective Glove Set

The chemical protective glove set consists of an outer glove for chemical protection and an inner glove for perspiration absorption. The outer glove is made of impermeable butyl rubber and the inner glove is made of white cotton. The gloves come in three thicknesses: 7, 14, and 25 mil. Soldiers such as medical, teletypist, and electronic repair personnel, whose tasks require extreme tactility and sensitivity, and who will not expose the gloves to harsh treatment, will use the 7-mil glove set. Aviators, vehicle mechanics, weapons crews, and other soldiers whose tasks require tactility and sensitivity will use the 14-mil glove set (Figure 16-17). Soldiers who perform close combat tasks and other heavy labor tasks will use the 25-mil glove set.

All of the glove sets protect against liquid chemical agents and vapor hazards. However, if the 7-mil glove set is contaminated, it must be replaced

Fig. 16-17. The 14-mil chemical protective glove set.

or decontaminated within 6 hours after exposure. The 14-mil and 25-mil glove sets will provide protection following contamination for 24 hours. All three glove sets can be decontaminated with a 5% bleach-and-water solution or a 5% HTH-and-water solution, then inspected, and reused. All gloves will become sticky and soft if exposed to DS2 or petroleum-based fluids and must be replaced. Replacement must occur following damage or degradation or both. Refer to *NBC Protection*[5] for protective capabilities.

Developmental Whole-Body-Protection Equipment Items

The Joint Service Lightweight Integrated Suit Technology (JSLIST) program is developing the next generation of overgarment, which will be fielded in Fiscal Year 1997. The JSLIST program provides the future whole-body chemical–biological protective equipment for the joint services (U.S. Army, Navy, Air Force, and Marine Corps). The JSLIST program encompasses a lightweight garment (undergarment, overgarment, duty uniform) and improved chemical protective handwear and chemical protective overboot. It will provide less bulk and heat stress by being constructed of state-of-the-art materials (the exact materials are not yet known, however) and will be more durable and launderable than current designs. The items in the JSLIST series are joint-service standardized items and are planned to be used by all services.[28,29]

In addition to the JSLIST, new agent-impermeable materials are being evaluated in conjunction with advanced fabrics to replace the carbon-impregnated fabrics, which have limited lifetimes. These new materials will be lighter, allow permeation of moisture while retaining protection, and cause less heat stress.

JSLIST Overgarment

The JSLIST Overgarment (OG) is a universal, lightweight, two-piece, front-opening garment that can be worn as an overgarment or as a primary uniform over personal underwear (Figure 16-18). It has an integral hood, bellows-type pockets, high-waist trousers, adjustable suspenders, adjustable waistband, and waist-length jacket. This design improves system compatibility, user comfort, and system acceptance, and maximizes individual equipment compatibility. The JSLIST OG provides optimum liquid, vapor, and aerosol protection and also flame protection.

JSLIST Aviation Overgarment

The JSLIST Aviation Overgarment (AVOG) is the aviator's version of the JSLIST OG and Duty Uniform (DU) configurations. It is a two-piece, front-opening, flame-resistant garment designed as a chemical protective overgarment or uniform. For cockpit compatibility, the integral hood and bellows-type pockets of the OG and the DU have been replaced with a crew-type collar and sewn-down pockets (Figure 16-19).

JSLIST Duty Uniform

The JSLIST Duty Uniform (DU) is a universal, lightweight, two-piece, front-opening garment that is worn as a primary uniform over personal underwear. It has an integral hood, bellows-type pockets, high-waist trousers, adjustable suspenders, adjustable waistband, and waist-length jacket (Figure 16-20). This improves system compatibility, user comfort, system acceptance, and ensures maximum individual equipment compatibility. The DU provides optimum liquid, vapor, and aerosol protection as well as flame protection.

JSLIST Vapor Protective Flame-Resistant Undergarment

The JSLIST Vapor-Protective, Flame-Resistant Undergarment (VPFRU) is a two-piece (jacket and drawers), front-opening, vapor-protective garment (Figure 16-21). It is configured with an integral form-fitting hood and detached vapor-protective, fire-resistant socks. Worn under standard duty uniforms, including the combat vehicle crewman coveralls and battledress uniform, the VPFRU is designed to provide the

Fig. 16-18. The Joint Service Lightweight Integrated Suit Technology Overgarment (JSLIST OG). Reprinted from US Marine Corps, Army, Navy, and Air Force. Joint Service Lightweight Integrated Suit Technology Program. *Joint Service Lightweight Integrated Suit Technology (JSLIST) Program.* Columbus, Ohio: Battelle Memorial Institute; May 1996: unpaginated brochure.

Fig. 16-19. The Joint Service Lightweight Integrated Suit Technology Aviation Overgarment (JSLIST AVOG). Reprinted from US Marine Corps, Army, Navy, and Air Force. Joint Service Lightweight Integrated Suit Technology Program. *Joint Service Lightweight Integrated Suit Technology (JSLIST) Program.* Columbus, Ohio: Battelle Memorial Institute; May 1996: unpaginated brochure.

Fig. 16-20. The Joint Service Lightweight Integrated Suit Technology Duty Uniform (JSLIST DU). Reprinted from US Marine Corps, Army, Navy, and Air Force. Joint Service Lightweight Integrated Suit Technology Program. *Joint Service Lightweight Integrated Suit Technology (JSLIST) Program.* Columbus, Ohio: Battelle Memorial Institute; May 1996: unpaginated brochure.

Fig. 16-21. The Joint Service Lightweight Integrated Suit Technology Vapor-Protective, Flame-Resistant Undergarment (JSLIST VPFRU). Reprinted from US Marine Corps, Army, Navy, and Air Force. Joint Service Lightweight Integrated Suit Technology Program. *Joint Service Lightweight Integrated Suit Technology (JSLIST) Program.* Columbus, Ohio: Battelle Memorial Institute; May 1996: unpaginated brochure.

Fig. 16-22. The Joint Service Lightweight Integrated Suit Technology Improved Chemical and Biological Protective Glove (JSLIST ICBPG). Reprinted from US Marine Corps, Army, Navy, and Air Force. Joint Service Lightweight Integrated Suit Technology Program. *Joint Service Lightweight Integrated Suit Technology (JSLIST) Program.* Columbus, Ohio: Battelle Memorial Institute; May 1996: unpaginated brochure.

chemical vapor and biological agent protective layer. For Special Operations Forces and armor crews, the VPFRU is intended to provide maximum vapor and aerosol protection and MOPP flexibility.

JSLIST Improved Chemical and Biological Protective Glove

The JSLIST Improved Chemical and Biological Protective Glove (ICBPG) is designed to provide protection against chemical and biological agents in liquid, vapor, and aerosol form (Figure 16-22). Its protection performance is not degraded by exposure to petroleum, oil, and lubricants and to field decontaminants. To prevent excessive moisture buildup and improve user comfort, the ICBPG is semipermeable. The glove can be worn for up to 30 days without performance degradation and is flame resistant.

JSLIST Multipurpose Overboot

The JSLIST Multipurpose Overboot (MULO) is designed to be used for daily wear as required by the weather and is flame resistant. It is a single-piece design with webbed straps, side-to-back chemical-resistant plastic buckle closures, and improved tread design (Figure 16-23). Protection is provided for environmental hazards as well as chemical and biological agents. Additionally, the resistance to agents is not degraded by exposure to petroleum, oil, and lubricants, and decontaminants.

Fig. 16-23. The Joint Service Lightweight Integrated Suit Technology Multipurpose Overboot (JSLIST MULO). Reprinted from US Marine Corps, Army, Navy, and Air Force. Joint Service Lightweight Integrated Suit Technology Program. *Joint Service Lightweight Integrated Suit Technology (JSLIST) Program.* Columbus, Ohio: Battelle Memorial Institute; May 1996: unpaginated brochure.

DETECTION AND WARNING

As noted in the introduction, timely detection and warning are critical to the protection of forces—especially since chemical agents act very quickly. Detection of an attack, with subsequent warning of affected forces downwind, can allow adoption of an effective protective posture and continuation of military operations with minimal degradation of operations. We discuss here those instruments most widely fielded; some special-purpose items are not discussed.

The army has recently fielded two new systems, the FOX and the Biological Integrated Detection System (BIDS), which are discussed below. Each of these new systems integrates a variety of detectors into a mobile, crew-served system; the composite detectors are vastly superior to any individual detector previously available.

Sources for this discussion are the *Worldwide Chemical Detection Equipment Handbook*[30] and experts at Aberdeen Proving Ground, whom readers who are interested in greater detail can consult.

Chemical Detection and Warning

This section briefly describes some of the fielded chemical detectors that may be of most use within the medical community. These detectors are divided into two groups: point detectors and standoff detectors.

Point Detectors

Point detectors sample the immediate area to determine the presence of chemical agents. The sample is most often taken from the atmosphere; however, specialized detection kits can be used to sample the soil or water. In addition to monitoring the atmosphere, the point detectors provide monitoring after an attack, identify the contaminated area, monitor collective protection areas, monitor effectiveness of decontamination, and identify chemical contamination during reconnaissance efforts.

M8 Chemical Agent Detection Paper

M8 Chemical Agent Detection Paper detects and identifies liquid chemical agents. It is tan in color and comes in a booklet containing 25 perforated sheets (2 in. x 3 in.), which are heat sealed in a polyethylene envelope. There are three sensitive indicator dyes suspended in the paper matrix. The paper is blotted on a suspected liquid agent and

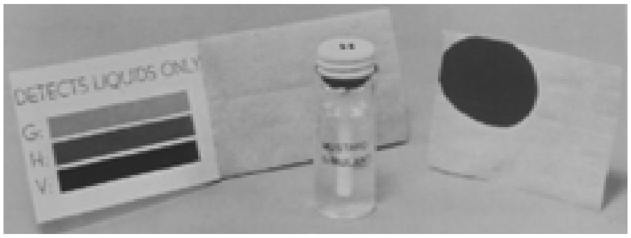


Fig. 16-24. M8 Chemical Agent Detection Paper. A drop of mustard (H) simulant from the vial has turned the paper red. Reprinted from Brletich NR, Waters MJ, Bowen GW, Tracy MF. *Worldwide Chemical Detection Equipment Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Analysis Center; October 1995: 407. Photograph: Courtesy of US Army Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Md.

observed for a color change, which will occur within 30 seconds: VX turns the paper dark green, the G series of agents turn the paper yellow (see Chapter 5, Nerve Agents), and blister agent turns it red (Figure 16-24). M8 paper will change color with many interferents such as sodium hydroxide and petroleum products; thus, it is unreliable to use to check for completeness of personnel decontamination and should always be verified with another means of identification.

M9 Chemical Agent Detection Paper

M9 Chemical Agent Detection Paper is a portable, single roll of paper that comes with a Mylar adhesive-backed and -coated tape. It contains a suspension of an agent-sensitive dye in a green-colored paper matrix. The agent-sensitive dye will turn pink, red, reddish brown, or red-purple when exposed to agent but does not identify the specific agent. M9 paper is more sensitive to nerve and blister agents and reacts more rapidly than M8 paper, although it also reacts to a wide range of interferents such as petroleum products, brake fluid, aircraft cleaning compounds, DS2, insect repellent, defoliant, and antifreeze.

M9 paper, which is similar to masking tape, is used by attaching strips to the individual overgarment and to equipment such as vehicle controls. The strips are then inspected routinely for color change (Figure 16-25). The paper should not be attached to hot surfaces, as this will discolor the tape and lead to a false positive reaction.

Fig. 16-25. Field use of M9 paper. Reprinted from Brletich NR, Waters MJ, Bowen GW, Tracy MF. *Worldwide Chemical Detection Equipment Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Analysis Center; October 1995: 417. Photograph: Courtesy of US Army Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Md.

Chemical Agent Monitor and Improved Chemical Agent Monitor

The chemical agent monitor (CAM) and improved chemical agent monitor (ICAM) are handheld, soldier-operated devices designed for monitoring chemical agent contamination on personnel, equipment, and surfaces. They use ion mobility spectrometry technology to detect and discriminate between mustard and nerve agent vapor. The concentrations of agents detected by the CAM and ICAM areas are as follows: for sarin (GB), 0.03 mg/m^3; for VX, 0.1 mg/m^3; and for mustard (HD), 0.1 mg/m^3.

The units are simple to operate, can be held in either hand while the user is wearing chemical protective equipment, and operate day or night (Figure 16-26).

Relative vapor hazard and malfunction information is displayed by bars on a liquid crystal display. As an example, the bar readings for concentrations of the nerve agent sarin are shown in Table 16-1. The CAM and ICAM are point monitors only and

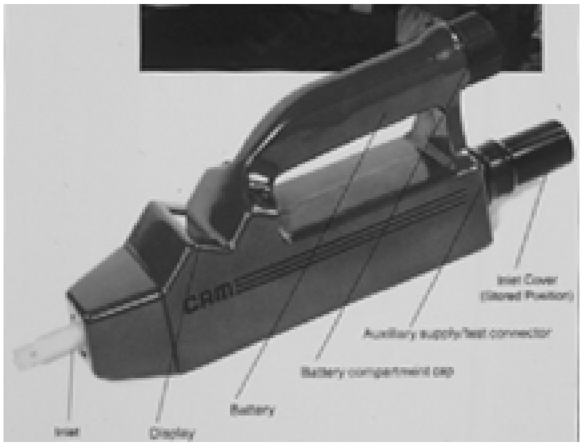
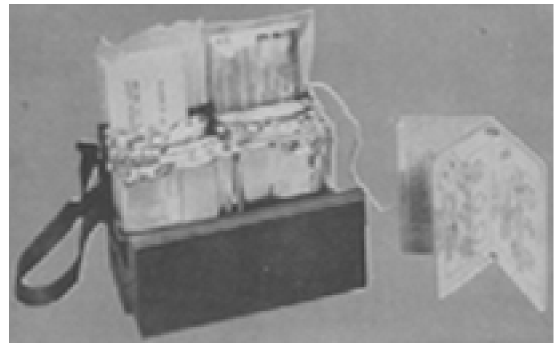


Fig. 16-26. The chemical agent monitor (CAM). Photograph: Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

a



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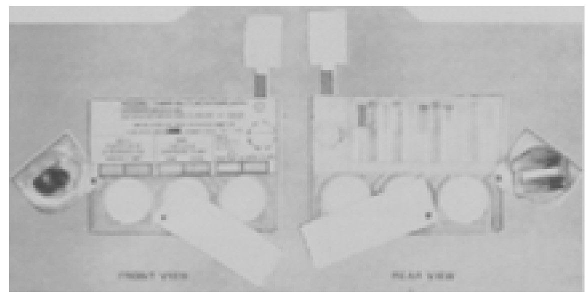


Fig. 16-27. (**a**) The M256A1 Chemical Agent Detector Kit and (**b**) the sampler/detector found inside the carrying case. Reprinted from Brletich NR, Waters MJ, Bowen GW, Tracy MF. *Worldwide Chemical Detection Equipment Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Analysis Center; October 1995: 429. Photograph (a): Courtesy of Environmental Technologies Group, Inc, Baltimore, Md.

cannot give an assessment of an area vapor hazard. The two may give false readings when used in enclosed spaces or when sampling near strong vapor sources such a dense smoke, aromatic vapors, cleaning compounds, exhausts from some rocket motors, and fumes from some munitions. Because of the technology employed, the CAM and ICAM are subject to saturation; they must be cleared to function properly.

TABLE 16-1

BAR READINGS FOR CONCENTRATIONS OF SARIN (GB)

Bar Reading	Concentration (mg/m^3)
1	0.03
2	0.05
3	0.08
4	0.14
5	0.30
6	1.0
7	10.0
8	30.1

Specific information in this discussion of the CAM and ICAM is drawn from *Chemical Agent Monitor Employment*[31] and *Operator's and Organizational Maintenance Manual for the Chemical Agent Monitor (CAM)*,[32] which interested readers may wish to consult.

Chemical Agent Detector Kit

The M256A1 Chemical Agent Detector Kit is a portable, expendable item capable of detecting and identifying hazardous concentrations of nerve and blister agents and cyanide (Figure 16-27). The kit is used after a chemical attack to determine if it is safe for personnel to unmask. Each kit consists of 12 disposable plastic sampler-detectors (ticket or card), one booklet of M8 paper, and a set of instruction cards. Each ticket (card) contains laboratory filter paper test spots for the various agents. The technology used is wet chemistry, enzymatic substrate–based reactions, where the presence of agents is indicated by a specific color change. Response time is about 15 minutes. Some smokes, DS2, petroleum products, and high temperatures may produce false readings.

The detection limits for the M256A1 are as follows: for the G series of nerve agents, 0.005 mg/m^3; for VX, 0.02 mg/m^3; for the vesicants mustard (HD) and Lewisite, above threshold concentrations of 3.0 mg/m^3 and 14 mg/m^3, respectively; and for hydrogen cyanide (AC), 11 mg/m^3, and cyanogen chloride (CK), 10 mg/m^3.

The M256A1 kit cannot be used to detect agent in water. It can, however, be used to check an area before a military unit moves in or to define clean areas or routes. Some chemical ingredients in the kit are considered possible carcinogens and should be handled as such. The emissions produced by this kit are also toxic; a mask and gloves must be worn while the kit is being used.

Chemical Agent Water Testing Kit

The M272 Chemical Agent Water Testing Kit is designed to detect and identify, via colorimetric reactions, hazardous levels of nerve agents, mustard, Lewisite, and cyanide in treated or untreated water (Figure 16-28). A full kit contains enough supplies to perform 25 tests for each agent, and simulants are included for training use. About 20 minutes is required to perform all four tests. All bodily contact should be avoided with the kit chemicals, as some can be very harmful and should only be handled while wearing protective gloves and equipment.

Detection limits are as follows: for the G-series nerve agents and VX: 0.02 mg/L; for the vesicants Lewisite (L) and mustard (H and HD): 2.0 mg/L; and for the cyanides (AC and CK), 20 mg/L.

Automatic Chemical Agent Alarm

The M8A1 Automatic Chemical Agent Alarm is an automatic chemical agent detection and warning system designed to provide real-time detection of the presence of nerve agent vapors or inhalable aerosols. The M8A1 consists of the M43A1 detector and up to five M42 alarms, which will provide both an audible and a visible warning (Figure 16-29). The M43A1 is an ionization product diffusion/ion mobility type detector; it will sound a false alarm in the presence of heavy concentrations of rocket propellant smoke, screening smoke, signaling smoke, engine exhausts, and whenever a nuclear blast occurs.

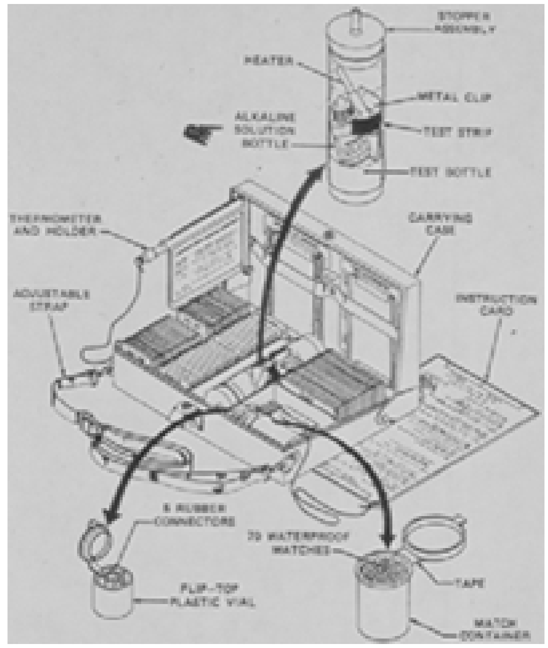


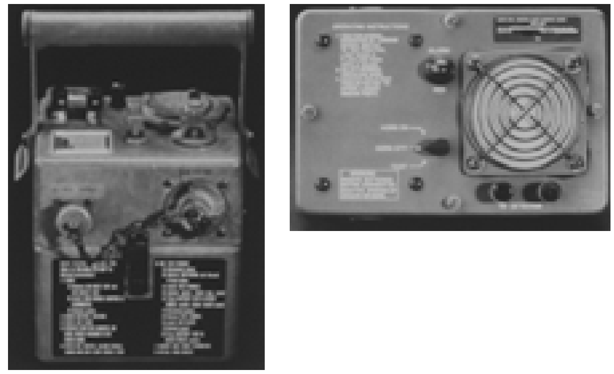
Fig. 16-28. The M272 Chemical Agent Water Testing Kit and its components. New kits have a test strip instead of a thermometer; this illustration shows both. Reprinted from Brletich NR, Waters MJ, Bowen GW, Tracy MF. *Worldwide Chemical Detection Equipment Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Analysis Center; October 1995: 433. Drawing: Courtesy of US Army Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Md.

The M8A1 can be located within a hospital complex, with alarm units placed to cover all critical care, treatment, and support areas. The M43A1 detects nerve agent vapors at concentrations of 0.2 mg/m^3 for sarin (GB) and 0.4 mg/m^3 for VX.

Standoff Detection

Early warning of chemical agents provides troops the necessary time to increase protective posture and to avoid contaminated areas. Standoff detectors provide this early warning at a distance of 1 to 5 km.

Optical remote sensing (ORS) technologies, employing infrared spectral analysis techniques, have been utilized in the development of chemical agent standoff detection technologies. Within the ORS technologies, there are two types of remote sensing systems: passive and active (laser). The section below only looks at the passive system, which employs a Fourier Transform Infrared (FTIR) spectrometer.



a b

Fig. 16-29. The M8A1 Automatic Chemical Agent Alarm system consists of (**a**) the M43A1 Detector and (**b**) the M42 Alarm. Reprinted from Brletich NR, Waters MJ, Bowen GW, Tracy MF. *Worldwide Chemical Detection Equipment Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Analysis Center; October 1995: 411. Photographs: Courtesy of US Army Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Md.

Alarm: Remote Sensing Chemical Agent Alarm M21

The M21 Remote Sensing Chemical Agent Alarm (RSCAAL) is an automatic scanning, passive, infrared sensor. The M21 detects nerve and blister agent clouds based on changes in the background infrared spectra caused by the presence of the agent vapor. It scans a horizontal 60° arc and can recognize agent clouds at line-of-sight ranges up to 5 km (Figure 16-30).

Usually, the M21 is placed facing into the wind. It measures and stores a background spectrum that is then compared by an onboard microcomputer, which makes agent/no agent decisions based on ambient radiance levels. Response time is 1 minute or less. The system is fielded to NBC reconnaissance units.

The sensitivity of the M21 for detecting nerve agents (GA, GB, and GD) is 90 mg/m^3; and for vesicants is 500 mg/m^3 for Lewisite and 2,300 mg/m^3 for HD mustard.

Developmental Detection and Warning Items

In the area of chemical detection, the next developments are

1. standoff detection systems that use laser systems and can provide advance warning from 30 to 50 km distant, and
2. point detectors that will be placed on attended air vehicles, with warning sent back by radio or forward-emplaced point detectors with radio links to a headquarters or a central warning network.

Combined nuclear, chemical, and biological detectors, which could serve as joint detection and warning devices, are also being developed and fielded.

Integrated Mobile Systems

M93A1 FOX Nuclear, Biological, Chemical Reconnaissance System

The M93A1 FOX Nuclear, Biological, Chemical Reconnaissance System (NBCRS) is a recently deployed, comprehensive solution to the prob-

Fig. 16-30. Field use of the M21 Remote Sensing Chemical Agent Alarm (RSCAAL). Reprinted from Brletich NR, Waters MJ, Bowen GW, Tracy MF. *Worldwide Chemical Detection Equipment Handbook*. Edgewood, Md: Chemical Warfare/Chemical and Biological Defense Information Analysis Center; October 1995: 425. Photograph: Courtesy of Brunswick Corporation (now Intellitec), DeLand, Fla.

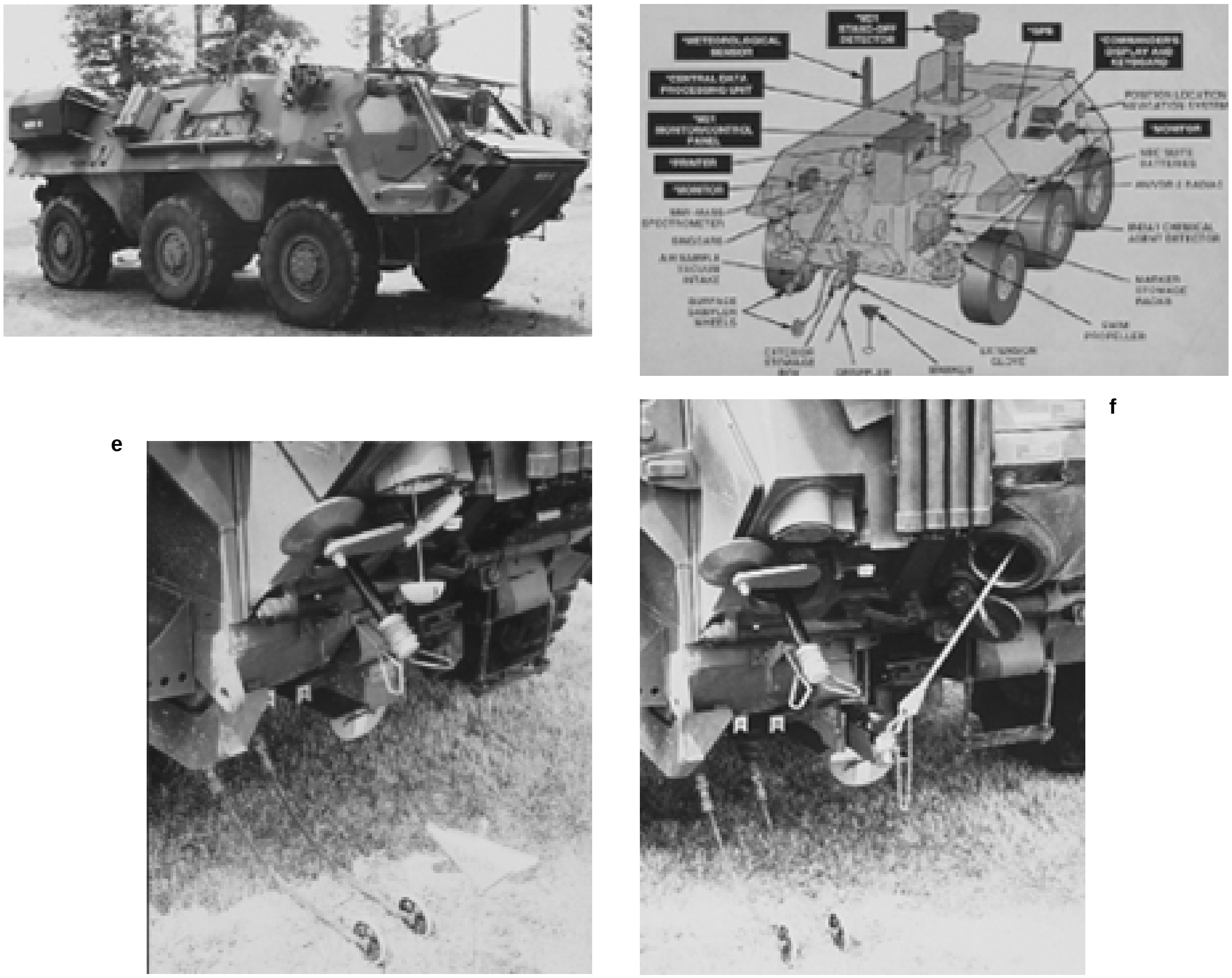


Fig. 16-31. (**a**) The M93A1 FOX Nuclear Biological Chemical (NBC) Reconnaissance System. The M21 remote sensing chemical agent stand-off detector is not shown in its deployed configuration. (**b**) The schematic shows important components of the FOX. Entries in black boxes are components that have been added to the original version. GPS indicates the location of the global positioning system instrument. (**c**) A FOX NBC suite operator is seen controlling the M21 detector. (**d**) The instrument at the top is the ANVDR2 Radiation Detector. Below it is the M43A1 Chemical Vapor Detector. (**e**) Chemical agents present on the ground adhere to the silicone-tired sampling wheels.

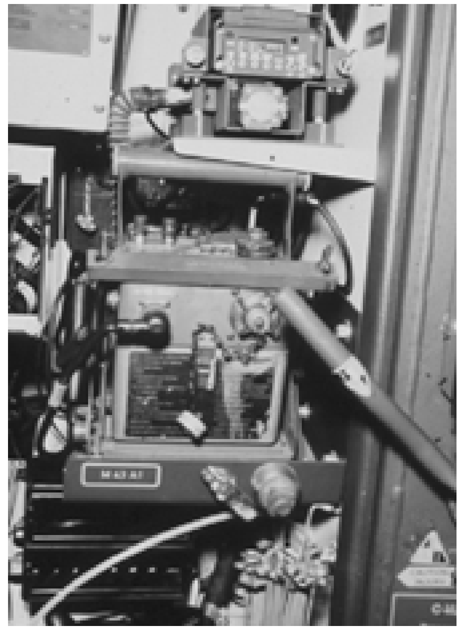
lem of early recognition of NBC threats on the modern battlefield. Numerous sophisticated instruments have been mounted in a fast, mobile, 6x6 armored vehicle that weighs about 19 tons and is manned by a crew of three (Figure 16-31). The vehicle is of German origin, and the name FOX is a translation of Fuchs, for whom the design was named.

The FOX is instrumented to detect chemical contamination in its immediate vicinity with a variety of probes, and at a distance via a standoff detector (M21). Meteorological data are also sensed. Data are analyzed, synthesized, and transmitted to higher-echelon units by a secure, jam-resistant communication system. The local area is marked by warning markers ejected through a hatch in the rear of the vehicle. A global positioning system makes possible accurate marking of the contaminated locale. The interior of the vehicle is pressurized and offers collective protection against threat agents.

XM31 Biological Integrated Detection System

The XM31 Biological Integrated Detection System (BIDS) consists of a lightweight, multipurpose, collective protection shelter mounted on a heavy high-mobility, multipurpose, wheeled vehicle c

d



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After sampling, the wheels are elevated into proximity of the vacuum port of the chemical sampling probe (black tubular object), which is connected to the MM1 mass spectrometer. Chemically contaminated terrain is marked by flags ejected from the FOX. (**f**) Objects that are possibly contaminated are retrieved by a pair of tongs manually operated from inside the FOX. The sample is placed in the small box-like receptacle for latter analysis. (**g**) The gloved arm of a crew member is shown manipulating a thermal probe used to measure ground temperature. This information is valuable in estimating the vapor hazard from liquid agent. Photographs: Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

(HMMWV) and equipped with a biological detection suite (Figure 16-32). In its present configuration, the BIDS can detect the bacteria *Bacillus anthracis* and *Yersinia pestis,* and the toxins botulinum toxin A and staphylococcal enterotoxin B.

Several technological approaches are used sequentially to detect and confirm the presence of specific biological threat agents. Since biological threat agents are likely to be dispersed as aerosols, ambient air is continuously sampled and the background distribution of aerosol particles determined. Aerosol particles in the 2- to 10-µm diameter range are concentrated and then subjected to analysis for

1. adenosine 5'-triphosphate (ATP) by bioluminescence,
2. bacterial cells by flow cytometry, and
3. specific antigens by two different antigen–antibody reactions.

Individual BIDS are combined together into a corps-wide network by a secure communication system. An improved BIDS is being developed with the capability to detect two species of *Brucella*, *Francisella tularensis*, and ricin toxin. Detection capabilities for additional agents will no doubt be added to future models.[33]

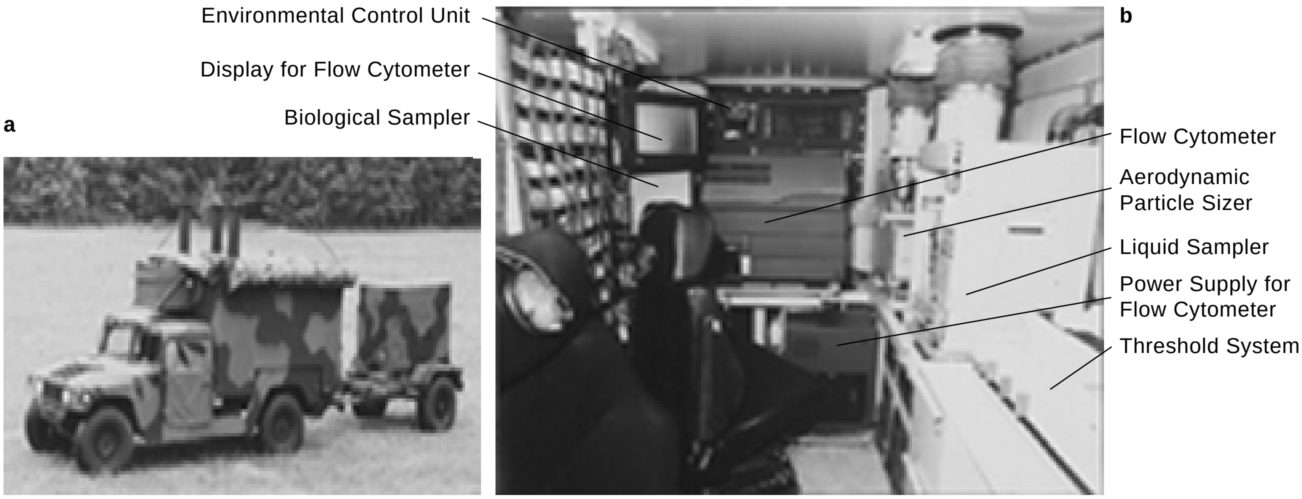

Fig. 16-32. (**a**) The XM31 Biological Integrated Detection System (BIDS) in its present configuration. Electric power is provided by a towed 15-kW tactical quiet generator. An additional high-mobility, multipurpose, wheeled vehicle (HMMWV) is used as a support vehicle for the crew of four, two of whom are required to operate the equipment that comprises the biological detection suite. The stovepipe-like structures perform the aerosol-sampling function. (**b**) Interior view of the biological detection suite. Photographs: Courtesy of Visual Information Division, US Army Chemical and Biological Defense Command, Aberdeen Proving Ground, Md.

COLLECTIVE PROTECTION

Collective protection serves a vital role in the medical area since treatment of casualties must continue even in a contaminated environment, thus collective protection is required to allow this critical function to continue. In addition, it allows individuals to rest and eat, and provides temporary relief from the individual protection equipment thus allowing continuing military operations in the contaminated environment. Collective protection systems have been designed to be used in either a medical or a nonmedical application.

The sources for this discussion are experts at the U.S. Army Chemical and Biological Defense Command,[34] and *Collective Protective Equipment*, U.S. Army Training Manual 34240-338-10,[35] which interested readers can consult for greater detail.

Medical Collective Protection Systems

The Medical Collective Protection Systems provide ample floor space and are accessible for litter patients through airlocks. Additionally, some of the systems provide airlocks through which ambulatory patients can pass. These options aid the medical community in its tasks when dealing with casualties in a chemically contaminated environment.

Chemically Protected Deployable Medical System

The chemically protected deployable medical system (CP DEPMEDS) consists of the M28 collective protection equipment (CPE), which is designed to protect critical areas within the hospital complex from chemical–biological contamination (Figure 16-33). The M28 CPE can only be used with the TEMPER (*t*ent, *e*xtendable, *m*odular, *per*sonnel) system. The entire composite hospital ensemble

Fig. 16-33. The chemically protected deployable medical system (CP DEPMEDS).

consists of expandable tentage, passageways, environmental control units, and ISO (International Organization for Standardization, from the French) shelters.

The M28 CPE consists of the following items: end sections, center sections, and vestibule liner fabricated from a plastic film that is resistant to liquid and vapor agents; a protective entrance airlock for ambulatory personnel that is made from a butyl-coated material and hung in a collapsible aluminum frame, creating a triangular shape; a tunnel airlock for litter-borne patients, consisting of a collapsible frame with entry and exit doors at opposite ends fabricated from an NBC protective cover; the hermetically sealed filter canister and the accessory package, which support the purge requirement during collective protective entry; and the recirculation filter, which is a portable self-contained unit designed to filter any chemical agent vapors brought in through the entry or exit.

Chemically Hardened Air Transportable Hospital

The U.S. Air Force utilizes the Chemically Hardened Air Transportable Hospital (CHATH) in its operations. The CHATH is basically the same as the CP DEPMEDS. The air force is developing a chemically hardened air-management plant (CHAMP), which will provide 800 cu ft/min of filtered air, environmental control, and power generation integrated into a single (albeit very large) package. The CHAMP is intended to replace all M20/M28 filter blower sets. Although the CHAMP is intended to be used with the CHATH, it is competing with the air force's field deployable environmental control unit (FDECU) as the system to actually be applied to the CHATH.

Chemical and Biological Protected Shelter

The Chemical and Biological Protected Shelter (CBPS) is a direct replacement for the M51 C/B shelter, which eliminates the excessive erection/striking time, the insufficient floor space, lack of natural ventilation, and the unavailability of prime movers, which were the problems with the M51. The CBPS can be set up or struck three times daily when operating as a Battalion Aid Station. Set-up times of the inflatable rib tent have been established at 15 to 20 minutes, and tear-down times at approximately 30 minutes. The CBPS consists of a power/support system and inflatable tent. The primary power source is the engine of a HMMWV variant and a backup generator mounted in a high-mobility multipurpose trailer. This system provides air conditioning or heating and electricity for lighting, equipment, and filter air.

The CBPS is staffed by a crew of four, who are carried in the HMMWV. The inflatable rib tent provides 300 sq ft of usable floor space, with a litter-patient airlock (Figure 16-34) and optional ambulatory-patient airlock. The CBPS has removable side entrances to allow side-to-side setup of additional CBPS.

Nonmedical Collective Protection

The nonmedical collective protection systems provide protection for two or more individuals from the effects of chemical agents present in the environment. These systems provide an area for individuals to perform their functions without experiencing deleterious effects.

M20 Simplified Collective Protection Equipment

The M20 Simplified Collective Protective Equipment (SCPE) is designed to provide a clean-air shelter for use in a contaminated environment, espe-

Fig. 16-34. The litter-patient airlock of the Chemical and Biological Protected Shelter. Treating casualties on a chemical-biological warfare battleground requires complicated procedures, even to get the casualty into a protected environment for examination. Special air locks for casualties and new procedures had to be developed. Photograph: Courtesy of Chemical and Biological Defense Command Historical Research and Response Team, Aberdeen Proving Ground, Md.

Fig. 16-35. The M20 Simplified Collective Protective Equipment (SCPE).

cially for command, control, and communication. The SCPE has a collapsible protective entrance, a hermetically sealed filter canister, a blower unit, and an accessory pack (Figure 16-35). It is designed to be employed inside an existing room of 200 sq ft of usable space, with or without a collapsible liner. The SCPE can be used without the liner only in rooms that are tightly sealed.[36]

Developmental Collective Protection Items

New developments in collective protection will center on

- improved adsorbents and impregnants as replacements for activated charcoal,
- methods to better determine filter lifetime, and
- new systems, such as pressure- and temperature-swing adsorption, which may provide significant improvements for collective protection applications in ships, aircraft, and armored vehicles.

Possible applications to military uses will be made of a number of civilian developments in environmental pollution abatement.

For these systems to provide environmentally controlled atmospheres, environmental control units are being developed to be compatible with collective protection systems. At the present, however, there are neither heaters nor air conditioners that can be used with collective protection equipment. The air force's FDECU, currently in late-stage development, is the primary candidate and is able to heat and cool.

DECONTAMINATION EQUIPMENT

The physical properties of chemical agents are highly variable. They range from nerve agent vapor, which usually dissipates in a few minutes to a few hours, to vesicants such as mustard, which can remain active for weeks (or in some cases, years: buried and recovered World War I mustard projectiles are often still quite toxic). It is imperative, then, that timely decontamination of the skin and personal equipment that has been exposed to agent, especially liquid agent, be completed. Skin decontamination should take place within 2 minutes if possible, and equipment decontamination should be completed within 1 hour.

To effectively perform complete personnel and equipment decontamination operations, decontamination units use truck-mounted tanks, pumps, and water heater units; and trailer-mounted pumps and water heater units. In these processes, reducing the exposure time of the individual or piece of equipment to the chemical contaminant is of the highest priority.

The sources for this discussion are *Decontamination of Chemical Warfare Agents*[37] and *NBC Decontamination*,[38] and experts at the U.S. Army Chemical and Biological Defense Command.[39] Readers interested in greater detail can consult these sources and the authors of this chapter.

Personnel Decontamination Items

Personnel decontamination is performed to reduce the level of contamination so it is no longer a hazard to the individual. Personnel decontamination consists of removal of clothing and decontamination of the skin. To expedite this procedure, personnel decontamination kits are used to remove the gross contamination. Complete decontamination, which is conducted by specialized decontamination units, is provided to troops to reduce the requirement for wearing complete NBC protective equipment. Additionally, when both crews and equipment are contaminated, combined complete personnel and equipment decontamination operations are scheduled as the situation and mission permit, bearing in mind the lengthy time required for such an operation. It is during this complete decontamination that commanders can give their soldiers rest and a change of personal protection equipment.[40]

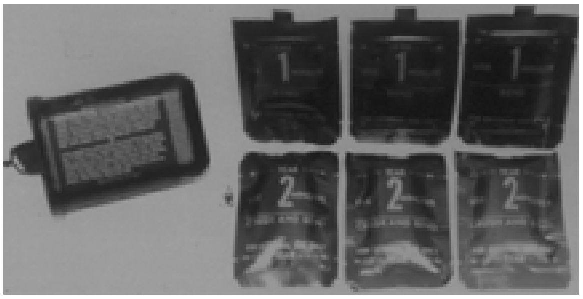

Fig. 16-36. The M258A1 Skin Decontamination Kit.

The personnel decontamination items described below would be used to quickly decontaminate the skin of an exposed individual. Open wounds, however, should be decontaminated with water, saline, or dilute hypochlorite solutions.

M258A1 Skin Decontamination Kit

The M258A1 Skin Decontamination Kit is designed to remove and neutralize liquid chemical agents on the skin. The kit consists of three number 1 liquid packets and three number 2 liquid packets (Figure 16-36). The number 1 packet will neutralize G-series nerve agents by hydrolysis, and the number 2 packet will neutralize VX and mustard agents by oxidation.[41]

The contents of the kit are highly caustic and should not be used near the eyes or mouth or to decontaminate wounds. A training kit that contains only an alcohol and water solution, the M58A1, has been developed to be used in lieu of the M258A1.

M291 Skin Decontamination Kit

The M291 Skin Decontamination Kit is a soft package consisting of two flexible pockets, each of which contains three decontamination packets (Figure 16-37). Each of the packets contains a black resin (a mixture of a carbonaceous adsorbent, a polystyrene polymeric compound, and an ion-exchange resin) that is both reactive and adsorbent. The decontamination pad is made from a nonwoven fiberfill that is impregnated with the dry resin mixture.[42]

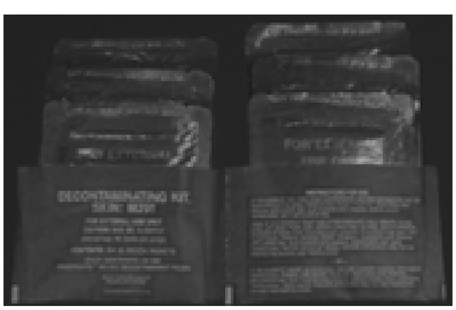

Fig. 16-37. The M291 Skin Decontamination Kit.

The decontamination is accomplished by merely opening the packet and scrubbing the skin surface with the applicator pad until an even coating of the resin is achieved. Use normal precautions to keep the powder from wounds, the eyes, and the mouth. The M291 kit is also used for training.

Equipment Decontamination Items

Equipment decontamination items are used to destroy, remove, or neutralize most of the NBC hazards from personal gear or unit equipment. Although all of the items that could be used for equipment decontamination are not listed below, those most useful to the medical community are described.

M295 Decontamination Kit, Individual Equipment

The M295 Decontamination Kit, Individual Equipment (DKIE) consists of a pouch containing four wipedown mitts, each enclosed in a soft protective packet (Figure 16-38). Each wipedown mitt is made of a dry, adsorbent, black resin (the same as in the M291 kit) contained within a nonwoven polyester material and a polyethylene film backing. This kit allows decontamination of exposed areas of the protective mask and hood, personal equipment, and protective boots. Decontamination is

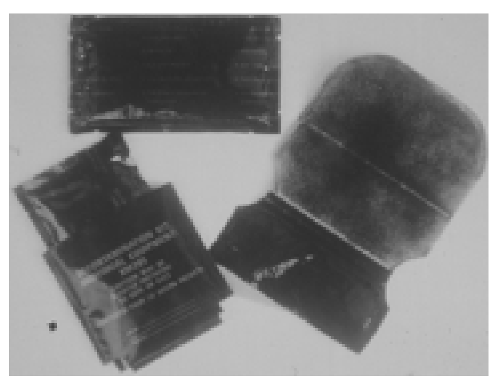

Fig. 16-38. The M295 Decontamination Kit, Individual Equipment (DKIE).

Fig. 16-39. The M11 Portable Decontamination Apparatus (PDA).

accomplished by adsorption of the liquid agent by the resin and the pad.

M11 Portable Decontamination Apparatus

The M11 Portable Decontamination Apparatus (PDA) is a hand-held, pressure-spray apparatus used to coat a surface with DS2 by equipment operators (Figure 16-39). The M11 contains $1\frac{1}{3}$ quarts of DS2 and will neutralize all agents within 30 minutes. It is pressurized using a nitrogen cylinder with a life of only 30 seconds. Any use of DS2 should be made with a protective mask and gloves, since it is highly irritating to the skin and can cause blindness. In addition, DS2 is highly flammable.

M17 Lightweight Decontamination System

The M17 Lightweight Decontamination System (LDS) is designed to draw water from any source and deliver it to the two installed spray wands at pressures up to 100 psi and at temperatures up to 120°C (Figure 16-40). The M17 LDS can be used to provide pressurized hot water before or after application of decontaminant at regulated pressures and temperatures. It has a liquid soap siphon hose attachment for use with mud, dirt, or grease removal (these may have absorbed chemical agent).

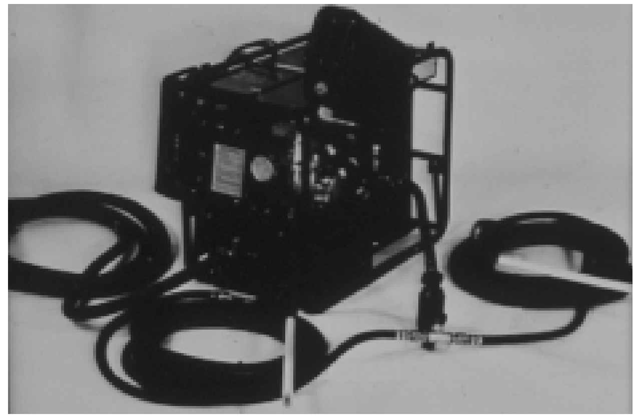

Fig. 16-40. The M17 Lightweight Decontamination System (LDS).

The M17 LDS has a 3,000-gal collapsible water tank that can be prepositioned and filled for hot water showers or hospital use.

M12A1 Power-Driven Decontamination Apparatus

The M12A1 Power-Driven Decontamination Apparatus (PDDA) is used to apply decontamination solutions or hot soapy water and rinses during field decontamination operations. The M12A1 PDDA consists of a pump unit, 500-gal tank, personnel shower assembly, and M2 water heater, all of which is mounted on a 5- or 10-ton truck with drop sides (Figure 16-41). The pump assembly can deliver 50 gal of water or super tropical bleach (STB) decontaminating agent per minute at a pressure of 105 psi to the two spray wands.

Fig. 16-41. The M12A1 Power-Driven Decontamination Apparatus (PDDA).

Developmental Decontamination Items

There is a need for an effective and environmentally safe reactive decontaminant that does not harm equipment and personnel. Bacterial enzymes, catalytic-type compounds, and other stable decontaminants (eg, quaternary ammonium complexes) are under consideration. Sorbent compounds and nonaqueous decontaminants are also being investigated for use on electronic components and other sensitive equipment.

ADDITIONAL PATIENT PROTECTION AND TRANSPORT EQUIPMENT

Patient Protective Wrap

The patient protective wrap (PPW) is designed to protect a patient during evacuation after the BDO has been removed and the patient has received medical treatment (Figure 16-42). A patient can remain in the PPW for 6 hours. The protective mask is not needed inside the PPW, but it should be evacuated with the patient.

The PPW is for one patient only and weighs approximately 5.5 lb. The top of the PPW is made of a material similar to that used in the BDO, with a charcoal lining and in a camouflage pattern. The bottom is made of impermeable rubber. The PPW has a continuous zipper along the outer edge for ease of patient insertion; a large, transparent window in the top to view the patient (or for him to see out); and a pocket for medical records. The patient's breathing air comes through the permeable top of the PPW.

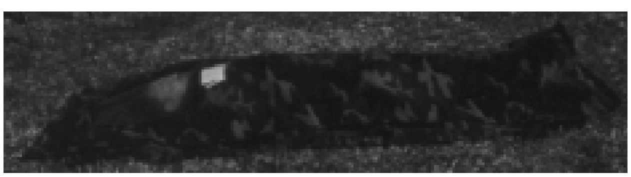

Fig. 16-42. A volunteer demonstrates the patient protective wrap (PPW).

Patient Transport: Decontaminable Litter

The decontaminable litter has been developed to meet the need for a litter that can withstand decontamination (Figure 16-43). The cover fabric is a honeycomb weave of monofilament polypropylene, which will not absorb agent and is not degraded by decontamination fluids. The cover fabric is flame retardant and rip resistant, and is treated to withstand weather and sunlight. It has aluminum poles, painted with chemical agent resistant coating, with round, grip-molded, retractable, black nylon handles. It conforms to all NATO standards and weighs about 15 pounds.

Fig. 16-43. The decontaminable litter.

SUMMARY

An integrated system of chemical defense equipment is required if we are to be successful in providing an adequate protective posture for all forces. The principal elements of that system include the following:

- Real-time detection and warning, preferably from remote sensors. This will provide more time, first, to assume a protective posture, and second, to identify the chemical agent.
- Personal protective equipment, consisting of a properly fitted mask and overgarment with gloves and boots as required. This equipment is the most critical component of chemical defense equipment, the first line of defense.
- Collective protection, which is necessary for optimal combat casualty care in a contaminated environment, whether the casualty's injuries are from exposure to chemical–bio-

logical weapons alone, or are combined with injuries from conventional weapons.

- Decontamination, which is required for personnel and equipment to maintain combat operations in a contaminated environment.

Medical treatment for chemical casualties has not been covered here since it is covered in other chapters, but it is essential that protective equipment be available to allow the proper treatment to be administered.

ACKNOWLEDGMENT

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PSYCHOLOGICAL PROBLEMS ASSOCIATED WITH WEARING MISSION-ORIENTED PROTECTIVE POSTURE GEAR

Prepared for this textbook by Elspeth Cameron Ritchie, M.D., Major, Medical Corps, U.S. Army, Department of Psychiatry, Walter Reed Army Medical Center, Washington D. C. 20307-5001

Personal respirators or protective masks, incorrectly but commonly called gas masks, have been worn since the Germans used gas in World War I. Now they are a routine part of a soldier's field gear, and in planning for combat, the military relies on the putative saving graces of protective masks. However, a few soldiers are unable to tolerate wearing a gas mask for a few minutes even in a peaceful garrison setting. Most soldiers have decrements in cognitive and physical functioning when the mission-oriented protective posture (MOPP) gear is worn for a few hours. How well would these soldiers tolerate wearing MOPP 4 gear for hours or days in a chemical environment?

There are three principal psychological reasons to avoid wearing gas masks: (1) "gas mask phobia," a form of claustrophobia; (2) malingering; and (3) feeling embarrassed at being thought a coward. "Gas hysteria," the panicked feeling that one has been gassed, can also occur.

Gas mask phobia may be categorized as a form of claustrophobia occasioned by the wearing of a protective mask. In psychiatric terms, it could be defined as a simple phobia.[1] Symptoms include hyperventilation, sweating, and panic. These usually cause the eyepieces to fog up, leading to an inability to see, move, shoot, and communicate. Many soldiers either break the seal and lift the mask off the face, or remove the mask completely. Prevention and initial treatment of gas mask phobia and malingering should be command issues, handled though the NBC (nuclear, biological, and chemical) officers; recalcitrant cases may be referred to the mental health service for further evaluation and desensitization techniques.

Prevention of fear of the mask is an important training issue. Consideration should be given to having soldiers in basic training wear the mask in a relaxed setting the first few times. Soldiers then need to train in MOPP gear to learn (*a*) how to handle communication obstacles, and (*b*) what they should do if they or their buddy develop difficulties with the equipment. Often proper fit is not given adequate attention when the mask is issued. If women wear their hair pinned up or if men have facial hair, for example, a tight fit is very difficult to obtain.

An ethical dilemma is raised with having soldiers in a potentially toxic environment who cannot wear the mask. Should these soldiers be removed from the combat environment, thereby risking an epidemic of soldiers claiming that they cannot wear the mask? Or should the soldiers be kept in that environment, risking their injury or death if gas is used?

Not discussed here but a factor to be considered in any potential deployment of soldiers in a biological or chemical environment is the intense fear of that form of warfare. The feelings of helplessness in the face of a ubiquitous and unseen killer can be overwhelming.

HISTORY

Gas was first used extensively in early 1915 by the Germans against both the French and the British. In the accounts of that war, over and over poor discipline is recorded as a significant source of gas casualties.[2] The American Expeditionary Forces used primarily the British small-box respirator, with the French M2 mask as a reserve. Both masks were very uncomfortable, and soldiers took them off at the first opportunity, often while gas still lingered in the area. Many casualties were sustained.[3] "In the recent gas attack practically all casualties had been caused by ignorance of the officers concerning the persistency of mustard, premature removal of masks, and failure to evacuate the camp promptly."[4(p11)]

Shame was another source of casualties:

> It is almost unbelievable nowadays that at one time one of the chief sources of these constantly occurring casualties was shamefacedness at being seen in a mask. Men would not protect themselves until absolutely forced to do so, for fear others would regard them as being too easily frightened....They (the soldiers) were met with jeers from some of the supporting troops who shouted "Hello, got the wind up?" and in this way induced the corporal, really against his better judgement, to order masks off. Not more than twenty or thirty yards further along the party ran into a particularly bad pocket of Green Cross and the corporal and several of his men were so badly gassed that they had to be sent to the rear.[5(pp166–167)]

Malingering and gas hysteria were two other sources of casualties. In World War I, many soldiers were evacuated to the aid stations who probably were suffering from gas hysteria. A Division Medical Gas Officer

> capped this account with his report that from 1–13 November a total of 763 men came in to aid stations and field hospitals as gassed. Of these, 339 were not considered gassed and were returned to their units via the casual camp set up in the rear.[6(p73)]

How many of these were judged malingerers is not recorded.

In World War II, gas was not a significant threat. The first volume of *Neuropsychiatry in World War II*, part of the official history of World War II issued by the Office of The Surgeon General, does not discuss difficulties with the protective mask as a problem leading to psychiatric disability.[7] Similarly in the Korean and Vietnam wars, gas posed little danger. Until 1990 and the outbreak of the Persian Gulf War, if a soldier in a routine job could not wear the protective mask, that fact was often ignored by the chain of command.

THE CURRENT SITUATION

American soldiers typically first learn to put on a mask during basic training, in a tear gas–filled tent. The environment is tense, and soldiers are burdened with hot, unfamiliar gear. They may be told to remove their masks long enough to get a whiff of tear gas, causing watery eyes and coughing. When soldiers put their masks back on, they are then sweating and teary, adding to their psychological and physical distress. In many cases, the mask is then worn in strenuous, hot conditions, such as on a road march or a field exercise. In practice, the mask interferes with verbal and visual communication, adding to a sense of isolation. Real casualties from heat stroke or injury are often suffered.[8–10]

Respirators are used in many occupations in the civilian world, including firefighting, and there are similar problems associated with industrial use. However, the self-selection process may eliminate those who can not tolerate a mask.[11]

In the military, donning the rest of the MOPP gear causes additional physiological and psychological difficulties. The wearing of the suit increases body temperature, which may be compounded by doing tasks in the hot sun. Numerous studies[12–18] have documented the decrement in function caused by wearing MOPP 4 for extended periods. Studies have also tested the effects on soldier performance of administering the nerve agent–antidotes atropine sulfate and pralidoxime chloride (2-PAM Cl)[19] and pyridostigmine bromide[20,21]; the combination of atropine and 2-PAM Cl significantly shortened endurance time for heat sessions for soldiers wearing MOPP 4 gear.[19]

Modern Case Studies

The following three case studies are of soldiers who could not tolerate wearing their protective masks during the Persian Gulf War. Little on the phenomenon had been published in the medical or military literature by the early 1990s; it is probable that many more cases were undiagnosed. These three previously published[22,23] cases highlight two issues: the question of trying to get out of combat by not being able to wear the mask, and the reluctance of motivated or senior soldiers to admit that they have had a problem with the MOPP gear.

Case 1. A 19-year-old single white male, stationed at the Demilitarized Zone in Korea, was unable to finish a 2-mile road march while wearing his protective mask. His chief complaint was "It's embarrassing to be unable to finish the march." This soldier had difficulty wearing his mask for more than a few minutes. After the first mile of a road march, he experienced confusion, shortness of breath, blurry vision, fainting sensations, and intense thirst. His background, past psychiatric history, and medical history were unremarkable. He did remember an incident when he was 6 years of age, when he and his friends were playing "mummy." He felt hot and agitated and scared; later his grandmother told him that he had been hyperventilating. A diagnosis of simple phobia was made. Treatment principles outlined below were followed. Initially he was told to wear his mask while listening to music. He did, but still felt "confined." He would try to adjust his mask constantly by moving it around, and getting cool air underneath. Gradually he felt more confident while wearing the mask and could increase the time he wore it. He was able to wear his entire MOPP gear during the annual "Team Spirit" exercise.[22(p105)]

Case 2. An officer with 20 years of military service was referred with depressive symptoms. These followed in the wake of a chronic gas mask phobia that had gone untreated for years because the officer had been too ashamed to admit it to anyone. He had remained on the front lines, enduring several gas mask alerts, and was identified when he finally sought assistance. He was eventually evacuated because his depression and phobia could not safely be treated in the desert environment.[23(ppA10–A11)]

Case 3. A specialist was brought to the hospital for treatment of gas mask phobia, which had been refractory to systemic desensitization by a unit medic. The treatment had been notable for the patient's overall compliance but insufficient "effort." She would remove the mask frequently and inexplicably during low subjective anxiety, or with sudden incongruous elevation in anxiety unaccompanied by any objective signs. It was decided to send the patient to the division rear to provide some improved safety, given that malingering could not be judged as certain.[23(pA-11)]

Treatment

The basic techniques of treating gas mask phobia are similar to those of treating other phobias, modified for the military culture and environment. They are desensitization, relaxation, and flooding. To avoid malingering, any secondary gain (ie, other benefits accrued by not being able to wear the mask, such as evacuation from the field environment) should be avoided.

In desensitization, the soldier needs to wear the mask enough that it becomes routine. Secondly, he needs to relax while wearing it. Thus, soldiers should begin by wearing the mask while watching television, ironing, or doing other household or barrack tasks. They should start wearing it for short periods (5 min), then lengthen the time (30 min).

Flooding, the next step, refers to the technique of having a patient imagine wearing a mask in tense situations. Gradually, the soldier actually wears the mask in more-tense and -fatiguing situations. To avoid secondary gain, benefits of not being able to wear a mask should be minimized. Therefore, soldiers should not be excused from road marches, field exercises, or other duties because they are unable to wear MOPP gear.[24]

Other primary strategies include (*a*) simulation training; (*b*) modeling training (ie, observation of live peer models); (*c*) self-management training (ie, training in self-control techniques); and (*d*) inoculation training, both as a soldier and as a casualty. Secondary prevention strategies include: (*a*) self-care; (*b*) buddy care; (*c*) leader management, to minimize the risk of symptom spread; and (*d*) medic care.[18]

SUMMARY

As threats of chemical and biological warfare become more routine, it is imperative that soldiers can wear their protective gear. Frequent practice should increase comfort and decrease problems with claustrophobia and embarrassment. In those who cannot initially tolerate the gas masks, treatment should be initiated as close to the front lines as possible, to minimize casualties in training and in combat.

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