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MILITARY HANDBOOK

CHEMICAL AND BIOLOGICAL (CB) CONTAMINATION AVOIDANCE AND DECONTAMINATION

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

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FOREWORD

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LIST OF ACRONYMS AND ABBREVIATIONS

AC = hydrogen cyanide
ADF = aircraft deicing foam
AFFF = aqueous film-forming foam
APD = all-purpose decontaminant
AR = Army Regulation
ASH = activated solution of hypochlorite
$Ba(OH)_2$ = barium hydroxide
BDO = battle dress overgarment
BDO = 3-bromo-4, 4-dimethyl-2-oxazolidinone
BG = Bacillus subtilis
BW = biological warfare
BZ = quinuclindinyl benzilate
CAB = cellulose acetate butyrate
CAC = contamination avoidance cover
CAD = chemical agent decontaminant
CAM = chemical agent monitor
CARC = chemical-agent-resistant coating
CB = chemical and biological
CDIW = chemical agent, detection, identification, and warning
CG = phosgene
C^3I = command, control, communication, and intelligence
CK = cyanogen chloride
CPE = collective protection equipment
CPS = collective protection shelters
CRDEC = US Army Chemical Research, Development, and Engineering Center
CX = phosgene oxime
DAP = Decontaminant Apparatus, Portable
DCCMP = Decontamination Contamination Control Master Plan
DFP = difluorophosphate
DKIE = Decontamination Kit, Individual Equipment
DNA = deoxyribose nucleic acid
DoD = Department of Defense
DS2 = decontaminating solution No. 2
ECS = environmental control system
EOD = explosive ordnance disposal
EPDM = ethylene propylene diene monomer
ETO = ethylene oxide
FLOT = forward line of own troops
FM = field manual
GA = tabun
GB = sarin
GD = soman
GF = cyclohexyl methyl phosphorofluoridate
H = mustard gas
HCPE = hybrid collective protection equipment
HD = distilled mustard
HL = distilled mustard mixed with lewisite
HTH = high-test hypochlorite
IBA = o-idosobenzoic acid
IBX = 5-nitro-2-iodoxy benzoic acid
ICBAD = intermediate chemical and biological agent decontaminant
IPE = individual protective equipment
KOH = potassium hydroxide
L = lewisite
LDS = Lightweight Decontamination System
MCBD = Multipurpose Chemical and Biological Decontaminant
MCPE = modular collective protection equipment
MEA = monoethanolamine
MOPP = mission-oriented protective posture
MRDC = US Army Medical Research and Development Center
NAEDS = nonaqueous decontamination system
NATO = North Atlantic Treaty Organization
NBC = nuclear, biological, and chemical
PAA = peracetic acid
PDDA = power-driven decontamination apparatus
PE = protective entrance
RAM = reliability, availability, and maintainability
RNA = ribose nucleic acid
ROC = required operational capability
SCPE = simplified collective protection equipment
SD = sodium dichloroisocyanurate
SLASH = self-limiting activated solutions of hypochlorite
SPM = special-purpose mask
STB = supertropical bleach
TAP = toxicological agent protective
TGD = thickened soman
THD = thickened distilled mustard
U.S.S.R. = Union of Soviet Socialist Republics
UV = ultraviolet
VFS = ventilated facepiece system

CHAPTER 1
INTRODUCTION

This chapter discusses historical events significant to an appreciation of chemical and biological (CB) warfare. It also out lines the scope of this handbook and describes the general content of each chapter.

1-1 PURPOSE

CB contamination can adversely affect both personnel and materiel. The modern objective of CB warfare is to reduce the fighting capability of enemy personnel either by direct production of casualties or by reduction of efficiency after donning protective gear. Exposure to CB agents can have a broad range of effects. Some agents may cause mild irritation, sickness, or slight degradation, which diminishes a soldier's willingness to fight or impairs his fighting skills. Other, more lethal, agents can have rapid and devastating effects on personnel who are not well protected against them. Small quantities of these agents can cause severe incapacitation or even death.

The primary military value of CB agents has been viewed traditionally as a means of producing adverse effects in enemy personnel. However, these agents have been found to have deleterious effects on the properties of materials used to construct military systems. These effects can reduce the capability of the system or equipment item to perform its functions. Moreover, the contaminated materiel and equipment can pose prolonged hazards to personnel and result in the spread of contaminants to other areas.

In May 1984 the US Army addressed the survivability of materiel in a nuclear, biological, and chemical (NBC) environment by establishing Army Regulation (AR) 70-71. *Nuclear, Biological and Chemical Contamination Survivability of Army Materiel.* This regulation requires that developers of equipment consider and address NBC survivability requirements in the design, development, engineering, test, and evaluation of all mission-essential military equipment. In June 1987 the Department of Defense (DoD) issued DOD Instruction No. 4245.13 entitled *Design and Acquisition of Nuclear, Biological, and Chemical (NBC) Contamination-Survivable Systems.* This instruction provides the general management and documentation requirements for the survivability of all DoD systems designed and acquired to perform mission-essential functions in an NBC-contaminated environment. This handbook devotes a chapter to design information on contamination avoidance as well as to contamination and decontamination effects on materiel.

This handbook is primarily for project managers, design engineers, and scientists who need an overview of potential threat agents, available decontamination and contamination avoidance countermeasures, and design and material selection guidelines that will enable them to design systems that can operate effectively in a CB-agent-contaminated environment.

Although written for the stated primary audiences, this handbook can also be used to enhance and augment knowledge in the CB defense programs.

1-2 SCOPE

This handbook contains six chapters. A brief description of each chapter follows.:

Chapter 1, "Introduction", briefly describes CB warfare history and agent threat effects on both personnel and materiel. and current countermeasures.

Chapter 2, "Contaminants", describes agent properties, toxic mechanisms, and their threats. Also systems currently available to deliver and disseminate CB agents are discussed.

Chapter 3, "Protection. Detection, and Contamination Control", introduces protection and contamination avoidance strategies. This chapter describes individual and collective protection equipment as well as support equipment and supply protection techniques. Detection and warning, an essential part of the contamination control strategy, is also addressed in this chapter.

Chapter 4, "Decontamination, Methods and Equipment", describes currently fielded decontaminants, equipment, and methods for personnel, equipment, vehicle, and aircraft decontamination. Levels of decontamination within the current Army doctrine are also discussed.

Chapter 5, "Material and Design Considerations", describes the effects of both agents and decontaminants on materials and discusses the CB survivability requirements of the Army outlined in AR 70-71. Examples of material compatibility test data with CB contaminants. decontaminants, and design methods to reduce system vulnerability to CB contaminants are discussed.

Chapter 6, "Future Concepts", describes current US Army development activities for providing new and improved decontamination methods to counter the current and future CB agent threats. Several decontamination concepts and their application feasibility are discussed.

1-3 HISTORY

1-3.1 CB WARFARE

The use of chemical weapons in warfare is not a modern tactic. Warriors in ancient India used incendiary devices against their enemies. Byzantine soldiers used a compound that, when burned, created toxic fumes. Smoke was said to have been used against the armies of' the Roman Empire. In the Middle Ages the Christians defeated the Turks with toxic fumes created by burning rags soaked in chemicals.

Modern chemical weapons were conceived during World War 1 and were used widely by Allied and Central Power forces. Harassing agents and, later, lethal agents were developed and used. The first lethal agent employed was chlorine, which was released from high--pressure tanks by the Germans against the French and British forces at Ypres in April 1915. At least 5000 troops were killed by that attack and 10,000 additional troops became casualties. The greatest losses inflicted by chemical weapons occurred in Russia; the number of' casualties was estimated to have been 500,000, of which 50,000 were fatalities. The reason for the heavy Russian losses was probably the lack of effective protection aggravated by poor training (Ret. I).

The use of chlorine gas and, later, phosgene (both respiratory agents) generated tremendous efforts on both sides to develop protective equipment. Various types of crude gas masks (respirators) were developed and used first by the Canadians and the British until an early version of the carbon canister filters that are used today came into widespread use.

The United States began preparations for war with neither a policy nor a capability for chemical warfare, and it took a considerable amount of time for the United States to catch up. US Forces were not provided with gas masks until late 1917, and US chemical munitions were not sent to the front until late 1918.

At the end of World War I, the military establishment in most of the participating countries was unconvinced about the value of chemical weapons for their own forces. However, the people in the participating countries were horrified by, and openly and loudly protested. the results of chemical weapons use, and efforts to prohibit repetition were initiated.

The Versailles Treaty of 1919 included a prohibition on the use of poisonous gases, and the Washington Disarmament Conference of 1922 considered a similar provision, but it never was enacted. At American and French initiatives, the Geneva Conference of 1925 addressed the subject of chemical warfare, and on 17 June 1925, the Geneva Protocol. considered the first step toward totally eliminating chemical warfare, was adopted by the League of Nations.

Between World War I and World War II, with the exception of' the development of chemical weapons delivery systems (both bombs and spray tank systems) for aircraft delivery, no significant advances in CB offense were made until the discovery of the nerve gases in Germany shortly before World War II. The basic research that culminated in the development of nerve agents had begun in Germany in 1934 with the discovery, during research seeking new types of insecticides, that fluorine compounds tended to be toxic.

“The first nerve agent developed was called tabun (GA) and the other G-series agents followed rapidly. Tabun was first prepared on 23 December 1936, and by 1939 a pilot plant had been set up to provide quantities for field testing. Later, a full-scale production plant was built. which operated between April 1942 and the beginning of 1945, and produced some 12,000 tons of tabun during that period. Sarin (GB), one of the most potent of the currently known nerve agents. was discovered in 1939. Although there were considerable difficulties in developing a manufacturing process for that agent, a potential satisfactory process was worked out and a production plant was begun in 1943. The plant, however, was overrun by the Soviets before it was finished. In 1944 soman (GD) was also discolored by the Germans. but it was too late in the war for the necessary development work to proceed very far.

Another class of potent nerve gases derived from organophosphate compounds was developed between 1952 to 1954. These new lethal compounds were called V-series agents. By 1958 the United States had selected one of the V-series compounds. named VX, for large-scale manufacture. In 1959 construction work on the factory began, and in 1961 production of VX commenced. This continued until 1968 when the plant was shut down.

Although the Geneva Protocol has prohibited the use of CB weapons since 1925, it has not prevented the use of these weapons. There have been several adequately substantiated and additional alleged but unsubstantiated instances of the use of chemical warfare on a relatively large scale since 1925.

The Italians used mustard gas (H) against Abyssinia in 1936 and 1937. It is believed that the use of CB weapons against the entirely unprepared Abyssinians had a decisive influence on the outcome of the war (Ref. 1).

Although the Germans manufactured CB agents during World War II, the agents were never used during that war. Most likely this was due to the German fear of' reprisal because the Germans were convinced that the Allies also had supplies of' nerve agents.

In more recent years claims of use of CB agents in various regions of the world have been made. During the Yemen War of 1963-1967. mustard gas, among others, was used in some inaccessible areas, but this fact was not internationally known until long after the war (Ref. l). By the end of the 1970s, an increasing number of press and intelligence reports had suggested that CB agents were being used in limited wars being conducted around the world. Claims were made that CB agents had been used by the Laotian government with Vietnamese and Soviet assistance since 1975 against the H'mong, a mountain people living in the central part of the country. In Kampuchea, Vietnamese forces were said to have used CB agents against resistance fighters. Allegations of the use of CB agents by the Soviet and Afghan armies against the Mujahideens, who were fighting the Soviet occupation of Afghanistan, have been made by the United States (Ref. l).

In 1983 and 1986 a team of scientists sponsored by the United Nations was sent to Iran to investigate claims of use of CB agents by the Iraqi troops against Iranian troops. Based on the evidence gathered during the second trip to Iran. the UN Mission unanimously concluded that CB agents had been used against Iranian troops by Iraqi forces (Ref. 2).

It is clear that potential adversaries of the United States currently possess the capability and willingness to wage chemical warfare. To develop systems that can survive in this environment a strong understanding of the CB threat agents and their interactions is essential.

1-3.2 CB AGENTS AND DECONTAMINANTS

The two primary goals of the deployment of CB agents are to (1) kill or incapacitate as many of the enemy as possible and (2) force the survivors into a chemically protected posture, which decreases their effectiveness.

The effects of CB agents on personnel are well documented as a result of World War 1. The US Expeditionary Force suffered approximate> 37,000 known gas casualties during World War I, of which approximately 27,000 were due to mustard gas (Ref. 3). The remaining casualties were a result of phosgene gas and unknown agents. It has been estimated that these CB casualties required 1.3 million man-days of lost effort for care and that the average casualty was confined to a hospital for six weeks (Ref. 4). Only 600 of the 126,000 American deaths could be attributed to mustard gas (Ref. 4). This indicates that earlier CB agents were much more effective in reducing war-fighting capability than inflicting fatal casualties.

In recent years much attention has been given to the effects of CB contaminants and their associated decontaminants on materials used to construct military systems and equipment items. These effects can reduce the capability of the system to perform its functions. The corrosive nature of mustard gas was exhibited in World War I when ammunition exposed for long periods to its vapors caused weapons to jam frequently and to require constant cleaning.

When examining the effects of CB agents and decontaminants upon materials, it is important to focus upon the function of that material or the component and or subsystem that the material is used to construct. Once a function has been established, the properties of the material critical to performing that function can be determined. Testing can then be performed to determine the effects of exposure to CB agents and decontaminants upon critical properties.

Testing in more recent years on alkyd paints exposed to mustard droplets has shown that even after decontamination enough mustard remains in the paint to blister bare skin coming in close contact with the surface (Ref. 4). In permeability tests of flexible barrier materials for collective protection equipment, mustard poses a most stringent challenge. In such tests, when mustard droplets are placed on a film of commercial low-density polyethylene 10-mm thick, mustard vapor emanates from the opposite side in under 10 min.

In most of the tests conducted prior to 1980 to collect information describing the effects of agents and decontaminants on materials, the effects on critical properties were not measured. In addition, standard exposure conditions and test methods were not employed. As a result, the data base of agent and or decontaminant effects on materials could not be reliably employed to predict the survivability of system components. To remedy the problem, the US Army has conducted or sponsored programs in which standardized methods were employed to collect data describing effects on critical performance-related properties. Selected results from these programs are presented in more detail in Chapter 5.

1-3.3 CB DEFENSE PROGRAMS

As mentioned previously, the LJS Expeditionary Forces in World War I were not prepared for chemical warfare. The United States was forced to develop protective mask technologies and offensive production capabilities to respond to the CB agent threats. After World War 1 chemical warfare research and development decreased to a low point. In the early 1920s, what is now called the US Army Chemical Research, Development, and Engineering Center (CRDEC) was organized at Edgewood Arsenal, MD, the site of munitions filling plants during the war. In the shadow of the Geneva Protocol of 1925, this facility conducted limited research in chemical warfare through the beginning of World War 11.

The Congressional appropriation for chemical warfare research jumped from two million dollars in 1940 to more than sixty million dollars in 1941. This increased level of spending lead to an expansion of facilities at Edgewood Arsenal and other facilities around the country. During World War II work was conducted in gas mask technology, collective protection, protective clothing, protective ointments, and medical kits. This work was conducted in response to the German discovery of the G-series nerve agents in the late 1930s. As was the case at the end of World War I, research in chemical warfare slowed at the end of World War 11. During the 1950s military research programs in chemical warfare emphasized the development of offensive systems; this emphasis resulted in the development of the V-series agent VX in 1958.

In the late 1960s and early 1970s the US chemical warfare capabilities went into a forced decline. By the mid- 1970s an effort to disband the Army Chemical Corps had been attempted and was almost successful, and the ability of US forces to conduct operations in a CB-contaminated environment decreased dramatically. The Chairman of the Joint Chiefs of Staff, commenting on the CB preparedness of the U. S., declared that US forces were not prepared to operate in a CB environment (Ref. 5).

After several analyses of captured Soviet equipment in the 1973 Middle East war, the U.S. discovered large gaps in its chemical warfare defense posture (Ref. 5). Improvement programs slowly began in the Army in the late 1970s that resulted in the development of manual chemical agent detection kits, portable decontamination equipment, and collective protection systems. By 1980, the Department of Defense had initiated a modernization program to reduce the gaps in chemical warfare defensive and retaliatory capabilities of the U.S.

Currently the major defensive areas for chemical warfare established by the services are

1. Detection, warning, and identification
2. Individual protective equipment
3. Collective protection
4. Contamination control (contamination avoidance and decontamination).

The CB defense program of the US Army currently involves the development of systems in the four defense areas that will enable the soldier to fight effectively in a CB environment. Fig. 1-1 illustrates the intricate interrelationships among the four CB defense areas. Overlapping areas in the Venn diagram represent the integration of the four key countermeasure technologies. For example, the overlapping of individual protection and contamination control results in solutions to problems of personnel decontamination. The overlapping of collective protection and monitoring systems results in the development of warning and detection capabilities inside shelters.

With the establishment of AR 70-71 in 1984, the US Army declared that CB survivability of weapon systems must be addressed. This regulation has broadened research activities from the four key defense areas previously described to areas including CB agent and’ or decontaminant interactions with materials of construction and design of systems for survivability in a CB agent environment.

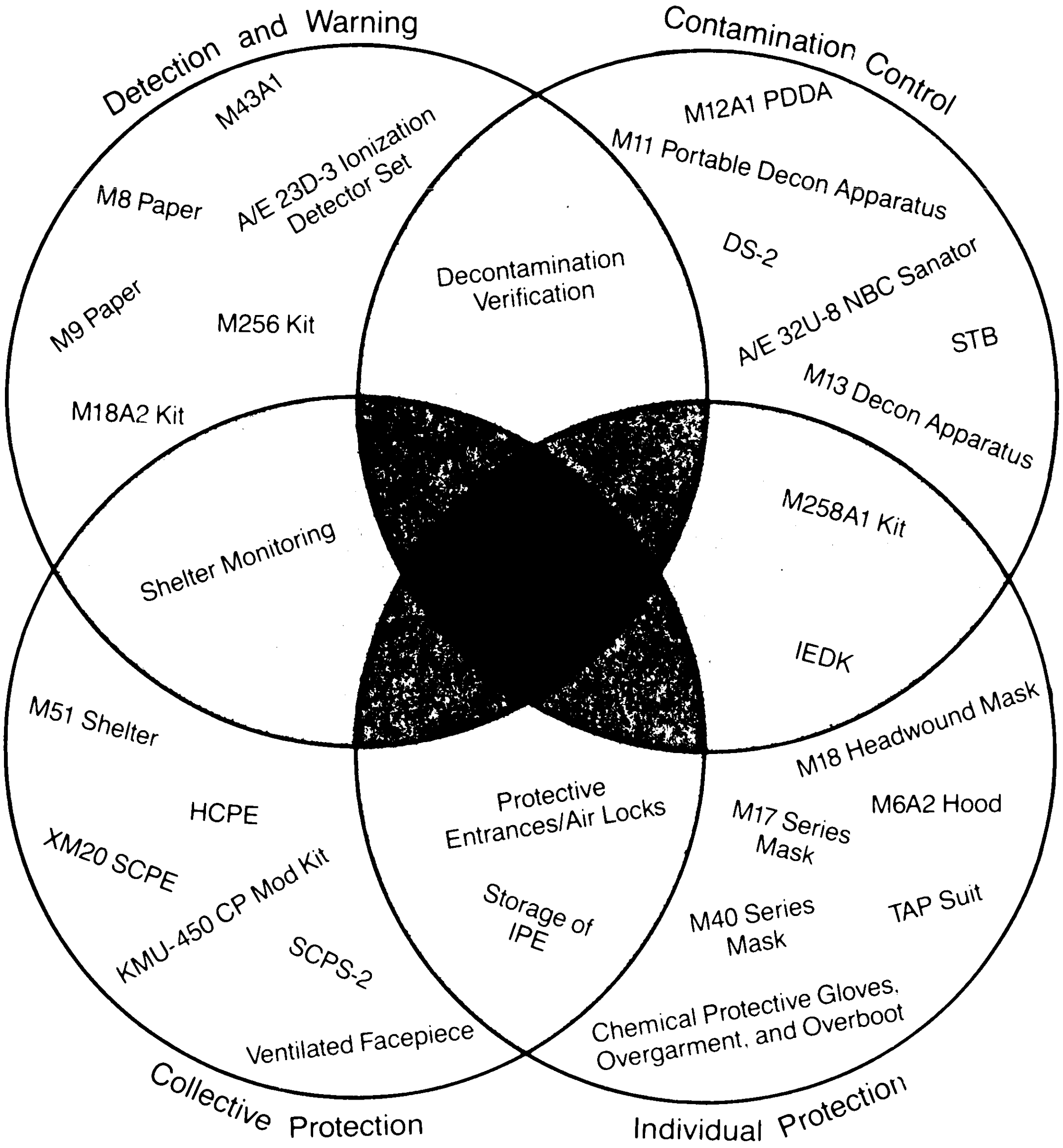

Figure 1-1. **The Interrelationship of US Army CB Defense Program Areas**

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CHAPTER 2
CONTAMINANTS

Chemical and biological (CB) warfare agents represent a very significant threat to the effective performance of military operations. CB agents can kill or incapacitate the soldier or seriously degrade his performance. Unprotected or inadequately protected personnel who are exposed to CB agents can suffer a range effects including skin irritation, sickness, disorientation, and death. Chemical agents can also contaminate and affect the performance of equipment that the soldier must rely on to function effectively. The agents and effects are described in pars. 2-2 and 2-3. A threat overview, given in par. 2-4, discusses agent delivery and dissemination systems and techniques. The chemical and biological hazards associated with agent delivery are also described.

2-1 INTRODUCTION

CB agents have a range of effects on unprotected personnel. Some agents cause mild irritation, sickness, and physical and mental degradation that diminish a soldier’s willingness to fight or impair his fighting skills. Other, more lethal, agents can have rapid and devastating effects. The severity of the effect of a CB agent on exposed personnel depends upon the entry route into the body as well as the dosage and type of agent. CB agents can enter the body through a number of routes: the respirator tract, the eyes, lesions on the skin, ingestion, and direct absorption through the skin.

CB agents can be dispersed by bombs, artillery rounds. rockets. grenades, land mines, and missiles. Additionally, CB agents can be sprayed from land vehicles, fixed-wing aircraft, and helicopters. The agents are disseminated in vapor, aerosol, or liquid droplet form. Vapor and aerosol forms can be readily and rapidly dispersed. They can easily penetrate buildings and vehicles through crevices, cracks, and small openings. Because of this insidious penetration. protection of personnel becomes a formidable task. Even if the personnel are fully protected by wearing protective gear, many gaseous, i.e.. vapor and aerosol, agents can saturate the filters of respiratory devices and render them useless. Liquid agents can gradually penetrate through protective gear to reach the skin and cause a contact hazard. Furthermore, continuous wearing of the protective overgarment and other protective gear will degrade mission performance due to the cumbersome nature of the gear and the thermal burden it imposes on the body. The use of CB agents before launching an attack with traditional weapons can be a decisive factor in the battle because defensive forces are likely to be so weakened that that are unable to defend their positions or to counterattack.

Chemical agents are synthesized chemicals. Although thousands of chemical agent candidates have been designed and tested for military use, only a few have been found to be of practical military value. Some of the criteria used to select suitable agents are

1. Toxicity in extremely small concentrations
2. Toxicity through various routes of entry into the body
3. Time required for onset of symptoms and duration of effect
4. Long-term storage stability
5. Ease of dissemination in practical munitions
6. Low cost (Ref. 1).

Chemical agents may be classified according to their chemical structure, physical and chemical properties, and mode of action. They also may be classified as persistent or nonpersistent depending on the length of time they remain on surfaces. Generally. the effects of chemical agents are acute, that is, the poisoning symptoms appear within minutes to hours.

There are two categories of biological agents: microorganisms and toxins. Microorganisms include bacteria, rickettsias, viruses, and fungi. Because of the incubation period required for the particular disease to spread throughout the body and for the onset of symptoms, microorganisms are considered delayed incapacitating or lethal agents. However, the delay period will be shortened and the symptoms can be much more severe than those of normal infection by the same species of microorganism if a very large dose of agent has entered the body. A mixture of two or more microorganisms can produce complex pathological effects. Furthermore, if agents that cause contagious diseases are employed, a disease can spread to cause an epidemic.

Toxins, the secretions or metabolic products of living organisms, i.e., animals, plants, and microorganisms, can be isolated and stored in munitions. Similar to chemical agents, toxins can produce immediate and acute toxic effects. The extent of the effects depends on the dosage and type of toxin. Some toxins have a cumulative effect, i.e., prolonged low-level exposure can result in the same toxic effect as short exposure at a higher level.

2-2 CHEMICAL AGENTS

2-2.1 CLASSIFICATION OF AGENTS BY MODE OF ACTION

Chemical agents can be classified according to their modes of action as blister, nerve, blood, choking, and incapacitating. Threat agents within each type, along with the common name, symbol, and selected properties, are summarized in Table 2-1. The toxicity of a particular chemical agent depends upon the route of assimilation of that agent into the human body. On the battlefield typical routes of entry include inhalation and or absorption through the eyes and or skin. The toxicities of various agents are provided as a function of route of exposure in Table 2-2. The table also lists the rates at which the body detoxifies agents.

2-2.1.1 Blister Agents

Examples of important blister agents are distilled mustard (HD), lewisite (L), HD and L mixture. and phosgene oxime (CX). The toxic effects of these agents result from their ability to react chemically with biological materials in tissues, including enzymes, proteins, and nucleic acids. The agents act first as cell irritants and finally as a cell poison on all tissue surfaces. Blister agents attack mainly the skin and eyes through absorption and the respiratory system through inhalation. Blister agents

TABLE 2-1. PROPERTIES OF CHEMICAL AGENTS (Refs. 2 and 3)

Agent Type	Common Name (Symbol)	Physical State, At 20° C	Melting Point, °C	Vapor Pressure, Pa	Volatility mg/m^3	Odor
Nerve	Tabun (GA)	Colorless to brown liquid	–50	9.3 @ 25° C	610 @ 25° C	Faintly fruity; none when pure
Nerve	Sarin (GB)	Colorless liquid	–56	385 @ 25° C	22,000 @ 25° C	Almost none when pure
Nerve	Soman (GD)	Colorless liquid	–42	53 @ 25° C	3900 @ 25°C	Fruity; camphor-like when pure
Nerve	VX	Colorless liquid	<–51	0.093 @ 25° C	10.5 @ 25°C	None
Blister	Distilled mustard (HD)	Colorless to pale yellow liquid	14.45	9.6 @ 25° C	610 @ 20°C	Garlic-like
Blister	Phosgene okime (CX)	Colorless solid	35 to 40	1490 @ 25° C	76,000 @ 40° C	Sharp, penetrating
Blister	Lewisite (L)	Colorless to to dark, oily liquid	–18	52 @ 20° C	4480 @ 25°C	Variable; may resemble that of geraniums
Blister	Mustard & lewisite mix (HL)	Dark, oily liquid	–25.4	33 @ 20° C	2780 @ 20° C	Garlic-like
Choking	Phosgene (CG)	Colorless gas	–128	186,200 @ 25°C	4,300,000 @ 7.6°C	Newly mown hay; Green corn
Blood	Hydrogen cyanide (AC)	Colorless gas or liquid	–13.3	98.700 @ 25°C	1,080,000 @ 25°C	Bitter almonds
Blood	Cyanogen chloride (CK)	Colorless gas	–6.9	133,000 @ 25°C	2,600,000 @ 12.8°C	Somewhat like AC; can go unnoticed
Incapacitating	Quinuclindinyl benzilate (BZ)	Beige to white solid	167.5	0.004 @ 70°C	0.5 @ 70°C	None

TABLE 2-2. TOXICITY OF AGENTS (Ref. 3)

Route of Exposure	Toxicity Parameter [(a)]	Toxicity Value [(b)]				
		GB	GD	VX	HD	AC
Whole Body	Detoxification Rate [(c)]	0.0008	0.0008	0.0008	ND	0.13
	Negligible Risk Value [(d)]	data are classified				
Eye	TCT_5	data are classified				
	ICT_{50}	4.0	2.0	4.0	90	ND
	LCT_{50}	70	25	35	ND	ND
	Bliss Slope	7.3	7.3	7.3	7.3	ND
Inhalation	TCT_5	data are classified				
	ICT_{50}	35	15	18	1000	750
	LCT_{50}	70	25	35	1500	1,330
	Bliss Slope	7.3	7.3	7.3	7.3	7.3
Percutaneous Vapor	TCT_5	data are classified				
	ICT_{50}	8500	1900	25	1000	ND
	LCT_{50}	I 5,000	2900	50	10,000	135,000
	Bliss Slope	6.0	6.0	6.0	6.0	6.0
Percutaneous Vapor	TCT_5 [(d)]	data are classified				
	ICT_{50} [(d)]	1,000	207	5	200	NA
	LCT_{50} [(d)]	1,700	350	10	7,000	NA
	Bliss Slope	4.8	4.8	4.8	4.8	NA

(a) TCT_5 = 5% of exposed population will experience recognizable symptoms; ICT_{50} = 50% of exposed population will be incapacitated; LCT_{50} = 50% of exposed population will die without treatment; Bliss Slope = probit slope of dose response

(b) Units are mg X min/m^3 unless specified otherwise; ND = no data; NA = not applicable

(c) in mg m^3

(d) in mg 70-kg man

Note: Information in this table was compiled by the Studies and Analysis Office at Chemical Research, Development, and Engineering Center and involves personal Judgments among data and estimating missing data. The information is subject to change as a result of reexamination of data base (underway within US Army Medical Research and Development Command.)

can also enter the body by ingestion of contaminated food or water. HD has delayed effects–i. e., victims may not notice any effects until 3 to 24 h after exposure. However, delayed action may be shortened if exposure to a large dosage has occurred. In contrast, the effects of exposure to L, HL, and CX are acute and immediately felt as an intense burning sensation. Depending on the degree of exposure, the effects of blister agents on skin range from itching, inflammation, and burning to the formation of large, water-filled blisters (ulceration). Blister agents cause conjunctivitis (inflammation) and swelling when absorbed into the eyes. In severe exposure, victims may suffer permanent loss of sight. Blister agents affect the respiratory system by causing nasal catarrh (inflammation of the mucous membrane), hoarseness, sore throat, and coughing. In severe cases chemically triggered bronchitis and pulmonary edema (abnormal accumulation of liquid in the lung tissues) may develop. After poisoning there is a risk of infection that may lead to death.

2-2.1.2 Nerve Agents

The most toxic nerve agents are tabun (GA), sarin (GB), soman (CD), and the V-series agents including VX. Nerve agents inhibit or inactivate the enzyme acetylcholinesterase that hydrolyzes acetylcholine released during neurotransmission. The resultant accumulation of acetylcholine interferes with the normal function of the central nervous system and muscles.

Nerve agents in vapor or aerosol form can be inhaled, and in liquid form they can enter the body through the eyes or by skin absorption. Poisoning can also occur by ingesting food or water contaminated with nerve agents. The route of entry is important with regard to the time required for the onset of symptoms. Onset is most rapid when nerve agents are inhaled. The degree of poisoning is dependent on the concentration of the agent inhaled. For large doses symptoms can appear minutes alter inhalation of agent-contaminated air and death can soon follow. Toxic symptoms usually do not appear for a half hour or so when the nerve agent enters the body through the skin. This delayed appearance of symptoms is dangerous because the victim may have received a lethal dose of the agent without realizing it. Consequently, the victim takes no countermeasures such as removing the remaining agent droplets from the skin.

The route of entry is also significant with regard to the degree of toxicity of the nerve agent. For example, GA is about five times more toxic if it enters the body via ingestion than if it penetrates through the skin. In this case GA absorbed through the skin is partially degraded by enzymes to form less toxic or nontoxic products.

The initial symptoms of nerve agent poisoning include irritation of the eyes. contraction of the pupils, and deterioration of vision, i.e., the victim feels pain when attempting to focus on nearby objects. The follow-on symptoms are headache, increased production of saliva, a runny nose, tightness of the chest, and difficulty in breathing. In the case of severe poisoning the symptoms described become intensified, and additional symptoms may develop such as excessive salivation, nausea, vomiting, involuntary urination and defecation, general muscular weakness, convulsions, and respiratory paralysis.

2-2.1.3 Blood Agents

The most commonly encountered blood agents are hydrogen cyanide (AC) and cyanogcn chloride (CK). Blood agents are toxic because they react with and inactivate cytochrome oxidase, the vital enzyme responsible for the exchange of oxygen from hemoglobin in the blood to the tissues. Blood agents attack victims via the respiratory system. Because blood agents must be inhaled to be effective, they are delivered typically in vapor or aerosol form.

Inhalation of a low dose of blood agents causes a feeling of weakness, giddiness, headache, confusion, nausea, and sometimes, vomiting and rapid breathing. These symptoms can be followed either by a decrease in respiration frequency (apnea) or by panting and finally by coma or death. Inhalation of a large dose of blood agents causes a rapid onset of the same sequence of symptoms. The victims can suddenly collapse and die within minutes. A remarkable feature of acute poisoning is that the skin has a faint pale red hue because of oxygen deficiency in the tissues.

2-2.1.4 Choking Agents

The most notorious example of a choking agent is phosgene (CG), which is thought to be responsible for 80% of the deaths by chemical poisoning that occurred during World War I. Chlorine gas is also classified as a choking agent. Choking agents irritate the eyes and attack the respiratory system including the throat, respiratory tract, and lungs. There have been no reports of poisoning resulting from choking agents introduced via skin absorption or by ingestion. Because choking agents affect mainly the respiratory system, they are delivered in either vapor or aerosol form.

The full effects of poisoning by choking agents are not apparent until several hours after exposure. This delayed action is highly dangerous because exposed victims may be unaware of their exposure; thus a medical remedy may not be taken immediately. The symptoms of choking agent poisoning include coughing (sometimes with bloody phlegm), choking. tightness of the chest, shallow breathing, and pulmonary edema.

2-2.1.5 Incapacitating Agents

The most common example of incapacitating agents is quinuclindinyl benzilate (BZ). The pharmacological action of BZ is the same as that of other anticholinergic drugs. e.g., atropine. BZ mimics and competes with acetylcholine and therefore interferes with the normal function of the nervous system. The effects of BZ persist for 3 to 5 days, and during this period victims are not fit for combat. Victims must also be closely supervised, which further reduces personnel resources.

BZ enters the body via ingestion or inhalation. The initial symptoms for BZ poisoning usually appear 2 to 4 h after exposure. Symptoms include deterioration of close-range vision, dryness of the mouth, and palpitation of the heart. The skin becomes dry, the face shovs a marked reddish hue. and body and skin temperatures rise. The victim starts to feel sick and vomits.

After 3 to 6 h the central nervous system is affected. and the victim experiences a loss of balance and difficult~ coordinating various muscular movements. The immediate memory deteriorates considerably and the victim becomes confused as to time and space. Optical illusions may follow and are succeeded by hallucinations that affect both sight and hearing. Sometimes a victim’s behavior may become abnormal, i.e., there may be a feeling of persecution and great anxiety or a desire to withdraw from the environment. One of the greatest risks involted in BZ poisoning is death due to an elevated temperature, especially in hot climates. In his degraded mental state the victim can injure himself or others. Although BZ affects mental functions for a relatively long duration, it usually produces no permanent effect.

2-2.2 CLASSIFICATION OF AGENTS BY PERSISTENCE

The length of time an agent remains in the environment is called persistence. Persistence is dependent upon several factors: agent volatility, agent droplet sizes (if liquid), meteorological conditions, and the types of surfaces and materials onto which the agent is deposited. persistence generally increases as agent volatility decreases or as agent droplet size increases. Wind speed, air temperature, and atmospheric stability greatly affect agent persistence. High wind speeds and high temperatures cause relatively rapid evaporation of an agent and thereby reduce persistence. Stable atmospheric conditions and cold temperature, however, increase persistence. The material onto which an agent is deposited has a significant effect on persistence. Persistence decreases if the surface is composed of impermeable materials that allow exposure of the agent to weathering. In the case of permeable surfaces, the agent can be absorbed into the material matrix. This absorption reduces exposure to weathering and increases persistence.

Based on volatility, chemical agents can be classified as persistent and nonpersistent. Persistent agents have a low volatility and evaporate slowly and thus are both a direct contact hazard and an indirect vapor hazard. Surfaces that have been exposed to a persistent agent can remain contaminated for hours, days, or even weeks after the initial chemical attack. Nonpersistent agents, however, are released in a gaseous form or as a liquid that evaporates rapidly. For this reason nonpersistent agents do not present as great a contact hazard as persistent agents. The classification of chemical agents on the basis of their persistence is an important tactical consideration because it enables military commanders, to predict the duration of the contamination and thus choose the proper offensive or defensive actions. which include the need for decontamination. Table 2-3 lists the persistence of several agents on soil under different enironmental conditions.

TABLE 2-3. PERSISTENCE OF CHEMICAL AGENTS ON SOIL UNDER DIFFERENT WEATHER CONDITIONS (Ref. 4)

Agent	Sunshine, Slight Wind, 15° C	Rainfall, 10°C	Sunshine on Snow, −10°C
GB	0.5-4 hours	0.25-1 hours	l-2 days
GD	2.5-5 days	3-36 hours	1-6 weeks
HD	2-7 days	12-48 hours	2-8 weeks
VX	3-21 days	1-12 hours	1-16 weeks

From *The Detoxification and Natural Degradation of Chemical Warfare Agents, Volume 3*, R. Trapp. Published by Taylor & Francis, Bristol, PA. Copyright @ 1985 by SIPRI (Stockholm International Peace Research institute).

To facilitate dispersion. prolong persistence, and, if possible, hinder decontamination operations, persistence of an agent can be increased significantly by adding polymeric thickeners that retard the evaporation rate. When the thickened agent is disseminated, the formation of larger droplets retards the evaporation rate. Larger droplets require more time to evaporate than the smaller droplets produced when a "neat" agent, i.e., unthickened agent, is disseminated. A neat agent differs from its thickened version primarily in viscosity. The use of a thickener increases the viscosity by one to two orders of magnitude. Most other physical properties are not affected because only 2 to 5% of the thickened agent is polymer.

2-2.2.1 Persistent Agents

As previously noted, persistent agents pose both direct contact and indirect vapor hazards. When an attack is intended to obstruct and delay enemy activities in critical areas, a persistent agent can be employed. Persistent agents are used to contaminate ground surfaces, impair the use of critical terrain, channel the attacking force. and prolong the contamination of military equipment and systems (Ref. 5). Persistent agents can be used to accomplish the following tactical tasks (Ref. 5):

1. Contaminate rear area depots
2. Defend avenues of approach
3. Neutralize personnel defending a strong point
4. Protect flanks.

Generally, VX, HD, thickened HD (THD), and HL are considered persistent agents:

1. VX. At room temperature, VX is a colorless and odorless liquid with low volatility. VX does not evaporate rapidly and may last for days to weeks at moderate temperatures.

2. *HD and THD.* HD and THD are persistent under temperate conditions. However, because of the relatively small droplet size produced when they are disseminated, neat HD evaporates fairly rapidly at higher temperatures and thus is less persistent in hot climates than THD.

3. *HL.* This is a variable mixture of HD and L that has a low freezing point which allows its use in cold weather operations or as a high-altitude spray. A eutectic mixture is prepared by mixing 63% L and 37% HD by weight. Other mixtures may be prepared to meet predicted weather conditions. The duration of its effectiveness depends on the type of munition used and the environmental conditions. Persistence may be for 1 to 2 days under normal weather conditions and a week or less in a ~er~r cold environment.

2-2.2.2 Nonpersistent Agents

Nonpersistent agents can be disseminated in vapor, aerosol. or liquid form. Once disseminated, liquid nonpersistent agents evaporate rapidly and, consequently. pose an immediate vapor hazard. If the attacker wants a short contamination period to facilitate a follow-on operation. nonpersistent agents are most suitable. Nonpersistent agents cause immediate casualties and thereby degrade the fighting capability of enemy forces (Ref. 5). The principal advantages are to

1. Induce casualties prior to an assault
2. Degrade the performance of troops by forcing them into a higher mission-oriented protective posture (MOPP) level
3. Allow occupation without decontamination.

A disadvantage in the use of nonpersistent agents in the vapor form is that their persistence and the direction of drift is greatly affected by environrnental factors such as air temperature. wind speed and direction, and atmospheric stability. Thus tactical use may be limited to a narrow range of environmental conditions.

Nonpersistent agents include nerve agents GA, GB, CD. and thickened GD (TGD); the choking agent CG; blood agents AC and CK; and the incapacitating agent BZ.

1. *G-series Agents.* These agents are liquid under ordinary atmospheric conditions. They are relatively volatile and thus evaporate rapidly. The persistence of G-series agents ranges from several minutes to days, depending on the individual agent, the form in which it is disseminated, and weather conditions. TGD can persist for several days under cold weather conditions.

2. *CG.* This choking agent is a gas at temperatures above 7.6°C. CG is extremely volatile even at low temperatures. For example, the volatility of CG is 422,000 mg/m^3 at –40^{0}C. Therefore, CG is always disseminated in the vapor form. Inhalation causes severe damage to the respiratory system that may lead to death. The persistence of CG is short; however, in low places with still air or light winds and stable atmospheric conditions, persistence increases.

3. *AC and CK.* These two blood agents are highly volatile. Because AC and CK are gases that are lighter than air. their persistence in a normal environment is very short. However, they can persist for longer times in Jungles and forests under stable atmospheric conditions.

4. *BZ.* This incapacitating agent is very stable in the natural environment, and because of its low volatility, it is disseminated as an aerosol rather than a vapor. Even though BZ can be deposited on surfaces. it is not readily reaerosolized. Therefore, its persistence as a hazard is short.

2-3 BIOLOGICAL AGENTS

Two categories of biological agents are microorganisms and toxins. Microorganisms are small. usually single-cell, life forms that infect the host and cause sickness and death by attacking a critical organ. Microorganisms applicable to biological warfare include bacteria, viruses, rickettsias, and fungi. Microorganisms often cause damage by the release of substances into the body. These substances, which may be digestive enzymes, intermediate metabolites, or waste products, are referred to as toxins the other category of biological contaminants. Microorganisms, plants, and animals can produce lethal toxins.

Toxins are complex natural chemical products produced by living organisms including microorganisms, animals, and plants. Toxins are chemicals in the sense that they do not reproduce themselves and have no infective properties, but because of their biological origin, they are classified as biological agents.

A toxin is generally extracted either from the organism that produces it or from a growth medium. Microbial toxins are the most likely candidates for large-scale production of biological agents because they can be produced by fermentation. Organic chemical synthesis of a toxin molecule is possible but not considered practical due to the intricacies of the processes involved. Recombinant genetic methods using living organisms are becoming increasingly feasible for large-scale toxin production. but no practical process is expected for at least 10 years.

The severity of the effects of microorganisms depends on the characteristics of the specific agent, the route of entry into the body, the natural defense systems of the body against the specific agent, and the speed of medical treatment. Because microorganisms require a comparatively long incubation period, symptoms and effects generally do not appear for several days after exposure. However, massive doses may shorten the incubation period and greatly accelerate the progress of the disease. Furthermore. the use of a mixture of more than one agent can produce such a complexity of symptoms that even the most experienced physicians fail to recognize the causal agent.

Biological agents may enter the body through the respiratory tract. lesions on the skin. or by ingestion of contaminated foodstuffs or liquids. Biological agents may also be introduced through a skin wound or by a bite from a vector (flea, tick, mite, etc.).

The ability of microorganisms to survive in the environment is influenced by such factors as light. temperature, and humidity. Most microbial agents are destroyed by prolonged exposure to sunlight. They also tend to die more rapidly at high temperatures and low humidity. Therefore. the most favorable conditions for their employment normally exist at night from about one hour before sunset to about one hour after sunrise.

2-3.1 MICROORGANISMS

The military applications of microbiology concern only those microorganisms that may be employed in weapon systems designed to cause disease or death in humans. As stated earlier, microbial agents include bacteria, viruses. rickettsias, and fungi. Although some protozoa and algae are also pathogenic microorganisms, at present they have little military value.

Almost any disease-causing microorganism is a candidate for use as a biological weapon. Consequently, the number and types of’ potential agents are boundless. A representative list of biological agents is given in Table 2-4. Mortality rate, incubation periods. and general symptoms are also presented in the table.

2-3.1.1 Bacteria

Bacteria are unicellular, microscopic, plant-like organisms. They outnumber all other forms of microorganisms. It is estimated that bacteria comprise approximately 60 to 65% of the different species of microorganisms. In most cases bacteria are in the active growth form, i.e., vegetative cells. Some bacterial vegetative cells are capable of sporulation, i.e., they hate the ability to form spores, when environmental conditions become unfavorable. During sporulation vegetative cells lose water, shrink somewhat, thicken their cell walls, and finally, transform into spores.

TABLE 2-4. BIOLOGICAL CONTAMINATION – MORTALITY RATES AND INCUBATION PERIODS OF MICROORGANISMS
(Data Extracted from Refs. 6 through 10)

Type	Mortality, %	Incubation Period, days	Symptoms
Anthrax (pulmonary) (*Bacillus anthracis)*	100	1-5	For inhalation, onset is mild; resembles upper respiratory infection. For skin, a painless pustule forms on exposed surface and causes mild fever, headache, and malaise followed by cyanosis, dyspnea, mediastinitis, and hemoptysis
Brucellosis *(Brucella)*	2-5	5-21	Low-grade fever, chills, headaches, weakness, insomnia, sweating. anorexia. pain over the spine, and malaise. Other complications include orchitis, subacute bacterial endocarditis, and ocular disorders
Cholera *(Vibrio cholerae)*	10-80	1-5	Sudden onset of diarrhea. vomiting, muscular cramps, and collapse. Dehydration leads to cyanosis, pinched facies, loss of skin turgor, and thready peripheral pulses
Glanders *(Actinobacillus mallei)*	100	1-5	Acute localizcd supportive infection, acute pulmonary infection, acute septicemia, and mucous membrane discharge
Plague (pneumonic) *(Yersini pestis* or *Pasteurella pestis)*	100	2-5	Severe lymph node infection with very tender and sometimes necrotic lymph nodes; also, prostration, cough, dyspnea, and cyanosis
Tulermia *(Pasteurella tularensis or Francisella tularensis)*	usually low	1-10	Sudden onset with high fever, chills, and prostration. Enlarged lymph nodes
Dysentery or Shigellosis *(Shigella species)*	<10	1-4	Fever, crampy lowerl abdominal pain, and diarrhea that may be bloody
Q-fever *(Coxiella burnetti)*	<1	14-26	Headache, chills, fever, rnalaise, myalgia. and anorexia
Rocky mountain spotted fever *(Rickettsia rickettsii)*	20	2-14	Severe headache, shaking, rigor, prostration, myalgia (especially in back and legs), nausea, vomiting, and fever
Typhus (epidemic) *(Rickettsia prowazeki*	10-40	5-15	Headache, chills. and fever followed by spasticity, agitation. stupor, and coma
Chikungunya fever	<1	3-12	Abrupt onset of fever, rigor, headache, pain in the large joints, skin rash on trunk, myalgia, and pharyngitis
Dengue fever	< 1	5-8	Abrupt onset ot headache, retro-orbital pain, backache, leg and joint pain, and pain with eye movement
Yellow fever	30-40	2-6	Sudden onset of headache, dizziness, fever, slowing of pulse followed by neck, leg, and back pain, nausea, and vomiting. In severe cases there are hemorrhages, 1oss of urine output, and delirium.

(con'd on next page)

TABLE 2-4. (cont'd)

Type	Mortality %	Incubation Period, days	Symptoms
Smallpox	25-40	6-22	Fever, backache, myalgia (especially of the back), abdominal pain followed by pustule formation. In severe forms there are severe prostration, bone marrow suppression, hemorrhagic skin lesions, and bleeding. Death occurs in 3 to 4 days from onset of symptoms.
Coccidioidomycosis *(Coccidioides immitis)*	<10	7-21	Half of victims are asymptomatic: others have fever, chills, fatigue, headache, severe arthralgia, skin rash, and symptorns of respiratory infection.

It should be noted that not all bacteria can form spores, and sporulation does not alway's occur in response to unfavorable conditions. Furthermore, bacteria sporulation is not a reproductive process; it is a mechanism for survival in unfavorable conditions. One vegetative cell can transform into only one spore. and the spore can eventually transform back into one vegetative cell. Bacterial spores are more resistant than their growth cell forms to unfavorable environments such as those characterized by nutrient depletion, extreme temperatures, dry weather. sunlight exposure, and oxidation. Because spores can remain quiescent for years without requiring nutrients and water, they pose a prolonged threat in a contaminated area. Spores can also be carried by animals and wind to spread far beyond the originally contaminated area. It is relatively difficult to destroy spores, so affected areas are difficult to decontaminate.

Bacteria in the growth form can be classified according to shape into three main groups: bacilli (rod shaped), cocci (round or spherical shaped), and spirilla (comma or spiral shaped). They cause many common diseases in man, animals, and plants. Of approximately 2000 identified species, however, only about 100 are known to be pathogenic and less than 10 are suitable as biological agents. Examples of bacteria-induced diseases include anthrax, tularemia, tuberculosis, typhoid fever. dysentery, plague, brucellosis, glanders, cholera, gonorrhea, and syphilis.

2-3.1.2 Viruses

Viruses are the smallest of the microorganisms; they range in size from about 0.01 to 0.27 pm across their greatest dimension. Viruses are so small that they can pass through filters that trap other microorganisms. Unlike bacteria, viruses must live in a living host cell in order to reproduce. Also viruses do not have the capability of sporulation, but because they have a protective protein coating, viruses are resistant to unfavorable environmental conditions.

Approximately 60% of all infectious diseases in humans are caused by viruses. Examples of virus-induced diseases are rabies, smallpox, yellow fever, encephalitis. mumps, measles, chickenpox, influenza, and the common cold. Unfortunately, most diseases of viral origin do not respond to antibiotic treatment.

2-3.1.3 Rickettsias

Rickettsias are considered intermediate in sizc between bacteria and viruses. They usually range from 0.3 to 0.5 μm in length and about 0.3 pm in diameter. Rickettsias resemble bacteria in shape and resemble viruses in their strict reproduction requirements for living host cells. Most rickettsias choose lower rank animals is their primary hosts. but they can be transmitted to human beings by vectors such as ticks. fleas, and mites. Examples of rickettsia-induced human diseases are typhus fever, spotted fever, scrub typhus, and Q fever.

2-3.1.4 Fungi

Fungi are unicellular or multicellular members of the plant kingdom ranging in size from 3 to 50 μm. They are usually rod-shaped and arranged end to end in strands or filaments. Fungi include molds, mildews, smuts, rusts, mushrooms, toadstools, puffballs, and yeasts. Examples of fungal diseases include ringworm, athlete's foot, coccidioidomycosis, favus, and thrush.

Unlike the requirement for bacteria, sporulation is an essential part of the reproductive process in the life cycle of fungi. One fungus vegetative cell can reproduce to form several to hundreds of spores. As with bacterial spores, fungous spores are resistant to unfavorable environmental conditions and are difficult to destroy. Therefore, they also pose prolonged threats.

2-3.2 TOXINS

Toxins are complex natural chemical products produced by living organisms including microorganisms, animals, and plants. Toxins are chemicals in the sense that they do not reproduce themselves and have no infective properties. Because of their biological origins, however, toxins are classified as biological agents.

A toxin is generally extracted either from the organism that produces it or from a growth medium. Microbial toxins are the most likely candidates for large-scale production of biological agents because they can be produced by fermentation. Organic chemical synthesis of a toxin molecule is possible but not considered practical because the processes involved are very complex. Recombinant genetic methods using living organisms are becoming increasingly feasible for large-scale toxin production, but no practical process is expected for at least 10 years.

The toxins are so varied that classification by structure, symptoms. or effects is difficult. Toxins generally have low vapor pressures and volatilities: they are stable components that persist for long periods, i.e., years, in the environment. Toxins are either solids or liquids in their pure state but may be dissolved or suspended in solution when present in a biological system. Toxins can be dispersed as liquid aerosols or powders.

As with chemical agents. toxins can enter the body through the respiratory tract, lesions on the skin. by ingestion, or even by absorption directly through the skin. The extent of the effects depends upon the dosage, and some toxins may have a cumulative effect.

Although there are hundreds of different types of toxins. only a few toxins are used as examples. The mortality rate and a brief description of poisoning symptoms for these toxins are given in Table 2-5.

Botulinus toxin, often mentioned in the discussion of biological weapons, is a highly lethal agent (1 billion times more lethal than VX on a molar basis). The mode of action and clinical manifestations of botulinus toxin poisoning are used as an example of toxin activity.

Botulinus toxin, the causative agent in certain cases of severe food poisoning, has been shown to prevent the release of the neurotransmitters in the synaptic areas of the nervous system and thus blocks the normal conduction of nerve impulses. This can result in respiratory paralysis and ultimately death.

The symptoms of botulinus toxin poisoning may vary from a mild to a fulminant disease ending in death within 24 h. Symptoms usually begin 23 to 36 h after ingestion of the toxin. although extremes of 3 to 14 days have been recorded. In general, the earlier the symptoms appear, the more serious the outcome. Symptoms first appearing in the ocular area include diplopia (double vision of a single object), blurred vision, and photophobia (intolerance of

TABLE 2-5. BIOLOGICAL CONTAMINATION – MORTALITY RATES OF TOXINS (Data Extracted from Refs. 6 through 10)

Type	Mortality, %	Onset Period, h	Symptoms
Botulinus toxin termed from *(Clostridum botulinum*	75	12-36	Most common symptoms are ocular: diplopia, blurred vision, and photophobia. Other symptoms include constipation, urine retention, and reduced salivation and lacrimation.
Mycotoxins (tricothecene type)	ND	ND	Effects vary considerably. In general tricothecenes act as hepatotoxins, nephrotoxins, dermatoxins. alimentary toxins, and neurotoxins.
Saxitoxin (shellfish toxin)	ND	0.25-4	Tingling numbness in the facial area with muscular weakness and prickly feelings in the fingertips followed by increasing lack of muscular coordination, paralysis, and respiratory failure.
Tetrodotoxin	ND	0.25-0.75	Nausea, vomiting, diarrhea, and epigastric pains; tingling and prickling in the extremities. dizziness, pallor. and malaise; followed by muscular paralysis, tremor, and coma.
Ricin (castor bean)	ND	6-10	Nausea, vomiting, bloody diarrhea, abdominal cramps, tenesmus. drowsiness. stupor, cyanosis, and dehydration followed by anuria that can pro~oke death by uremia.

ND = no data

light). Constipation, urine retention, and reduced salivation may follow. Finally, muscular and respiratory paralysis may occur, which lead to death.

2-4 THREAT OVERVIEW

The capability for conducting CB warfare has proliferated beyond the U.S. and Union of Soviet Socialist Republics (U.S.S.R.). A recent Department of Defense (DoD) publication estimated that 15 nations are currently known to possess stocks of chemical agents (Ref. 1l). Because these chemical agents can be so readily produced or purchased, this number could easily increase. Any nation with an industrial chemical base is capable of producing chemical agents.

Specific details of biological warfare (BW) capabilities are difficult to gather and nearly impossible to verify. Part of the problem is the ease with which the production and dissemination of biological agents can be disguised. Facilities that are normally used to produce pharmaceutical products can produce BW agents. Deliberate dissemination of BW agents might be labeled a natural occurrence. For instance, an apparently accidental release of anthrax (an identified Soviet BW agent) from a probable Soviet BW facility in Sverdlovsk was believed to have infected over 3000 Soviet citizens. The Soviet government blamed the anthrax outbreak on the illegal sale of contaminated meat in the black market. Although not easily proven, the available evidence strongly indicates that biological weapons are a viable threat and may be available to several nations. The Soviet Union is known to have an active biological weapons research and development program. In addition, the Soviet Union and its allied nations have been accused of employing toxins in Afghanistan and Southeast Asia.

2-4.1 DELIVERY AND DISSEMINATION SYSTEMS

Because the Soviet Union is believed to be the best-prepared nation in the world for waging CB warfare, the paragraphs that follow will focus on currently fielded Soviet delivery and dissemination systems and the threats they pose.

Almost all Soviet conventional weapon systems are believed to have compatible chemical munitions or warheads. The various delivery and dissemination systems include

1. Tactical rockets and missiles
2. Aerial bombs
3. Multiple rocket launchers
4. Artillery and mortars
5. Fixed-wing aircraft or helicopters equipped with spray tanks (Ref. 1l).

The probable agent fills, as well as the fuzing mechanisms associated with each of the major delivery systems, are described in Ref. 12. This classified document also identifies the phase of the agent hazard, vapor or liquid, that is expected to result from the various combinations of agents and fuzing mechanisms. Nonpersistent agents delivered as vapors or aerosols produce an immediate, short-term, and severe hazard. Unprotected personnel will quickly become casualties. The persistent agents are generally delivered as liquid droplets or “rain”. The intent is to deny the enemy access to various assets and areas or force him to employ protective measures for extended periods of time.

Under a hypothetical attack scenario, CB agents of all three persistency types persistent (lasting for days), semipersistent (lasting for hours), and nonpersistent (lasting for minutes) could be delivered at the forward line of own troops (FLOT). In this case a cloud of nonpersistent agent is used at the point of attack and immediately decimates the unprotected troops. Because the cloud rapidly dissipates, the offensive troops have a clear path for advance. A persistent agent is laid down on the flanks so that the effectiveness of the defending force will be decreased and any attempt to counter attack will be hampered. Semipersistent and nonpersistent agents are employed immediately behind the FLOT to impair operations. Nonpersistent agents kill any unprotected soldier, and semipersistent agents force the surviving troops into their individual protective equipment. These agents also force the mobile units and semimobile units to abandon contaminated positions. Semipersistent agents insure that these areas will be free of contamination when the attacking forces arrive. The rear-echelon elements are attacked with long-range missiles and tactical bombers using nonpersistent and persistent agents. Again the unprotected troops are killed immediately with a cloud of nonpersistent agent, and surviving troops are threatened with the residual persistent agents and are forced to operate in protective equipment, which severly decreases their fighting effectiveness. The most likely targets for this type of attack include points of debarkation, supply centers. command and control centers, and air bases.

Microencapsulation, the technique of encasing extremely small liquid droplets or solid particles of CB agents in a protective and functional coating, is possibly a new method for chemical agent delivery. The technique can also be used to control agent volatility, stability, and durability and to provide a controlled mechanism for timely release of chemical agents. This use would aid in the tactical use of agents to achieve a desired goal. Most of the information regarding microencapsulation for this application is classified, and detailed discussion can be found in Refs. 13 and 14.

2-4.2 RESULTANT HAZARDS

2-4.2.1 Chemical Agent Hazards

The hazards that result from chemical attack are usually categorized as being liquid, vapor, or aerosol.

Liquid hazards result primarily from persistent agents disseminated by aerial techniques. These techniques, sometimes called "rain" dissemination techniques, may include the use of spray tanks or missiles and bombs that release their chemical payloads before impact. The liquid droplets formed upon release fall to earth with little vaporization and persist for an extended time. The most severe vapor and aerosol hazards result from the employment of nonpersistent agents because these agents vaporize rapidly upon dissemination.

2-4.2.1.1 Liquid Hazards

Liquid droplets are more persistent than vapors or aerosols. Depending on the type of agent and the atmospheric conditions, liquid agents may persist for days or weeks. Liquid droplets produce both secondary vapor, i.e., vaporization after falling to the earth. and contact hazards. In liquid form agents can penetrate the individual protective gear and reach the skin where they can be directly absorbed. Even a small droplet on the skin—for example, about 1 mg of VX —can be lethal.

Some liquid agents damage and degrade equipment and systems. In severe cases the agents may deteriorate systems to a level of malfunction. Liquid agents. if deposited onto porous material surfaces. can be absorbed into the material matrix, and decontamination becomes difficult. In this case the contaminated equipment and systems not only become difficult to handle due to potential contact hazards, but also may later desorb agents, which would cause a vapor hazard for an extended time period. A vapor hazard is particularly a threat in a warm environment. Furthermore. the contaminated vehicles, tanks, and other equipment may spread contamination to other areas if not properly decontaminated.

2-4.2.1.2 Vapor Hazards

Nonpersistent agents in vapor or aerosol form rapidly disperse over large areas. Unprotected personnel, even within an enclosed building, can be affected because gaseous agents diffuse through small holes, crevices, and cracks in the structure or through windows and doors that are not tightly sealed. inhalation of agent vapors can cause either immediate or delayed casualties. Exposure of an hour or more may be required to develop cumulative dosage effects. Concentrated agent vapors can be absorbed through the skin. Agent vapors, especially if in a high concentration, can also be absorbed into material matrices. Resorption of absorbed agents may later produce prolonged residual vapor hazards, and the desorbed agents may be more hazardous to personnel than traditionally believed because after several hours of combat, soldiers unaware of agent resorption may doff cumbersome protective gear and thus expose themselves directly to the toxic vapors.

2-4.2.2 Biological Agent Hazards

Biological agents disseminated in aerosol, liquid, or solid form can enter the body through inhalation, lesions on the skin, and ingestion. Such agents generally affect only living organisms and do not damage or degrade materiel quality. Delayed casualties result if microbial agents contact the body, and immediate and acute effects result if toxins enter the body. When microbial agent-affected victims are not properly treated or isolated, the agents may spread and reach epidemic proportions. Even if the proper countervailing actions—such as isolation, immunization, and sanitation— are taken, available manpower and other resources can be exhausted quickly. Furthermore. bacterial and fungous spores are very persistent in virtually all environments. They may survive for years in a harsh environment without nutrients and water. Then when conditions become favorable, spores may transform into vegetative cells to produce casualties in the area several years after the original contamination.

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CHAPTER 3
PROTECTION, DETECTION, AND CONTAMINATION CONTROL

The USA Army has established chemical and biological (CB) defense programs to reduce the threat posed by CB agent contamination. The programs focus on (1) protection (individual, collective, and equipment and supplies), (2) detection (identification, monitoring, and warning), and (3) contamination control (contamination avoidance and decontamination). A description of these CB defense areas, with the exception of decontamination, is given in this chapter. Current and future decontamination concepts are discussed in Chapters 4 and 6, respectively.

3-1 INTRODUCTION

The overall objective of protection, detection, and contamination control is to prevent CB hazards or reduce their effects. The CB defensive elements discussed in this chapter contribute individually and collectively to the integrated CB defense management. Therefore. the interactions among these defense elements must be understood. For example, effective collective protection shelters (CPS) allow individuals to survive in a CB environment without donning cumbersome individual protective gear, but time-consuming procedures are required for entering and exiting the CPS. Although the donning of individual protective gear allows an individual to perform his mission safely in a CB environment, he may suffer from the psychological burdens of heat stress and impaired sight. speech. hearing, and dexterity. As a result, mission performance is degraded and the amount of time that an individual can wear the protective gear is limited. To minimize the adverse effects o! protective measures, chemical agent detection, identification, and warning (CDIW) can be used for detecting and monitoring CB agents to determine when the level of contamination is sufficiently low so that protective gear and the CPS are no longer required.

3-2 PROTECTION

Protection generally can be divided into three categories: individual, collective, and military equipment and supply. The equipment associated with each of these three categories is discussed in pars. 3-2.1, 3-2.2, and 3-2.3. respectively. Detailed descriptions of each are provided in FM 3-4 (Ref. l).

3-2.1 INDIVIDUAL PROTECTION

The purpose of individual protection is to protect personnel against CB hazards while they perform their mission without interruption. During a CB attack the personnel in an affected area must protect their respiratory systems and eyes against gaseous agents and the skin from direct contact hazards. After a CB attack protective measures may still be required to protect individuals against desorbed agent vapors from the ground, materials, and equipment.

The individual protective equipment (IPE) of the US Army includes masks, hoods, clothing, gloves, and footwear. Currently fielded Army IPE items and their users are listed in Table 3-1.

3-2.1.1 Masks and Hoods

3-2.1.1.1 Mask, Field Protective, M9A1

The M9A1 field protective mask, shown in Fig. 3-1, is designed for the Army special teams. These teams include explosive ordnance disposal (EOD) experts and selected workers assigned to positions of chemical surety in materiel destruction facilities. The mask. when worn with the M3 toxicological agent protective (TAP) mask hood, will protect the wearer's face, eyes, and respiratory tract from gaseous CB agents. The mask also provdes protection for the face and eyes against contamination from liquid droplets and splashed agents. The M9A1 mask has either a right- or left-cheek-mounted M11 canister filter and is available in small, medium, and large sizes (Refs. 2 and 3).

3-2.1.1.2 M11 Canister Filter

The M11 canister filter is an aluminum canister for use with the M9A1 mask. It contains a particulate filter for removal of particulate and aerosols and 250 ml of activated charcoal for removal of chemical agent vapors. The canister is 106.4 mm in diameter and 82.6 mm in length (Refs. 2 and 3).

3-2.1.1.3 Mask Hood, Toxicological Agent Protective (TAP), M3

The M3 TAP mask hood is designed for semipermanent mounting on the M9A1 field protective mask and provides protection for the wearer's head, neck, and shoulders (Ref. 3).

TABLE 3-1. US ARMY FIELDED INDIVIDUAL PROTECTIVE EQUIPMENT (Refs. 2 and 3)

Masks and Hoods			
Mask	Filter	Hood	Users
M9A1	M11	TAP, M3	Special teams
M17 Series	M13A2	M6A2	Infantry teams and all ground support personnel
M24	M10A1	M7	Pilots and aircrews
M25 Series	M10A1	M5	Tankers and vehicle crews

Suit and Overgarments	
Types	Users
Chemical Protection Overgarments	Infantry troops and all ground support personnel
Battledress Overgarment	Troops, pilots, tankers, and vehicle crews
Suit, TAP, M3	Special teams
Coveralls, TAP, M3	Special teams
Apron, TAP, M2	Special teams

Gloves	
Types	Users
Glove Set, Chemical Protective	Infantry troops and all ground support personnel
Gloves, TAP	Special teams

Footware, Covers, and Overboots	
Types	Users
Footwear Covers, Chemical Protective Overboots	Infantry troops and all ground support personnel
Boots, TAP, M2A1	Special teams
Boot Covers, TAP	Special teams

TAP = toxicological agent protective

The hood is made of butyl rubber-coated nylon cloth and has three adjustable openings for the mask eyepiece and canister. To prevent leaking of the CB agent through the needleholes, butyl rubber-coated tape is cemented over the sewn seams of the hood. The lower portion of the hood is a two-layer shawl; the inner layer is placed inside the collar of the protective coveralls and the outer layer rests on the wearer's shoulders. The shawl is held in place by attached tie cords and two adjustable straps worn under the arms and secured in front by snap fasteners (Refs. 2 and 3).

3-2.1.1.4 M17-Series Protective Masks

The M17-series masks are used to protect the face, eyes. and respiratory tract of the wearer against CB agents, but they do not protect the wearer from ammonia or carbon monoxide fumes. The masks are not effective in confined spaces when the oxygen content of the atmosphere is too low (below 18%) to support the individual's functional capability. The M17 masks are used by infantry troops and all ground personnel who are not assigned any special type of mask.

The M17 mask, shown in Figs. 3-1 and 3-2, consists of a rubber facepiece with two replaceable M13A2 filter elements held in cheek pouches. Molded into the facepiece are openings for eye lenses, a nose cup, voicemitter outlet valve assembly, and inlet valves. Clear plastic eye lenses are sealed in the faceblank openings by metal eye-rings, and eye lens outserts are available for installation over the eye-ring to protect the eye lens from scratches. The M17 mask comes in three sizes (Refs. 2 and 3).

Two modified versions of the M17 mask have been developed: the M17A1, which is an M17 mask with both a drinking tube and resuscitation provision, and the M17A2, which has a drinking tube but no resuscitation provision. The M17A2 is the preferred version for the US Army because current doctrine eliminates the use of a resuscitation tube with the protective mask. Current doctrine specifies use of direct pressure, such as the chest push arm lift maneuver, for resuscitation. A special canteen cap issued with the M17A1 and M17A2 masks is required to interface with the liquid-intake provision of the masks. The M17A1 mask and M17A2 mask come in four sizes (Refs. 2 and 3).

3-2.1.1.5 M13A2 Filter Element

An M13A2 filter element is mounted on each of the cheek pouches of the M17 mask. The filter element can filter out CB agents in gaseous, liquid, and particulate forms. but it cannot filter out carbon monoxide and ammonia in ambient air (Refs. 2 and 3).

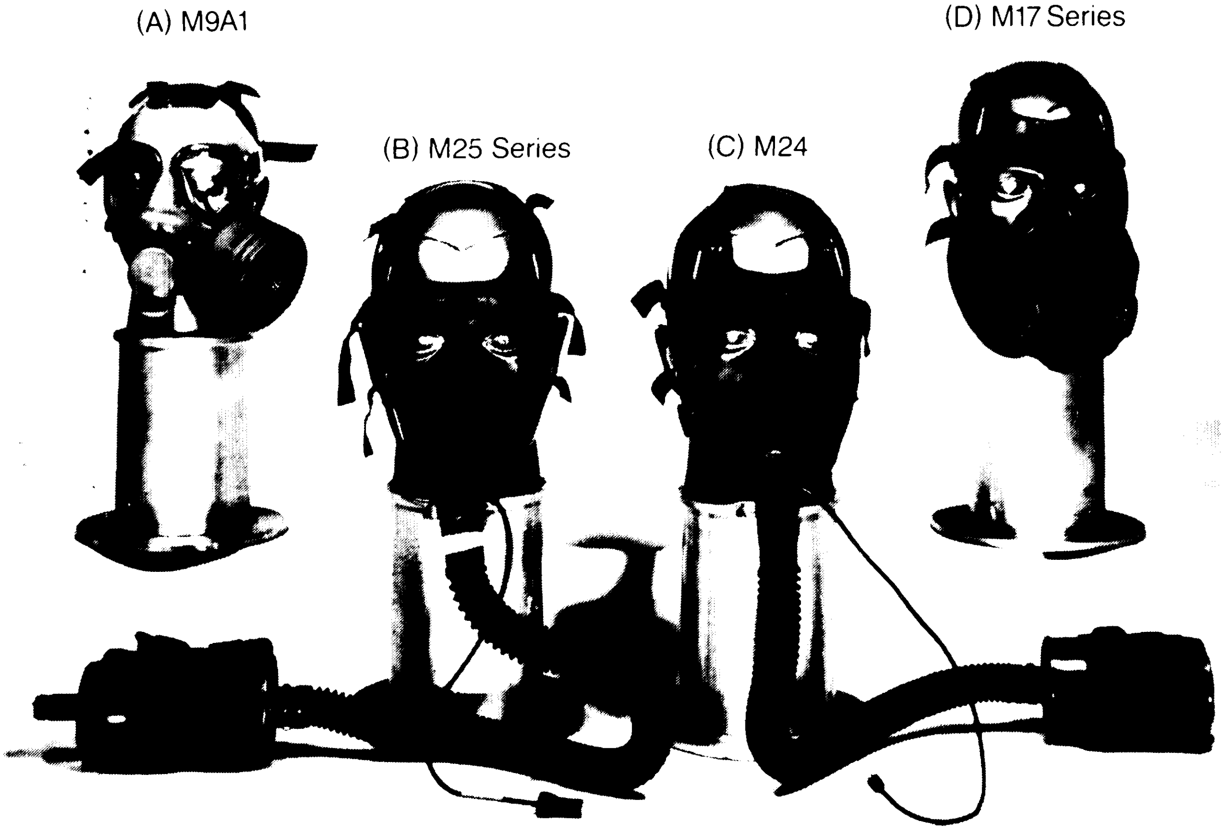


Figure 3-1. Protective Masks

3-2.1.1.6 M6A2 Protective Hood

The M6A2 hood, shown in Fig. 3-2. is used to cover the wearer's head, neck, and shoulders. The hood protects portions of the skin not covered by the mask against gaseous and liquid chemical agents and biological agents.

The hood. which is made of butyl rubber-coated nylon cloth, has openings that fit around the eye-rings, inlet valve assemblies, and voicemitter outlet valve assembly of the mask. The hood also has a zipper below the voicernitter opening to facilitate donning and doffing. A neck cord is provided to hold the hood snugly around the wearer's neck. Two adjustable underarm straps on the cape of the hood hold it in position on the shoulders. These are secured with hook and pile (Velcro®) fastener tape. The M6A2 hood was designed specifically for use with the M17-series mask. It is produced in only one size (Refs. 2 and 3).

3-2.1.1.7 M24 Mask

The M24 aircraft protective mask, shown in Fig. 3-1, is used by aircraft pilots and crewmen, both in flight and on the ground, to provide respiratory protection against CB agents,

The M24 aircraft protective mask consists of a facepiece group with a microphone assembly, an M8 hose, an M10A1 canister, and an M17 mask carrier. An M1 antifogging kit and an M2 antiglare eye lens outsert are also provided. Inhaled air is purified as it passes through the canister. Exhaled breath is discharged through the outlet valve at the chin position (Refs. 2 and 3).

3-2.1.1.8 M1OA1 Canister Filter

The M10A1 canister filter is an aluminum canister. It contains a particulate filter for removal of particultites and aerosols, and it contains 345 ml of activated charcoal for the removal of chemical agent vapors. The canister is 87.3 mm in diameter and 168.3 mm in length. Although the canister does not have a threaded fitting, it does have an adapter for connection to hose-type masks. The canister is specifically designed for use with the M24 aircraft and M25A1 protective masks (Refs. 2 and 3).

3-2.1.1.9 M7 Aircraft Mask Hood

The M7 hood is used in conjunction with the M24 mask to protect the wearer's head, neck, and shoulders against gaseous and liquid chemical agents and biological agents.

The M7 hood is made of butyl rubber-coated nylon cloth and has a neck cord to hold it snugly around the wearer's neck. The hood has an opening that fits around the eye lens of the mask, and two adjustable underarm straps on the cape of the hood to hold it in position on the shoulders. The M7 hood is provided in one size (Ret. 4).

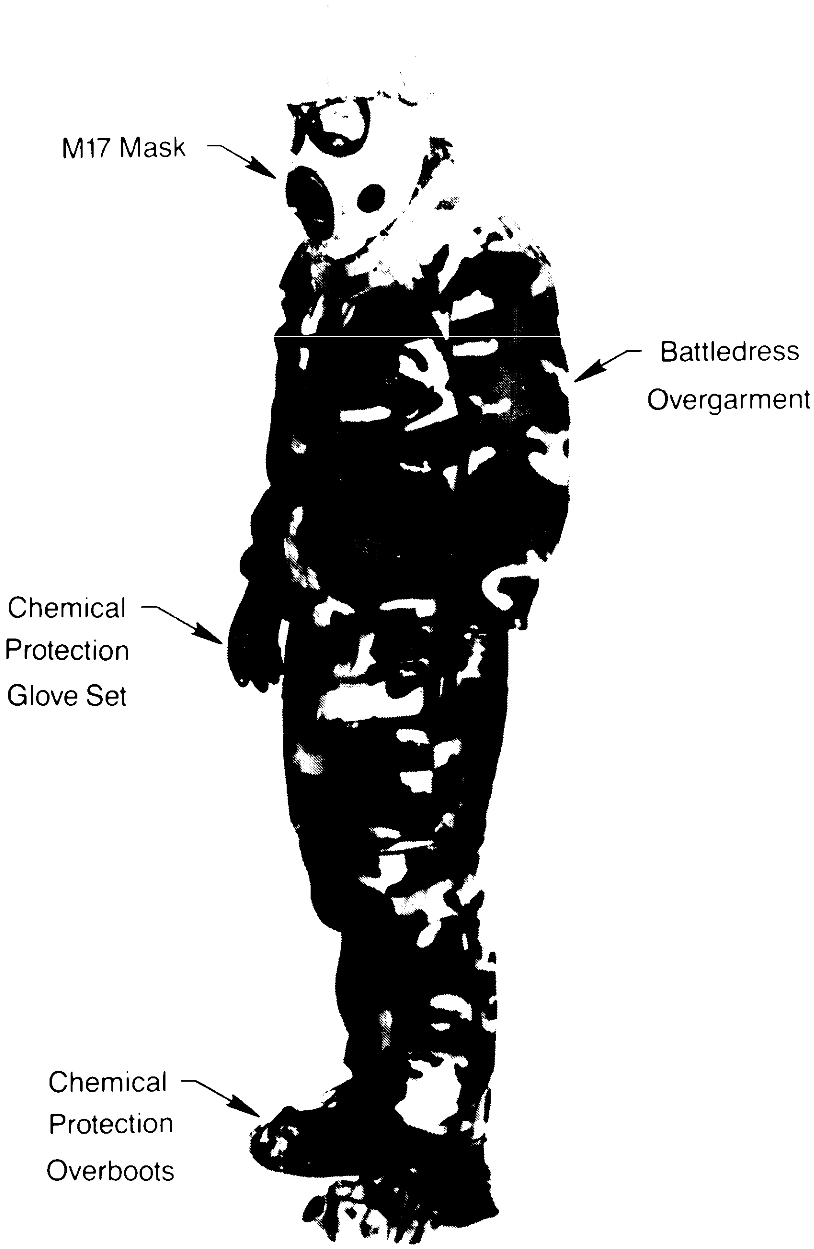


Figure 3-2. Individual Protective Equipment (IPE)

3-2.1.1.10 M25-Series Masks

The M25 and M25A1 tank protective masks are used to provide respiratory protection against CB agents to the wearer either in a combat vehicle or dismounted. The M25-series masks, shown in Fig. 3-1, consist of a facepiece group, a hose, an M10A1 canister, a carrier, and an M1 antifogging kit (antidim set). An adapter on the canister connects to the tank filter unit. A microphone assembly in the mask facepiece permits the wearer to communicate with other crew members through the AN/VRC-12 and AN/PRC-25 radios in a combat vehicle.

The M25 is a modified M14A2 tank mask; the M25A1 is nearly indistinguishable from the M25 mask except for a slight difference in the head harness latches (Refs. 2 and 3).

3-2.1.1.11 M5 Tank Mask Hood

The M5 tank mask hood is used in conjunction with the M25-series masks to protect the wearer's head, neck, and shoulders against CB agents.

The M5 hood is made of butyl rubber-coated nylon cloth. The hood has an opening that fits around the eye lens of the mask. The hood is secured in position by an adjustable neck cord and two underarm straps (Ref. 4).

3-2.1.1.12 M40 and M42 CB Protective Masks

The M40 and M42 CB protective masks will replace current issue masks. The M40 mask will replace the M17 mask and will serve as the basic field protective mask. A variation of the M40. the special-purpose mask (SPM), will replace the M9A1 mask and will be used with the TAP ensemble. The M42 mask will replace the M25A1 mask and will be used by combat vehicle crewmen in collective protected vehicles.

The M40 and M42 CB protective masks are designed to provide the soldier with increased respiratory protection from field concentration of all chemical and biological agents in vapor or aerosol form and from inhalation of radioactive fallout particles. The M40 and M42 masks retain the two nonflexible, fixed eye lenses of the M17 series mask, the inturned periphery in the faceblank, and the changeable check-mounted canister. A front voicemittcr, side voicemitter, exhalation valve assembly, drink tube. nose cup assembly, inlet valve assembly, head harness, and lens outserts arc also attached to the facepiece. The canister, the air-filtering medium for the mask, can be mounted on either be left or right side of the facepiece to accommodate the wearer's preference or an operational requirement. These protective canisters are interchangeable with the protective canisters used by North Atlantic Treaty Organization (NATO) countries. The front voicemitter, used for face-to-face communication, consists of aluminum baffles and a speech diaphragm. The side voicernitter is similar to the front voicemitter and is used for telephone communication. The M42 mask has a microphone adaptor and an adaptor for connection to the on-board collective protection filter systems.

3-2.1.1.13 M43 AH-64 Helicopter Mask

The M43 mask, shown in Fig. 3-3. was initially designed for use in the AH-64 helicopter. This mask is now being considered for general aviation applications and is designed to replace the M24 mask.

The M43 mask consists of a form-fitting facepiece with lenses fitted close to the eyes; an integrally attached hood and skull-type suspension system; an inhalation air distribution assembly for regulating the flow of air to the mouth and nose, lenses, and hood assembly; an electronic microphone; a standard C-15-type exhalation valve assembly; and a portable motor blower filter assembly for maintaining overpressure in the mask hood at all times. The mask provides the required CB protection and is compatible with the Integrated Helmet and Display Sighting System and the Optical Relay Tube of the AH-64. The mask provides AH-64 crewmembers the required respiratory and skin protection from CB agents and radioactive fallout.

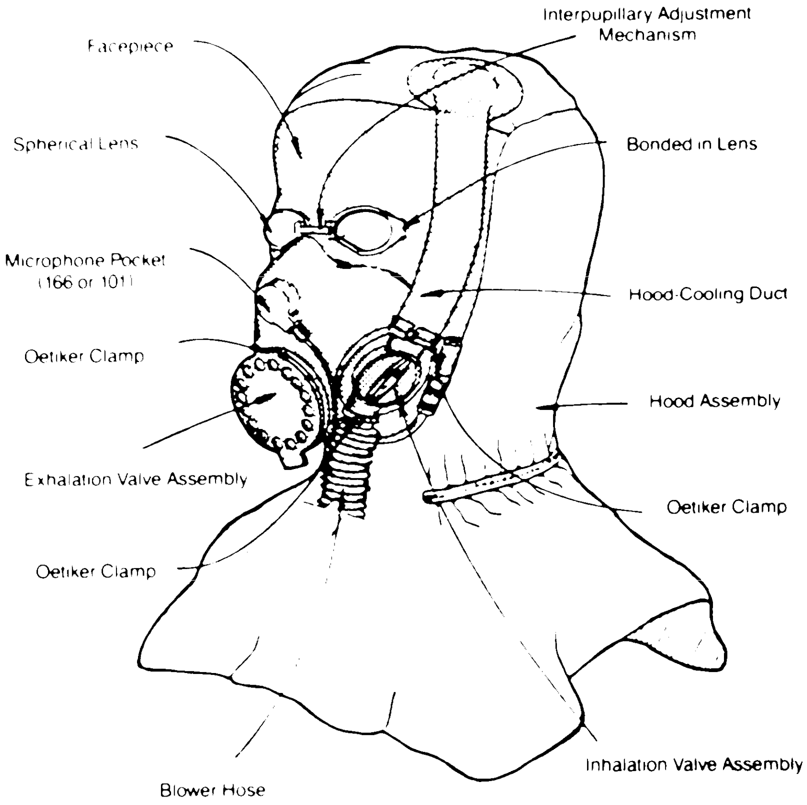


Figure 3-3. M43 CB Protective Mask

3-2.1.2 Suit And Overgarments

3-2.1.2.1 Chemical Protection Overgarment

The chemical protection overgarment is designed to protect the individual's torso, arms, legs, and body against gaseous and liquid chemical agents and biological agents and affords at least 6 h of protection against liquid agent penetration. The overgarment is used by all personnel who are not assigned any other type of protective suit.

The overgarment is a permeable protective clothing system that permits the passage of air and moisture through the fabric to reduce the physiological burden and increase comfort and performance effectiveness in a CB environment.

The chemical protection overgarment is a two-piece suit designed to be worn over normal mission attire. The maximum assemblage of clothing to be worn under the overgarment should not exceed heavy winter waffle weave underwear and the standard fatigue uniform. Heavy winter Jackets, parkas, and foul weather clothing items and accessories are to be worn over the chemical protection overgarment when necessary. The Jacket has a short, stand-up collar, elastic sleeve closures. two outer butyl-lined pockets positioned at chest level, and a full-length, front zipper covered by a double protective flap secured by snap fasteners. The trousers have a zipper fly front, adjustable waist take-up straps, suspender loops, belt loops, an outer pocket on each thigh, and zipper closures on the outside lower section of each leg with double protective flaps secured by Velcro® fasteners.

The back tail of the jacket and the back edge of the waistband are fitted with three, snap fasteners to prevent Jacket-trouser separation during bending or stooping.

The overgarment is made of a two-layer, permeable fabric. The outer layer is a nylon-cotton twill (171 mg/m^2) dyed olive drab and treated with a water-repellent chemical. The outer layer of the suit material serves as a chemical agent wicking system that spreads the contamination along the surface of the garment to reduce the liquid contamination density. The inner layer is a charcoal-impregnated polyurethane foam laminated to a nylon tricot substrate. The inner layer adsorbs chemical agent vapors or liquids that penetrate the outer layer (Refs. 2 and 3).

The overgarment comes in six sizes and is designed to fit over the complete range of combat clothing. The fitting criteria are based on waist circumference. The overgarment is to be used by both male and female ground support personnel in a CB environrnent.

3-2.1.2.2 Battledress Overgarment

The battledress overgarment. shown in Fig. 3-2, is the newest fielded IPE of the Army. and is designed to protect the individual's torso. arms, legs, and body against gaseous and liquid chemical agents and biological agents. The battledress overgarment provides better protection against CB hazards than the chemical protection overgarment because it provides at least 24-h protection against CB agents in all forms after 22 days of field wear. The battledress overgarment is designed for infantry troops, pilots, and vehicle crews.

The features of the battledress overgarment are similar to those of the chemical protection overgarment, except that the outer layer of the battledress overgarment is of higher density of nylon-cotton twill (239 mg/m^2) with a woodland camouflage pattern.

The battledress overgarment is a two-piece overgarment consisting of coat and trousers. The hip-length coat has a stand-up collar and full-length sleeves with hook and pile adjustable tab, and each sleeve has an outside bellows pocket with flap. The coat has two side-opening chest pockets, a slide fastener front closure with snap fasteners, and an elasticized drawcord in the hem. The trousers have a slide fastener front opening with a protective flap, two bellows pockets with flaps located at thigh side, two hip pockets with flaps. waist adjustment buckles and straps, and suspender and belt loops. Each leg has a slide fastener at the outside to control the adjustment opening and a drawcord in the hem. The battledress overgarment is manufactured in eight sizes: XXX-small. XX-small, X-small, small, medium. large, extra-large, and double extra-large.

3-2.1.2.3 M3 TAP Suit

The M3 TAP suit is used by Army special teams. Because of the bulkiness of this suit, a preferred item for specialized applications is the M2 TAP apron used over the standard ground support personnel ensemble. The M3 TAP suit is used in conjunction with the IPE items that follow (Refs. 2 and 3):

1. Mask, Field Protective, M9A1 (par. 3-2.1.1.1)
2. Mask Hood, TAP, M3 (par. 3-2.1.1.3)
3. Coveralls, TAP, M3 (par. 3-2.1.2.4)
4. M2 TAP Apron (par. 3-2.1.2.5)
5. Gloves, TAP (par. .3-2.1.3.2)
6. Boots, TAP, M2A1 (par. 3-2.1.4.2)
7. Boot Covers. TAP (par. 3-2.1.4.3).

3-2.1.2.4 Coveralls, TAP, M3

The olive drab M3 impermeable protective coveralls are made of nylon cloth coated on both sides with butyl rubber. They have a 152.4-mm-wide gusset extending from collar to crotch with an inner zipper and outer button flap. Other features include an adjustable collar, double sleeve cuffs, trouser cuffs with elastic snap bands, and an adjustable belt. When properly adjusted, the coveralls provide liquid agent protection for the portion of the body covered. To be effective, the coveralls must be closed securely, i.e., zippers must be closed completely and buttons must be fastened (Refs. 2 and 3).

3-2.1.2.5 M2 TAP Apron

The M2 TAP apron is a wraparound style apron (similar to a surgeon's gown) that covers the arms and body from boot to neck. The material is essentially the same as that of the TAP M3 coveralls suit. The apron is worn in conjunction with other chemical defense IPE, such as the ground support personnel ensembles. The M2 TAP apron is available in five sizes ranging from extra-small to extra-large (Refs. 2 and 3).

3-2.1.3 Gloves

3-2.1.3.1 Chemical Protection Glove Set

The chemical protection glove set, shown in Fig. 3-2, is designed to protect the wearer's hands and wrists against CB agents and affords a minimum of 6 h of protection against liquid agent penetration. The chemical protection glove set is used by all troops and personnel who are not issued any special type of glove.

The hand forms are designed to maximize dexterity and tactility and to lessen hand fatigue by reducing the "rubber band" effect across the back of the hand during grasping movements. When the wearer must handle extremely rough or sharp objects, it is recommended that the standard leather hand wear be worn over the chemical protection glove set.

The chemical protection glove set is a five-finger, gauntlet type made of black, impermeable, unsupported butyl rubber. The glove is designed to form a shape like a human hand in a relaxed position. The chemical protection glove is 368.3 mm long and 0.6 mm thick, and it is worn over a very thin white cotton glove that serves to absorb perspiration.

The butyl rubber protective glove is manufactured in four sizes: small, medium, large. and extra-large. The cotton inner glove is produced in only two sizes: small and medium. One pair of cotton inner gloves is packaged with each pair of rubber chemical protection gloves. The small-sized cotton glove is packed with the small-sized rubber glove. Medium-sized cotton gloves are packaged with the medium. large, and extra-large rubber gloves (Refs. 2 and 3).

3-2.1.3.2 Gloves, TAP

The TAP glove is designed for the Army special teams. It is made of 0.64-mm thick butyl rubber that provides protection against CB agents and is worn over cotton knit chemical protective gloves. The cotton knit gloves are a work-type glove with seamless palms and knit cuffs and are impregnated with the standard XXCC3 impregnite emulsion, an oxidant. The impregnated knit gloves are not necessary unless the mission requires them, such as for the handling of agent-filled rounds (Ref. 3). The gloves are available in four sizes: small, medium, large, and extra-large.

3-2.1.4 Footwear, Covers, and Overboots

3-2.1.4.1 Chemical Protection Overboots

The overboots are designed to protect the wearer's feet and ankles against CB agents and to provide at least 6 h of protection against liquid agent penetration. The butyl rubber sole and upper portion of the footwear provide an impermeable barrier that protects the wearer from splashes and direct contact with liquid agents while he is walking through heavily contaminated areas. The overboots are used by all Army personnel who are not issued any special type of boot.

The chemical protection overboot, shown in Fig. 3-2, is a rectangular butyl rubber sheet with reinforced eyelets located on the sides, front, and rear. The boot is now produced in a fishtail design with two eyelets in the heel end. The thickness of the upper is 0.6 mm, and the sole has a minimum thickness of 2.9 mm with raised, disc-shaped protrusions to 4.7 mm. The discs on the sole of the overboot are provided to improve traction and durability.

The overboot is produced in one size only and may be used on either foot. It is designed to fit over the entire range of US Army boots and combat footwear. Laces are threaded through the eyelets, around the ankle, and over the arch of the foot to secure the footwear cover in place (Refs. 2 and 3).

3-2.1.4.2 Boots, TAP, M2A1

The M2A1 knee boots are made of butyl rubber. They have a safety toe with a yellow overlay compound applied to the outside and a hobnail tread design on the sole and heel. The boots are normally worn with the M3 TAP suit (Refs. 2 and 3).

3-2.1.4.3 Boot Covers, TAP

The boot covers are designed to protect the M2A1 rubber boots from gross liquid agent contamination and provide a rapid means of removing the contamination.

The boot covers are made of nylon cloth coated with buty1 rubber. The outer sole is made of alternating layers of cotton duck and butyl rubber. Tie tapes are located at the top and bottom of the covers. There are no differences between the left and right boot covers; they are made from the same pattern and may be worn on either foot. Boot covers may be decontaminated if they have not been torn. damaged, or grossly contaminated. If damage or gross contamination occurs, the boot covers must be removed and replaced. Covers are available in three sizes: small (for shoe sizes up to 6-½), medium (for sizes 7 to 11½), and large (for sizes 12 and above) (Refs. 2 and 3).

3-2.1.5 Mission-Oriented Protective Posture (MOPP) Levels

Although IPE provides protection for the individual against CB hazards, it degrades the wearer's mission performance due to its cumbersome nature. For example, wearing the protective mask may restrict vision, reduce mobility, and increase thermal burden. Tasks that depend heavily upon vision, such as flying aircraft, cannot be performed as efficiently as they can be without protective gear. In addition, wearing the protective overgarment is known to impose a thermal burden on personnel. The problem becomes severe for personnel in warm climates and for individuals performing physically strenuous tasks for extended periods of time in mild climates. For these reasons the degree of individual protection must be optimize to correspond to the status and degree of CB contamination, i.e., personnel in different levels of a CB-contaminated environment should be given different levels of protection. Therefore, the MOPP concept with various levels of protection was developed.

Currently there are five standard levels of MOPP: Levels 0 (minimum protection) through 4 (maximum protection). In addition to the five MOPP levels, there is a "mask only" posture. The standard MOPP Level I through 4 are shown in Fig. 3-4 (Ref. I).

3-2.1.5.1 MOPP Level 0

At MOPP Level 0 the protective mask is carried on the individual with other load-bearing equipment. The protective overgarment, overboots, and gloves are carried in a rucksack on the individual's back. This allows personnel to hate protective gear readily available when needed. The overgarment should not be removed from the vrapor barrier bag until needed. When issued, the M258A1 decontamination kit, M8/M9 detector paper, and the nerve agent antidote hit are also carried by the soldier. Approximately 8 min are required for an individual to upgrade his protection from MOPP Level 0 to Level 4.

3-2.1.5.2 MOPP Level 1

At MOPP Level 1, shown in Fig. 3-4, the overgarment is worn. In hot weather the overgarment may be worn directly over the underwear, and the coat may be left open for ventilation. The M9 detector paper is attached to the overgarment. It takes approximately 4 min for tin individual to upgrade his protection from MOPP Level 1 to Level 4.

3-2.1.5.3 MOPP Level 2

MOPP Level 2, shown in Fig. 3-4, is the same as MOPP 1, with the exception that overboots are worn. It takes about 3 to 4 min to put on the overboots. Once at MOPP 2, an individual can upgrade his protection to the higher MOPP levels (Levels 3 and 4) in seconds. In hot weather the overgarment may be left open for ventilation.

3-2.1.5.4 MOPP Level 3

At MOPP Level 3, shown in Fig. 3-4. the protective mask and hood are added to MOPP Level 2 posture. In hot weather the overgarment and hood to the protective mask may be left open for ventilation.

3-2.1.5.5 MOPP Level 4

At MOPP Level 4, shown in Fig. 3-4, a pair of rubber gloves with cotton liners are worn to protect the hands. The overgarment is then closed, and the hood is pulled down and adjusted. This makes protection complete.

3-2.1.5.6 Mask Only

In addition to MOPP Levels 0 through 4, there is a "mask only" command that may be given when there is a low level of vapor agent in the environment. Personnel within tanks, vans, buildings, and shelters are likey to encounter only low-level vapor CB hazards; therefore, "mask only" posture provides sufficient protection for them. It should be noted that "mask only" posture is not appropriate when blister agent vapors are present.

3-2.2 COLLECTIVE PROTECTION

Collective protection provides an agent-free environment in which a group of personnel can carry out tactical missions without the burden of wearing IPE. Collective protection also provides a clean area in which personnel can rest, eat, drink, and sleep until they must exit to perform essential tasks outside the protection enclosure. Some of the areas requiring collective protection in a CB environment are (Ref. 1):

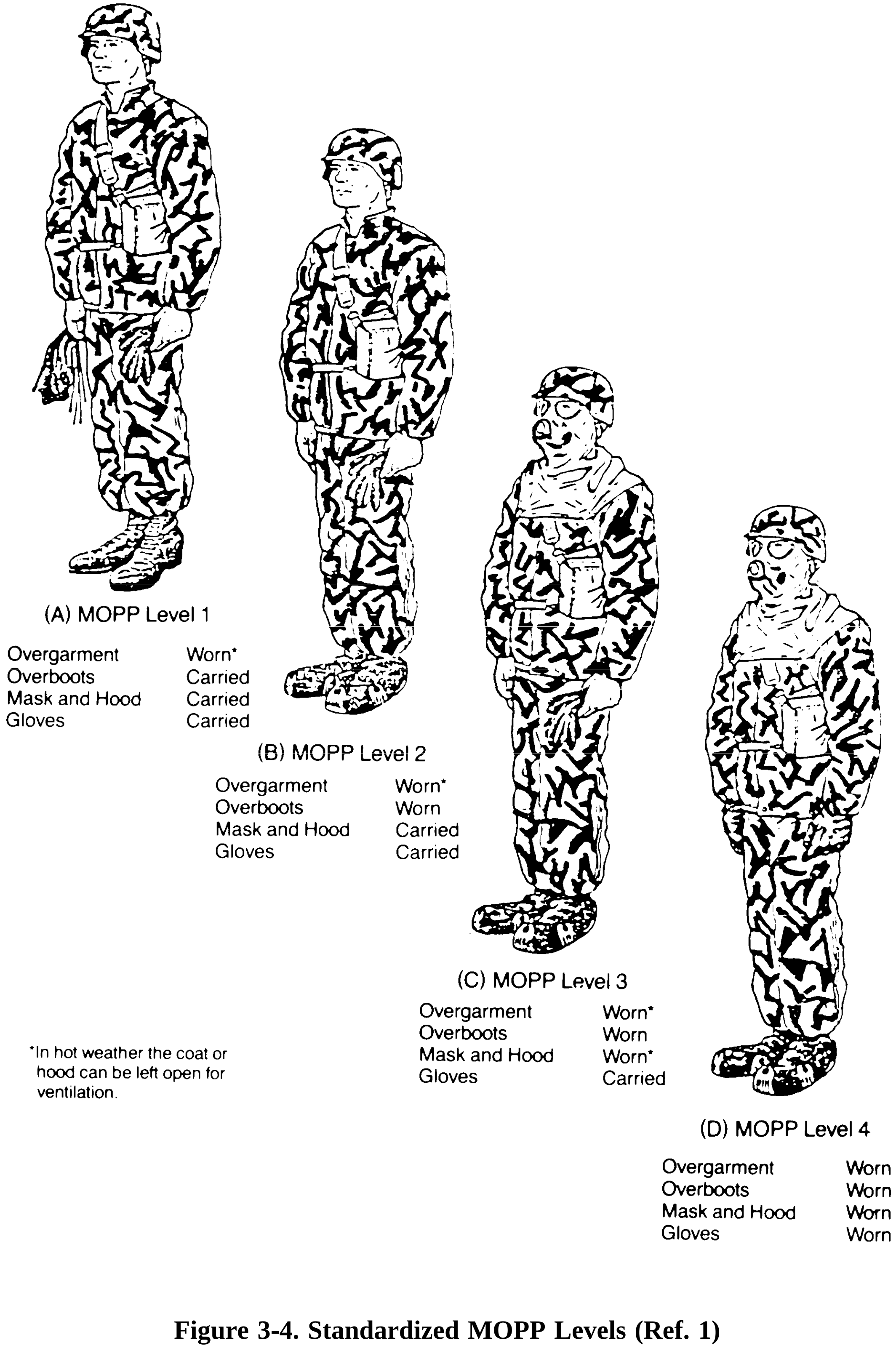
1. Command posts
2. Communication centers
3. Fire direction centers
4. Missile control complexes
5. Combat vehicles
6. First-aid stations
7. Hospitals
8. Rest and relief stations
9. Fixed maintenance facilities.

Although collective protection equipment (CPE) provides long-term collective protection for personnel in a CB environment without the necessity for donning IPE, the entry and exit procedures must be carefully performed by personnel to avoid spreading CB agents inside agent-free areas of the shelters. Detailed information on CPE entry and exit procedures is given in FM 3-4 (Ref. 1).

CPE can be divided into four types: the ventilated facepiece, overpressure, hybrid, and total. The description. conditions justifying the use of the equipment, and examples of each type are summarized in Table 3-2 (Ref. l).

3-2.2.1 Ventilated Facepiece System (VFS)

In the VFS a filter unit (such as the M13A1, M8A3, M7A1, or M14) supplies filtered air through hoses to the facepieces (masks) of individuals in the area. An example



(A) MOPP Level 1

Overgarment	Worn*
Overboots	Carried
Mask and Hood	Carried
Gloves	Carried

(B) MOPP Level 2

Overgarment	Worn*
Overboots	Worn
Mask and Hood	Carried
Gloves	Carried

(C) MOPP Level 3

Overgarment	Worn*
Overboots	Worn
Mask and Hood	Worn*
Gloves	Carried

(D) MOPP Level 4

Overgarment	Worn
Overboots	Worn
Mask and Hood	Worn
Gloves	Worn

*In hot weather the coat or hood can be left open for ventilation.

Figure 3-4. Standardized MOPP Levels (Ref. 1)

TABLE 3-2. TYPES OF COLLECTIVE PROTECTION FOR VEHICLES AND FIXED FACILITIES (Ref. 1)

System	Description	Conditions Justifying the Requirement	Example Systems
Ventilated Facepiece	Series of individual respiratory systems (or masks) serviced by a common filter	Clean working area subject to inadvertent entry of contamination High work rate; reduced breathing resistance Frequent entry and exit movements Brief inside occupation.	Infantry fighting vehicles (crew only) Self-propelled howitzers
Overpressure	A collective NBC filter and overpressure inside a vehicle or shelter.	Critical manual dexterity skills Limited entry and exit movements Lengthy inside occupation	Air defense; command posts; medical; patient evacuation vehicles; maintenance and supply sites; rest and relief.
Hybrid	Combination of overpressure and ventilated facepiece systems	Flexibility for Lengthy inside occupation Emergency entry and exit movements	Armored fighting vehicles (tanks); helicopters; air defense; multiple rocket launcher systems
Total	Hybrid or overpressure plus an environmental control system	Same as hybrid Extreme climates	Same as hybrid

of the VFS is shown in Fig. 3-5. Combined use of MOPP gear with the M25A1 protective mask and the VFS provides complete protection to personnel in a CB environment. The VFS extends the capabilities of the MOPP gear by supplying filtered and pressurized air to the individual. This pressurized air reduces the breathing resistance through the mask and aids in the evaporation of sweat. The VFS can also provide warm air to the facepiece during cold weather (Refs. 1, 3, and 5).

The VFS consists of a motor blower, a dust separator, and a gas and particulate filter system that provides filtered air under slight pressure at 0.34/m^{3}min (M8) or 0.56 m^3/min (M13). The VFS maintains a positive pressure within a mask, and the resistance to breathing is overcome through the use of a standard mask canister. A headwound version of the system is also a standard Army item. These systems hate been fielded since approximately 1960 (Refs. 1, 3, and 5).

Advantages and disadvantages of the VFS are (Ref. 1)

Advantages:

1. Reduces stress from breathing
2. Reduces eye lens fogging
3. Allows open-hatch operation
4. Increases protection level of the mask

Disadvantages:

1. MOPP gear must be worn.
2. Attached by umbilical cord
3. Does not protect vehicle interior from vapor contamination.

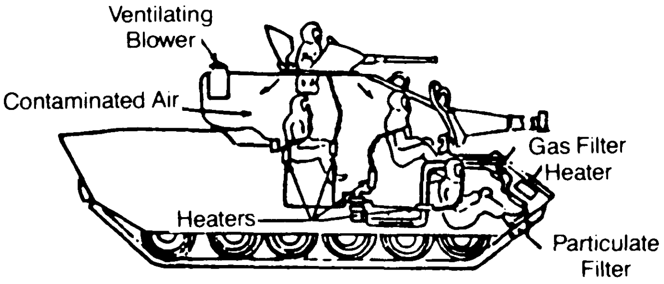


Figure 3-5. Ventilated Facepiece System (M13A1) (Ref. 3)

3-2.2.2 Overpressure System

In an overpressure system the air inside an enclosure is purified by forcing it through particulate and gas filters. Pressurizing the air presents the penetration of gaseous agents from outside through leakage. When individuals exit and enter an overpressure system in a CB environment, a protective entrance or air lock prevents CB agents from entering the enclosure. Protective entrances are discussed under associated equipment in FM 3-4 (Ref. 1).

The M51 shelter, shown in Fig. 3-6, is an example of an overpressure system. Simplified CPE and modular CPE also use the overpressure method to provide collective protection to fixed and mobile assets, respectively).

3-2.2.2.1 M51 Shelter System

The M51 shelter system is a trailer-mounted overpressure collective protection system with environmental control. It is currently used by battalion aid stations and other medical units (Ref. l).

The M51 shelter system consists of a dual-wall, inflatable structure with a protective entrance, an environmental control system (ECS) to provide heating and cooling, a power generation unit, collective protection components that provide filtered air for overpressure protection, and a high-volume recirculation filters system. The entire system is loaded on a 1.5-ton trailer and is air-droppable.

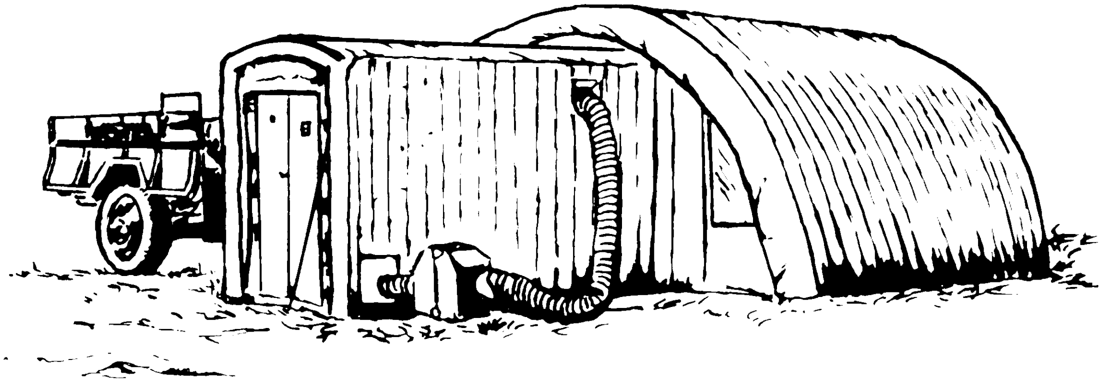


Figure 3-6. M51 Shelter System (Ref. 1)

3-2.2.2.2 Simplified Collective Protection Equipment (SCPE)

Simplified collective protection equipment (SCPE), shown in Fig. 3-7, provides collectible protection capabilities to fixed assets and is a lightweight, mobile, and field-expedient system. The SCPE can convert a room within an existing building to a chemically hardened command, control, communication, and intelligence (C^3I) system, for example. The SCPE consists of three inflatable polyethylene liners, a collapsible and pressurized protective entrance (PE), a filter blower unit, and a support kit that provides ducting, lighting, sealing, repair material, and a doorway bib. The polyethylene liners are 5.33 m in diameter and 3.33 m in height and can be rapidly inflated within an existing structure. A PE provides an entry exit capability, and the filter blower unit provides 5.60 m^3/min of filtered air to both the liner and the PE. The doorway bib permits the use of the system without the liner in low-leakage rooms such as vaults (Refs. 1, 3, and 5).

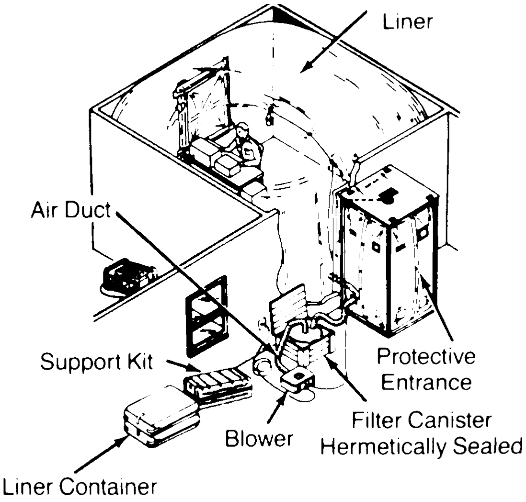


Figure 3-7. Simplified Collective Protection Equipment (SCPE) (Ref. 1)

3-2.2.2.3 Modular Collective Protection Equipment (MCPE)

Modular collective protection equipment (MCPE) provides collective protection capabilities to mobile weapon systems, such as the AN/TSQ73 Air Defense Command and Control System shown in Fig. 3-8. The basic components may include a gas and particulate filter unit, a protective entrance, and an installation kit.

The MCPE offers collective protection against CB hazards for a variety of vans, vehicles, and shelters by providing filtered, ventilated air and maintaining positive pressure within the collectively protected enclosure. MCPE systems are currently available in three standard sizes: 5.60, 11.20, and 16.80 m^3/ min. Three different protective entrances and a static frequency converter (the XM5) are available. Current efforts on MCPE include development of a 2.80-m^3/min system, an integrated protective entrance shelter door, and an integrated filter unit/environmental control unit, as well as logistical support, including manuals and support hardware (Refs. 1, 3, and 1)

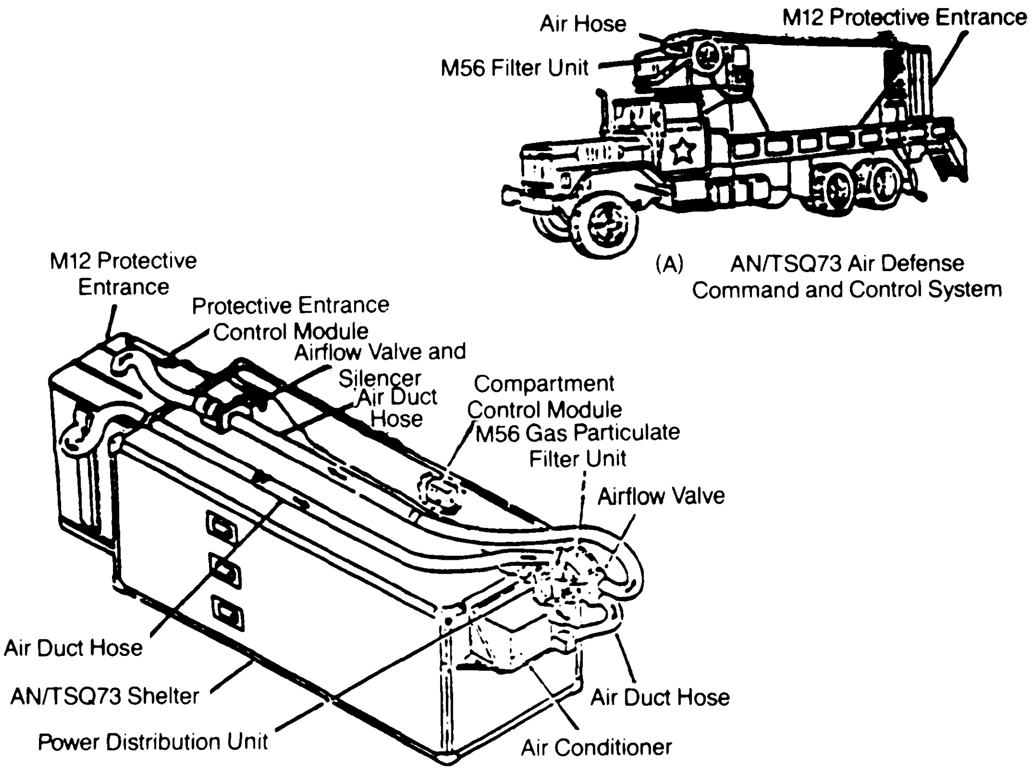
Advantages and disadvantages of the MCPE

Advantages:

1. Allows reduction of MOPP operations level
2. Reduces vapor contamination procedures
3. Provides relief from continuous wearing of MOPP gear

Disadvantages

1. Requires closed-mode operations to unmask safely
2. Requires entry and exit inside vehicle
3. Increases logistical support requirements.



(A) AN/TSQ73 Air Defense Command and Control System

(B) Collective Protection Equipment Installation and Airflow on the AN/TSQ73 Shelter

Figure 3-8. AN/TSQ73 Shelter With MCPE Installed (Ref. 1)

3-2.2.3 Hybrid System

Hybrid collective protection equipment (HCPE), shown in Fig. 3-9, combines the overpressure and ventilated facepiece methods of collective protection. In a hybrid system the gas and particulate filter unit is capable of filtering and pressurizing air within the vehicle. The ventilated facepiece mode is activated when the tactical situation requires the hatches to remain open or whenever the interior becomes contaminated. If the hybrid mode is used during open-hatch operations, the positive pressure prevents gaseous agents from entering the vehicle or reduces the amount entering. If contamination does occur inside the vehicle, the overpressure system can purge the CB agents from the vehicle. The hybrid system provides the advantages of both the overpressure collective protection and the ventilated facepiece system and thereby gives the commander greater flexibility (Ref. l).

The basic components of an HCPE system include a centrifugal dust separator, a blower, a gas and particulate filter (XM48) assembly. a control module, a pressure measurement assembly, and a fan system. The fan system is comprised of inverter-driven motor-fan combinations capable of either 2.80-m^3/min operation or 5.60- to 8.40-m^3/min operation (Refs. 1, 3. and 5).

The advantages and disadvantages for the two modes o! a hybrid system are (Ref. l):

VENTILATED FACEPIECE MODE

Advantages:

1. Reduces breathing resistance of the mask
2. Reduces eye lens fogging
3. Increases the protection level of the mask
4. Allows open-hatch operations

Disadvantages:

1. Does not protect vehicle interior from contamination
2. MOPP gear must be worn
3. Needs to be attached by umbilical cord

OVERPRESSURE MODE

Advantages:

1. Reduces vapor contamination inside the vehicle
2. Can provide relief from continuous wearing of MOPP gear
3. Allows reduction of MOPP level

Disadvantages:

1. Requires entry and exit procedures
2. Increases logistical support requirements
3. Requires closed-mode operations to unmask safely.

3-2.2.4 Total System

A total system, shown in Fig. 3-10, combines hybrid collective protection and some form of environmental control (Refs. 1, 3, and 5). An example of a total system is that used in the M1A1 tank.

The advantages and disadvantages of using a total system are (Ref. 1)

Advantages:

1. Same as hybrid system
2. Reduction of heat-stress casualties

Disadvantages:

1. Same as hybrid system
2. Increases logistical burden, primarily maintenance.

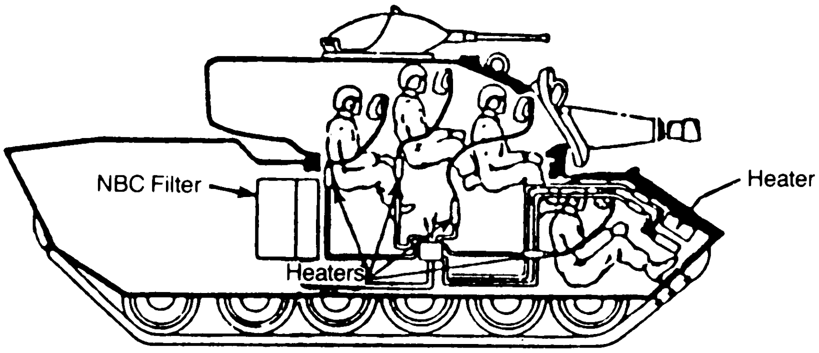


Figure 3-9. Hybrid Collective Protection Equipment (HCPE) (Ref. 1)

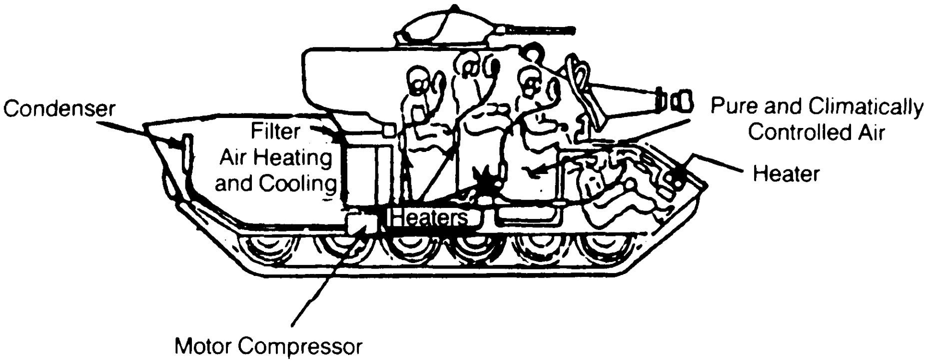


Figure 3-10. Total System (Ref. 1)

3-2.3 EQUIPMENT AND SUPPLY PROTECTION

Equipment and supplies e.g., food, water, and ammunition must be protected from contamination before a CB attack. If contaminated, equipment and ammunition pose both contact and desorbcd vapor hazards to personnel. Contaminated military items must be properly decontaminated before reuse. However. decontamination usually is both time- and resource-consuming.

If food and water are contaminated, they are usually discarded because the process for decontamination of' food and water is very complicated.

Because thorough decontamination of contaminated equipment and supplies is difficult, contamination avoidance and protection of these items become essential. Three techniques packaging, contamination avoidance covers, and chemical-agent-resistant coatings for equipment and supply protection in a CB environment are discussed here.

3-2.3.1 Packaging

Packaging involves the use of barrier to isolate items from CB agents. If items are properly packaged, CB agents will remain on the outside surfaces of the barriers in a CB environment. After attack, precautions must be taken to protect items from contamination by agent-laden barriers. It is best to decontaminate barriers before rcmoving them. If decontamination is not possible (for example, if's delicate barrier material would be destroyed by decontamination), however, (other procedures, such as weathering, must be used. Weathering may take several days to reduce contamination to a negligible level.

Currently there are several fielded packaging barriers used for equipment and supply protection. These barriers are described in the paragraphs that follow (Ref. 6).

3-2.3.1.1 Metal Cans

Metal cans are the safest packaging barriers because the contents of unopened cans will not be contaminated in a heavily contaminated CB environment. Canned foods can be safely eaten after an attack if the cans are unbroken. Visual examination of cans for leakage, cracks. swollen ends, or rust will identify whether the contents are likely to be contaminated. It is necessary to decontaminate the outside of the can before opening if there has been a possibility of contamination.

3-2.3.1.2 Glass Jars

Glass is also an effective packaging barrier against CB contamination. It is recommended that a sheet of plastic be used to cover the junction of the cap and jar or bottle to insure total protection. A cap that does not hale this kind of' protection may permit gaseous agents to leak into the jar.

3-2.3.1.3 Laminated Plastic Foils

Containers made of laminated plastic foils are impervious to CB agents. However, if exposed to and contaminated by liquid agents, contaminated plastic foils are more difficult to decontaminate than cans. Items within laminated plastic foils should be protected from liquid contamination by being sheltered in a room, under shelves or drop cloths.

3-2.3.1.4 Polymers

Polymers refer to materials such as plastics or rubber. Margarine tubs, garbage bags, and drop cloths are examples of items made of polymers. Experiments show that some polymers are imperious to chemical agents, whereas others are not. Because it is difficult to know which type of polymer has been used for agent protection, packaging barriers made of polymers should always be assumed to be permeable to agents; thus precautions should be exercised.

Polyethylene is a common polymer that is extensively used for commercial purposes, such as garbage bags and food containers. Chemical agents permeate polyethylene slowly; therefore, polyethylene garbage bags or sheets cannot be used alone to wrap food or utensils for agent protection, but they may be used as part of a multiple layer.

In contrast, Saran® wrap, a food wrap made from vinylidine chloride and acrylonitrile, provides good protection for food. Food containers enclosed in Saran® wrap may be considered clean if there are no holes (not even very small ones) or tears in the wrapping and if the edges adhere together.

A good means of protecting equipment and supplies is to wrap the items first in Saran® wrap and then store the wrapped pieces in a garbage bag. This approach applies particularly to cutlery, small appliances, arts of disassembled equipment, and food within permeable packages.

3-2.3.1.5 Paper and Fiberboard

Paper, cardboard, waxed cardboard, and fiberboard have porous surfaces and are permeable to both vapor and liquid agents. These materials cannot give reliable protection for food and equipment. Items packed within cartons made of these materials can be used only if they have been protected in a sale room or package.

3-2.3.2 Contamination Avoidance Covers (CACs)

Contamination avoidance covers (CACs) provide an easy and simple method by which to prevent equipment and supplies from agent contamination during CB attacks. CACs not only provide a quick and effective means of protecting equipment and supplies from CB contamination, but also they are inexpensive and commercially available. Although standard CACs have not been fielded by the US Army, many field-expedient cover materials are available. These materials include tarpaulins, pallets, canvas, cardboard, dunnage, plastic sheets and bags, and drop cloths. These field-expedient CACs can be quickly placed over equipment and supplies before agent attacks. If properly used, CACs will not only protect equipment and supplies from agent contamination but also will eliminate or greatly reduce subsequent complicated decontamination procedures with associated requirements for manpower, time, and resources.

It is important to know that even though CACs provide good protection for equipment and supplies against CB agents, a delayed vapor hazard may exist that is caused by the resorption of agents from contaminated CACs. Also, if CACs are heavily contaminated by CB liquid agents, CAC materials maybe penetrated by agents. Therefore, it is strongly recommended that agent-contaminated CACs be quickly removed for disposal after a CB attack.

Several types of materials that may be fabricated into CACs are (Refs. 7 and 8)

1. Mylar® (polyethylene terephthalate)
2. Epichlorohydrine
3. Polyethylene
4. Rubberized materials
5. Saran® (vinylidine chloride and acrylonitrile)
6. EPDM (ethylene propylene diene monomer) plasticized paper bag material.

3-2.3.3 Chemical-Agent-Resistant Coatings (CARCs)

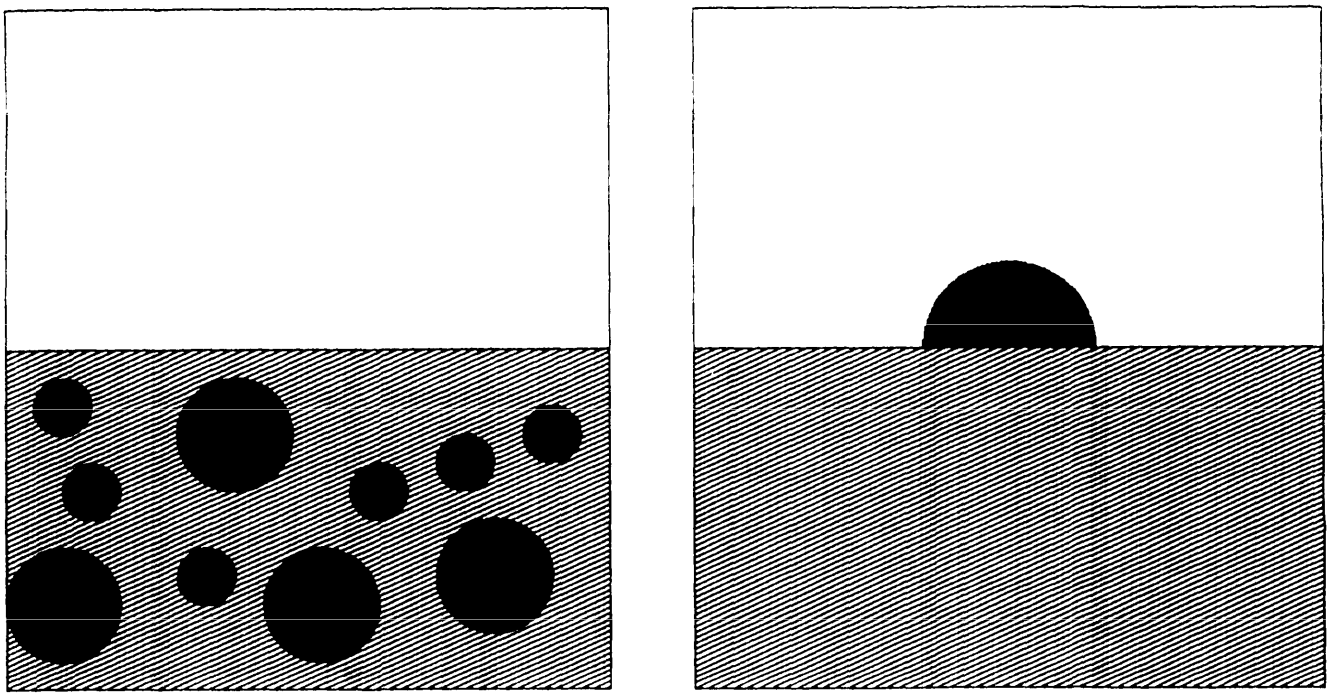
Traditionally, the military has used lacquers, alkyd polymeric materials, or modified alkyd polymeric materials as the bases for paint formulations. Unfortunately, all of these paints readily sorb chemical warfare agents. Once sorbed, the agents do not readily desorb from these paints. Resorption rates are much slower than sorption rates. As a result, surfaces coated with these paints pose residual contact and respiratory hazards long alter being contaminated by chemical agents and even after decontamination. Timely elimination of the hazard can be achieved only by removing the paint or by heating the surface for extended periods.

Chemical-agent-resistant-coatings (CARCs) have been developed to be much more resistant to agent sorption. Instead of penetrating the CARC, agents will remain on the surface until they evaporate or until the) can be actively) removed or decontaminated by a variety of physical or chemical means. Fig. 3-11 depicts how agents penetrate into the polymeric matrix of standard alkyd paints but not into CARC. CARC is also relatively resistant to the corrosive effects of decontaminating solution No. 2 (DS2), the standard decontaminant.

The application of CARC involves four distinct steps: cleaning, pretreating, priming. and applying the topcoat. The specifications for these steps, called out in military specification MIL-C-53072(ME) (Ref. 9), are listed in Table 3-3. Although care must be taken to insure that the wash primer drying or reacting is completed so that CARC adhesion is not affected, the cleaning and pretreating steps are standard methods that are required in most finishing processes. The anticorrosive primers are epoxies. The topcoats for exterior surfaces are polyurethancs and for interior surfaces, epoxies.

3-3 DETECTION AND MONITORING

CDIW is vital to an integrated CB defense program and provides the necessary information on types and levels of agents in a CB environment. This information is important forcommanders and personnel in the area so that the proper countermeasures can be taken to prevent or minimize CB hazards.



Standard Alkyd

CARC

Figure 3-11. Agent-Coating Interactions

TABLE 3-3. THE CARC SYSTEM

Process	Ferrous Metal	Nonferrous Metal
Cleaning	TT-C-490 MIL-T-7O4	TT-C-490 MIL-T-704
Pretreating	TT-C-490. I (Zn phosphate)	DOD-P-15328 (wash primer) MIL-C-85I4 (wash primer)
	TT-C-490, 1 I (Fe phosphate)	MIL-C-5541 (chromate conversion)
	TT-C-490, III (wash primer)	MIL-A-8625 (anodilc)
Priming	MI L-P-52192 MIL-P-53022 MIL-P-53030	MIL-P-23377 MIL-P-53022 MIL-P-53030
Applying Topcoat	MIL-C-22750 (interior only) MIL-C-46168 MIL-C-53039	MIL-C-22750 (interior only) MIL-C-46168 MIL-C-53039

CDIW serves many purposes for an integrated CB defense program, depending on the situation. These purposes are

1. To provide early warning to individuals and units if CB agents are being employed by the enemy. This warning allows individuals and units to prepare fully a series of precautionary measures. such as which MOPP level is needed and whether nearby transportable medical facilities should be relocated, before encountering CB hazards.

2. To measure and evaluate the levels and type of contamination. Individuals are able to estimate the degree of the agent threat and determine the type of decontamination actions required and can also use this information to determine whether a filter should be changed due to saturation. Medical personnel can determine the degree of a victim's poisoning and thus the necessary medical treatment.

3. To monitor levels of CB contaminants in a post-CB attack environment. Commanders are able to give proper instructions such as whether personnel can remove individual protective gear, whether equipment and supplies can be safely used, the need for decontamination,

and where an uncontaminated proximity area exists for personnel to go for long-term rest and refurbishment.

4. To measure agent residue on decontaminated equipment to determine whether CB agent concentrations have been reduced to an acceptable level.

Ideally, CDIW systems must be versatile enough to meet the requirements of all typcs of CB contamination situations. The information gathered by CDIW systems should include

1. The nature of the agents, i.e., chemical or biological
2. The specific agent types, e.g., VX, GA, T-2 toxin, anthrax bacterium
3. The concentrations of the agents
4. The distance of agent clouds from CDIW systetns (remote sensing)
5. The estimated agent arrival time according to existing meteorological conditions.

CDIW systems should also have high sensitivity to and specificity for all agents in any enviroment and should be capable of continuous monitoring for a relatively long period without complicated maintenance procedures or attendance.

3-3.1 MONITORING EQUIPMENT

The rapid and accurate identification of CB agents used by enemy forces is essential for initiation of effective countermeasures. The US Army has fielded a number of CDIW systems. These are listed in Table 3-4 (Refs. 3 and l0).

TABLE 3-4. CDIW SYSTEMS FIELDED BY US ARMY (Refs. 3 and 10)

1. ABC-M8 VGH Paper Chemical Agent Detector
2. M9 Paper Chemical Agent Detector
3. M256 and M256A1 Detector Kits, Chemical Agent
4. M18A2 Detector Kit, Chemical Agent
5. M272 Water Testing Kit, Chemical Agents
6. M43A1 Detector Unit, Chemical Agent Automatic Alarm
7. Chemical Agent Monitor

In contrast to the CDIW equipment for chemical agents, there is a void of equivalent equipment for detecting and monitoring biological agents. This is especially true for forward units. Although laboratory facilities are available at a number of battalion levels, the detection and identification procedures for biological agents are difficult and time-consuming. The procedures involve sampling, microscopic examination, culturing, testing, and identification. Therefore, efforts are needed to focus on development of monitoring equipment for all known biological agents.

3-3.1.1 ABC-M8 VGH Paper Chemical Agent Detector

M8 chemical agent detector paper is designed specifically for liquid agent detection. The M8 paper, tan in color, is contained in a booklet of 25 sheets (0. I mm thick), which are perforated for easy removal, and each booklet is heat-sealed in a polyethylene envelope. There are three sensitive dyes suspended within the paper matrix. The paper is blotted, not rubbed, on the suspected liquid agent. and a distinctive color is produced depending upon the type of agent present. A color chart on the inside cover of the M8 booklet enables direct comparison for agent identification. The M8 paper detects and differentiates between nerve and blister agents in a liquid state (Refs. 3 and 10).

Problems are encountered in night operations because the M8 paper must be read under white light. Therefore, during night reconnaissance operations, the monitoring personnel may take several marked samples to suspected areas and then take them back to the vehicle for reading (Ref. 1l).

3-3.1.2 M9 Paper Chemical Agent Detector

The M9 paper is also designed for the detection of liquid chemical agents. But unlike the M8 paper, it has no agent specificity, i.e., it does not differentiate among agents. It contains a suspension of an agent-sensitive dye in a paper matrix. The paper is colored green by the use of insoluble camouflage pigments but will turn red or reddish-brown in those places exposed to liquid agent. It is issued as a single roll of Mylar®-laminated paper with an adhesive backing and comes in a cardboard dispenser with a serrated metal edge for cutting. The M9 paper is designed to be attached to clothing or equipment (Refs. 4 and 11). When attached to equiprnent, it must be placed in an area free from dirt, grease. and oil. This is especially important because petroleum products and DS2 (a standard decontaminant cause the paper to change color and thereby cause a false reading (Ref. 10).

M9 paper is useful for detecting on-target attacks and thus keeps soldiers from entering contaminated areas. Whenever pink, red, reddish brown. or purple colors appear on the paper, the presence of chemical agents is suspected.

As with the M8 paper, night operations present some problems because color changes show up only under white light (Ref. 11).

3-3.1.3 M256 and M256A1 Detector Kits, Chemical Agent

The M256 chemical agent detector kit, shown in Fig. 3-12, is a portable and expendable item capable of detecting both liquid and vapor concentrations of chemical agents.

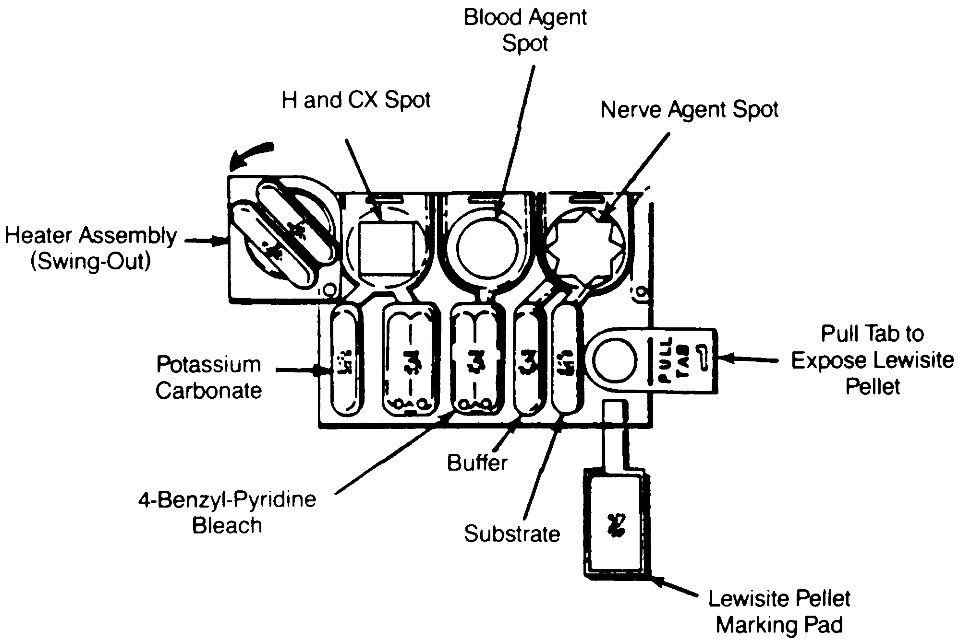


Figure 3-12. M256 Detector Kit, Chemical Agent

Each M256 detector kit consists of 12 disposable plastic sampler-detectors, one booklet of M8 paper, and a set of instruction cards attached by a lanyard to a plastic case. The case is made of high-impact plastic and has a nylon carrying strap and a nylon belt attachment. The sampler-detector in this kit will detect and identify low vapor concentrations of nerve, blister, and blood agents following a 10-min static exposure.

The M256A1 detector kit is a new version of the M256. Although the M256A1 kit is nearly indistinguishable from the M256 kit. it has higher sensitivity to nerve agents. The sensitivity of the M256A1 detector kit to a variety of agent vapors is given in Table 3-5 (Refs. 6 and 1l).

TABLE 3-5. M256A1 SENSITIVITY LEVELS (Refs. 6 and 11)

Agent	Minimum Concentration Detectable, mg/m3
G series	0.03 ± 0.02
VX	0.10 ± 0.05
H	2.0 ± 1.0
L	9.0 ± 5.0
CX	3.0 ± 2.0
AC	9.0 ± 2.0
CK	8.0 ± 2.0

3-3.1.4 M18A2 Detector Kit, Chemical Agent

The M18A2 chemical agent detector kit is a portable and expendable item capable of surface and vapor analyses. The M18A2 consists of an aspirator bulb assembly, detector sampling tubes, detector tickets, reagent packets, substrate solutions, a booklet of M8 detector paper, and an instruction booklet. Air is sampled by drawing it through a detector tube or detector ticket treated with an enzyme-substrate solution. The presence of agent is identified by a color change in the tube or on the ticket. The intensity of color development and the time required for color change provide a qualitative measure of agent concentration (Refs. 3 and 10). The M18A2 kit is only used by technical escort and explosive ordnance disposal teams and other special Army units.

3-3.1.5 M272 Water Testing Kit, Chemical Agent

The M272 kit is capable of detecting hazardous levels of mustard, nerve agents, Lewisite, and blood agents in water over a wide temperature range (0° to 51.7°C). The kit contains Type I and II detector tubes (similar to those in the M18A2 detector kit), nerve agent detector tickets, a test bottle, test reagents, and training simulants. Agent detection in water samples is indicated by specific color changes in the tubes or on the tickets. All components are packaged in a molded plastic carrying case of dimensions 154.0 mmX 158.8 mmX70.0 mm; the overall kit weighs about 1.14 kg. Each kit is an expendable Army stock fielded item with a 5-yr shelf life (Refs. 3 and 10).

3-3.1.6 M43A1 Detector Unit, Chemical Agent Automatic Alarm

The M43A1, shown in Fig. 3-13, is an ionization-type detector in which the agent molecules, ionized by the radiation source, combine with water molecules to form ions and then pass through a baffle to a detector element. The electronic module monitors the current produced at the ionization detector and triggers the alarm, which has a variable pitch and a maximum volume of 70 dB. A service check is required every 24 h, and periodic replacement of the filter and battery is required.

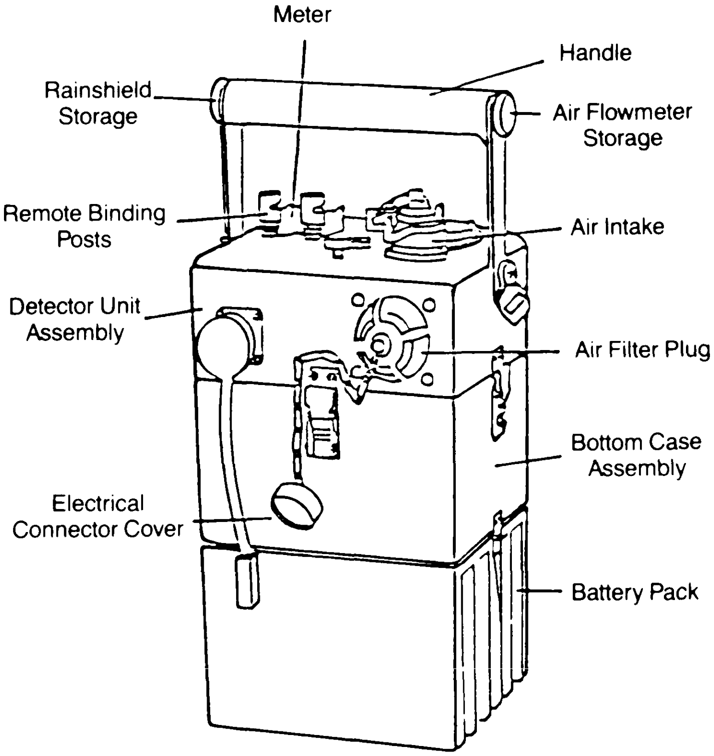


Figure 3-13. M43A1 Detector Unit, Chemical Agent Automatic Alarm (Ref. 11)

The M43A1 detects nerve agents at low concentrations in less than one minute (Ref. 11). The threshold concentrations of various nerve agents that are detectable by the M43A1 are given in Table 3-6.

TABLE 3-6. M43A1 SENSITIVITY LEVELS (Refs. 11 and 12)

Agent	Minimum Concentration Detectable. mg/m^3
GA	0.4
GB	0.2
GD	0.4
VX	0.4

3-3.1.7 Chemical Agent Monitor (CAM)

The CAM is a hand-held, man-operated device for monitoring chemical agent contamination of personnel and equipment. Its operation is based on the conncept 01 ion mobility spectrometry. Chemical agent vapors are detected by sensing molecular ions of spccific mobilities (time of flight) and using timing and microprocessor techniques to reject interferences. The CAM detects and discriminates between vapors of nerve and mustard agents. A strap allows personnel to carry the CAM with both hands free. With integral accessories the CAM is 101.6 mmX177.8 mmX381.0 mm and weighs 2.27 kg (Refs. 3 and 10).

The CAM, shown in Fig. 3-14, has been demonstrated to meet and exceed its required operational capability (ROC) to detect a concentration of 0.1 mg/m^3 of any of the chemical agents (G agents, VX, and HD) within one minute. In laboratory conditions (room temperature and 50% relative humidity), the CAM has detected concentrations as low as 0.03 mg/m^3 of the G agents and 0.05 mg/m^3 of VX. The VX concentration was detected within 30 s.

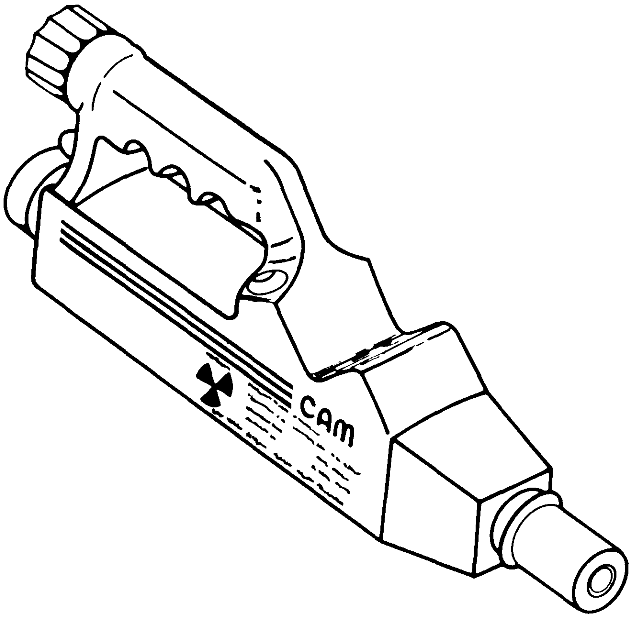


Figure 3-14. Chemical Agent Monitor (CAM)

3-4 CONTAMINATION CONTROL

Contamination control is a precautionary action taken before or after CB attack in order to prevent or minimize the effects of CB hazards. These actions include protection as well as isolation from the CB environment. Protection is implemented before a CB attack and involves protection of personnel and covering or coating of equipment and supplies. Protection prevents personnel and military items from being contaminated if a CB attack should occur. isolation entails marking contaminated areas and restricting personnel and equipment from these areas until the level of contamination is no longer a threat. Isolation also includes prohibiting contaminated personnel or items from moving to a clean area without proper decontamination. in this way the spread of contamination can be avoided.

Contamination control is the most fundamental defense element against CB attacks. If properly carried out, not only can CB contamination be prevented or minimized, but the time and resources required for subsequent decontamination operations can be reduced. Contamination avoidance techniques are discussed in detail in FM 3-3 (Ref. 13). A brief summary of contamination control techniques for working or training to work in a CB-contaminated environment is given in the paragraphs that follow:

1. *Passive Defense Measures.* Personnel should take passive defense measures to reduce the possibility of being directly hit by CB attacks or to minimize the effects of the attacks. Passive defense measures include good communication procedures, tight discipline, concealing camouflage, hardening of positions and equipment, and using covers.

2. *Warning and Reporting.* Once a CB attack has been detected, personnel within the potentially affected areas must be warned immediately. Warning and reporting of CB contamination is done by using standardized, simple messages from the nuclear, biological, and chemical (NBC) warning and reporting system.

3. *Locating and Identifying CB Hazards.* Types and levels of CB contaminants within the attack area should be monitored and evaluated. The collected information allows commanders to determine what type of countermeasures or actions should be taken.

4. *Limiting Exposure to CB Contaminants.* Exposure to CB contaminants should be limited as much as possible. This limited exposure can be accomplished by moving personnel and equipment away from CB contaminated areas or, if the mission makes moving impossible, by employing individual and/or collective protection measures.

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CHAPTER 4
DECONTAMINATION METHODS AND EQUIPMENT

This chapter describes the methods and equipment currently available for decontamination. The reasons for decontamination are presented in par. 4-2. Chemical decontamination methods are described in par. 4-3, and physical methods are given in par. 4-4. Decontamination equipment is detailed in par. 4-7.

4-1 INTRODUCTION

In general, chemical and biological (CB) agent decontamination methods can be classified into the three broad categories of biological, chemical, and physical processes. Biological decontamination processes are methods such as cell-free enzymatic systems, microorganisms, algae, and state-of-the-art genetic engineering. These methods have been cited in the literature in regard to their potential use as CB agent decontaminants (Ref. 1). Biological methods for agent decontamination may prove useful in the future; however, they are not sufficiently developed in the 1980s for realistic application. Because in this time frame the US Army employs only physical and chemical methods of decontamination, this handbook does not address biological methods.

Chemical decontamination methods are those in which the CB agent undergoes some reaction that results in a change in the chemical nature of the agent. The standard military decontaminant, supertropical bleach (STB), is an example of a chemical method because STB may react chemically with the agent to convert it into some other, nonagent product.

Physical decontamination methods are those in which the CB agent undergoes a change in physical state. The weathering process by which the agent is allowed to evaporate (agent going from the liquid to the vapor state) is an example of a physical method. Some decontamination methods combine chemical and physical processes; for example, the use of steam as a decontaminant involves both the physical process of enhancing agent evaporation and the chemical process of hydrolytic reaction between the water and the agent. These processes are described further in pars. 4-3 and 4-4.

The relationship between the primary CB agents and the chemical and physical decontamination methods discussed in this chapter is summarized in Table 4-1.

Decontamination of CB agents is a vital component to sustained operations on the CB-agent-contaminated battlefield. Decontamination, considered a permanent solution for CB agent contamination, involves removal, neutralization, destruction, or containment of CB agents. Successful and timely decontamination will render CB agents harmless to personnel and reduce the adverse effects of these agents on equipment.

Army Regulation (AR) 70-71 defines nuclear. biological, and chemical (NBC) contamination survivability as the capability of a system and its crew to withstand an NBC-contaminated environment, including decontamination, without losing the ability to accomplish the assigned combat mission (Ref. 2). From a tactical viewpoint there are two levels of decontamination: partial and complete. The objective of partial decontamination is to reduce contamination to a level at which combat units are able to sustain their fighting capability. The objective of complete decontamination is to reduce contamination to a level at which combat units can function normally without wearing individual protective gear. These levels of decontamination are described further in par. 4-5.

4-2 REASONS FOR DECONTAMINATION

A military unit commander or an individual soldier may have one or more compelling reasons to decontaminate. Among these are four primary reasons, which are

1. To prevent or reduce fatalities and incapacitation
2. To reduce performance degradation caused by the burden of necessary protective measures
3. To compensate for the limitations of protective equipment
4. To avoid the spread of contamination (Ref. 3).

These reasons are discussed in subpars. 4-2.1 through 4-2.4.

4.2.1 FATALITY AND INCAPACITATION

CB agents can have various effects upon contami-personnel. These effects, as detailed in Chapter 2, from irritation to sickness to incapacitation and, finally, to death. The severity of the effect on exposed personnel depends upon several factors including the route by which the agent enters the body— e.g., inhalation or through the skin—dosage, and agent type. If unprotected individuals have encountered CB agents, it may be necessary to decontaminate immediately the agent on exposed skin. Timely removal of the CB agent hazard may reduce the adverse effects experienced by exposed personnel.

TABLE 4-1. CHEMICAL AND PHYSICAI. METHODS FOR DECONTAMINATING CB AGENTS

		Effect of Decontaminant on CB Agent*						
Method	Decontaminant	H Series	Lewisite	G Series	V Series	Toxins	Spores	Organisms
Chemical	Decontaminating Solution No. 2 (DS2) (STD)	●	●	●	●	●	o	●
	STB (STD)	●	●	●	●	●	●	●
	Household Bleach	●	●	●	●	●	●	●
	High-Test Hypochlorite (HTH)	●	●	●	●	●	●	●
	Activated Solution of Hypochlorite (ASH) and Self-Limiting Activated Solutions of Hyprochlorite (SLASH)	●	●	●	●	●	●	●
	Mask-Sanitizing Solution (STD)	●	●	●	●	●	o	●
	Sodium Hydroxide	?	?	●	●	?	●	●
	Sodium Carbonate	?	?	●	?	?	?	?
	Hexacloromelamine	●	●	?	?	?	?	?
	Ammonium Hydroxide	●	●	●	●	?	?	?
	Chloramine-B or -T	●	●	●	●	o	o	o
	Dichloramine-B or -T	●	●	●	●	?	?	?
	XXCC3	●	●	●	●	?	?	?
	C8 Emulsion (STD)	●	●	●	●	●	●	●
	CD-1	●	●	●	●	?	?	?
	Perborate Solution	?	?	●	●	?	?	?
	Incineration	●	●	●	●	●	●	●
	Weathering	●	●	●	●	?	?	?
	Soap Solution	●	●	●	●	●	●	●
	Iodine	?	?	?	?	?	?	●
	Formalin	?	?	?	?	?	●	●
	Detrochlorite	?	?	?	?	●	●	●
	Petacetic Acid (PAA)	?	?	?	?	?	●	●
	Ethylene Oxide (ETO)	?	?	?	?	?	●	●
	Carboxide	?	?	?	?	?	●	●
	Hyamines	?	?	?	?	?	?	?
	Chlorine Dioxide Solution	?	?	?	?	?	●	?
Physical	Hot Water	●	●	●	●	●	●	●
	Steam	●	●	●	●	?	?	?
	Organic Solvents	●	●	●	●	●	●	●
	Dry Heat	●	●	●	●	?	o	?
	Dry Sorbents	●	●	●	●	?	?	?

*KEY: • = has some decontamination effect; o = not effective: ? = effective not known.

4-2.2 PERFORMANCE DEGRADATION

Protective measures can protect personnel and equipment from the adverse effects of CB agents, but the use of these protective measures can also result in mission-degrading, man-equipment incompatibilities. For example, currently available individual protective equipment (IPE) reduces the wearer's mission effectiveness because of its cumbersome nature. IPE may restrict the wearer's vision, reduce his tool-handling dexterity, and impose on him a mission degrading thermal burden. It is very difficult for an individual in IPE to perform physically strenuous tasks in warm climates for extended periods or to perform bodily functions such as eating, drinking, urinating, defecating, resting, and sleeping. For these reasons, decontamination is a defense measure essential to maintaining combat mission effectiveness in a CB-agent-contaminated environment.

4-2.3 EQUIPMENT LIMITATIONS

IPE has certain limitations in the protection afforded to the individual. For example, an agent might ultimately saturate the protective filter of respiratory devices and render the filter useless. Liquid agents might gradually penetrate through IPE material to reach the wearer's skin and cause a contact hazard. In addition, the protective quality of IPE might be degraded if it is contaminated by ordinary materials such as water, fuels, greases, and oils. Therefore, CB agents should be removed from contaminated IPE to minimize delayed adverse effects.

4-2.4 SPREAD

Contaminated personnel or equipment may pose a potential CB agent threat due to the prospect of spreading the contamination to otherwise uncontaminated areas. For example, contaminated personnel climbing into a combat vehicle. such as a tank, could spread CB agents inside the crew compartment. Contaminated equipment evacuated for repair could spread agent along the passing route. Contaminated supplies and ammunition, if delivered to forward units, could spread CB agents to uncontaminated units receiving the supplies. Therefore, contaminated personnel or items should be decontaminated before they are moved to uncontaminated areas. Spread of contamination can thus be avoided.

4-3 CHEMICAL METHODS

CB agent decontamination methods involve chemical processes for agent removal, neutralization, or destruction. In chemical methods the agent undergoes a reaction that alters its chemical nature. Oxidation and hydrolysis are the two primary chemical reactions used to decontaminate chemical agents and toxins because the chemical nature of agent and toxin molecules makes them susceptible to oxidative and hydrolytic attacks. Oxidation, chlorination, and reduction are the primary chemical reactions proven successful in destroying microorganisms.

Many chemicals have been examined, tested, and used as CB agent decontaminants. The paragraphs that follow focus on some of the most popular and traditional chemical decontaminants. The effects that these decontaminants have on military materials and equipment are discussed in Chapter 5.

4-3.1 FOR CHEMICAL AGENTS

Some chemical agents, such as blister, blood, choking, incapacitating, and V-series agents, contain either an unsaturated chemical bond or a sulfur moiety that is readily subject to oxidation. Other chemical agents, such as V-series and G-series agents, contain phosphorous and chemical groups that can be hydrolyzed. Therefore, most chemical decontaminants are designed to either oxidize or hydrolyze chemical agents (Ref. 3).

In general, the stronger the oxidizing power of a chemical, the faster the reaction rate between that chemical and agent. The hydrolysis rate, however, has more variables involved and is dependent upon the chemical structures of the decontaminant and agent and on reaction conditions such as pH, temperature, solvent, and catalysis. The hydrolysis rate increases sharply at a pH above 8. Under alkaline conditions the reaction rate is proportional to the concentration of hydroxide ion. in general. the reaction rate increases tenfold with each additional pH unit. Temperature also influences these rates. It has been estimated that the rate increases about fourfold for every 10-deg C temperature rise (Ref. 4). The type of solvent used can also affect the hydrolysis rate.

Three tyrpes of chemical methods have been studied extensively for application to chemical agent decontamination. These methods are chemical reactions, incineration, and weathering. Incineration involves both the physical process of heating the agent to induce a change of state and the chemical process of oxidation. Therefore, it is discussed with other chemical methods. Weathering also involves both chemical and physical processes, and is discussed in par, 4-3.1.3 under chemical methods and in par. 4-4.2.3 under physical methods.

4-3.1.1 Chemical Reactants

Although thousands of chemicals have been examined for use as decontaminants, relatively few have been found to be successful for military use. In this paragraph those chemicals currently in the military inventory are discussed along with field-expedient decontaminants. Decontaminants and their effectivness on specific target agents are summarized in FM 3-5 (Ref. 3).

4-3.1.1.1 Decontaminating Solution No. 2 (DS2)

DS2 is a relatively corrosive superbase consisting of 70% diethylenetriamine, 28% ethylene glycol monoethylether, and 2% sodium hydroxide. It is intended to be an all-purpose decontaminant effective against all known chemical agents (Ref. 3). DS2 is a standard military decontaminant and is currently recommended for use as a decontaminant for equipment and vehicles.

In a field evaluation of US decontamination capabilities, the effectiveness of various decotaminants on thickened soman* (TGD) and thickened distilled mustard** (THD) on painted and unpainted surl'aces was measured. DS2, applied with scrubbing, removed 100% of the TGD applied to unpained metal and polyurethane-painted metal and 98.5% of the TGD applied to alkyd-painted metal. Decontamination was per-

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*The abbreviation for soman is GD.

**The abbreviation for distilled mustard is HD.

formed between 0.25 and 1 h after the agent was applied. When the agent was weathered for a longer period (2 to 12 h) prior to decontamination, 99.99%, 97.47%. and 95.11% of of the agent was removed from the polyurethane-painted, bare, and alkyd-painted surfaces, respectively (Ref. 5).

DS2, applied with scrubbing, removed 100%, 98.7%, 98%, and 88.2% of the initial THD deposited on bare metal, alkyd-painted metal, polyurethane-painted metal, and canvas, respectively. DS2, applied with no scrubbing, removed 93.5%, 87.3%, 97%, and 59% of the initial THD from the same surfaces. respectively (Ref. 5).

DS2 is considered to be logistically burdensome because it is not water based and must be stored and transported. DS2 has been reported to remain stable in storage for up to six months at an elevated temperature of 77°C and for several years or more at lower temperatures. This shelf life is considered acceptable for military purposes (Ref. 6).

DS2 is caustic to the skin and eyes and poses an inhalation hazard to personnel; therefore, when handling DS2, personnel must wear protective masks, toxic agent protective (TAP) aprons, and rubber gloves. DS2 is flammable and has a low flash point (75.5°C), so it should not be used on hot surfaces. Furthermore, DS2 should not be mixed with STB or other strong oxidizers because the mixing of the two solutions results in a violent reaction (Ref. 3).

4-3.1.1.2 Supertropical Bleach

Supertropical bleach is effective against blister and nerve agents; therefore, it is considered to be an all-purpose decontaminating agent. STB, a mixture of chlorinated lime and calcium oxide, contains at least 30% available chlorine. It is a standard military decontaminant recommended for applications on contaminated roads and terrain or metals and fabrics (Ref. 3).

STB, prepared as a paste by mixing the solid STB with water (approximately 70% STB by weight), is useful as a decontaminant for surfaces and terrain. Sample application rates for STB slurry on selected surfaces are given in Table 4-2. Slurries of 13% and 40% STB in water (by weight) are recommended for horizontal and vertical surfaces, respectively (Ref. 7).

In tests performed at Dugway Proving Ground, STB slurry was applied both hot and cold and with and without scrubbing to various surfaces contaminated with TGD and THD. Hot STB slurry applied with scrubbing removed 99.64%, 98.33%, and 99.98% of the initial TGD from unpainted, alkyd-painted, and polyurethane-painted surfaces, respectively. Decontamination was performed between 0.25 and 1 h after contamination. Unheated STB applied with scrubbing removed 97.8% 95.75% and 100% of the initial TGD from the respective surfaces following a weathering period of between 0.25 and 1 h. For longer weathering periods (2 to 12 h), comparable removals were achieved for both heated and cold STB slurry (Ref. 5).

TABLE 4-2. APPLICATION RATE OF STB SLURRY FOR SELECTED SURFACES AND TERRAINS (DATA EXTRACTED FROM REFS. 7 AND 8)

Surface/Terrain	Application $1.0 \times 10^{-3} m^3/m^2$
Concrete	2.8
Gravel	2.1
Short Grass	3.1
Long Grass	4.5
Porous Surface	0.57
Smooth Surface	2.3

Hot STB slurry applied with scrubbing removed 100% of the initial THD from metal surfaces that were bare, alkyd-painted, or polyurethane-painted and 95.9% of the initial THD from canvas. Hot STB slurry applied without scrubbing removed 90.7%, 98.1%, 99.4%, and 91.9% of the initial THD from the respective surfaces (Ref. 5).

Unheated STB slurry applied with scrubbing was less efficient than hot STB applied with scrubbing but more efficient than hot STB applied without scrubbing. Unheated STB applied without scrubbing was the least effective of the four methods. Unheated STB applied with scrubbing removed 100%, 98.9%, 100%. and 95.8% of the initial THD from bare metal, alkyd-painted metal, polyurethane-painted metal, and canvas, respectively. Unheated STB applied without scrubbing removed 99.4%, 97.5%, 99.4%, and 60.8% of the initial THD from the respective materials (Ref. 5).

STB is more stable in storage than ordinary laundry bleach; it has a shelf life of six weeks when stored at 70°C and a shelf life of several years or more at lower temperatures. STB causes fewer logistical burdens than DS2 does because STB requires less storage space. For example, STB slurry can be prepared locally by mixing with water prior to use.

Because STB is caustic to the skin and eyes and presents a vapor hazard to personnel, personnel must wear protective masks and rubber gloves when using STB. STB should not be mixed with DS2 because the mixing of the two chemical formulations results in a violent reaction (Ref. 3).

4-3.1.1.3 Mask-Sanitizing Solution

Mask-sanitizing solution is used on previously decontaminated masks with the filter elements removed. The solution is prepared either by adding a 0.5-g tablet of calcium hypochlorite into a standard plastic canteen filled with water or by adding 2.0 g of calcium hypochlorite to one gallon of water. One gallon of solution is sufficient to clean approximately 10 masks (Ref. 3).

4-3.1.1.4 C8 Emulsion (Intermediate Chemical and Biological Agent Decontaminant (ICBAD))

CB emulsion (also known as "German emulsion") is a mixture of 7.5% calcium hypochlorite, 15% tetrachloroethylene, 76.5% water, and 1% emulsifier. It has been reported to be effective against all known nerve agents. Two applications of 15 min each are recommended for effective decontamination (Ref. 9).

CB is water based, which reduces storage requirements, and it can be prepared up to two days before use. CB is normally white in color, but dyes can be added to the emulsion for camouflage purposes. Because CB contains available chlorine, it can be corrosive to the skin and caution should be exercised when applying it.

4-3.1.1.5 Sodium Hypochlorite Solution (Household Bleach)

Sodium hypochlorite solution, also known as ordinary household bleach, is a solution of sodium hypochlorite in water. Depending upon the producer, the percentage of chlorine varies somewhat, however, household bleach usually contains 5% sodium hypochlorite. It can be used for chemical agent decontamination without additional preparation and is effective against blister and nerve agents. The reaction time is rapid (within 5 min) (Refs. 10, 11, and 12). Because bleach solutions are harmful to skin and eyes, precaution should be exercised when applying bleach solutions as decontaminants (Ref. 3).

4-3.1.1.6 High-Test Hypochlorite (HTH)

High-test hypochlorite (HTH) is a powder of calcium hypochlorite containing approximately 70% available chlorine. HTH is effective in destroying blister and V-series agents. The reaction time is rapid (within 5 min) (Refs. 10, 11, and 12).

HTH can be used for agent decontamination without additional preparation. It can also be mixed with water to form a slurry in much the same manner that STB slurry is formed. Specific information related to quantities of HTH required for effective decontamination is described in detail in FM 3-5 (Ref. 3).

Because it is a strong oxidant, HTH is very corrosive. Chemical reactions involving HTH in solid form are frequently very violent and exothermic. When applying HTH as a decontaminant, personnel must wear protective masks and rubber gloves. HTH should not be mixed with DS2 because a violent reaction results (Ref. 3).

4-3.1.1.7 Activated Solution of Hypochlorite (ASH) and Self-Limiting Activated Solutions of Hypochlorite (SLASH)

Activated solution of hypochlorite (ASH) and self-limiting activated solution of hypochlorite (SLASH) are both formed by the addition of small amounts of calcium hypochlorite to water. They behave similarly to the other hypochlorite solutions, e.g., STB, HTH, household bleach; however, ASH and SLASH are not as strongly alkaline as are the other hypochlorite solutions.

ASH is comprised of 0.5% calcium hypochlorite, 0.5% sodium dihydrogen phosphate, 0.05% detergent, and 98.85% water. SLASH is comprised of 0.5% calcium hypochlorite, 1.0% sodium citrate dihydrate, 0.2% citric acid monohydrate, 0.05% detergent, and 98.25% water (Ref. 13).

Both ASH and SLASH contain additives that neutralize the solution by balancing the alkaline hypochlorite ion concentration with the hypochlorous acid concentration. ASH is neutralized by the addition of the weak acid sodium dihydrogen phosphate, and SLASH is neutralized by the addition of sodium citrate, which shifts the equilibrium by constant consumption of the hypochlorous acid (Ref. 14). ASH and SLASH have been used as decontaminating agents for buildings, floors, the ground, and other large areas.

Hypochlorites have been demonstrated to be effective decontaminants for G, V, and mustard agents. A hot solution of ASH is approximately as effective as either a hot solution of STB or a hot solution of soap and water in the removal of TGD from surfaces. ASH is approximately as effective as hot soapy water and less effective than DS2 and STB in the removal of THD from surfaces (Ref. 6). Although SLASH was not tested, it may be slightly less effective than ASH due to the continuous reduction of the hypochlorite ion concentration in SLASH (self-limiting).

Both ASH and SLASH are much less corrosive than STB. However, larger quantities of these solutions are required to achieve decontamination comparable to that achievable with STB.

4-3.1.1.8 Sodium Hydroxide (Caustic Soda or Lye) and Potassium Hydroxide (Caustic Potash)

An aqueous solution of sodium hydroxide (caustic soda or lye) or potassium hydroxide (caustic potash) effectively hydrolyzes Lewisite and all nerve agents (Ref. 3). The hydrolysis rate is dependent upon the chemical structures and reaction conditions such as pH, temperature, solvent, and catalysis (Ref. 4).

Sodium hydroxide or potassium hydroxide solutions have been suggested for hydrolyzing HD, although effectiveness is uncertain because of contradictory experimental results (Refs. 6 and 15). Aqueous sodium hydroxide has been used as a standard decontaminant for bulk G-series agents in munitions and occasionally for VX (Ref. 16). Sodium hydroxide or potassium hydroxide solutions have been used for large-scale equipment and terrain decontamination. Sodium hydroxide is a component of the M258A1 personal Decontamination Kit to neutralize nerve agents and a component of DS2. Sodium hydroxide and potassium hydroxide solutions are highly corrosive to the skin and eyes. The mist or dust of these two chemicals can severely damage the respiratory system when inhaled. Therefore, personnel are required to wear masks, protective clothing, TAP aprons, and rubber gloves when applying these decontaminants (Ref. 3).

4-3.1.1.9 Sodium Carbonate (Washing Soda, Soda Ash, or Laundry Soda)

Sodium carbonate (also referred to as washing soda, soda ash, or laundry soda) when mixed with water (10% sodium carbonate by weight) will rapidly hydrolyze sarin (GB) (Refs. 12 and 17). Sodium carbonate imposes less logistical and storage burdens than, for example, DS2 and poses a negligible hazard to personnel who use the solution as a decontaminant.

4-3.1.1.10 Hexachloromelamine

Hexachloromelamine is a strong oxidant and is \ery effective against HD. It can be used either as a powder or in solution with an organic solvent such as gasoline, kerosene, and paint thinner. Hexachloromelamine causes damage to skin, eyes, and the respiratory system. Personnel must wear masks and rubber gloves when using hexachloromelarnine as a decontaminant (Ref. 3).

4-3.1.1.11 Ammonia and Ammonium Hydroxide (Household Ammonia)

Nonaqueous ammonia and aqueous ammonia (as a solution of ammonium hydroxide) promote the hydrolysis of nerve agents and HD. Gaseous ammonia can react easily with GB and V.X but less rapidly with HD (Ref. 18). Currently. ammonia and ammonium hydroxide are recommended field-expedient decontaminants (Ref. 19).

Ammonium hydroxide is less corrosive than many other bases; therefore, it is easier to handle, store. and apply. However. personnel using ammonia must be protected. Furthermore, a moderate to high concentration of ammonia in air can be explosive. When using ammonia as a decontaminant, precautions should be taken to avoid these hazards (Refs. 3 and 10).

4-3.1.1.12 Chloramine-B and Chloramine-T

Chloramine-B (sodium benzenesulfochloramide) and chloramine-T (sodium para-toluenesulfochloramine) are water-soluble powders containing between 11.5 and 13% available chlorine (Ref. 20). Although relatively expensive, chloramine-B has been incorporated into the M258 M258A1 and the M280 Decontamination Kits (described in pars. 4-7.3 and 4-7.7) to destroy HD and V-series agents (Ref. 3).

Chloramine-B and chloramine-T are more stable and less corrosive to the skin than other available chlorine-containing materials, such as HTH. and they are relatively easy to handle, store, and apply.

4-3.1.1.13 Dichloramine-B and Dichloramine-T

Dichloramine-B (benzenesulfodichloramide) and dichloramine-T (para-toluenesulfochloramine) are water-insoluble powders containing approximately 30% available chlorine (Ref. 20). They are readily soluble in many organic solvents in which blister and V-series agents are also soluble, and hence they have been used to decontaminate these agents (Ref. 1l). These powders are often prepared as a 10% solution in dichloroethane, but this solution is not effective in decontaminating G-series agents (Ref. 6).

Although dichloramine-B and dichloramine-T have less potential for harm to the skin and respiratory system than do chloramine-B and chloramine-T, users should wear a protective mask and rubber gloves when applying these two chemicals as decontaminants (Ref. 3).

4-3.1.1.14 XXCC3

XXCC3 is a combination of CC2[bis-(2,4,6-trichlorophenyl) dichlorourea], 10% zinc oxide (a stabilizer). and a solvent binder. XXCC3 has been incorporated into the ABC-M13 Decontamination Kit, which is described in par. 4-7.5, and has been impregnated into clothing materials for agent protection. especially against HD and V-series agents (Ref. 21). Its principal use has been to impregnate projectile clothing and garments. XXCC3 has not been used for large-scale decontamination operations. most likely because of its high cost.

4-3.1.1.15 CD-1 (also known as APD)

CD-1 (also known as all-purpose decontaminant (APD)) consists of 55% by volume monoethanolamine. 45% by volume 2-hydroxyl-propylamine, and 25% by weight-to-volume lithium hydroxide monohydrate. CD-1 has been found to destroy blister and nerve agents effectively (Refs. 10. 11. and 22).

In comparison to DS2 under the same laboratory conditions, CD-1 is less desirable for decontamination not only because CD-1 destroys HD more slowly than DS2 but also because the end product of the CD-1 and HD mixture is toxic (Refs. 10, 22, and 23).

CD-1 is corrosive to the skin. Furthermore, vinyl chloroethyl sulfide and divinyl sulfide are produced from the reaction between CD-1 and HD, and these are toxic. Personnel who use CD-1 as a decontaminant must wear a mask and rubber gloves.

4-3.1.1.16 Perborate Solution

Sodium perborate and perborate-containing cleaning compounds when applied in excess (for example, 2.0×10^{-3} m^3 of a 20% perborate solution per gram of nerve agent) achieved greater than 99% removal of G-type nerve agents in 1 to 2 min at temperatures at or above 0°C (Ref. 24). 98% removal of VX was obtained in 15 min at 60°C and in 2 h at 25°C by using the excess perborate solution treatment. However, the corrosive nature and relatively slow reaction rates of perborate solutions when compared to analogous active chlorine compounds reduce their use as a field decontaminant.

4-3.1.1.17 Monoethanolamine (MEA)

Monoethanolamine (MEA) is an effective decontaminant for HD. MEA was used to decontaminate several one-ton containers of HD at Fort McClellan, AL (Ref. 25). MEA was selected for decontamination because it is noncorrosive, nontoxic, inexpensive, and relatively nonflammable. The reaction of MEA with HD is relatively fast (half-life of 16 min at 52°C and 321 min at 25°C, both at a 10 to 1 molar ratio of MEA to HD). HD and the nontoxic products formed from reaction of HD with MEA are miscible in MEA. MEA is an effective decontaminant for GB but less effective for VX. 99.8% of GB was decomposed by MEA after one min at 25°C, whereas only 46.0% of VX was decomposed by MEA after 1440 min at 25°C (Ref. 18).

4-3.1.1.18 Chemical Agent Decontaminant (CAD)

Chemical agent decontaminant (CAD) is an aqueous-based Fichlor solution developed and used by the British as a standard decontaminant. It is a mixture of 5.0% sodium dichloroisocyanurate (Fichlor 60S), 2.5% sodium hydroxide, 0.5% boric anhydride, 0.01% Santomers detergent, and water (remainder).

4-3.1.1.19 Miscellaneous Oxidants

Perchloryl fluoride ($C1O_3F$) and dinitrogen tetroxide (N_2O_4) were tested as decontaminants, and the results indicated that neither can effectively decontaminate agents (Ref. 26). Sodium chlorite and sodium chlorate were tested for their ability to decontaminate HD but were no more effective than bleaching powder (Ref. 21).

Polyacrylamidoxime and an unknown product formed by reaction of chloroacetylhydroxylamines with alkyldimethylamines showed very good reactivity with difluorophosphate (DFP) and paraoxon (agent stimulants), but no detailed data were given (Ref. 27). Potassium permanganate in acetone is an effective decontaminant for HD (Ref. 28).

Many oxidants (such as chlorine dioxide, ozonated air, perchloryl fluoride, and dinitrogen tetroxide) can be grouped generically into reactive gases and or aerosols, which have the ability to flush through the interiors of aircraft, vehicles, and shelters for agent decontamination.

4-3.1.2 Incineration

Incineration is a process of thermal oxidation, i.e., burning or combustion of materials in an excess of air and at very high temperature (400° to 1200°C) under tightly controlled gas flow conditions. Toxic agents can be thermally decomposed by incineration with no foreseeable toxic end products (Ref. 29). The relationship between incineration conditions and agent destruction is presented in Table 4-3.

4-3.1.3 Weathering

Weathering is an important decontamination procedure and may be the method of choice if time limitations are not a factor. Both chemical and physical decontamination processes are at work during weathering. The chemical processes of weathering cause degradation of chemical agents by hydrolysis, oxidation, and photodecomposition; these are discussed in this paragraph. Physical weathering includes thermal evaporation and aeration; these processes are discussed in par. 4-4.2.3.

Chemical agents can be decomposed gradually through chemical reactions in a natural environment. Decomposition rate depends on several factors, including

1. Meteorological conditions (temperature, humidity, rain, windspeed, stability, and amount of sunshine)
2. Type of surfaces and materials onto which agents are deposited (soil, concrete, water).

High air temperature and high moisture content promote agent hydrolysis. Although rain and melting snow also enhance agent hydrolysis, the rates of agent volubility and hydrolysis in water are generally slow. Water dissolves and hydrolyzes agents at different rates, depending on agent types and water pH values. Generally, seawater degrades chemical agents more rapidly than

TABLE 4-3. THERMAL EFFECTS DATA FOR SELECTED AGENTS

Thermal Effects Test Data

Agent	Temperature, °C	Residence Time, s	Atmosphere	Destruction Efficiency	Ref.
GB	395	0.65	Nitrogen	86.1%	30
	650	2.7	Nitrogen	"Complete"	31
	1,000	0.3	Oxidizing	99.996%	31
VX	700-750	0.14-0.20	Direct fired	99.91 to 99.99997%	32
	1000-1100	0.25	Oxidizing	99.995%	32
HD	220	7200	Nitrogen	86%	33
	400	0-4	Oxidizing	98.8%	30
	600	2.0	Oxidizing	99.999%	34
	800	0.14-2.22	Oxidizing	99.9994%	29

fresh water because of its higher pH value and its many metal ions that catalyze agent hydrolysis reactions. Water also plays an important role in diluting and transporting chemical agents (Ref. 29).

Sunlight enhances agent decomposition rates through ultraviolet light oxidation, ring fusion, condensation, chemical structure rearrangement. reduction, and functional group replacement. Agent photodecomposition takes place much faster on nonpermeable surfaces than on porous surfaces.

If concrete is contaminated by chemical agents, natural weathering is sufficient for agent decontamination. Concrete absorbs and degrades most chemical agents rather rapidly due to its porous surface, high pH (12 to 13), ionic chemical constitution, and ability to retain occluded water within the matrix. Thus, concrete provides a microenvironment that is conducive to agent degradation (Ref. 18).

Soils are complex mixtures of inorganic minerals, organic matter, water, and living organisms. Soils may absorb, retain, and degrade chemical agents, depending on the type of soil. The factors that follow affect the destruction of agents in soil (Ref. 35):

1. Soil Properties and Constituents
    a. Soil type
    b. Inorganic constituents (selected inorganic materials can adsorb agent and or catalyze agent decomposition by hydrolysis)
    c. Organic matter (may absorb and or react with agent)
    d. Water content (necessary for hydrolysis)
    e. pH (affects rate of agent decomposition by hydrolysis)
2. Microorganisms (may metabolize agents to innocuous products)
3. Soil Temperature (affects hydrolysis, adsorption, and evaporation)
4. Soil Porosity
    a. Mass flow (liquid agent may leach into soil)
    b. Diffusion (agent vapor may diffuse into porous soils).

Generally, clay soils have a higher capacity and a faster rate of hydrolysis in agent destruction than soils of sand and silt.

4-3.2 FOR BIOLOGICAL AGENTS

Most microorganisms can be destroyed by sunlight (i.e., ultraviolet radiation), heat, cold, desiccation, osmosis, and chemicals. However, there are spores produced by cells of a number of infectious bacterial species that are not easily killed and can remain viable for years. Spores are produced when the environment becomes too unfavorable for existence of the vegetative forms. The great resistance they exhibit is due to their high lipoid content, which is largely responsible for their increased impermeability to substances. Toxins, which are classified as biological agents, are potent poisons produced from a variety of biological sources. They vary in their response to conditions for destruction due to variation in their chemical structure. Toxins, such as aflatoxins and botulinum toxin, generally can be destroyed by several means including heat, oxidation, and hydrolysis. Staphylococcus enterotoxin, Type B, is stable in the environment and is more resistant to physical and chemical inactivation than the chemical nerve agents such as GB and V agents.

Bleaching powder, a chlorine-containing compound, is one of the most effective germicides because of its ability to produce vigorous oxidations. It will effectively destroy most toxins, whereas moderate heat, such as boiling water. will destroy only a few types of toxins. Although microorganisms and toxins can be removed from a surface or individual by washing with a detergent-water solution, these agents usually are not destroyed by the solution. After washing, water containing biological agents will have to be collected for disposal and must be handled carefully to avoid spreading the biological contamination,

Ideally, biological decontaminants should be readily available, fast acting, effective against most agents, and inexpensive. Two types of biological decontaminants generally used are discussed in pars. 4-3.2.1 and 4-3.2.2.

4-3.2.1 Chemical Reactants

Although a variety of biological agent decontamination mechanisms is available, the chemical reaction of oxidation is the most effective. Therefore, oxidants used for chemical agent decontamination (such as bleaches, chloramine, and perborate solution) may also be used for biological agent destruction. Bleaches containing hypochlorite are currently favored over other reactants for biological agent decontamination. Other chemical oxidants specifically designed for biological agent decontamination are summarized in FM 3-5 (Ref. 3). The paragraphs that follow discuss chemical reactants used for biological agent decontamination.

4-3.2.1.1 Soap and Detergent Solutions

Soaps and detergents are comprised of wetting agents or surfactants and emulsifiers. When dissolved in water, these components lower surface tension, form colloidal solutions, cause water to wet surfaces more rapidly, and disperse insoluble substances to be removed in solution, and thus are able to cleanse. Soaps and detergents, therefore, primarily act to remove biological agents; some hydrolysis does take place over a period of time (dependent on the activity of the solution).

At present, soap and detergent solutions are preferred decontaminants for removal of biological agents from contaminated personnel (Ref. 3). Rapid removal of toxins from the skin is highly encouraged, and if available, soap and water or the M258A1 towellettes should be used. Soap and water removed 87% to 88% of T-2 toxin applied at room temperature to the shaved skin of rats (Ref. 36).

4-3.2.1.2 DS2

DS2 is currently a standard decontaminant for chemical agents; however, it also destroys biological agents, with the exception of spores (Ref. 3). Ten percent DS2 in water neutralized 91% T-2 toxin after 0.5 h (as determined by cytotoxicity assay). No further neutralization of T-2 toxin was observed after 4 h exposure to the 10% DS2 in water solution (Ref. 36). (DS2 is to be used as packaged, i.e., undiluted). If other, less corrosive, decontaminants are not available, DS2 may be used carefully to decontaminate biological agents. Because DS2 is a strong irritant to the eyes and skin, personnel must wear a protective mask, TAP aprons, and rubber gloves when applying it (Ref. 3).

4-3.2.1.3 STB and HTH

STB and HTH are strong oxidants, and they are effective against biological agents including spores. STB and HTH are more effective when prepared in slurry than they are in dry form to decontaminate wood, terrain, concrete, and other porous surfaces that are not damaged by chlorine. When bleaches are applied, safety precautions are recommended. STB and HTH are usually formulated into a 7% by weight slurry with water and applied to contaminated surfaces for 30 min (Ref. 3). An STB slurry neutralized 96.8% of T-2 toxin after 0.5 h and 99.79% after 4 h as determined by cytotoxicity assay (Ref. 36).

4-3.2.1.4 Bleaches

Commercial brands of household bleach (aqueous sodium hypochlorite solutions) are effective for destroying microorganisms including spores (Ref. 3). To avoid unnecessary damage to fabrics, bleaches should be diluted before use (for example, M cup of bleach to $3.8\ X10^{-3}\, m^3$ of water for decontaminating cotton clothing). The clothing should be immersed in the solution for 30 min (Ref. 3). The hypochlorous acid (HC1O) then breaks down to hydrogen chloride and releases oxygen during oxidation. The germicidal activity is directly proportional to the extent to which reactions of hydrolysis proceed in solution.

Sodium hypochlorite bleach (2.57% NaOCl in water (weight to volume)) neutralized more than 95.8% of T-2 toxin after 10 min. The degree of neutralization decreased to 77.7% and 47.7% for the same period for NaOCl concentrations of 1.0% and 0.25%, respectively (Ref. 36).

Two drops of sodium hypochlorite (as common household bleach) are recommended for decontamination of $1.0X10^{-3}\, m^3$ of potable water in 30 min. The germicidal activity of hypochlorite solution is dependent upon pH, temperature, available chlorine content, and the presence of other organic matter. Acidifying hypochlorite converts the germicidally inactive hypochlorous ion $(OC1^{-})$ to the germicidally active hypochlorous acid (HCIO). As in chemical reactions, an increase in temperature increases the rate of hypochlorite reaction with biological agents. The decontamination rate of biological agents is approximately proportional to the available chlorine content. A doubling of available chlorine content reduces the time required to destroy Bacillus subtilis (BG) and anthrax spores by about 50%. The presence of organic matter other than biological agents would reduce the decontamination effectiveness of hypochlorite as a result of consumption of hypochlorite by the organic matter (Ref. 37). The organic matter inactivates the HC1O by combining with the chlorine which reduces the ionic concentration.

4-3.2.1.5 Mask-Sanitizing Solution

Mask-sanitizing solution is used on previously decontaminated masks with the filter elements removed. It is effective for destroying microorganisms except spores. The solution is prepared either by adding a O. S-g tablet of calcium hypochlorite to a standard plastic canteen filled with water or by adding 2.0 g of calcium hypochlorite to $3.8X10^{-3}$ m^3 of water. This amount of solution is sufficient to clean approximately 10 masks (Ref. 3).

4-3.2.1.6 Chloramine-B

Chloramine compounds containing active chlorine attached to a nitrogen atom are also strongly germicidal. Their activity is directly proportional to the extent of hydrolysis in solution. They have been incorporated into the M258/M258A1 kit for chemical agent decontamination. If soap and detergent solutions are not available, however, M258A1 towelettes soaked with chloramine-B are recommended to wipe biological agents from the skin. The M258A1 kit (described in par. 4-7.3) decontaminated 99.9% of T-2 toxin applied at room temperature to the shaved skin of rats. The results indicated no chemical detoxification of T-2; rather physical removal was responsible for the decontamination (Ref. 36). Chloramine-B kills microorganisms, but it may not destroy toxins and spores.

4-3.2.1.7 Iodine Water Purification Tablets

Iodine is an oxidant and is effective against most microorganisms found in drinking water. In comparison with chlorine and bromine, iodine is not appreciably hydrolyzed in acid solution; hence it acts as molecular 12 or in the form of I_3^- ion. These forms seem to be equally effective. The mechanism of action of iodine is apparently different from that of HC1O. If boiling of water is impracticable, two iodine tablets can be added to a canteen of water for microorganism destruction (Ref. 3).

4-3.2.1.8 Formalin (Formaldehyde)

Formalin (formaldehyde) produces a germicidal action by its power of reduction. It is a very efficient germicide it is effective against both vegetative cells and spores. A 5% solution of formaldehyde (Commercial Formalin is a 40% solution of formaldehyde gas in water.) destroys anthrax spores in 1 to 2 h. It is recommended as an interior decontaminant for relatively closed areas (Ref. 3). Formalin is available in a solution or gaseous form for biological agent decontamination inside buildings. The ideal temperature for its use is between 21° and 26°C with a relative humidity of 85%, and the vapor should be allowed to remain within a closed structure for 16 h. Formalin vapor is harmful to personnel: thus when personnel remain in a formalin-filled building, they should wear a self-contained respiratory protection device.

4-3.2.1.9 Detrochlorite

Detrochlorite is a mixture of calcium hypochlorite, diatomaceous earth, and wetting agent. The diatomaceous earth (a fine, white siliceous powder) acts as a binder for the calcium hypochlorite, and this combination acts as a germicidal and absorbing component of the solution as biological agents are released from surfaces by the wetting agent. It can be used for biological decontamination of vertical surfaces to which the application of corrosive material is permissible. After a contact period of 30 min. the mixture should be removed by washing the surface with a stream of water. Procedures for use of detrochlorite are detailed in FM 3-5 (Ref. 3).

4-3.2.1.10 Peracetic Acid (PAA)

Peracetic acid (PAA) is a strong oxidant and is effective against all microorganisms including spores. It is obtained as a 40% solution and should be diluted to 2% with water by volume before use (Ref. 3). The toxic effect that the acetic acid produces on microorganisms may be due to the amount of dissociated hydrogen in the acetic acid or to the additional effect of undissociated molecules or both.

The 40% PAA solution is highly flammable, and it should be used carefully and kept away from fire. Contaminated small items can be decontaminated by immersing them into 2% PAA for 10 min. Contaminated surfaces can be swabbed with 2% PAA (Ref. 3).

4-3.2.1.11 Ethylene Oxide (ETO)

ETO is effective against all microorganisms including spores (Ref. 3). It is usually formulated into an aerosol-type mixture (12% ETO and 88% fluorinated hydrocarbons). Vapors of this ETO and fluorinated hydrocarbon mixture are used to decontaminate clothing and small items in an airtight plastic bag. The vapors can also be used to decontaminate large equipment, such as vehicles, under a tarpaulin.

Although the ETO vapor mixture is not corrosive, its condensed liquid form may damage skin, other human tissues, and some materials. “Therefore. a respiratory device and rubber gloves should be worn when using the ETO mixture. The recommended decontamination temperature is 21°C or above for several hours (Ref. 3).

4-3.2.1.12 Carboxide

Carboxide is a mixture of ethylene oxide and carbon dioxide that is effective against all microorganisms and spores. It is nonflammable and is recommended for decontaminating the interior of items or buildings. Decontamination of an enclosure is accomplished by filling the enclosure with the gas for 12 h (Ref. 3).

4-3.2.1.13 Hyamines

Hyamines are the trivial name given to quaternary ammonium-type (for instance, benzethonium chloride) bactericide (Ref. 20). These compounds are effective against all bacteria. but they may not destroy other microorganisms and spores. Hyamines are used as a 0.1 to l% solution. When applying hyamine for biological agent decontamination, caution should be taken to avoid inhalation of hyamine powder (Ref. 3).

4-3.2.1.14 Sodium Hydroxide, Barium Hydroxide, and Potassium Hydroxide

A 10% sodium hydroxide or potassium hydroxide (KOH) solution is ef!ectiie against all microorganisms and spores (Ref. 3). of these, potassium hydroxide shores the greatest germicidal action because of its greater degree of dissociation, but there are some exceptions to the ionization rule. Barium hydroxide, $Ba(OH)_2$, for example. is less dissociated than KOH, yet it is considerably more effective. This is due to the high toxicity of the barium ion. The combined action of the barium and hydroxyl ions produces a greater germicidal action than that exhibited by the action of either ion alone. Barium hydroxide is used mainly to decontaminate agent-contaminated surfaces, and the contact time should be no less than 15 min.

Caution should be taken when using sodium hydroxide solution as a decontarninant because the solution is quite corrosive and can damage the skin and eyes.

4-3.2.1.15 Activated Solution of Hypochlorite (ASH) or Self-Limiting Activated Solutions of Hypochlorite (SLASH)

Activated solution of hypochlorite has slightly more germicidal power toward Bacillus subtilis spores than does dilute bleach. A 99.6% reduction of spores from polyurethane-painted steel strips contaminated at an average density of $1.96X10^6$ spores/strip was achieved with ASH sprayed from an M13 Decontaminating Apparatus compared with a 98% reduction achieved with bleach. ASH significantly reduced secondary aerosol hazard when sprayed as compared with water and rapidly decontaminated contaminated runoff (Ref. 38).

ASH was recommended for use as a field-expedient decontaminant for biological-agent-contaminated clothing, masks, foods, equipment, skin, and small areas of terrain. The ASH solution should have a minimum of 400 ppm available chlorine and a pH of 6 (Ref. 37).

A solution of ASH acidified to pH 5.5 with acetic acid neutralized 86.7% of T-2 toxin after 0.5 h as determined by cytotoxicity assay. A 99.9% neutralization of T-2 toxin was achieved after 4 h. Under similar test conditions SLASH was ineffective in neutralizing T-2 toxin (Ref. 36).

4-3.2.1.16 C8 Emulsion

C8 emulsion neutralized 58.6% of T-2 toxin, as determined by cytotoxicity assay, after an exposure time of 0.5 h. 95.2% of T-2 toxin was neutralized by C8 after 6 h (Ref. 36).

4-3.2.1.17 Chlorine Dioxide Solution

A 97.1% reduction in BG spores was achieved by spraying a solution (0.8% by weight) of chlorine dioxide in water on polyurethane-painted steel, with an exposure time of 5 min. Reduction increased to 99.9% after an exposure time of 10 min and to nearly 100% after 20 min (Ref. 39). The action of chlorine dioxide is due principally to the slight increase in hydrogen ion concentration induced in the liquid surrounding the spores. The fact that chlorine directly attacks the protein molecule and replaces the hydrogen in the amino groups also contributes.

4-3.2.2 Oxidation by Ultraviolet (UV) Radiation

Nucleic acids are found in all living cells. There are two types of nucleic acids: ribose nucleic acid (RNA) and deoxyribose nucleic acid (DNA). RNA is found predominantly in the cytoplasm, although a small amount is also found in the nucleus, whereas DNA carries genetic properties and is located exclusively within the nucleus. Nucleic acids absorb a significant amount of ultraviolet (UV) light; maximum absorption occurs at a wavelength of 260 pm. This energy absorption during irradiation in the presence of atmospheric oxygen induces oxidation of the nucleic acid chemical structure to produce hydrogen peroxide. Both the ozone and the hydrogen peroxide formed during irradiation are powerful factors in the destruction of microorganisms. Light exposure causes DNA mutation, whereas excess exposure damages DNA structures severely and hence kills the living cells. Spores of Bacillus anthrax required approximately twice the exposure as vegetative cells to produce the same percentage of reduction. Many hospital rooms are irradiated to sterilize or greatly decrease the number of organisms in the air. Therefore, UV radiation can be used to destroy microorganisms including bacterial spores, and sunlight is the best source of large-scale UV radiation.

4-4 PHYSICAL METHODS

Various physical methods have been used to decontaminate CB agents. These methods include thermal decomposition, separation by osmotic pressure, and sorption processes. Because physical methods involve a change of physical state rather than any chemical changes, physical decontamination alone generally does not destroy CB agents. The agent hazard may be removed from the contaminated surface, but the chemical nature of the CB agent remains unchanged. However, some physical methods also promote chemical reactions that destroy the agent.

In pars. 4-4.1 and 4-4.2 physical decontamination methods are divided into aqueous and nonaqueous approaches. This division was made because most military equipment can be grouped into two categories: water-sensitive and water-resistant equipment.

4-4.1 AQUEOUS APPROACHES

Aqueous approaches to physical decontamination of CB agents involve the use of equipment and water to remove CB agents by both mechanical force (where pressurized aqueous solutions are used) and solubilization. Aqueous approaches have the added benefit of including chemical decontamination processes for those CB agents that are subject to hydrolysis.

The two fielded aqueous decontamination methods—described in pars. 4-4.1.1 and 4-4.1.2—are hot water and steam.

4-4.1.1 Hot Water

Hot water is an effective means of decontaminating many CB agents. Most agents are more soluble in hot water than in cold water; therefore, use of hot water increases physical removal by increasing agent solubilization. VX is an exception in that its volubility in water decreases as the temperature increases. Many agents are also subject to hydrolytic destruction; consequently, use of hot water promotes chemical decontamination by increasing the rate of agent hydrolysis.

Several actions can enhance the decontamination efficiency of hot water. These actions are

1. Adding detergent, surfactant, or disinfectant to water. These chemical additives increase chemical agent volubility and promote destruction of microorganisms and spores.
2. Mixing strong base chemicals with water to increase the pH level and thus accelerate the rate of agent hydrolysis
3. Using highly pressurized hot water to facilitate physical removal of agents
4. Combining hot water with equipment to allow scrubbing and brushing of contaminated surfaces; this action facilitates agent removal.

There are, however, certain disadvantages to the use of hot water for physical decontamination. For example, HD is sparingly soluble in water, even with the addition of surfactant (Refs. 40 and 41), and VX has greater volubility in cold water than in hot water (Ref. 10).

4-4.1.2 Steam

Steam can be employed to remove and to hydrolyze CB agents and has been reported effective in decontaminating HD, which is the most difficult agent to remove due to its low volubility in water (Refs. 10 and 42).

The effectiveness of steam as a decontaminant can be further improved with the addition of soaps, detergents, organic solvents, and reactants such as ammonia, CD-1. and sodium hydroxide (Ref. 10).

Steam may volatilize agents before they are effectively destroyed. Therefore, decontamination of CB agents with steam should be accomplished in an open space so that volatilized agents can be dispersed into the air.

4-4.2 NONAQUEOUS APPROACHES

Nonaqueous approaches to physical decontamination, i.e., physical processes that use no water, can be grouped in four principal categories:

1. Organic solvents
2. Dry heat
3. Weathering
4. Dry sorbents.

These categories are described in subpars. 4-4.2.1 through 4-4.2.4.

4-4.2.1 Organic Solvents

Volubility affects both the ease of physical removal of the agent and the rate of interaction among reactive components. Solvents with polarities similar to those of the agents will be effective in solubilizing agents, and such solubilization may allow contact between the agent and any reactive decontaminant. This contact, in turn, may mean enhanced decontamination. CB agents are either slightly polar or relatively nonpolar; consequently, they are likely to be more soluble in relatively nonpolar solvents than they are in polar solvents (Ref. 10). Use of an organic solvent offers an advantage over water-based systems because the volubility of agents in organic solvents is generally much greater than it is in water.

Many organic solvents are used for industrial applications. Certain of these solvents are also used for military applications. For example, ethylene glycol is used in military vehicles as antifreeze. Gasoline, JP4, diesel fuel, and kerosene are other examples of readily available organic compounds that might be used as solvents for CB agent removal.

A disadvantage to the use of organic solvents for agent removal is that the solvent solution may require additional steps in order to destroy the toxic agents completely before solvent disposal. Other disadvantages are the flammability and toxicity of many organic solvents.

Many organic solvents may both solubilize and destroy microorganisms. These solvents can denature protein and damage cell membrane structures. Perchloromethane, various alcohols, acetone, and formalin have been used successfully for destruction of microorganisms.

4-4.2.2 Dry Heat

Heat can volatilize, pyrolyze, or oxidize chemical agents. The effects that heat will have on agents depend greatly on the temperature and the availability of oxygen. Volatilization of chemical agents usually occurs a little above the boiling temperature of the agent. Because agents are not thermally decomposed during volatilization, adequate and forced ventilation become essential if a thorough decontamination is required. Pyrolysis of an agent occurs at high temperatures in an inert atmosphere. However, potentially hazardous and toxic end products may be produced during HD pyrolysis; these products include ethyl mercaptan, diethyl sulfide, and vinyl chloride. Consequently, adequate ventilation is essential to safeguard personnel. Complete oxidation or combustion of agents occurs in an excess of air and at very high temperatures; few, if any, toxic end products should be expected (Refs. 10, 18 and 35).

Dry heat may kill some biological agents because microorganisms tend to die rapidly at high temperature and low humidity, However, microorganisms in spore forms and some toxins may not be destroyed by dry heat (Ref. 43). Dry heat techniques often mentioned for agent decontamination include forced hot air heat and radiant (infrared) heat.

Forced hot air can be used to volatilize agents and thus remove them from contaminated surfaces. Use of hot air closely resembles the weathering process, i.e., hot air accelerates the natural volatilization and, as a result, decontaminates the agent-contaminated surface.

The effectiveness of the hot air for physical removal of an agent depends in part on interactions between the agent and the surface on which it resides (the substrate) and on the thermal resistance of this substrate. For example, polymers are generally more susceptible to agent penetration and less heat resistant than metals are. As a result, agents would be more easily removed from uncoated metal panels than they would be from alkyd-painted surfaces. An added dimension must be considered in evaluating the effectiveness of forced hot air for physical removal of thickened agents because hot air will likely leave behind a residue of the thickening substance, which may contain low levels of agent.

A hot-air stream with a nozzle temperature in the range of 200% to 245°C was very effective in removing agents CD, TGD, HD, and EA1699 from both canvas and painted steel surfaces within 1 min (Ref. 44). Hot air flowing through a conventional oven was effective in removing GD, THD, GB, and VX from the fielded protective gloves, boots, and butyl-rubber-coated cloth. It was, however, ineffective in removing these agents from the protective overgarment: Greater than 25% of the agent remained after the forced hot air treatment (Ref. 45).

Forced hot air was evaluated for use on both the interior and exterior of several military vehicles, namely, B-29 bomber, 5-ton truck, M60A1 tank, and M113A1 armored personnel carrier. Samples of agent-contaminated materials were placed in various locations within the equipment and subjected to a flow of hot air (66°C) for as long as 4 h. Test results indicated that some of the tested materials remained contaminated at potentially hazardous levels (Refs. 6 and 46).

Although forced hot air may be effective in removing CB agent contamination, this process may have adverse effects on the substrate such that the material or item is no longer usable. For example. testing of forced hot air for decontamination of IPE demonstrated that all items were severely damaged when heated to 260°C for 1 h (Ref. 47).

4-4.2.3 Weathering

The principal physical mechanisms of decontamination by weathering are evaporation and transportation of the agent from the contaminated surface. Weathering provides an inexpensive and effective method for large-scale agent decontamination. The rate of agent decontamination is governed by several factors:

1. *Agent Volatility.* The more volatile an agent is. the faster it will evaporate. For example, GB is more volatile than VX. Consequently, GB is more readily decontaminated by weathering than VX.
2. *Wind Speed.* Wind speed significantly influences the agent evaporation rate. High wind speed hastens dispersion of the agent in the air and minimizes diffusional limitations. As a result, agents on contaminated surfaces become less persistent.
3. *Temperature.* Temperature has pronounced affects on the agent evaporation rate. High ambient temperature accelerates the agent evaporation rate and thus reduces agent persistence on contaminated surfaces. The combined effect of temperature and wind speed on agent persistence is depicted in Fig. 4-1.
4. *Rain and Snow.* Rain and melting snow may wash agents away from contaminated surfaces, but they may cause the contamination to spread to other areas, especially into drainage and other lowland areas.

Physical weathering processes may be effective decontamination for microorganisms. Sunlight, elevated temperature, high wind speed, and low humidity can cause dehydration of microorganisms and consequently kill

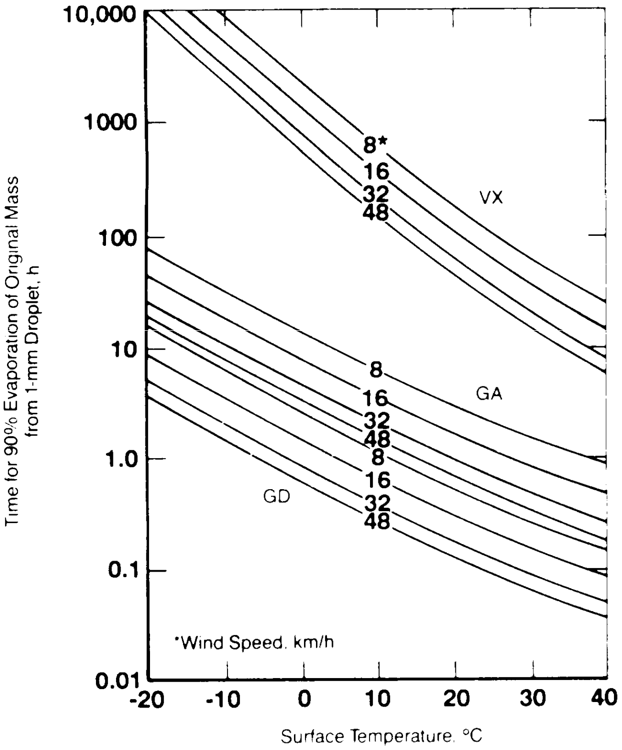


Figure 4-1. Evaporation Time for 90% of Original Agent Mass (1-mm Droplet) as a Function of Temperature and Wind Speed (Ref. 48)

them. Rain and melting snow may wash microorganisms away from contaminated surfaces. However, the effectiveness of weathering for microorganism decontamination varies widely.

4-4.2.4 Dry Sorbents

Dry sorbents are solid powders that are used to absorb agents. Traditional dry sorbents used by the military for physical decontamination include activated carbon (activated charcoal) and fuller's earth. Other dry sorbents include silica gel, alumina powder, and phenolic resins.

Activated carbon is one of the best sorbents for gases because of its nonspecific nature, high sorptive capacity. and fast sorption rates. For this reason, ASC whetlerite (a steam-activated bituminous coal impregnated with various metals) is currently used as filter material in many masks and collective protection devices; activated charcoal is impregnated into clothing.

Fuller's earth is a highly sorptive clay-type material consisting primarily of montrnorillonite and having a high (50 to 80%) silica content. The physical removal efficiency of fuller's earth for VX and G-series agents from rabbit and human skin has been reported to be as high as 85 to 95% in laboratory studies, although somewhat lower results were obtained in field studies (Ref. 49). Fuller's earth may permit some agent resorption, but use of an excess amount of fuller's earth should be effective in retaining the absorbed agents. Although silica gel has a low sorptive capacity, it can be a good sorbent powder if purified and activated. For this reason, Warsaw Pact nations have used powdered silica gel in their individual medical protection kit (Ref. 49). When silica gel is combined with clay powder and formulated into a pressurized aerosol spray system, up to 80% of an agent can be removed from clothing without additional rubbing (Ref. 30).

Alumina powder has the highest sorption rate among the dry sorbents that have been measured, but its sorption capacity is less than that of tuner's earth (Ref. 30). Therefore, alumina powder may be the dry sorbent of choice if speed of sorption, rather than capacity. is critical.

Phenolic-type resins are known to hold G-series agents effectively by hydrogen bonding and are considered to be possible sorbent material for agents. Testing of nitro- and fluoro-phenol resin-impregnated clothes indicated that these phenol derivatives effectively held G-series agents and VX but were inadequate against HD (Ref. 30). Sawdust, soil, silicone, coal dust, amine- and sulfonic-acid-containing polymers, organic and inorganic ion-exchangc materials, and metal oxides have been suggested as absorbing agents (Ref. 33) but have not proved practical. Testing of several household products for CB agent removal has shown that flour, followed by treatment with water (wet tissue paper), can effectively remove till agents from freshly contaminated skin (Ref. l).

Three novel types of high-surface-area polymeric resins for application in agent decontamination are carbonaceous adsorbents, polymeric absorbents, and reactive resins. A brief description of each type of adsorbent follows (Ref. 16):

1. *Carbonaceous Resin Adsorbents.* This material has higher gas-phase dynamic capacities for simulants and agents (HD, GD, and cyanogen chloride) than does granular actitvatcd carbon. The dynamic capacity of this adsorbent is not reduced when the relative humidity is increased, even to 100%. Carbonaceous adsorbent activity can be regenerated under mild conditions, such as being purged with low-pressure steam, hot air, or an organic solvent. Under normal opreating conditions these resins reportly retain the agents more tenaciously than granular, activated carbon. The individual resin beads are very strong and resistant to attrition.

2. *Polymeric Adsorbents.* This material has high capacities for simulants. Capacities are more than twice those of granular, activated carbon. These polymeric adsorbents function well at high humidity and can be regenerated under mild conditions.

3. *Reactive Resins.* These resins are highly functionalized forms of the polymeric absorbents. They

combine the high capacity of the polymeric absorbents with a wide range of active chemical groups. These chemical groups include the groups normally used in ion exchange resins and groups prepared specifically for decontamination applications. The rates of reaction of functional groups attached to polymeric resins can exceed the rates of reaction of these same groups when attached to small molecules. Incorporating reactive groups into a larger, polymeric molecule has the added benefit of making these groups less corrosive toward such substrates as metal, paint, and skin than these groups would be if attached to smaller molecules.

No explicit data on hazards are available for these sorbent powders. In general. agent-laden dry sorbents may be desorbed to be residual vapor hazards to personnel. Therefore, personnel who use dry sorbents as decontaminants may need to wear protective masks to protect their respiratory system from residual vapor hazards.

4-5 LEVELS OF DECONTAMINATION

Under ideal conditions personnel using protective gear should be thoroughly decontaminated immediately following exposure to any CB agent. This desire for immediate decontamination applies equally to any equipment that should become contaminated. However, immediate decontamination may be unrealistic in a combat environment for various reasons. For example. thorough decontamination requires considerable time and may call for resources, including equipment and personnel, that are unavailable in the combat area. Furthermore, contaminated personnel may still need to complete their assigned combat mission.

In recognition of these constraints the US Army specifies two levels of decontamination—partial and complete—to respond to the CB battlefield situation.

4-5.1 PARTIAL

The term “partial decontamination” pertains to the process of removing or neutralizing a portion of the total CB agent contamination from affected protective gear or military equipment. The portion that is decontaminated must be sufficient to allow operations to be sustained.

Partial decontamination may be accomplished by reducing the total amount of contamination or by completing decontamination of a small area on a piece of equipment. Examples of the latter case include thorough decontamination of small areas such as the operator’s controls on a generator, the firing controls on a weapon, and the exit and entry paths from a contaminated vehicle.

Partial decontamination slows the spread of contaminants and thus sustains the combat capability of a contaminated force. Partial decontamination benefits combat operations by

1. Reducing the risk to personnel using mission-oriented protective posture (MOPP) gear because they are not constantly touching lethal contaminants and they are less likely to spread contamination to uncontaminated areas
2. Allowing personnel to enter collective protection shelters without risk of spreading CB agents inside shelter
3. Reducing the total amount of CB agents on equipment surfaces. This reduction expedites the weathering process and facilitates follow-on complete decontamination (Ref. 3).

4-5.2 COMPLETE

The term “complete decontamination” describes the process of extensive removal or neutralization of CB agents on contaminated equipment surfaces. Decontamination is complete from an operational perspective when contamination is reduced to a level that permits personnel to operate for extended periods without wearing a protective mask or protective gloves (Ref. 3).

If an item is designed for NBC survivability, complete decontamination should reduce contamination levels to negligible risk values. These CB agent negligible risk values are defined in AR 70-71 (Ref. 2) to be those levels of CB agents that will cause no more than 5% mild incapacitation among unprotected personnel working inside, on. or within 1 m of agent-contaminated items.

Even at this stage of decontamination, residual contamination may exist. Therefore, equipment surfaces and areas should be monitored periodically for at least 12 h, and personnel should be examined for symptoms of agent poisoning.

4-6 MATERIAL TO BE DECONTAMINATED

Agents can be transferred to the surface of the skin, protective gear, and equipment by contact. Once skin and material surfaces are contaminated, agents (especially liquid agents) begin to penetrate into the inner layers of the contaminated skin and materiel. The rate of penetration is dependent on several factors, including

1. Concentration and quantity of CB agent initially transferred to the person or equipment
2. Physical and chemical nature of the agent, including presence of additives to the agent, particularly thickener
3. Agent form (vapor, liquid. or solid)
4. Characteristics of the person or equipment contaminated
5. Weather factors.

The higher the initial CBagent concentration or the larger the initial agent droplet size that appears on the surface of a contaminated area. the faster the penetration rate. The penetration rate of an agent is also dependent upon its physical characteristics. Thickened agent droplets remain beaded upon most surfaces and penetrate slowly into the inner layer of the material. With respect to the agent form, neat liquid agent can be absorbed by or penetrate into permeable materials very quickly, i.e., almost immediately upon contact with the material.

The whole process of agent penetration, absorption, and resorption continues in persons and materials, especially clothing, until all agent phases reach an equilibrium. This equilibrium is determined by the material absorption isotherm and the ambient meteorological conditions. It is generally agreed that decontamination processes become inefficient once agents have penetrated into the skin or inner layer of the material. Therefore, for skin or material decontamination, the sooner the decontamination action is performed, the better the results will be. The rate of agent resorption and evaporation depends partly on weather factors such as wind speed, temperature, humidity, and sunlight.

4-6.1 INDIVIDUAL (SKIN)

If the skin is contaminated by a CB agent, steps should be taken immediately to decontaminate in order to prevent agent absorption through the skin. Immediate action should reduce both the prospect that adverse toxicological effects will occur and the severity of the effects that do occur.

4-6.1.1 For Chemical Agents

The M258/M258A1 kits (described in par. 4-7.3) are intended for use in decontaminating chemical agents including blister and nerve agents from the skin. It M2581 M258A1 kits are not available, detergent soap and water or an aqueous bleach solution maybe used as a field-expedient decontaminant. If detergent, soap or bleach is used, the skin should be neutralized with water or dilute acid, such as vinegar (acetic acid). After decontamination, the exposed individual should be treated by medical personnel.

If decontamination kits, detergent/soap, and bleach are not available, the contaminated skin area may be pinch blotted with cloth and then flushed with water. Pinch blotting is superior to rubbing because blotting prevents spreading of the agent.

4-6.1.2 For Biological Agents

Currently there are no decontamination kits fielded for biological agents. However, the M258A1 kit has effectively removed T-2 toxins from the skin (Ref. 36). These toxins enter the body by absorption through the skin. Most biological agents, except certain toxins, pose their primary threat through inhalation of aerosols or ingestion of contaminated food or water. Biological agents are generally solids; consequently, skin is an effective barrier against many biological agents if there are no open sores or cuts on the skin. Decontamination by washing with soap and water is usually effective for removing biological agents from the skin. A 1.5% sodium hypochlorite (household bleach) solution is also an effective biological decontaminant. Showering and bathing diminish the occurrence of infection and disease by removing chemical or biological hazards from skin surfaces.

4-6.2 PERSONAL EQUIPMENT

Personal equipment includes individual protective equipment (such as the mask and protective clothing), weapons, and individually carried items (such as ammunition and field pack). CB agent contamination of personal equipment may be both a contact hazard and a delayed vapor hazard. To reduce the risks from both types of hazards. contaminated personal equipment should be decontaminated as soon as the combat mission allows. Procedures for the decontamination of personal equipment are detailed in pars. 4-6.2.1 through 4-6.2.4.

4-6.2.1 Protective Mask

Contamination can be removed from the external parts of the protective mask by use of the M280 Decontamination Kit, Individual Equipment or by washing with warm, soapy water.

The M280 kit provides the capability to decontaminate G-series, V-series, H, and biological agents from a soldier’s personal equipment. i.e., mask, gloves, hood, overboots, and weapon. The towelette containing Solution 1 from the M280 kit is used to wipe off any liquid agent from the lenses and mask while decontaminating the G-series agents. Application of Towelette 2 immediately following application of Towelette 1 completes the decontamination procedure with the decontamination of the H and V-series agents. If the M280 kit is unavailable, the M258A1 kit should be used. It employs the same technology, except for a smaller sized towelette, and is applied in the same manner as the M280 kit.

When decontaminating the mask by washing, it is important to avoid getting water into the filter element. If the time required for decontamination is not a limitation, masks can be decontaminated by weathering. Additional details for decontaminating the protective masks are provided in the operator-level maintenance technical manual for each mask.

4-6.2.2 Protective Clothing

The protective overgarment, also known as the battle dress overgarment (BDO), is not designed to be decontaminated. It has been designed to wick agent through the fabric into the charcoal inner layer and remain there until the garment is removed and disposed of properly. Recycling of the overgarment through the use of a laundering facility has been one approach considered to alleviate the logistic burden of resupply of overgarments.

4-6.2.3 Weapon

The M280 kit or hot soapy water can be used to decontaminate a contaminated weapon. Towelette 1 from the M280 kit is applied, followed by application of Towelette 2, for the decontamination of G-series, V-series, H, and biological agents. Again, the M258A1 kit can be used in the absence of the M280 kit for weapon decontamination.

4-6.2.4 Individually Carried Items

Individually carried items include ammunition, field pack, and personal belongings. The decontamination method of choice depends largely on the components of the contaminated item. For example, fabric items such as the mask carrier, ammunition pouches, canteen cover, the M258A1 Decontamination Kit, and load-bearing equipment should be decontaminated with STB. Bleach solutions (dilute) are also recommended for decontaminating water contaminated by biological agents (Ref. 37).

initially unpainted metal surfaces and delicate parts should be washed with warm soapy water or organic solvents such as gasoline or alcohol. DS2 may be applied after this rinsing. If DS2 is used, decontaminated surfaces or parts should be rinsed with soapy water and then immersed in fresh water for 30 min. After decontamination, the item surfaces and parts should be dried and coated with a thin layer of oil to guard against corrosion.

Painted surfaces and parts should also be decontaminated with hot soapy water or organic solvents. However, use of DS2 will likely result in removal of the paint, but in some situations this paint loss may be acceptable.

4-6.3 VEHICLES

If the vehicles are contaminated during combat, drivers or operators, who usually wear protective gear, should continue the mission until the tactical situation permits individual decontamination of vehicles. Aeration will cause some decontamination during continuous operation of vehicles. For example, while the vehicle is operating, heat generated by the engine and wind from the motion of the vehicle will accelerate agent evaporation. When the situation permits, the three levels of decontamination described in pars. 4-6.3.1 through 4-6.3.3 should be performed.

4-6.3.1 Individual Decontamination

When the combat mission and the tactical situation permit, the driver should make a short stop outside the contaminated area and all occupants should conduct as much decontamination as possible. For vehicle exteriors DS2 maybe sprayed from the ABC-M11 decontaminating apparatus, which is described in par. 4-7.1. Solvents such as gasoline may be applied with swabs made from materials at hand. If the interior should become contaminated, DS2 may be applied. If DS2 is unavailable, rags, mud, gasoline, or any other expedient may be used.

4-6.3.2 Unit Decontamination

Unit decontamination is performed by personnel of a particular unit under the supervision of the NBC officers or noncommissioned officers of that unit, using decontaminating equipment belonging to the unit. When the tactical situation permits, the unit should decontaminate its vehicles by using decontaminants available and the procedures given in FM 3-5 (Ref. 3).

Contarnirmted wood surfaces and rubber tires may be decontaminated with STB slurry. Generally, a thick slurry is applied, left on for approximately 30 min, and followed by rinsing with water. No decontaminant, however, will completely decontaminate wood and rubber.

If standard decontaminants are not available, most chemical agents on vehicles can be removed by repeated scrubbing with mud and thorough rinsing. Dry sand or earth will absorb considerable amounts of CB agents. Such treatment, followed by aeration, will decontaminate a vehicle so that it can be used safely.

The prospect of residual contamination persists despite what may appear to be complete decontamination. Some CB agent maybe driven into cracks or sorbed into surface materials and this agent may resist the initial decontamination and be available later to come off the surface. Therefore, every precaution should be observed, and testing should be performed to determine the extent of residual contamination.

4-6.3.3 Field Decontamination

Field decontamination is performed at equipment decontamination stations by specially trained and equipped personnel. The same procedures are followed as for unit decontamination. Field decontamination is distinguished from unit decontamination by the establishment of dedicated stations that are intended to be available to any unit.

4-6.4 AIRCRAFT

Three techniques have been developed for use by military units to decontaminate aircraft and related aviation assets:

1. Aircraft spot decontamination
2. Aircraft washdown
3. Detailed aircraft decontamination.

Aircraft spot decontamination is intended both to limit the spread of contamination and to allow sustained flight and functional operations. Six functional activities or systems areas suitable for spot decontamination are refueling, arming, entering and exiting aircraft and aircrew compartments, inspection, maintenance, and battle damage repair (Ref. 6). Spot decontamination may be carried out by either aircrew or ground crew personnel by using the procedures and equipment discussed in par. 4-6.2 for personal equipment, DS2 and STB slurry are not used for aircraft decontamination.

Aircraft washdown is similar to the vehicle decontamination discussed in par. 4-6.3. Detailed aircraft decontamination involves complete decontamination of both the exterior and the interior of a contaminated aircraft. As with aircraft washdown, specific techniques will have to be developed for each kind of aircraft. Aircraft decontamination of some kind must be performed before an aircraft can be overhauled or made available for cannibalization.

4-6.5 OTHER EQUIPMENT (SUPPLIES AND AMMUNITION)

Military supplies, particularly food and water, ammunition, and hardware items present special challenges for effective decontamination. When decontamination of these materials is required, four general principles aid in establishing decontamination procedures (Ref. 3). These principles are to decontaminate

1. As soon as possible
2. Only what is absolutely essential for sustaining combat operations
3. As far forward as possible
4. By priority.

Pars. 4-6.5.1 through 4-6.5.3 provide guidance on how to decontaminate vital mission materials.

4-6.5.1 Food and Water

Contaminated food and water can be segregated into groups based on the extent of contamination, type of packaging material, and method used to seal the containers. Distinct decontamination procedures exist for each group, as detailed in pars. 4-6.5.1.1 through 4-6.5.1.3 (Ref. 3).

4-6.5.1.1 Group I (Exposure Limited to Chemical Vapor Only)

Packaged food and packaged water exposed only to chemical vapors make up Group I, and the packaging materials must be impermeable to CB agents. Glass bottles, metal cans, aluminum foil, heavy waxed paper, and plastic used to seal food and water and to exclude air afford excellent protection against vapor and liquid contamination. Subsistence items stored inside refrigerators could also be classed in Group I. Cans stored in a cardboard box might be classified in Group I as long asany liquid contamination on the box failed to spread to the cans.

Group I items may be decontarninated by aeration for 1 h or more. Before these items are opened for consumption, the external surfaces must be checked by a detection as the M256A1 Chemical Agent Detection Kit (See also par. 3-3.1.3 for a discussion of applicable detection equipment.) to insure the absence of contamination.

4-6.5.1.2 Group II (Exposure to Liquid Chemical Agents or to Biological Agents)

Group II consists of food or water sealed in protective packaging that has been contaminated with either liquid chemical agents or biological agents. For example, food in a can contaminated by liquid blister agent would be in Group II. If the can had been stored in a cardboard box, the can might be classed in Group I if the liquid contamination on the box had not spread to the can. The selection of an appropriate decontaminant for Group II items depends largely on the type of material used for packaging. In general, STB slurry or DS2 can be used for decontamination of Group II items.

4-6.5.1.3 Group III (Unsealed Foods or Foods in Nonprotective Packaging)

Group III consists of food itself, food in unsealed containers, and food in nonprotective packaging that has been exposed to CB agents. Decontamination of Group III items is difficult or impossible to achieve, and general guidance on appropriate decontamination methods for these items is lacking. Heavily contaminated food stuffs should be isolated immediately until they can be disposed of or decontaminated.

4-6.5.2 Ammunition

Decontamination of ammunition should be performed by applying cool, soapy water with brushes, mops, rags, or brooms. Use of DS2 and STB should be avoided. DS2 may removed critical markings from the ammunition crate, casing, or container. Dry STB may cause a fire if it comes in contact with blister agent or DS2, and any fire around ammunition would have devastating consequences. In general, decontamination of ammunition should be carried out by using mild decontaminants, particularly water and weathering, to avoid removing critical markings from the ammunition.

4-6.5.3 Hardware

Corrosive decontaminants should be avoided for certain hardware materials. DS2 and STB have adverse effects on hardware and therefore may be unsuitable for use in decontamination. Electronics and optical equipment are especially vulnerable. Some components, such as canvas and rubber, tend to absorb chemical agents. As a result. absorbent surfaces are extremely difficult, if not impossible, to decontaminate.

In this paragraph military hardware is grouped into the three categories of electronics, optics, and canvas. Decontamination methods for each type are described.

4-6.5.3.1 Electronics

Most electronic equipment is water-sensitive and can be damaged by aqueous decontaminants. Therefore, immersion of electronic equipment in an aqueous decontaminant or use of high-pressure application of a decontaminant should be avoided to preclude damage. An excellent method for decontamination of electronic equipment is use of forced hot air (discussed par. 4-4.2.2) and followed by weathering (aeration).

4-6.5.3.2 Optics

Optical equipment, including glass, plastic, and crystals, are extremely vulnerable to chemical decontaminants and their application methods. Optical lenses especially may be damaged by the decontamination chemicals or by scratches caused by rubbing the decontaminant onto the lens. For example, exposing coated lenses to STB slurry removes some of the magnesium from the coating. Therefore, hot, soapy water is a preferred decontaminant. Soft nonabrasive material such as lens-cleaning tissue, cotton wadding, or soft cloth dipped in hot soapy water can be used to wipe the optical system. Use of forced hot air or weathering is also effective for optical equipment decontamination.

4-6.5.3.3 Canvas Items

Canvas items, such as the web gear associated with the field pack and the webbing on certain load-bearing equipment, readily sorb CB agents. This sorption makes decontamination difficult. and it may be necessary to burn or bury these items if they are heavily contaminated. Decontamination methods include using STB dry mix or slurry, boiling in soapy water, and weathering.

4-6.6 TERRAIN

Terrain decontamination can be resource intensive, requiring specialized equipment and materials, trained personnel, and time. In certain combat situations, investment of these resources may be needed to support the overall combat mission. When terrain decontamination is justified, this decontamination effort should concentrate on those steps that will allow normal combat operations to resume as soon as possible. One example might be to build a causeway or a path through a contaminated area. Several terrain decontamination methods are described in pars. 4-6.6.1 through 4-6.6.6. Additional details are provided in FM 3-5 (Ref. 3).

4-6.6.1 Weathering

Weathering is the simplest and easiest form of terrain decontamination. Warm, windy weather can significantly reduce terrain contamination. Many weather-related variables affect persistency of CB agents and make it difficult or impossible to predict precisely how long it will take for CB agent contamination to dissipate by weathering. Additional comments on weathering are provided in par. 4-4.2.3.

4-6.6.2 Flushing

Flushing with large quantities of water or other liquid will remove contamination. A pressurized stream of hot, soapy water can remove significant amounts of CB agent especially if scrubbing methods are also applied. Flushing has the added benefit that it may speed up the follow-on weathering process.

4-6.6.3 Burning

Burning is an effective method to decontaminate CB agents on contaminated vegetation. Gasoline or explosives may be used to burn or blow away vegetation. Burning may also destroy agents on dirt surfaces by soaking the area with a flammable liquid (kerosene, diesel fuel) and then igniting remotely. Gasoline should not be used for this purpose because it burns too quickly. Burning may create a vapor hazard in downwind areas; therefore, commanders must warn downwind units of the potential vapor hazards (Ref. 3).

4-6.6.4 Covering

Covering contaminated terrain areas does not destroy the CB agents, but it does contain the hazards. Roofing paper, plastic sheets, wood mats, or earth materials can be used for covering purposes. This is a temporary measure because the agents may eventually penetrate the covering materials and thereby cause the CBagent hazard to return (Ref. 3).

4-6.6.5 Clear

“Clear” is defined as removing the top layer of soils from agent-contaminated areas. Most chemical agents will not penetrate into the soil more than 50 mm. Biological agents penetrate even less. When contaminated areas are scraped aside, a passageway will be created that is free of contact hazards. However, resorption on either side of the passageway will continue to pose vapor hazards.

4-6.6.6 Slurry

Terrain can be decontaminated with STB slurry (discussed in par. 4-3.1.1.2). This process requires trained chemical decontamination personnel along with specialized equipment. STB slurry is applied to terrain by spray hoses attached to an M12A1 decontamination apparatus, which is skid-mounted to a vehicle (discussed in par. 4-7.2). Operators wearing toxic agent protective aprons atop their MOPP gear and sitting on the front fenders of the vehicle spray the slurry. Approximately one load of slurry will decontaminate a surface area of 100 m in length and 10 m in width.

4-7 DECONTAMINATION EQUIPMENT

The US Army has fielded several items of decontamination equipment. These items are listed in Table 4-4 and are described in pars. 4-7.1 through 4-7.7. In addition, several items of equipment that are routinely used for purposes other than decontamination might be used as field-expedient decontamination equipment. These items are discussed in par. 4-7.8.

TABLE 4-4. US ARMY-FIELDED DECONTAMINATION EQUIPMENT

Item	Description and Use	Dimensions	Technical Data Reference
ABC-M11. Decontaminating Apparatus, Portable, DS2, 1 1/2 Quart NSN 4230-00-720-1618	A fire extinguisher-like device used to spray DS2. Comes with mounting bracket for attaching to vehiclcs. Used to spray DS2 on vehicles and equipment. Comes with spare nitrogen cylinders.	330 mm height 102 mm diameter 2.7 kg (full) 1.4 kg (empty)	TM 3-4230-204-12&P TM 43-0001-26-1
ABC-M12A1, Decontamination Apparatus, Power-Driven, Skid-Mounted (PDDA) NSN 4230-00-926-9488 LIN F81880	Includes pump unit, tank unit, personnel shower assembly, M2 water heater, all mounted on skids. Used to spray water or foam; for deicing, vehicle washing, and personnel showering.	1.42X0.81X1.30 m (pump) 2.13X1.14X1.30 m (1895-dm^3 tank) 1.35X0.53X1.09 m (M2 heater)	TM 3-4230-209-34P TM-3-4230-209-ESC TM 3-4410-201-12 TM 3-4410-201-20P TM 43-0001-26-1
M258, Decontamination Kit, Skin NSN 4230-00-123-3180	Kit consists of' pads. scrapers. and decontamination solutions in plastic carrying case. Used for skin decontamination	110X80X60 mm (plastic case) 0.35 kg (full)	TM 3-4230-213-10 TM 43-0001-26-1
NOTE: This item is being replaced by the M258A1 Kit and may not be available.			
M258A1, Decontamination Kit, Personal NSN 4230-01-101-3984	Kit consists of foil-packaged towelettes in plastic carrying case. Used for skin decontamination	110X80X60 mm (plastic case) 0.30 kg	TM 3-4230-216-10
M13, Decontamination Apparatus, Portable (DAP) NSN 4230-01-13.3-4124	Self-contained device used to apply DS2 to metal surfaces. Has a disposable 14-dm^3 DS2 container. Can be mounted to standard 19X10^{-3} m^3 fuel can mounts on vehicles and equipment.	14X10^3 capacity 27 kg (filled)	TM 3-4230-214-12&P TM 43-0001-26-1
ABC-M13, Decontaminating and Reimpregnating Kit, Individual NSN 4230-00-907-4828	Decontaminating materials in a plastic case. Used to decontaminate interior of mask and other IPE.	110X8OX6O mm (plastic case) 0.40 kg (filled)	TM 3-4230-211-10
NOTE: This item is being replaced by the M258A1 Kit and may not be available.			

(cont'd on next page)

TABLE 4-4. (cont'd)

Item	Description and Use	Dimensions	Technical Data Reference
M17, Transportable, Lightweight Decontamination System [Same item as Air Force A/E32U-8 LDS] NSN 4230-01-153-8660	Designed to draw water from any source and deliver it at pressures up to 689 kPa and temperatures up to 120°C. Includes accessory kit with hoses, cleaning jets, and personnel shower. Includes collapsible, rubberized fabric tank.	1.02X0.59X0.86 m 163 kg (basic unit) 1.06X0.52X0.39 m 65 kg (accessory kit) 32 kg (empty) (5500-dm tank)	TM 3-4230-218-14&P
M280, Decontamination Kit, Individual Kit (DKIE)	Kit consists of 20 containers of two towelettes each. Towelettes have same decontaminates as do the M258A1 towelettes. Used on individual weapon and equipment.	77 kg (full)	TM 43-0001-26-1

4-7.1 ABC-M11, DECONTAMINATION APPARATUS, PORTABLE, DS2, l ½ QT

The ABC-M11 is a standard equipment item that is issued to operator and crew level. The ABC-M11, illustrated in Fig. 4-2, is filled with DS2 and is ready to use as issued. It is a steel cylinder pressure bottle with an aluminum spray-head assembly and arming pin and is similar in appearance to a CO$_2$ fire extinguisher. A small nitrogen cylinder is used to propel the DS2 decontaminating solution from the apparatus. The M11 is refillable. A bracket is provided for mounting the unit on vehicles. Detailed technical information is contained in the technical manuals for this item, as noted in Table 44.

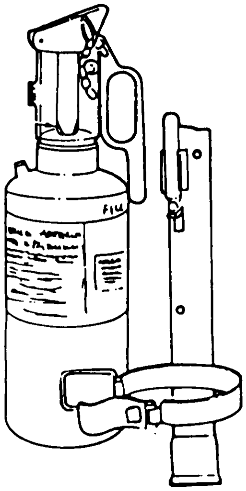


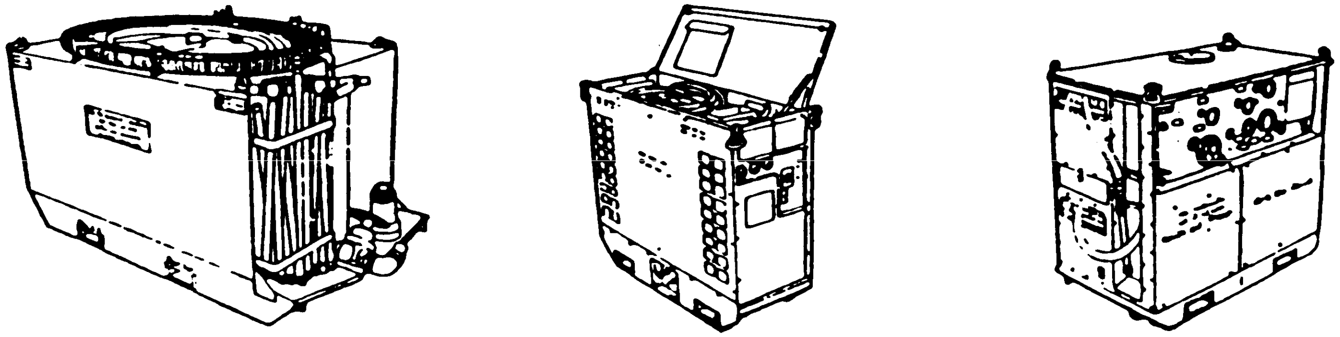
Figure 4-2. ABC-M11, Decontamination Apparatus, Portable, DS2, 1 1/2 Qt

The ABC-M11 is used to decontaminate vehicles, crew-served weapons, or other equipment to the extent necessary to make them safe for continued use (hasty decontamination). It is not intended for decontamination of an entire vehicle. One filling of DS2 is sufficient for operations such as emergency decontamination of the operator controls of two ½-ton trucks or one %-ton truck. For instance, the steering wheel, gearshift lever, door handles, dashboard, and other items that are likely to be touched should be decontaminated (Refs. 3 and 6).

4-7.2 M12A1, DECONTAMINATING APPARATUS, POWER-DRIVEN, SKID-MOUNTED (PDDA)

The M12A1 decontaminating apparatus, which is shown in Fig. 4-3, is the current standard decontamination equipment issued to battalion-level crews and chemical company level. It is intended for field use to spray hot water, STB slurry, HTH slurry, caustic solutions, alkaline scrubbing soap, detergent solutions, and other water-based decontaminants. It can also be used for non-CB warfare operations such as fire fighting with water or foam, deicing operations, washing vehicles, spraying water-based paints and solutions, and field personnel showering (Ref. 3).

The apparatus consists of three skid-mounted units, which are a 1.9 m^3 tank unit with a personnel shower attachment, a pump and hose unit, and the M2 water heater. The apparatus can be used as a stationary or mobile unit by transporting and operating from a flatbed truck of suitable size and load capacity. The apparatus can also be transported by aircraft having suitable load capacity. Detailed technical information is contained in the technical manuals for this item, as noted in Table 4-4.



(A) Tank Unit Assembly (B) M2 Water Heater (C) Pump Unit Assembly

Figure 4-3. M12A1, Decontaminating Apparatus, Power-Driven, Skid-Mounted

4-7.3 M258 DECONTAMINATION KIT AND M258A1 DECONTAMINATION KIT INDIVIDUAL EQUIPMENT (DKIE)

The M258 and M258A1 are issued as individual decontamination kits. The M258 kit is being phased out in favor of the M258A1 kit. Detailed technical information is contained in the technical manuals for these items, as noted in Table 4-4.

The M258 kit consists of a plastic container having two capsules that contain decontamination solutions, two flat wooden scraping sticks, and four gauze pads. The two capsules are labeled “Solution 1” and “Solution 11”. Solution I consists of sodium hydroxide, ethanol, and phenol and is used to destroy G-series agents. Solution II contains chloramine-B (discussed in par. 4-3.1.1.12) and zinc chloride in a water-ethanol solution and is used to decontaminate HD and V-series agents. Additional guidance on the use of this kit is printed on the kit itself. One of the gauze pads is to be used to soak up as much liquid agent from the contaminated skin as possible. A second gauze pad wetted with Solution 1 is then rubbed over the contaminated area. A third pad should then be used to apply decontamination Solution II. The scraping sticks are to be used to help remove thickened agent.

Because the components in Solution 11 are temperature sensitive, this kit should not be stored in the places where the temperature exceeds 44” C. In addition, these solutions are caustic and potentially poisonous; therefore, care must be taken to keep them out of eyes, mouth, and wounds. On skin, Solution 1 should always be followed by Solution II.

The M258A1 kit is an improved version of the M258 kit. The decontaminants have been sorbed onto towelettes in the M258A1 kit and thus reduce some of the difficulties experienced with the M258. The M258A1 is housed in a plastic case (identical in size to that of the M258) with a metal strap hook for easy attachment to clothing or equipment. The kit contains two types of towelettes, labeled “decon 1” and “decon 2” respectively. The towelettes are sealed in tearaway, impermeable foil packets. The “decon 1” packet contains a pad pretreated with ethanol, phenol, sodium hydroxide, ammonia. and water and is intended for use against G-series agents. The “decon 2” packet contains a pad impregnated with chloramine B and has sealed glass ampoules filled with a solution of ethanol, zinc chloride, and water. The glass ampoules are enclosed in a plastic mesh bag to prevent injury to fingers or hand when crushing the ampoules. Both packets have distinctive tabs for immediate identification at night.

4-7.4 M13, DECONTAMINATING APPARATUS, PORTABLE, 14 LITER

The M13 apparatus, as depicted in Fig. 4-4, is intended for dispensing DS2 solution. The M13 consists of a prefilled decontaminating agent container, a manual pump. a hose, two wand sections, and an attachable brush. Dimensions and other data are provided in Table 4-4. It can be vehicle mounted and is man portable, manually operated, and easily maintained. It is issued for operator-and crew-level decontamination operations and may be used on wheeled and tracked vehicles. combat construction equipment, towed and self-propelled artillery, and crew-served weapons larger than 20 mm to decontaminate those areas of the vehicles to which access is required for normal operations and maintenance (hasty decontamination). Selected surfaces of the vehicles will be covered with decontaminant and scrubbed with the brush, after which the crew will continue the mission. Detailed technical information is contained in the technical manuals for this item, as noted in Table 4-4.

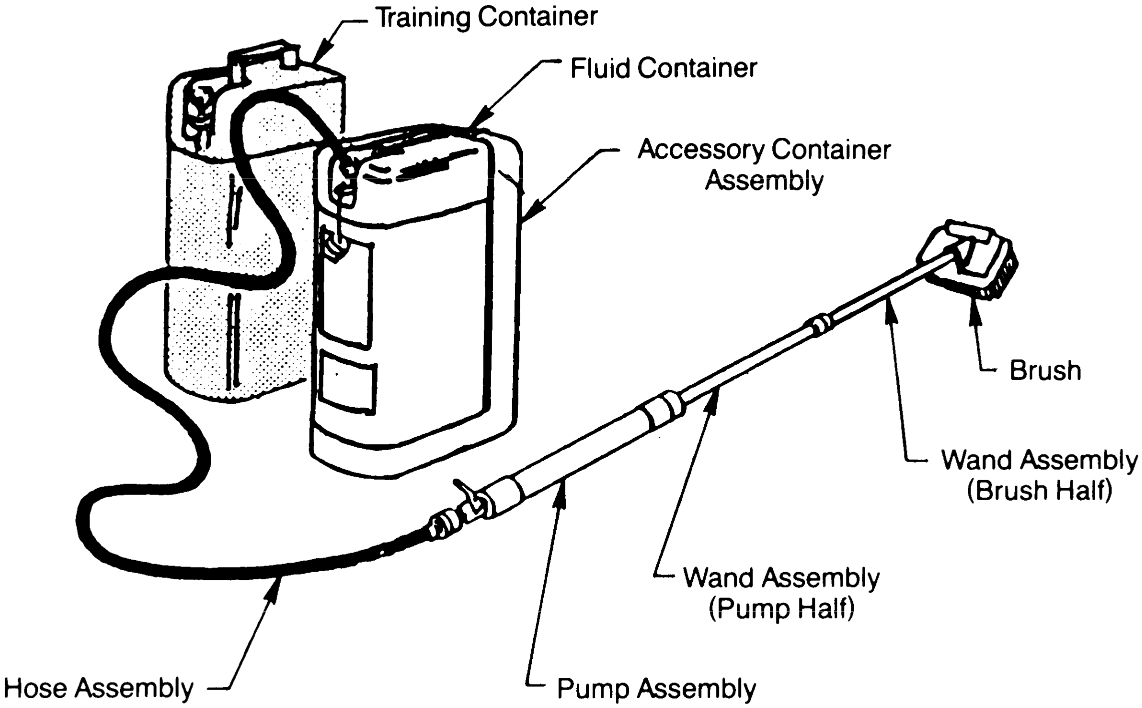


Figure 4-4. M13, Decontaminating Apparatus, Portable 14-Liter

4-7.5 ABC-M13, DECONTAMINATING AND REIMPREGNATION KIT, INDIVIDUAL

The ABC-M13 Individual Decontaminating and Reimpregnating Kit is designed to be used by individuals to decontaminate droplets of all chemical agents on skin, clothing, and personal equipment. It is, however, being phased out and has been replaced by the M258A1 kit. Detailed technical information is contained in the technical manuals for this item, as noted in Table 4-4.

The ABC-M13 kit consists of a pad containing fuller's earth powder (discussed in par. 4-4.2.4) and two cloth bags, which contain a dye capsule and chloramine powder (XXCC3) (discussed in par. 4-3.1.1.14). If skin is contaminated, the pad can be used to cover the contaminated area. After gently slapping the pad to release the fuller's earth powder, which absorbs the liquid agents, the powder should be rubbed over the contaminated skin area. The pad may also be used to absorb agent droplets on personal equipment, such as a contaminated mask. The chloramine powder can be used to destroy blister and V-agent droplets on clothing. Before use, the dye-containing capsule should be crushed and completely mixed with the powder. This mixture should be dusted over and lightly rubbed onto the clothing with the bag. If there is any blister or nerve agent, the dye will react to produce a red or brownish-red color. The ABC-M13 kit should not be stored in places where temperatures exceed 50°C. If the dye capsule should be crushed during training or exercises, the whole kit should be disposed of because the dye chemical is carcinogenic.

4-7.6 M17, TRANSPORTABLE, LIGHTWEIGHT DECONTAMINATION SYSTEM

The M17 Transportable, Lightweight Decontamination System is a portable, compact, gasoline-driven pump with a water-heating unit. This same system is fielded by the Air Force as the A/E32U-8 Lightweight Decontamination System (LDS). The M17 is issued for operator- and crew-level use in decontamination. Dimensions and other operating data are summarized in Table 4-4. The system is designed to provide a hot water and steam rinse for contaminated vehicles, shelters, and equipment. It can draw water from any source, such as lakes, ponds, streams, suitable wells, and drinking water systems. It can deliver water at controlled temperatures up to 120°C and pressures up to 689 kPa. Water-soluble detergents can be sprayed by a wand equipped with a siphon injector, which mixes the hot water and detergent so that the hot water and detergent are not run through the equipment in order to reduce potential damage to the pump (Ref. 34).

The M17 is two- or three-man-portable and can be readily transported by aircraft, helicopter, and small vehicle. The unit is generally used with two men, although one-man operation is possible if manual portability is not required.

4-7.7 M280, DECONTAMINATION KIT INDIVIDUAL EQUIPMENT (DKIE)

The M280 Decontamination Kit Individual Equipment (DKIE) consists of 20 individual containers packaged in a container that is intended to be issued to a squad-sized unit, Each individual container has sufficient decontaminating capacity to service an individual's protective mask, hood, gloves, boots, and weapon. The individual container holds two foil packets, which are used in sequence. Packet 1 contains a prewetted towelette. Packet 2 contains a chemically impregnated towelette and glass ampoules, which are broken to wet the towelette. These two towelettes contain the same chemicals as those used in the M258A1 kit. The principal distinction between the M280 DKIE and the M258A1 kit is the size of the towelettes, i.e., the M280 towelettes are 10 times larger. Detailed technical information is contained in the technical manuals for this item, as noted in Table 4-4.

4-7.8 FIELD-EXPEDIENT DECONTAMINATION EQUIPMENT

In addition to standard decontamination equipment, there are many equipment items readily available to military units that have excellent potential for use as field-expedient decontamination equipment. A prime example of this would be fire-fighting equipment. If fire-fighting equipment on a military post were not required for its primary duty of pumping water and foam for putting out fires, this equipment might be used to pump water and other decontaminants to aid in decontamination.

General types of equipment available include, but are not limited to, items such as flight line heaters; cleaning equipment (steam cleaners, degreasers, wash carts, and foam generators); deicing equipment; and fire-fighting equipment. A few commercially available equipment items are also described, but the majority of commercially available items that appear to be applicable for decontamination are currently available within the military inventory.

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CHAPTER 5
MATERIAL AND DESIGN CONSIDERATIONS

This chapter acquaints US Army equipment developers with certain material and design considerations that may enhance system survivability. These considerations affect the ability of a system and, consequently, its credit to accomplish the assigned mission in a chemical and biological (CB) contaminated environment. Requirements associated with CB agent survivability are presented in par. 5-1. The effects of these agents and their attendant decontaminants are discussed in par. 5-2, *and selected design considerations and guidelines are provided in par. 5-3.*

5-1 INTRODUCTION

Army Regulation (AR) 70-71, entitled *Nuclear, Biological, and Chemical Contamination Survivability of Army Materiel* (Ref. 1), establishes Army policy and procedures for the development and acquisition of mission-essential materiel to insure its survivability on the nuclear, biological, and chemical (NBC) battlefield. AR 70-71 states that mission-essential materiel is that necessary to accomplish the primary or secondary functions of the unit or organization. NBC contamination survivability is the capability of a system and its crew to withstand an NBC-contaminated environment, including decontamination, without losing the ability to accomplish the assigned mission (Ref. 1). Some of the major requirements of AR 70-71 are

1. If an item is designated as mission essential or is a critical component of one or more mission-essential end-items, it must be NBC-contamination survivable.
2. Requirements for NBC contamination survivability are to be considered early in the acquisition process.
3. Analyses, tests, and evaluations are to be planned and conducted, before the production and deployment phase, to determine the levels of survivability achieved.
4. Criteria for NBC contamination survivability, applied during research and development, are to be maintained throughout production and deployment of the selected equipment.
5. Possible tradeoffs are to be identified among achievable survivability levels; operational characteristics; developmental parameters; reliability, availability. and maintainability (RAM); and user-system interface characteristics (Ref. 2).

The importance of materiel developers in lessening the operational and logistical burdens imposed by NBC contamination is emphasized in AR 70-71. The requirement in this regulation that possible tradeoffs be identified is significant. Because it may be impossible to completely achieve NBC contamination survivability for any equipment item within the constraints of cost and other system requirements, careful analysis of the tradeoffs involved is needed (Ref. 2).

The focal point of this regulation is the acquisition of materiel to insure its survivability and sustainability on the NBC-contaminated battlefield. This focus leads to the three characteristics of NBC contamination survivability: decontaminability, hardness, and compatibility.

5-1.1 DECONTAMINABILITY

Decontaminability is the capability of being rapidly decontaminated to a negligible risk level for unprotected persons who operate, maintain, and resupply the materiel (equipment). The developer must consider materials, design, contamination control measures, and use of NBC detection equipment.

The decontaminability criteria state that the exterior and interior of materiel should be developed such that contamination remaining on, or desorbed or reaerosolized from, the surface following decontamination shall not result in more than a negligible risk to unprotected personnel working inside, on, or 1 m from the item. The following worst case conditions apply

1. Exterior surfaces initially are uniformly contaminated with 10 g/m^2 of thickened droplets of distilled mustard (HD) or soman (GD) having a mass median diameter of 2 to 5 mm, or 10 g/m^2 of unthickened VX, or with 10^5 spores/1 m^2 of biological agent 1 to 5 μm in size. Suitable simulants may be used.
2. Initial contamination levels on interior surfaces subject to contamination are a factor of 10 lower than on exterior surfaces.
3. Decontamination begins 1 h after contamination using standard field decontaminants, equipment and procedures, and the decontamination process, excluding monitoring, lasts no longer than 75 min.
4. Exposure of unprotected personnel to the decontaminated materiel is based on the mission profile determined by the combat developer but is not to exceed 12 h (Ref. 3).

The negligible risk values for CB chemical contaminants are currently classified. These values correspond to agent (contaminant) concentration levels that cause 5% mild incapacitation to unprotected personnel.

5-1.2 HARDNESS

Hardness refers to the ability to withstand materiel-damaging effects of both CB contamination and decontaminants (procedures and chemicals). Decontaminability and hardness are distinct qualities. Decontaminability standards concern the residual hazard to personnel, whereas hardness standards concern damage to materiel.

The hardness criterion states that materiel developed to perform mission-essential functions shall be hardened to insure that over a 30-day period degradation does not exceed 5% in selected quantifiable essential characteristics, to be tested by 5 cycles of exposure to CB contaminants, decontaminants, and decontaminating procedures encountered in the field (Ref. 3).

5-1.3 COMPATIBILITY

Compatibility is the capability of being operated. maintained and resupplied by persons wearing the full NBC protection ensemble (MOPP 4)* or individual protective equipment (IPE) in all climatic categories for which the item is designed and for a period specified in the requirements document. Collective protection equipment (CPE) does not require compatibility in that the personnel using CPE are not wearing any IPE. ** For some systems, however, the combat developers may elect to substitute CPE for compatibility. In doing so, they accept the possibility of crew degradation if contamination enters the CPE, because it would force the crew to don individual protective ensembles.

The compatibility criterion states that design of materiel developed to perform mission-essential functions shall take into consideration the combination of equipment and anticipated CB protection. This combination shall permit performance not to exceed 12 h of mission-essential operations. communication, maintenance, resupply. and decontamination tasks by trained and acclimatized troops over a typical mission profile in a contaminated environment. This profile must also reflect the meteorological conditions of the areas of intended use. There can be no degradation, excluding heat stress. of crew performance of mission-essential tasks greater than 5% below levels specified for these tasks when accomplished in a non-CB environment (Ref. 3).

Heat stress is not a factor for this criterion because the main concern is the man-in-MOPP equipment interface and what designs can be incorporated to increase effectiveness. Heat stress is a serious problem and is included in the discussion of designing better IPE.

5-2 MATERIALS

The significant military value of CB agents, in the historical sense, has been their adverse effects on personnel. However, military systems and equipment are also adversely affected by chemical contaminants. This fact makes it necessary to choose materials of construction. particularly those used in critical components. that have the proper degree of hardness in order to assure that the entire system will have adequate hardness. Biological agents have little or no degrading interactions with standard materials and, therefore, have been excluded from consideration during development and imlplementation of the hardness requirements.

5-2.1 CONTAMINANT EFFECTS

Contamination may result from a direct attack with CB weapons, from exposure to wind-carried agents from another area, or from moving ovcr ground or vegetation that has been contaminated. Regardless of the cause, the result is the same, i.e., equipment or vehiclcs are contaminated and, in turn, become potential sources of contamination to personnel (Ref. 4).

5-2.1.1 Sorption And Resorption

Sorption of chemical agents takes place by two main routes, namely, absorption and adsorption. Absorption occurs when the contaminant is taken in and made part of the item. Adsorption refers to the adhesion of an extremely thin layer of molecules to the surface of solid bodies or liquids with which they are in contact. Contaminants may be absorbed by paints, lubricants, fabrics, and a wide variety of materials. They may be adsorbed on exposed surfaces and retained in pores, crevices, seams, concavities, and on horizontal surfaces. Agents may also be absorbed or adsorbed by dust, soil, mud, or vegetation, which may adhere to equipment surfaces (Ref. 4).

Once an agent has been sorbed, there is also the possibility that the contaminant may be desorbed from the material back into the environment and thus present a new threat to personnel and equipment. This occurs, for example, when a chemical agent is absorbed by a silicone rubber seal and the contaminant outgases, i.e., vaporizes, when the environmental conditions, such as temperature, humidity, and vapor pressure, are appropriate.

5-2.1.2 Deterioration

Once an item has been contaminated, through absorption, adsorption, or surface contamination, chemical reactions begin to take pace because the agents are reactive species. In particular, the nerve agents and mustard react with many materials—metals, plastics, and elastomers, to name a few—and dissolve in other organic-based polymers. The concentration of agents on materials is not anticipated to be very large or in discrete droplets; therefore, the amount of agent reacting with a material

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*mission-oriented protective posture Level 4 (See Chapter 3 for a full description.)

**(See Chapter 3 for more detail on IPE and CPE.)

will be very small. Generally, this small extent of interaction will not be sufficient to cause equipment damage or to affect the structural integrity of the equipment. The problem of equipment failure occurs when either the nature of the chemical-material interaction is extensive or the item being attacked is a critical component of the system. This is especially true with electronic equipment (Ref. 5).

If unfiltered, contaminated air is forced into electronic equipment for cooling, the agents will be brought into direct contact with the electronics and at concentrations much higher than those normally anticipated. In addition, some of the electronics will be sensitite to possible surface corrosion. HD and the G- and V-series agents are known to corrode some of the metals used in electronic components and circuitry. These agents also react with many of the plastics and coatings used for insulation and protection of circuits. When used on electronics, the coatings will protect the circuitry from corrosion or at least retard chemical agent corrosion. If the agent reacts with the coating, however, some long-term (weeks or months) corrosion may occur (Ref. 5).

Uncoated electronics tire more vulnerable and will be subject to both short-and long-term effects. In the short term, even small surface effects and surface layer corrosion may affect the conductivity and degrade the circuit performance. This is especially true for high impedance circuits, which are affected by small changes in conductivity. Long-term effects may be more extensive corrosion and may include structural damage and short circuits (Ref. 5).

5-2.2 DECONTAMINANT EFFECTS

Decontaminants are substances that remote. absorb. or detoxify CB agents. They include liquids, slurries, and powders. No one decontaminant is entirely effective against all CB agents, and some decontaminants are more effective against some agents than against others. Because of this lack of a universal decontaminant and because it is impossible to predict the type or category of agent that will be encountered, equipment and vehicle design cannot be based upon the probable use of any single decontaminant. Designers must be aware of the nature and properties of the range of decontaminants that may have to be used, and they should take these factors into consideration whenever practical and especially when selecting materials of fabrication (Ref. 2). Decontamination can be accomplished in many ways, as described in Chapter 4. In general, however, there are two levels of decontamination partial and complete.

Partial decontamination is the limited removal of CB agents from equipment. In this chapter partial decontamination specifically refers to the surface removal of liquid agent that has not penetrated into the materiel. This hazard-eliminating process can be accomplished by wiping or by using chemical decontaminants. After partial decontamination, agent that has penetrated into the materiel will continue to evolve from the surface and present a vapor and, to some extent, a contact hazard. In general. the effectiveness of partial decontamination is significantly superior to the alternative of simple weathering (Ref. 5).

Complete decontamination is the total removal of CB agents, including those absorbed into materiel. After complete decontamination, all agent has been removed, so the item no longer presents a hazard. Complete decontamination can be difficult, time-consuming, and perhaps impossible to accomplish; furthermore, it may prove impracticable for most field conditions.

Chemical decontaminants are, in general, corrosive and either acidic or caustic. Because of their reactive nature, they can deteriorate and adversely affect the equipment or surfaces that they are intended to clean. For example, decontaminating solution No. 2 (DS2) has adverse effects on sevreral polymeric materials such as elastomers, adhesives, plastics, and coatings. Metals, in general, are not adversely affected by DS2.

Decontamination of electronics, except by weathering, is often impossible. Sometimes the effects of the decontaminant may be more damaging to the equipment than the agent is. Various systems are under development to decontaminate effectively electronic systems. One such approach dissolves and removes chemical agents by using fluorocarbon solvents. Ultrasonic baths hate also been considered for the decontamination of electronic equipment, especially when the items are encapsulated with epoxy or parylene coatings (Rcf. 6).

Table 5-1 presents representative information concerning the effects of the two standard decontaminants—DS2 and supertropical bleach (STB) on selected metals. Table 5-2 summarizes data regarding the effects of both agents and decontaminants on polymeric materials. More comprehensive listings of the effects of agents and decontarninants are available in assorted summary publications such as Refs. 2 and 3.

5-3 DESIGN

The length of time that contaminated equipment is a threat to personnel depends on the amount of agent remaining on the equipment. Primary among the determining factors are the

1. Properties of the agent
2. Initial contamination density of the agent on the equipment
3. Duration of exposure of the equipment to the agent prior to decontamination
4. Environmental conditions
5. Sorptive properties of the equipment components and surfaces
6. Physical features of the equipment.

TABLE 5-1. EFFECTS OF DS2 AND STB ON SELECTED METALS (DATA EXTRACTED FROM REF. 7)

Material	Decontaminant Effects	
	DS2	STB
Aluminum Alloy 1100-0-Bare	NT	C
2024-T3-AluminumAlloy—Chemical Conversion Coat	NT, P	C
5052-0 Aluminum Alloy Anodized	A, P	NT
Aluminum Alloy Anodized	NT, P	B
7075-T6 Aluminum Alloy—Hard Anodized	NT, P	B
Cast Aluminum Alloy 356-T6-Bare	A, P	NT

Key to Ratings:
A = Minor/no material, property degradation
B = Moderate material/ property degradation
C = Major material/ property degration
NT = Not tested
P = Preferred decontaminant

or that can create a vapor hazard to personnel. Secondarily, designing to minimize contamination and aid in decontamination is a matter of providing adequate air circulation and exposure to sunlight to items that cannot be shielded from contaminants (Ref. 4).

Unfortunately, the two concepts described in this paragraph may lead to extremes in designing to minimize contamination. One concept presumes that any agent absorbed, adsorbed, or otherwise retained on or in exterior items will dissipate or will naturally become detoxified before it can affect any one coming into contact with the equipment and that any agent gaining access to interior areas will be rendered ineffective by the use of personnel protective gear. These beliefs can result in few, if any, countermeasures in design to prevent or to minimize contamination. A second concept presumes that any degree of exposure of the equipment will be severe, that the agent will be the most harmful and longest lasting, and that the contaminant will be absorbed, adsorbed, and retained and will penetrate into interior spaces unless every conceivable area of retention or possible entrance is eliminated or shielded. This view can result in considerable overdesign with potentially adverse effects on the primary function of the equipment (Ref. 4).

TABLE 5-2. EFFECTS OF AGENTS AND DECONTAMINANTS ON SELECTED POLYMERIC MATERIALS (DATA EXTRACTED FROM REF. 7)

Material	Decontaminant Effects				Agent Effects	
	DS2		STB			
	23°C	71°C	23°C	71°C	GD	HD
Natural Rubber (No. 1 RSS)	A	C	A	A	B	A
Isobutylene-Isoprene Rubber	A	B	A	A	ND	ND
Styrene-Butadiene Rubber	B	C	A	A	ND	ND
Silicone Rubber	C	C	A	A	A	A
Butyl Rubber	A	B	A	A	B	A
Polybutadiene Rubber	A	B	A	A	ND	ND
Bromobutyl Rubber	A	B	A	A	A	A
Epichlorohydrin Rubber	B	C	A	A	B	A
Polysulfide Sealant	C	C	A	A	A	A
Acrylic-Base Adhesive	A	B	A	A	B	C
Silicone Adhesive Sealant	C	C	B	B	B	A

Key to Ratings:
A = Minor no material property degradation
B = Moderate material property degradation
C = Major material property degradation
ND = No data

Design is important because proper design can reduce the amount of agent remaining on the equipment, and it can affect the interaction of the environment with the agent. Thus designing to minimize contamination and aid in decontamination is. primarily. a matter of eliminating. restructuring, or shielding items that may trap or retain contaminants in areas that can be contacted by personnel

The first concept is unacceptable under current Army doctrine, and the second is impractical. Therefore, the designer must elect some less extreme view that results in the best protection against contamination and facilitates decontamination of the equipment. Three design considerations will be investigated in order to reach a practical and safe compromise. These considerations are material and coating selection, design configuration, and contamination avoidance (Ref. 4).

5-3.1 MATERIALS AND COATINGS

Decontaminability of equipment can be improved by selecting the correct materials and coatings. Some materials, such as many polymers and plastics, will absorb chemical agents, and these materials can be difficult or even impossible to decontaminate. Thus the designer should increase the ease of decontamination by selecting a material that does not absorb these contaminants. The decontamination process will then be much easier because the contaminants will remain on the surface where they can be washed off or easily broken down into nontoxic components (Ref. 2).

The selection of a suitable coating should also be used to ease decontamination. Parts that must be made of materials that absorb and trap contaminants should be coated with a nonabsorbing material to make them easy to decontaminate. Coatings should also be used to seal the cracks and crevices that occur between mating parts at assembly. Painting these cracks after assembly will seal them and prevent contaminants from entering and becoming difficult to decontaminate (Ref. 2).

The materials used to fabricate the equipment must be capable of withstanding specific exposures to the contaminants, decontaminants, and decontamination procedures. These decontaminants and procedures are described in FM 3-5 (Ref. 8). Many materials will be damaged through corrosion or by chemical reaction with contaminants and or decontaminants. By selecting a more resistant material, the hardness criterion can be met. In addition, those components that must be made from a material that is damaged by exposure to contaminants and or decontaminants should be coated with a resistant material to meet the hardness criterion.

5-3.2 CONFIGURATION DESIGN

It is essential that an equipment item be as easy to decontaminate as possible. Configuration design techniques should be used to assist in accomplishing this goal. First. the design should be selected to reduce the accessibility of contaminants to the components.

Second, each component that is accessible to contaminants should be made as smooth and uniform as possible. Rough surfaces on castings and similar components should be eliminated. Braided wire, chain, and bundled electrical cables should be replaced with solid. smooth components such as rods or single cables.

Third, the interfaces between parts should be designed to eliminate cracks, crevices, and any other traps for contaminants. Fasteners, such as slotted, Phillips head, and socket head screws, should not be used. Hex head bolts and similar fasteners without depressions or cavities in the heads are better. Individual washers should be eliminated where possible, especially lock washers, and replaced with washers that are integral to the bolt head so no crack is present between them. Lock washers should be replaced with self-locking bolts. The spaces between components should be small enough so they can be sealed or large enough to allow decontamination between them (Ref. 2).

5.3.3 CONTAMINATION AVOIDANCE

Many components of military equipment cannot be (1) designed to eliminate areas in which contaminants can collect, (2) made of nonsensitive materials, or (3) coated to enhance decontamination efficiency. If possible, such items should be enclosed by a protective structure, whether of permanent or temporary design, to eliminate the threat of hazard and subsequent decontamination. In addition, such items might be protected by contamination avoidance covers (CACs).*

5-3.4 SUMMARY OF THE DESIGN GUIDELINES

In general, any feature that can trap or retain a solid, liquid, or gaseous material indicated poor design with respect to contamination and decontamination. Such features not only tend to hold contaminants—and thus represent potential hazards to personnel—but also are difficult to clean adequately. Crevices where hatches meet deck plates, exposed springs connected to hatch covers, and restricted areas under tie-downs are representative of entrapment and hard-to-clean features. Anything that can be done to eliminate or to reduce the number of such features will improve the overall NBC survivability of the equipment (Ref. 2).

Present designs frequently incorporate canvas, elastomeric materials, and paints that absorb contaminants. If canvas must be used, the item should be designed so that the canvas is easily removable with a minimum of handling. If absorbent elastomers must be used, they should be shielded to the greatest extent possible from contaminants; alternatively, they should be incorporated as easily replaceable items that can be removed and discardedwith a minimum of contact by personnel. If surfaces must be painted chemical-agent-resistant paints should be used. Such paints can also be used to seal small crevices and capillaries under fasteners. In short, materials that absorb contaminants should not be used. If they must be used, they should be designed as disposable items and made easily removable. If they cannot be made disposable, they should be shielded to the greatest extent possible (Ref. 2).

Use of nonabsorbing seals and sheaths, metal covers and wider spacing between adjacent parts improves the overall NBC survivability of equipment, but these features

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*See par. 3-2.3.2 for a more comprehensive discussion of CACs.

must be used with care to insure that the intended effect is realized without introducing a contamination or function problem of equal or greater magnitude. For example, eliminating a concave surface may eliminate a contaminant trap, but if the function of the concavity is to deflect bullets or shrapnel, elimination is not feasible. In other words, the surface must be designed for its functional purpose, and its configuration should be adjusted to the greatest extent possible for ease of decontamination and minimal trapping contaminants (Ref. 2).

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CHAPTER 6
FUTURE CONCEPTS

This chapter describes current US Army development activities and technologies for future decontamination concepts. The criteria used in evaluating decontamination concepts are presented in par. 6-1. These criteria led to selection of the concepts deemed most promising for future research and development. The selected concepts have been categorized in accordance with their potential applicability to the three types of decontamination defined infield manual (FM) 3-5: basic soldier skills, hasty, and deliberate. Descriptions of these concepts are provided in par. 6-2.

6-1 INTRODUCTION

The US Army Chemical Research, Development, and Engineering Center (CRDEC) and the US Army Chemical School completed a master plan in 1987 entitled “Decontamination/Contamination Control Master Plan (DCCMP)’’(Ref. l), which defines a roadmap to develop decontamination systems to meet effectively future chemical and biological (CB) agent threats. The master plan focuses on defining research and development to satisfy Army decontamination needs well beyond the year 2000. The plan projects the research and exploratory development for exploiting the emerging technologies that have the greatest potential for satisfying user-defined requirements for systems to decontaminate chemical agents.

The decontamination concepts described in this chapter were evaluated in the DCCMP against requirements established by the potential users of these systems. These concepts represent technologies that meet a broad range of user requirements; this fact makes these concepts attractive for further development activities. Criteria on which future decontamination concepts were evaluated are

1. Effectiveness on all CB agents
2. Nontoxicity
3. Noncorrosiveness
4. Ease of application
5. Rapidity of action
6. Nontoxicity of end products
7. Stability for long-term storage
8. Effectiveness in all weather conditions
9. General availability
10. Logistics supportability.

The definitions of these requirements follow:

1. *Effectness on all known agents.* The ability to decontaminate all known chemical and biological agents is desirable and would eliminate the need for agent-specific decontamination systems.

2. *Nontoxicity.* The decontamination system poses no threat to personnel during normal handling and use throughout the life cycle.

3. *Noncorrosiveness.* The decontamination system does not further degrade material properties through the corrosive reaction process.

4. *Ease of application.* The decontamination system does not require any special equipment. mixing. or training.

5. *Rapidity of action.* The decontamination system must work instantaneously in the ideal case.

6. *Nontoxicity of end products.* The end products of the decontamination process are nontoxic and therefore are no threat to personnel.

7. *Stability for long-term storage.* The decontamination system must be able to be stored for long periods of time in all environmental conditions with no degradation of effectiveness.

8. *Effectiveness in all weather conditions.* The decontamination system must operate in all environments in which a chemical and biological agent threat is possible.

9. *General availability.* The decontamination system must be available in sufficient quantities for all scenarios involving CB agents.

10. *Logistics supportability.* The decontamination system must be capable of being supported in the logistic chain.

6-2 DECONTAMINATION CONCEPTS

This paragraph describes the decontamination technologies that have been evaluated as the most promising (as defined in the DCCMP) as well as those that show strong potential for meeting user requirements for the three types of decontamination, namely, basic soldier skills, hasty, and deliberate. The DCCMP also defines the requirement for a strong research and development program in catalysis to obtain the optimum benefit at a minimum logistical cost for the most promising technologies.

6-2.1 BASIC SOLDIER SKILLS

The objective of basic soldier skills decontamination is to remove or neutralize contamination on the skin and on the surfaces the individual soldier must contact to perform a mission. This type of decontamination is the least complex and the least complete of the three types. There are three types of basic soldier decontamination skills: skin decontamination, personal wipedown, and operator's spray down.

In the DCCMP sorbents and reactive solids were identified as the most promising technologies for basic soldier skills decontamination.

6-2.1.1 Sorbents and Reactive Solids

The US Army has been investigating the potential of various sorbents and reactive solids as replacements for the solutions currently used in the M258A1 Decontamination Kit. These solutions may irritate and damage eyes and skin structure. In turn, damage to the skin structure reduces its agent barrier properties. In addition to overcoming these problems, it is hoped that in the future the new sorbents or reactive solids can be employed to provide prophylactic protection (Ref. 2). The current M258A1 solutions do not provide any prophylactic protection.

6-2.1.1.1 Reactive Resins

Reactive resins are currently being developed as replacements for the M258A1 Decontamination Kit. As mentioned in par. 4-4.2.4, these resins are highly functionalized forms of the polymeric absorbents. They combine the high capacity of the polymeric absorbents with a wide range of active chemical groups. These functional groups are immobilized on a polymeric support within a porous network. Agents diffuse into the network, react with the functional groups, and are detoxified. These systems are attractive as a passive type of decontamination.

Reactive groups within polymeric networks are far less corrosive than similar free functional groups toward such substrates as metal, paint. and skin. In addition, many functional groups that are normally incompatible with each other can be mixed once they have been immobilized within polymeric structures. Therefore, mixtures that are reactive toward a wide range of agents can be developed. and such mixtures can be easily stored and delivered as powders.

The US Army Medical Research and Development Center (MRDC) has done an extensive amount o! research and development on reactive resins for use in skin decontamination. This work has resulted in the development of a new decontaminant that is much safer than the solutions used in the M258A1 Decontamination Kit. This new decontarninant is actually a blend of two functionalized resins and a sorptive resin. One of the functional groups is a strong acid (sulfonic acid) and the other is a strong base (hydroxide). The third resin is a finely ground sorptive carbonaceous resin. Current plans are to field a new skin decontamination kit (XM291).

6-2.1.1.2 Reactive Clays

The US Army has developed and tested modified clays in an attempt to find replacements for the solutions used in the M258A1 Decontamination Kit. Although the work on reactive clays is currently not as advanced as the work on reactive resins, the following types of clay modifications have been investigated:

1. Clays with amines bound to the surface
2. Beneficiated clay materials
3. High surface area, large-pore materials
4. Clays with intercalated metal ions
5. Acid-activated clay materials
6. Oxidative clay materials.

Most of these clays have shown a high capacity for adsorbing and decomposing simulants. Beneficiated clays and copper clays have significantly higher sorptive capabilities than fuller's earth (Ref. 3).

Potentially, clays may be used in any or all of the following modes:

1. As powders to dust on contaminated areas
2. As a component of an agent barrier salve or film
3. In a pad or mitt for removing contamination from skin (Ref. 3).

6-2.1.2 Other Reactive Compounds

Although reactive resins and clays are currently receiving the most attention. particularly for skin decontamination. other reactive compounds have been investigated and may have potential as improved decontaminants for basic soldier skills decontamination.

6-2.1.2.1 Microencapsulated Reactive Decontaminants

Microencapsulation is defined as the encapsulation of reactive decontaminants within an agent-permeable polymeric capsule. Agents permeate the polymeric coating and are subsequently destroyed by the encapsulated decontaminant. The technology has been demonstrated to decontaminate agents; however, additional work is required to further develop the technology. Candidate polymeric coatings that have been tested include cellulosics, polyamides, and polyureas. Decontaminants that have been evaluated as potential core materials for microencapsulation include nucleophilic reagents for the destruction of G and V agents and oxidizing reagents for the destruction of H and V agents. Nucleophiles considered include aqueous NaOH, monoethanamine diethylenetriamine, hexamediamine, polyethylenimine, dimethylaminopyridine, imidazole. and catechol. Oxidants considered include XXCC3, RH195, calcium hypochlorite, 5% aqueous sodium hypochlorite, chloramine T, chloramine B, sodium dichloroisocyanurate, trichlorotriazinetrione, and bromodimethyl oxazolidone.

6-2.1.2.2 Crown Ethers

These organic complexes ha~e been examined for their decontamination capability at near room temperature in nonaqueous solvents (Ref. 4). Of the five macrocyclic ethers investigated, cryptand (2,2,2) and 18-crown-6 were most effective in facilitating agent destruction. in absolute ethanol, with a 1:1 equivalent concentration ratio of crown ether and agent, the crown salt with potassium hydroxide complex destroyed 98. 99, and 100% of distilled mustard (HD), VX, and cyclohexyl methyl phosphorofluoridate (GF), a sarin (GB) analog, respectively, in 5 min (Ref. 4). Because alkali metal hydroxides are too corrosive for use on skin, a salt of this reagent (the potassium-acetate-crown complex in benzene) has been tested for its decontaminating capability against agents. The results showed that 54% of GF, 82% of VX and 99% of HD can be destroyed within 2 min (Ref. 4). Although the preliminary study on agent decontamination by macrocyclic ether-alkali metal salt complexes is quite promising. the relatively high toxicity of these compounds has limited their decontamination application (Ref. 5).

6-2.2 HASTY DECONTAMINATION

The objective of hasty decontamination is to sustain the combat potential of a contaminated force by limiting the spread of contamination and potentially allowing for quicker reduction in mission-oriented protective posture (MOPP). Hasty decontamination consists of two techniques: MOPP gear exchange and vehicle washdown. both of which typically are squad-sized operations. Until recently. the emphasis in decontamination development has been placed on finding new techniques for deliberate decontamination. These techniques have tended to be labor intensive. logistically unmanageable, and tactically impractical. Unfortunately. attempts to develop hasty decontamination techniques that overcome these limitations have not been as successful as anticipated. Therefore, new decontamination systems that provide more efficient hasty decontamination capabilities are needed. In the DCCMP the development of new coatings was identified as the best approach for improving upon and replacing the vehicle washdown system currently used for hasty decontamination.

6-2.2.1 Coatings

To fulfill hasty decontamination requirements, effort has focused upon developing a type of coating called a sacrificial coating. A sacrificial coating is one that can be applied as a liquid in a thin wet layer on a contaminated surface. will entrap contamination as it dries and hardens, and can then be removed from the surface along with entrapped contamination. Three different types of sacrificial coatings have been investigated: dissolvable, peelable, and self-stripping. These coatings vary in composition, method of application, and method of removal.

The dissolvable coating is a noncorrosive, water-soluble, polymeric solution. The coating is sprayed onto a contaminated surface, allowed to form a film while absorbing contamination, and stripped from the surface with a weak detergent solution.

The self-stripping coating is a commercially available, water-based solution containing a copolymer. The material is usually brushed on a contaminated surface and allowed to dry. As the coating polymetrics and flakes from the surface, contamination is trapped within its matrix.

The peelable coating is a commercially available solution of a copolymer in a hydrocarbon solvent. The coating is applied to a contaminated surface, allowed to dry, and then peeled from the surface.

Of the three coatings described, the self-stripping coating has been determined to be the one that shows the most promise for meeting the short-term needs of hasty decontamination. In the analysis to determine the most promising coating, the assumptions that follow were made: the coating will be used for hasty vehicle decontamination by individual Army field units without the support of a chemical company, and it will be used to reduce or eliminate the spread the of contamination and to speed the reduction in MOPP. As a result of this analysis, development of a self-stripping coating has been undertaken.

A potential variation of the technology may be the development of sacrificial coatings that have the capability to destroy agents. The long-term plans of the US Army call for the development of a coating containing catalysts that promote agent decomposition in the presence of elements such as light, oxygen (air), or moisture.

6-2.2.2 Hot Air

Hot air can be used effectively to volatilize chemical warfare agents which results in their removal from a contaminated surface. Hot air most closely resembles the weathering process that naturally takes place with agents over a period of time. Hot air accelerates the natural volatilization and, as a result, decontaminates the agent-contaminated surface.

Hot air decontamination has undergone significant development activity during the mid-1980s. lt has been demonstrated for applications such as electronics and other sensitive systems that tire susceptible to corrosion or damage from more standardized water- or solvent-based or gaseous decontaminants. For example, hot air has been considered as a potential decontaminant for vehicle interiors, aircraft cockpits, aircraft avionics, and personal protective clothing items (both during and after processing into a shelter).

Substrate/agent interactions and thermal properties of the substrate have a great deal to do with the effectiveness of the hot air agent removal technique. Materials that are good candidates for hot air decontamination are those that resist agent sorption, do not degrade at elevated temperatures, and whose temperatures can be elevated easily, i.e., materials with low heat capacities and high thermal conductivities. For example, most unpainted metals can be effectively decontaminated because they do not sorb agents and they can be heated quickly to high temperatures without being deformed. Many polymeric materials, on the other hand, cannot be decontaminated by using hot air techniques because they will sorb agents and they will stress or warp when exposed to too much heat (sheet acrylics, for example). Aircrafts canopies and faceplates on gages have been deformed when exposed to too much heat during hot air decontamination tests.

The type of agent to be decontaminated and the potential for condensation after decontamination will also have an impact upon how effective decontamination with hot air will be. Thickened agents are formed by adding polymeric substances to agents in ordeer to reduce their volatility and thus increase their persistency. These thickened agents are much more difficult to remove completely and, when treated with hot air, will likely leave behind a residue of the thickener, which may contain low levels of agents. Once agents have been removed from a surface by using hot air, there is the potential danger that these agents may condense on a nearby surface that has not been heated. Because of this danger, areas other than the initially contaminated area may need to be heated before decontamination can be completed. Taking such a precautionary measure may take more time than is available during hasty decontamination.

A 1985 study examined the optimum temperature and flow regimes required to achieve peak contaminant removal efficiency (Ref. 6). This study determined that heated forced air is a potentially effective and versatile means of removing agents from metal surfaces. Results indicate that high removal efficiencis can be achieved in 30 s at relatively low air temperatures of 37.7°C and air velocities of 1036 m/s and 1951 m/s.

In tests that were performed to measure the effectiveness of various techniques in the decontamination of personal protective equipment (Ref. 7), hot air flowing through a conventional oven was effective in removing GB, HD, soman (GD), and VX from gloves, boots, and butyl rubber cloth but was not effective in removing those agents from the protective overgarment. Over 25% of the agents initially deposited on the protective suit remained after decontamination. The clothing items had been placed in a conventional oven for 45 min and exposed to a 1-dm^3/m flow of air at approximately 150°C.

The US Army has developed and tested experimental hot air decontamination equipment. Although the development programs were cancelled before production, the XM15 and the XM16 remain viable concepts for special-purpose decontamination of vehicle systems.

The XM15 was an oil-fired, one-man-portable, hot-air-generating apparatus intended to decontaminate crew compartments and interior surfaces of combat vehicles, wheeled vehicles, shelters, electronic equipment, command and control vans, aircraft interiors, watercraft, and other enclosures sensitive to aqueous-based solvents. The XM15 was small enough to be stored close to the area to be decontaminated, so that it would be available for immediate use. This system progressed into the advanced development stage but was terminated because it was too slow and a logistic burden (one unit required per vehicle or shelter).

The XM16, which had achieved the engineering development stage, was designed to provide large-scale, rapid decontamination of combat vehicles. aircraft. and other major equipment items in order to permit user personnel to operate at lower MOPP levels. The prototype XM16 consisted of a jet engine, operator cab, and main control unit mounted side by side on a turntable at the rear of a six-wheeled drive, five-ton truck. The apparatus also included tanks for fuel and decontaminating liquid or smoke-producing liquid. The advantages of using high velocity to decontaminate vehicles include (1) elimination of the requirement for water resources results in a reduced logistic burden and (2) reduced manpower requirements because personnel are not directly involved in the decontamination process.

The US Army is currently developing a system, the XM56 Dual-Purpose Smoke and Decontamination System, that may be used for generating smoke for obscuration purposes as well as high-pressure hot water and hot air for decontamination. The system will also have an interior decontamination module that will be a preplanned product improvement.

6-2.3 DELIBERATE DECONTAMINATION

Deliberate decontamination is the most complex and complete of the three types of decontamination. The objective of deliberate decontamination is to lower contamination to levels that will allow soldiers to operate equipment at reduced MOPP levels for extended periods of time.

In the DCCMP, aqueous-based decontaminants were evaluated as being the most promising technologies for deliberate decontamination.

6-2.3.1 Emulsions

An emulsion, by definition, is a colloidal suspension of small globules of one liquid in a second liquid. Examples are oil or fat particles in water. The intimate and uniform mixture of naturally immiscible liquids is made possible by the action of emulsifying agents, commonly fatty acids or long-chain alcohols. in water oil interface solutions.

A potential decontamination problem can result from low agent volubility in water. This is especially true for

HD. If the agent low volubility problem could be solved, the resulting decontaminant would be much more capable of covering the entire agent spectrum. Emulsifying agents decrease the surface tension between two immiscible liquids, such as HD and water, and this decrease results in increased surface area interaction, which allows for increased volubility. Thus an emulsion-based decontaminant would allow aqueous decontamination of HD and other agents that exhibit low volubility in water. An all-purpose C8 emulsion decontaminant has been developed by the Germans for vehicle and equipment decontamination. Tests indicate that this formulation is capable of H, G, V, and biological agent decontamination. C8 emulsion maybe selected as the US Army's Improved Chemical and Biological Agent Decontarninant (ICBAD). The emulsion is a mixture of 7.5% to 8.0% calcium hypochlorite, 15% perchloroethylene, 1% emulsifier, and 76.5% water. (All percentages are by weight.) Once mixed, the emulsion is a thick, white substance that adheres to surfaces. It can be dyed to a camouflage green color to decrease its signature. Current plans are to mix and apply the emulsion using the M12A1 Power Driven Decontamination Apparatus (PDDA) (Ref. 8).

6-2.3.2 Microemulsions

A microemulsion is a specific type of emulsion. Because it is an emulsion, it also is a uniform mixture of naturally immiscible liquids formed by the suspension of globules of one liquid in another. Again, this suspension is made possible by the use of emulsifying agents. As its name implies. however. the globules are much smaller and are actually not visible to the naked eye. More surfactant is required to form a microemulsion than is required to form an emulsion.

Microemulsions offer several advantages over emulsions. Most importantly, microemulsions are thermodynamically stable solutions. Because they are stable, once they have been formed, microemulsions will not phase separate as emulsions have a tendency to do. Thus microemulsions will have longer shelf lives than emulsions. Thermodynamic stability also means that the final properties of the microemulsion are not dependent upon the mixing process used to form the solution. (If the components are all present in the appropriate proportions, microemulsions will actually form spontaneously over time without any mixing.) As a result, the production of microemulsions will not pose the inconsistency and quality control problems associated with the production of emulsions.

The US Army is currently investigating the potential of various microemulsion formulations as candidates for the Multipurpose Chemical and Biological Decontarninant (MCBD). The formulations being considered consist of a micro emulsion of perchloroethylene in water with cationic surfactants and co-surfactants, a catalyst. and an oxidant. Perchloroethylene is being used because it is the only one of the commercially available solvents that has the characteristics that make it attractive as a decontaminant—it dissolves agents and thickeners, it is not flammable, and it has a high boiling point. Fichlor (sodium N, N-dichloroisocyanurate) is being considered as the oxidant because it offers advantages over the high-test hypochlorite (HTH) used in the ICBAD/C8 emulsion. The chlorine in Fichlor does not become available for reaction at the same time the Fichlor dissolves. Rather, the amount of available chlorine is regulated by an equilibrium process in the microemulsion. As a result, the microemulsion is less corrosive and the oxidation process may be more efficient. Currently, 5-nitro-2-iodoxybenzoic acid (IBX) is being investigated as a potential G-agent catalyst.

The composition of the microemulsion being investigated is as follows (in percentages by weight): 64.3% water, 8.2% perchloroethylene, 23.3% emulsifier, and 4.2% reactive materials (Fichlor and lBX).

Because the current microemulsion-based decontaminants do not meet all of the current or future requirements, long-range concepts will use catalytic reagents to increase the decontamination efficacy. An aqueous microemulsion with partial catalytic reactivity is scheduled for fielding in the early 1990s. A fully catalytic aqueous microemulsion system capable of full reactivity with all known threats is scheduled for fielding in the late 1990s. The fielding of this aqueous microemulsion decontaminant will provide the capability for deliberate decontamination (Ref. 1).

6-2.3.3 Catalysis

Catalysis involves the modification and increase in the rate of a chemical reaction and is brought about by a substance or substances that are themselves chemically unchanged by this reaction. Thus one part by volume of a catalyst can activate thousands of parts of reactants. Though the mechanism of their action is not completely known, the electronic configuration of the surface molecules of the catalyst is often the critical factor (Ref. 9). The surface irregularities give rise to so-called "active points", at which intermediate compounds can form. Most industrial catalysis is performed by finely divided transition metals or their oxides (Ref. 9).

The use of catalytic compounds to neutralize chemical warfare agents has been looked at with interest in recent years. Because there are a large number of potential catalytic compounds whose chemistry is well understood, the chances of developing a catalytic-based decontaminant are good. lnvestigations have concentrated on identifying compounds that catalyze the air-oxidation, auto-oxidation, or hydrolysis of agents and are active with all agents of interest. At present. most work effectively with only G agents (Ref. 10).

A number of metal ions. especially those of copper(II), uranium (VII), zirconium (IV), thorium (IV), and molybdenum (VI). have been observed to increase the hydrolysis rate of agents in water. Some metallic salt solutions. which are less corrosive, have been experimentally tested for their feasibility in decontamination of agents, e.g., uranyl nitrate with tetramethylethylenediamine, and uranium-dioxy-bis-(5-sulfo-8-hydroxyquinoline). However, preliminary test results indicate that these chemicals are too slow for agent decontamination (Ref. 11).

Enzymes have also been investigated as potential catalysts for decontamination reactions. Enzymes are protein molecules that have catalytic properties due to specific activation in the biological system. In an equivalent biological condition, a typical enzymatically driven chemical reaction is 10^8 to 10^{12} times faster than the same reaction without enzymes. The chemical reaction rate can be further accelerated be optimizing the reaction conditions, such as temperature, pressure. and pH. Due to the advanced state-of-the-art genetic engineering technologies, the development of new enzymes to degrade agents becomes feasible. Examples include new species of bacteria that degrade petroleum hydrocarbons resulting from spills and bacteria to degrade kepone, a highly persistent chlorinated pesticide pollutant discovered in the James River in Virginia. Enzyme degradation offers two important advantages. It is noncorrosive and it poses minimum logistic burden (The enzyme is never consumed.).

A disadvantage of enzyme-based decontaminants is that a highly reliable knowledge of the threat is required due to the specificity of the enzyme reaction. Currently, only basic research has been conducted in the development of enzymes that attack and destroy chemical agents through catalytic action.

Results of basic research programs in catalyis being conducted by CRDEC will advance developments in aqueous micro emulsion systems, self-decontaminating coatings. and solid sorbcnts as defined in DCCMP (Ref. 1).

6-2.3.4 Fluorocarbons

Fluorocarbons arc compounds containing carbon, one or more halogens, and sometimes hydrogen. The lower members of the various homologous series are used as refrigerants, propellant gases, fire extinguishing agents, and blowing agents for urethane foams (Ref. 9). Fluorocarbons are organic solvents that can be employed to dissolve and remove agents from surfaces but do not detoxify the agents.

Fluorocarbon-113 (FC-113) is a product designation for 1,1,2 trichloro-1,2,2 trifluoroethane. It is a widely used nonpolar solvent and cleaning agent in aerospace application and is preferred because of its liquid temperature range (–35°C to +48°C) and its inertness. Its major value as a cleaning agent is that, when pure, it evaporates rapidly and leaves no residue. It is dense enough to remove small metal chips mechanically, is inert with respect to most engineering materials, and dissolves most greases, including both preservative coatings and the potentially corrosive greases from fingerprints. It is also relatively safe because it is noncorrosive, nonflammable, and under most circumstances, it has relatively low toxicity. Because it is heavier than air, FC-113 poses no harm to the ozone layer of the earth.

Other solvent cleaning concepts are possible but have not been investigated in detail. These concepts are chiefly variations on vapor degreasing techniques used in industry and would pass solvent vapor through the aircraft or in a controlled stream across contaminated surfaces. The vapor application equipment would be more complex than that needed for solvent washing, but these concepts would have the advantage of applying very highly purity vapors. The use of vapor rather than liquid would be less likely to stir up particulate that could physically contaminate sensitive avionics equipment.

An experimental program resulted in the removal of 95% of the HD and GD from polyester-cotton, rubber, and Nomex cloth (Ref. 12). The effectiveness of FC-l13 in removing agents from clothing materials has been denlonstrated, and the solubilities of the liquid agents of interest (nerve and mustard components) in FC-113 have been determined. HD, GD, and VX are infinitely soluble in FC-113.

In addition to the solubility of agents in FC-113, the low surface tension and high density of FC-113 add to its attractiveness as a decontaminant. Both properties enhance the capability of the solvent to displace organic residues from surfaces (Ref. 12). These enhanced displacement capabilities will be important for the displacement of thickened agents and VX that have high affinities for metal surfaces.

FC-113 is a very nonpolar solvent and at temperatures below 100°C does not attack (dissolve or react with) most materials common to the manufacture of aircraft components. Temperature of application would have to be below 48°C, the boiling point of FC-113. FC-113 is compatible with most metals, paints, ceramics, and most common plastics except elastomers. FC-113 dissolves petroleum greases and causes elastomers to swell when they are soaked or drenched. Some common elastomers used in aircraft or personnel protective equipment are n;itur:il rubber and silicone rubber. In the case of elastomcr,. the FC-113 diffuses into the structure and causes the entire elastomeric structure to swell uniformly but does not cause the structure to dissolve. Such swelling is largely reversible when the fluorocarbon evaporates. Accordingly, if FC-113 is spilled briefly washed across an elastomer surface, only a small amount penetrates the surface. The amount of swelling upon thorough soaking varies considerably with the specific fluorocarbon and with the elastomer. The major concern when using FC-113 around equipment and some gas masks is the effect on silicone rubber. Based on some very preliminary tests with FC-113 on silicone sealant and silicone rubber gas mask material, it appears that swelling is a problem that can be tolerated, especially if operational personnel understand and are trained to wash, rather than soak, the equipment. It is expected that any petroleum grease in the equipment would be removed by fluorocarbon washing and new greases would have to be reapplied. However, the removed greases might contain dissolved agents, so removal would probably be necessary anyway..

FC-113 is the decontaminant chosen for use vith the XM19 Nonaqueous Decontamination System (NAEDS). The NAEDS is similar to a commercial decreasing chamber. The system consists of a glove box (spray chamber) and an FC-113 regeneration and agent neutralization system. Equipment items to be decontaminated are passed into the spray chamber through access doors on either end of the system. In the chambers spray gun sprays FC-113 on the equipment item. Two operators can participate in the decontamination process by using the four butyl rubber sleeves that project into the chamber from the window in the front of the unit. Both a fixed-site and a mobile version of the NAEDS have been developed (Ref. 8).

6-2.3.5 Foams

In many applications foam-based decontaminants are more attractive than their liquid-based counterparts. Foams hale thicker decontaminant layers that act to retard agent resorption while they enable the reactive component of the foam to detoxify the agent. Foams can also be developed to adhere to surfaces for time periods that exceed those expected for liquid decontaminants. This adherence, particularly on vertical surfaces, increases the length of time that the reactive component of the foam remains in contact with agents. As the contact time increases, the decontamination efficiency increases.

In a recent study performed for CRDEC, over 250 foams were formulated and evaluated as potential decontaminants for military aircraft. Foams developed with materials already available Within the military supply inventory, aircraft deicing fluid (ADF) and the fire-fighting foam, aqueous film-forming foam (AFFF), showed the most promise. The three most promising ADF foams were formulated using sodium dichloroisocyanurate (SD), 3-bromo-4,4-dimethyl-2-oxazolidinone (BDO), or o-iodosobenzoic acid (IBA) as the reactive component. Four promising AFFF foams were formulated using SD, BDO, IBA, or HTH as the reactive component.

These foams were comparable to DS2 in decontaminating alkyd-painted metal samples contaminated with GD. HD, VX, thickened soman (TGD), and thickened distilled mustard (THD). Further more, the foams had less deleterious effects than the DS2 upon the alkyd paint. In addition, the teams were reasonably compatible with the following military materials: butyl, silicone, and epichlorohydrin rubbers; acrylic and cellulose acetate butyrate (CAB) plastics; and silicone and polysulfide sealants.

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GLOSSARY

A

ABC-M13. An individual decontaminating and reimpregnating kit designed to be used for decontamination of droplets of all chemical agents on skin, clothing, and personal equipment. This kit has been replaced by the M258A21 skin decontamination kit.

Acidic Hydrolysis. Reaction during which water reacts with a substance under acidic conditions

Activated Solution of Hypochlorite (ASH). Decontaminant effective for G-series, V-series, H, and biological agents. It has been used for decontaminating buildings, floors. the ground, and other large areas.

Aeration. The process of supplying or impregnating with air or oxygen

Aerosol. Gaseous suspension of liquid or solid chemical particulate; examples are mist and fog.

Af/atoxins. Any of several carcinogenic mycotoxins that are produced in stored agricultural crops by molds

Agent. Threat warfare material referring to either a chemical, biological, or toxic substance

Air Oxidation. oxidation reaction in air

Alkaline Hydrolysis. Hydrolysis reaction in which water reacts with a substance under basic conditions

Anorexia. Lack of or loss of appetite for food

Anthrax. An infectious, often fatal disease, characterized by ulceration of the skin, enlargement of spleen, and general collapse

Aqueous Decontamination. Removal of a chemical or biological hazard with a water-based solution

ASC Whetlerite. A steam-activated bituminous carbon, impregnated with various metals, that is currently used as filter material in many masks and collective protection devices

Auto-Oxidation. Oxidation reaction that takes place in the presence of air

B

Bacilli. Rod-shaped bacteria

Bacteria. Microorganisms often composed of a single cell

Biological Agent. Either microorganisms or toxins that cause casualties and have military applications

Blister Agents. Agents that affect the eyes, lungs, and skin. In liquid or vapor form these agents can burn or blister any part of the body they may contact, either internal or external. They are effective in small quantities and cause delayed casualties.

Blood Agents. Agents that are usually disseminated as vapors or gases and are taken into the body by breathing. They affect the circulatory and respiratory systems by preventing the use by cells of the oxygen carried by the blood. They can act very quickly and cause symtoms ranging from convulsions to coma and death.

Botulinum Toxin. A toxin produced by a spore-forming bacterium that causes acute food poisoning

Bronchitis. Inflammation of the respiratory tract

Brucellosis. A disease characterized by remittent freer

C

C8 Emulsion. Hypochlorite-containing decontaminant effective against all known threat agents

Carboxide. Decontaminant that is a mixture of ethylene oxide and carbon dioxide and is effective against all microorganisms to include spores

Catalysis. A modification in the rate of a chemical reaction induced by material unchanged chemically at the end of the reaction

Catarrh. Inflammation of the mucous membrane

Cellulosics. Semisynthetic polymers based on cellulose

Chemical-Agent-Resistant Coating *(CARC). A* polymeric coating system that is resistant to liquid agent sorption

Chemical Agent. A chemical compound that produces lethal or deleterious effects in man and has characteristics suitable for rnilitary use

Chikungunga Fever. A disease characterized by high fever, headache, and pain in the large joints

Chlorination. To treat or cause to combine with chlorine or a chlorine compound

Choking Agents. Agents that are usually disseminated as gases and are taken into the body by inhalation. They affect the respiratory system by damaging the nose, throat, and lungs. In extreme cases membranes swell, lungs become filled with liquid. and death results from lack of oxygen.

Cholera. An acute, infectious, and often fatal disease characterized by profuse diarrhea, vomiting, cramps, and dehydration

Cocci. Round or spherical bacteria

Coccidioidomycosis. A disease, mainly affecting the lungs and skin. characterized by the production of excessive sputum and the development of nodules

Collective Protection Equipment (CPE). Equipment that provides protection of an enclosure against hazardous concentrations

Compatible. The capability of being operated, maintained. and resupplied by persons wearing the full NBC protection ensemble (MOPP 4) or individual protective equipment (IPE) in all climatic categories for which the item is designed and for a period specified in the requirements document

Complete Decontamination. The reduction of contamination to a level at which combat units can function normally without wearing individual protective gear

Conjunctival Suffusion. A disease symptom characterized by overspreading liquid around the mucous membrane that lines the inner surface of the eyelids

Conjunctivitis. Inflammation of the eyes

Contact Hazard. Any contaminated surface from which contamination can be transferred upon contact, usually skin contact

Contaminants. Chemical or biological agents

Contamination Avoidance. Measures taken to prevent contamination of items or surfaces by CB agents. Two types of contamination avoidance are protection and isolation.

Contamination Avoidance Covers. Any cover used to prevent contamination of items or surfaces by CB agents

Contamination Control. Decent amination. contamination avoidance, and the knowledge to implement them

Cumulative Effects. The effects that are additive for separate exposures over a finite time frame

Cyanosis. Blueness of the skin due to insufficient oxygen in the blood

D

Decontaminability. The capability of being rapidly decontaminated to a negligible risk level for unprotected persons who operate, maintain. and resupply the materiel.

Decontaminants. The substances used to remove or detoxify a chemical or biological hazard

Decontaminating Solution No. 2. The standard decontaminant for chemical agents; however, it also destroys biological agents, with the exception of spores.

Decontamination. The process of removing, neutralizing, containing, and detoxifying a chemical or biological hazard

Deliberate Decontamination. Method of extensive decontamination performed at equipment decontamination sites and intended to allov MOPP reduction

Delirium. A temporary disorder of mental properties, such as excitement, delusions, and hallucinations

Detection. Measures taken to determine the presence of CB agents

Detrochlorite. A thickened bleach used for biological decontamination of vertical surfaces to which the application of corrosive material is permissible

Dichloramine B and Dichloramine T. Decontaminants effective against mustard and V agents

Diplopia. Double vision of a single object

Dosage. Total concentration of a chemical or biological agent to which an individual is exposed integrated over the time of exposure

Dose. Quantity of agent that has entered an individual body

Dry Sorbents. Solid powders used by the military for physical decontamination by absorption

Dysentery. Disorder marked by inflammation of the intestines. particularly the colon, and accompanied by pain in the abdomen, straining, and frequent stools containing blood and mucus

Dyspnea. Difficulty breathing

E

Edema. Abnormal accumulation of liquid in the lung tissues

Emulsifier. A surface-active agent, such as soap, that promotes the formation and stabilization of a mixture of two or more immiscible liquids

Emulsion. A stable mixture of two or more immiscible liquids held in suspension by small percentages of substances called emulsifiers

Encephalitis. Inflammation of the brain

Endocarditis. Inflammation of the serous membrane that lines the cavities of the heart

Enzymatic. Being produced by any of numerous, complex proteins that catalyze specific reactions at mild temperatures

Enzyme. Protein produced by a living organism. which accelerates or catalyzes one or more chemical reactions

Epidemic. An outbreak of a contagious, infectious disease

Ethylcellulose. An ethyl ether of cellulose used in protective coatings

Ethylene Oxide. Decontaminant effective against all microorganisms to include spores

Eutectic. A mixture whose melting point is lower than that of any other mixture of the same ingredients

F

Favus. A skin disease characterized by dry incrustations, i.e., formation of hard scale or coating

Field-Expedient. Task easily performed or structure quickly constructed by personnel in the field, often using locally procured material and equipment in place of standard issue items

Fluorocarbon. A compound containing carbon, fluorine, and sometimes hydrogen

Formalin (Formaldehyde). Decontaminant effective against all microorganisms to include bacterial spores

G

G-Series Agents. Chemical warfare agents that directly affect the nervous system of man and are highly toxic in both liquid and vapor forms. These agents can be absorbed through the skin or inhaled and quickly act to cause casualties and death. Essentially, these agents cause an increase of the chemical acetylcholine in the body by their interference with the enzyme acetylcholinesterase and thus affect the transmission of nerve impulses. The main G-series agents are GA, GB, and (GD)

Gaseous Agent. An agent in its vapor or aerosol form

Glanders. A disease with the characteristics of swellings beneath the jaw and a and a mucous discharge from the nostrils

Gonorrhea. A venereal inflammation of the urethra or vagina

H

Hallucination. Sensory experience of something that does not exist outside the mind

Hardness. The ability to withstand materiel-damaging effects of both CB contamination and decontaminants (procedures and chemicals)

Hasty Decontamination. Method of rapid decontamination using primarily soap and water

Hemoglobin. The oxygen-carrying protein in the blood

Hemoptysis. Expectoration of blood, usually due to hemorrhage from the lungs

Hexachloromelamine. Decontaminant effective against mustard agents

High-Test Hypochlorite (HTH). Decontaminant effective against all threat agents

Host. Any animal or plant that nourishes another organism

Hyamines (Benzethonium Chloride). Decontaminant effective against all bacteria

Hybrid Collective Protection. A combination of positive pressure and ventilated facepiece systems

Hydrated Metal Ions. Ions formed when metallic ions react with molecules of water and the H-OH bond is not split

Hydrolysis. A chemical reaction during which water reacts with another substance to form two or more new substances

Hydrolytic Reaction. See Hydrolysis.

Hypochlorites. Strong oxidizing agents

I

ICT$_{50}$. Median incapacitating dosage: the amount of inhaled vapor or liquid agent sufficient to disable 50% of exposed personnel

Identification. Determination of CR agents by name or type

Immiscible. Two substances of the same phase or state of matter that cannot be uniformly mixed or blended except with an emulsifier

Impermeable. Not permitting the passage of a fluid or vapor through a material

Incapacitating Agents. Agents producing phybiological or mental effects that may persist for hours or days after exposure to the agent has ceased

Incapacitation. The prevention, disablement, or serious degradation of the ability of exposed troops to perform their mission

Incineration. Disposal of solid and liquid organic materials by combustion at temperatures from 1200° to 1500°C

Incubation Period. Time interval between the introduction into the body of an infectious microorganism and the appearance of the first symptoms of disease

Individual Protective Gear. The aggregate of all clothing and equipment worn to prevent contact with CB hazards

Individual Protective Equipment (IPE). See Individual Protective Gear.

Inflammation. Reaction of tissue to injury that is characterized by pain, heat, redness, and or swelling of the affected areas

Isolation. The containment of contaminated areas, materials, or persons to prevent the spread of contamination

J

JP-4. Jet fuel for military aviation

L

Lacrimation. Abnormal or excess secretion of tears

LCT$_{50}$. Median lethal dosage, i.e., the amount of inhaled vapor or liquid agent sufficient to kill 50% of exposed personnel

Lesion. Injury caused by either mechanical or pathological means

Lethal Agent. A CB agent used against enemy forces to inflict fatal casualties

Lewisite. An arsenical blister agent

Ligand. A molecule, ion, or atom that is attached to the central atom of a coordination compound, a chelate, or other uomplck

M

Macrocyclic Ether-Alkali Salts. A nonaqueous organic sorbent

Malaise. A condition of general bodily weakness and discomfort

Mask Sanitizing Solution. Standard solution effective for destroying microorganisms except spores and used to decontaminate previously cleaned masks

Mediastinitis. Inflammation of median septa or partitions between two organs

Microencapsulation. A technique of encasing extremely small droplets or particles

Mission-Oriented Protective Posture (MOPP). The level of protective equipment to be worn by individuals that is determined by a command decision based on detected threat levels

Monitoring. The continuous or periodic checking for the presence of a CB agent

MOPP Gear. Combination of all individual protective equipment including protective overgarment, boots, gloves, and mask with hood

Mya/gia. Pain in the muscles

N

NBC Contamination Survivability. The capability of a system and its crew to withstand an NBC-contaminated environment. including decontamination, without losing the ability to accomplish the assigned mission

Neat Agent. Agent that is not mixed with thickener or diluent

Negligible Risk Value. That level of biological or chemical contamination that should not produce a dosage in excess of the threshold effect level to unprotected persons operating or maintaining the system (equipment)

Nerve Agents. Agents that directly affect man’s nervous system and are highly toxic in low concentrations in both liquid and vapor forms. These agents can be absorbed through the skin or inhaled and quickly act to cause casualties and death. Essentially, these agents cause an increase of the chemical acetylcholine in the body by their interference with the enzyme acetylcholinesterase and thus affect the transmission of nerve impulses.

Neurotransmission. Chemical transmission to propagate messages in the nervous system

Nonaqueous Decontamination. Removing or detoxifying a chemical or biological hazard with a nonwater-based solvent or by physical means

Nonpolar. Molecule in which the centers of positive and negative charges coincide so no permanent dipoles are produced

Nucleophilic. A reaction during which an ion or molecule donates a pair of electrons to form a covalent bond

O

Ocular Disorder. Pathological problems around the eyes

Orchitis. Inflammation of the testicles

Organometallic Compound. An organic compound containing a metal

Overpressure. Difference in the higher pressure inside a vehicle or shelter relative to that of the ambient air

Oxidation. The term originally meant a reaction during which oxygen combines chemically with another substance, but its usage has been broadened to include any reaction during which a moiety loses electrons.

P

Partial Decontamination. The reduction of contamination to a level at which combat units are able to sustain their fighting capability

Persistence. Duration of the presence of a chemical agent in the environment or on structures or equipment

Persistent Agent. Agent that remains in the environment for a long period of time or on structures or equipment

pH. A value taken to represent the acidity or basicity of an aqueous solution

Pharyngitis. Inflammation of the mucous membrane of the pharynx

Phenolics. A class of synthetic thermosetting resins obtained by the condensation of phenol or substitution of aldehydes for phenols

Photophobia. Intolerance of light

Plague. An infectious and epidemic disease characterized by fever, chills, and prostration

Polyamide. A high-molecular-weight polymer in which amide linkages occur along the molecular chain

Potassium Hydroxide (Caustic Potash). Decontaminant effective against G agents, lewisite, and all biological materials including bacterial spores

Power-Driven Decontamination Apparatus. Equipment intended for field use to spray hot water. STB slurry, HTH slurry, caustic solutions, alkaline scrubbing soap, detergent solutions, and other water-based decontaminants. (The M12A1 is the current standard decontamination equipment issued to Army battalion level and chemical company level.)

Prophylactic Mode. Application of a sacrificial coating prior to decontamination of a surface. See also Sacrificial Coatings and Therapeutic

Prostration. Extreme exhaustion

Protection. Action taken to prevent contamination of a clean item or surface, for example, a covering

Pulmonary. Pertaining to the lungs

Q

Q Fever. An infection exhibiting pneumonia-like symptoms

R

Rabies. An acute infectious viral disease of the nervous system

Reactive Resins. Resins that combine the high capacity of the polymeric absorbents with a wide range of active chemical groups

Reduction. Any reaction during which electrons are consumed

Removal Efficiency. Ratio of the amount of contamination removed from to the amount of contaminant originally deposited on a surface

Ringworm. Any of a number of contagious skin diseases characterized by the formation of ring-shaped eruptive patches

Rocky Mountain Spotted Fever. A disease characterized by high fever; pain in the joints, bones, and muscles; and a cutaneous eruption

S

Sacrificial Coating. Coating that crosslinks after application to form a hard coating that entraps agents and is then stripped off by either chemical or mechanical methods. See also Prophylactic Mode and Therapeutic

Self-Limiting Solutions of Hypochlorite (SLASH). Decontaminant containing dilute HTH. It has been used for decontaminating buildings. floors. the ground, and other large areas. SLASH is less corrosive and less effective than ASH.

Septicemia. The invasion and persistence of pathogenic bacteria in the blood stream

Shelter. A place of protection from CB hazards

Slurry. Various mixtures of STB or HTH and water

Smallpox. An acute and highly contagious disease characterized by a pustular eruption that often leaves permanent pits or scars on the skin

Sodium Hypochlorite Solution (Household Bleach). Decontaminant effective against blister and V agents and all biological materials

Sodium Hydroxide (Caustic Potash). In solution, a decontaminant effective against G agents, lewisite, and all biological materials including bacterial spores

Sodium Carbonate (Washing Soda) Soda Ash, Sal Soda, or Laundry Soda). Decontaminant effective against G agents

Solubility. The ability or tendency of one substance to dissolve in another

Solvent. A liquid substance capable of dissolving one or more other substances

Sorbents. Materials that exhibit absorption or adsorption characteristics

Sorption. The process of either adsorption or absorption

Spirilla. Comma- or spiral-shaped bacteria

Spores. Resistant, dormant cells of some bacteria; primitive reproductive bodies of fungi

Sporulation. Formation of spores

Spotted Fever. Any of several fevers characterized by spots on the skin

Stoichiornetric Reaction. A reaction that involves substances that are in the exact proportions required for a given reaction

Substrate. Underlying structure of a surface

Surfactant. A surface-active substance, such as a detergent

Syphilis. A chronic infectious disease, usually of venereal origin, often affecting almost any organ or tissue in the body

T

TCT_5. Amount of inhaled vapor or absorbed liq agent that causes 5% of affected population to experience recognizable symptoms

Therapeutic. Application of a sacrificial coating after the contamination of a surface. See *also* Prophylactic Mode *and* Sacrificial Coatings

Thermal Burden. The physiological stress experienced by an individual wearing IPE

Thickener. A high-molecular-weight polymer that, when mixed with agent, increases the droplet size upon dispersion

Thrush. A disease characterized by whitish spots and ulcers on the membrane of the mouth, fauces, etc.

Total Collective Protection. A combination of hybrid or overpressure collective protection plus an environmental control system

Toxin. Any poisonous secretion product from a microorganism. animal. or plant. It may also be produced by organic synthesis.

Tuberculosis. An infectious disease that may affect almost any tissue of the body, especially the lungs

Tularernia. A disease resembling the plague characterized by an irregular fever that lasts several weeks

Typhoid Fever. An infectious, often fatal disease, characterized by intestinal inflammation and ulceration

Typhus. An acute, infectious disease characterized by prostration, severe nervous symptoms, and a peculiar eruption of reddish spots on the body

U

Ulceration. Formation of large, water-filled blisters

Ultraviolet (UV) Light Oxidation. An oxidation reaction initiated by UV light

Uncontaminated. The state of not having made any contact with a biological or chemical hazard or of being completely decontaminated

Unicellular. Made up of a single cell

V

V-Series Agents. Chemical warfare agents that directly affect man's nervous system and are highly toxic in both liquid and vapor forms. These agents can be absorbed through the skin or inhaled and quickly act to cause casualties and death. Essentially, these agents cause an increase of the chemical acetylcholine in the body by their interference with the enzyme acetylcholinesterase and thus affect the transmission of nerve impulses. The main V-series agent is VX. The vapor pressure of VX is so low that minimum vapor hazard exists.

Vapor. Chemical in a gaseous state

Vector. Organism, usually an insect or tick that carries disease-producing microorganisms and transmits disease from one host to another

Vegetative Cells. Bacteria or fungi in their active growth phase

Ventilated Facepiece. Series of individual respiratory systems (or masks) serviced by a common filter blower

W

Weathering. A form of passive decontamination

X

XXCC3. Chlorine decontaminant effective against HD and V agents. Its principal use has been for impregnation of protective clothing and garments.

Y

Yellow Fever. An acute, often fatal disease characterized by vomiting and and hemorrhages

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