APPENDIX B: CHEMICAL AGENTS

APPENDIX B: CHEMICAL AGENTS

Chemical agents, in the context of terrorism, are combinations of chemicals that yield a toxic (i.e., poisonous) effect upon exposure. That is, they are designed to kill, sicken, or harm people when they are released. There are, of course, a multitude of chemicals; only a relative few are used as chemical agents in weapons of terrorism.

Chemical agents produce their effects as a result of chemistry rather than through the physical effects (e.g., blast, fragments, projectiles, heat) of conventional weapons—although when dispersed by means of an explosive device, both kinds of effects may occur. Chemical agents differ from biological agents in that they do not have a "live" biological component. Therefore, the spread of disease is not an issue with chemical agents.

However, inhalation of or contact with volatile chemicals can present a major danger of mass casualties. The main differences between industrial chemical accidents and chemical terrorist incidents may be intent and magnitude.

CHEMICAL ATTACK SCENARIOS

Chemical incidents are likely to be overt (and in some instances easily identifiable) events. Chemical incidents are characterized by the rapid onset of medical symptoms (minutes to hours) and easily observed signatures (colored residue, dead foliage, pungent odor, dead insects and animals). Dispersion methods may be as simple as opening a container or using conventional (garden) spray devices, or as elaborate as detonating an improvised explosive device.

A chemical terrorist event is likely to be discovered in one of two ways: (1) the local discovery of the environmental release or exposure incident or (2) the diagnosis of the resultant patient cases. ***Some chemical agents produce delayed effects, and some produce immediate effects, so considerable damage may have occurred by the time the incident is detected and the cause identified.*** Indicators of a possible chemical terrorist incident are listed in the following table.

CHEMICAL AGENTS (CONTINUED)

CHEMICAL ATTACK SCENARIOS (CONTINUED)

Chemical Attack Indicators

- **Mass casualties:** Unusual numbers of sick or dying people with symptoms such as nausea, disorientation, difficulty breathing, convulsions, localized sweating, red eyes, red or blistered skin.
- **Pattern of casualties:** Casualties distributed downwind (if outdoors). Casualties grouped within a confined area (e.g., that shares an air ventilation system) if indoors.
- **Unexplained odors:** Unusual smells (e.g., fruity, flowery, sharp/pungent, garlic/horseradish-like, bitter almonds/peach kernels, new mown hay) that are out of character with the surroundings.
- **Dead animals/birds/fish:** Numerous dead animals (wild and domestic, small and large), birds, and fish in the same area.
- **Lack of insect life:** Normal insect activity (ground, air, and/or water) missing.
- **Different looking areas:** Trees, shrubs, bushes, food crops, and/or lawns that are dead, discolored, or withered, in the absence of drought conditions.
- **Unusual fogs, clouds, mists, liquids:** Numerous surfaces with oily droplets or film, when there has been no recent rain. Low-lying cloud/fog-like condition that is not consistent with its surroundings. Pools of liquid with unusual/unidentified source.
- **Abandoned spraying devices.**
- **Unusual metal debris:** Unexplained bomb/munitions-like material, especially if it contains a liquid.
- **An explosion.**

TYPES OF CHEMICAL AGENTS

Chemical agents can be broadly grouped into three categories:

- **Casualty agents:** Agents intended to produce casualties (dead and injured people). They include nerve agents, blister agents, choking agents, and blood agents.
- **Irritant agents:** Agents which produce unpleasant sensations meant to harass or temporarily incapacitate victims (also called *riot control agents*). These agents include vomiting agents and tearing agents.
- **Psychochemicals:** Agents that produce changes in mental function, such as hallucinations or general confusion, also meant to temporarily incapacitate victims. Examples include LSD and BZ.

These categories can be further divided according to their primary effect on the human body. The chemical agents most often identified as potential weapons of terrorism are grouped within the following types: nerve agents, blister agents, choking agents, blood agents, and vomiting agents. In addition, a few chemical agents are classified as incapacitants (this term sometimes includes both irritants and psychochemicals).

CHEMICAL AGENTS (CONTINUED)

TYPES OF CHEMICAL AGENTS (CONTINUED)

Types of Chemical Agents

TYPE OF AGENT	DESCRIPTION
Nerve Agents	Nerve agents interfere with the normal functioning of the central nervous system. The ultimate result of exposure can be convulsions, paralysis of the muscles used to breathe, and death. All nerve agents in military inventories are organophosphates. Although often referred to as "nerve gases," these agents are actually liquids at normal temperatures and pressures. Exposure is primarily through contact with the liquid (via skin and eyes) and secondarily through inhalation of the vapor. The most common nerve agents are tabun (GA), sarin (GB), soman (GD), and VX. Nerve agents act quickly (in vapor form, within seconds), and they are the most lethal of the chemical agents. A small quantity of sarin can produce a vapor concentration high enough to kill a person with a single breath, and an amount of VX the size of the head of a pin could kill a person. (One needs to be careful when extrapolating from individual dosage to mass casualties, however, because environmental and other factors affect how far and in what concentrations the agents will spread.)
Blister Agents	Blister agents (also called vesicants) are substances that cause reddening and blistering of the skin. Exposure is through liquid or vapor contact with any exposed tissue (eyes, skin, lungs). They include several families of chemicals: mustards (e.g., sulfur mustards, nitrogen mustards), organoarsenic compounds (e.g., Lewisite), and halogenated oximes (e.g., phosgene oxime (CX)).
Blood Agents	Blood agents produce effects by interfering with the exchange of oxygen and carbon dioxide between blood and tissues. They cause loss of consciousness and convulsions and interfere with breathing. The most prominent blood agents are cyanide agents, including hydrogen cyanide (AC), cyanogen chloride (CK), and cyanogen bromide.
Choking Agents	Choking agents (also called lung-damaging agents or pulmonary agents) primarily attack the lungs. Exposure is through inhalation. In extreme cases, pulmonary edema (filling of the lung sacs with body fluids) occurs, which prevents oxygen from being absorbed by, and carbon dioxide from being removed from, the blood. Death results from lack of oxygen (the victim is "choked"). Common choking agents include chlorine, phosgene, diphosgene, and chloropicrin.

CHEMICAL AGENTS (CONTINUED)

TYPES OF CHEMICAL AGENTS (CONTINUED)

TYPE OF AGENT	DESCRIPTION
Vomiting Agents	Vomiting agents produce nausea followed by vomiting (usually preceded by runny nose, sneezing, and coughing). The most common vomiting agent is Adamsite (DM).
Incapacitants	Incapacitants are agents that temporarily incapacitate the victim but ordinarily do not cause serious harm. They include tearing agents and psychochemicals. **Tearing agents** (also called *irritants, riot control agents,* or *tear gases*) irritate the eyes and breathing passages and induce copious production of tears along with runny nose and coughing. These agents are usually not gases. They are usually solids or liquids close to their freezing points, dispersed as aerosols. Common tearing agents include tear gas (CS and CR), Mace® (CN), and capsaicin (pepper spray) (OC). **Psychochemicals** (e.g., BZ) produce symptoms ranging from confusion to hallucinations to delirium. Their effects are fairly unpredictable.

CHEMICAL AGENTS (CONTINUED)

ROUTES OF EXPOSURE

There are five possible routes of exposure for chemical agents: absorption, inhalation, dermal contact, ingestion, and intravenous entry.

EXPOSURE ROUTE	DESCRIPTION
Absorption (mucous membranes)	Many chemical agents can be absorbed through mucous membranes that line the mouth, nose, and throat.
Inhalation (lungs)	Chemical agents in gas, vapor, or aerosolized form can be inhaled. Once in the lungs, the agent can damage the lungs and interfere with breathing or enter the circulation.
Dermal Contact (skin)	Some agents can be absorbed through the skin and eyes, into the circulatory system.
Ingestion (by mouth)	The agent can be ingested if a victim eats contaminated food or drinks contaminated water.
Intravenous Entry (bloodstream)	If a victim gets cut by a contaminated article (e.g., a piece of shrapnel, flying glass), the chemical agent is injected directly into the circulatory system.

ADVANTAGES OF CHEMICAL AGENTS AS WEAPONS OF TERRORISM

A number of factors favor the use of chemical weapons by terrorists:

- **Widespread availability:** The ease with which ingredients can be inexpensively obtained, and the ease with which the agents can be synthesized without highly specialized scientific knowledge, puts chemical weapon production within reach for terrorist organizations.
- **High level of toxicity:** A small amount can do considerable damage. This fact eases problems associated with production, storage, transport, security, and placement.
- **Difficulty of detection:** Chemical agents are difficult to detect by conventional anti-terrorism countermeasures (e.g., sensor systems).
- **Time lag:** The delayed effects of some agents makes it easier for perpetrators to escape before the incident is recognized and responded to.

CHEMICAL AGENTS (CONTINUED)

ADVANTAGES OF CHEMICAL AGENTS AS WEAPONS OF TERRORISM (CONTINUED)

- **Anonymity:** Because they can be synthesized relatively simply from commercially available ingredients, chemical agents cannot be traced back to a particular "strain" or origin in the way some biological agents can.
- **Societal disruption:** The degree of terror associated with a chemical or biological terrorist attack has the potential for seriously disrupting the normal workings of society among the target population. The potential economic toll on society for response, treatment, recovery, investigation, countermeasures, and other aspects of the aftermath could be astronomical.

WHAT HAS INTERFERED WITH WIDE-SCALE USAGE OF CHEMICAL WEAPONS?

Considering the relative infrequency of past large-scale chemical terrorist incidents, there appear to be some perceived disadvantages of this form of terrorism. The following are some of the possible reasons for past reluctance to use chemical agents as weapons of terrorism:

- Fears concerning the uncontrollability of chemical agents and potential harm to the perpetrator.
- Unpredictability of the consequences (whether it will act as planned and whether it will have greater consequences than intended).
- Potential for alienating political supporters (or potential supporters) on moral grounds.
- Fear of governmental retribution.
- Lack of perceived need for such indiscriminate, large-scale human casualty relative to the goals of the organization.
- Reluctance to experiment with unfamiliar weapons.

CHEMICAL AGENTS (CONTINUED)

WHAT FACTORS POINT TOWARD INCREASED FUTURE USAGE?

Authorities in terrorism cite the following factors as pointing toward the likelihood of future use of chemical and biological agents by terrorists:[1]

- Increased security against traditional types of terrorist attacks.
- Public indifference to traditional forms of terrorism, requiring more spectacular acts to gain attention.
- Recent increases in high-casualty, less discriminate attacks.
- Growth of state-sponsored terrorism.
- Worldwide proliferation of chemical and biological weaponry.
- Increased inter-ethnic and religiously inspired violence.
- Decrease in humanitarian inhibitions.
- Availability of materials and expertise from the former Soviet Union and its allies, and the growth of organized crime in those countries.

CHEMICAL AGENTS: METHODS OF DISSEMINATION

Generally speaking, a chemical weapon is comprised of two parts: the chemical agent and the means of delivering it. Chemical agents can be disseminated in a wide range of forms using many different delivery systems.

PHYSICAL FORMS

Chemical agents can be delivered in any physical form: vapor, gas, aerosol, spray, liquid, or solid.

- **Vapors and gases.** Vapors and gases are slightly different. Gases are materials in the gaseous state that remain gases when compressed at ordinary temperatures. Vapors are produced by evaporating liquids or sublimating solids. They resume their liquid or solid state under high pressure at ordinary temperatures. However, the terms “vapor cloud,” “vapor,” and “gas” are often used interchangeably.
- **Aerosols and sprays.** Aerosols and sprays are liquid droplets or dry particles suspended in air that are released into the air. The difference is in the size of the droplets/particles released by the device nozzle. Aerosols have droplets/particles small enough to remain suspended and be inhaled. Sprays have bigger droplets/particles which fall to the ground more quickly and are more likely to contaminate surfaces and be absorbed through the skin or ingested.

[1] Source: “The Threat of Chemical/Biological Terrorism,” Commentary No. 60. Canadian Security Intelligence Service, August 1995. Published at: www.csis-scrs.gc.ca/eng/comment/com60_e.html.

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

PHYSICAL FORMS (CONTINUED)

- **Liquids.** Many agents are liquids at normal temperatures and pressures. Others are solutions of solids or of viscous liquids. They are dissolved to improve flow characteristics and make them easier to disseminate. Liquid agents can be dispersed as liquids (e.g., to form pools or saturate the ground) or as aerosols which act like gases (to be inhaled). Most liquid agents are somewhat volatile (i.e., they form a vapor easily as they evaporate), and their volatility increases with higher temperatures. The resulting vapor cloud is hazardous.
- **Solids.** Solids may take the form of particulates (i.e., powder) which can be inhaled or absorbed through mucous membranes, eyes, or sweat-dampened skin. They can also be dissolved to form liquid agents. In either form—powder or solution—these agents can be dispensed as aerosols.

Most chemical agents that are used as weapons are liquids. Delivering a chemical agent as a cloud of droplets ¾ especially if disseminated in an enclosed public space ¾ has the greatest potential for mass casualties.

Dissemination Systems and Devices

Chemical agents can be disseminated using a wide variety of systems devices, ranging from quite sophisticated to almost simplistic. The following are some examples of possible ways to deliver chemical agents.

Military-Type Munitions

Chemical munitions are designed to convert bulk chemical agent into an aerosol or spray that can contaminate large areas, penetrate the skin, and be inhaled. Weaponization involves several steps:

- Adding stabilizers to prevent the degradation of the agent.
- Adding thickeners to increase viscosity and persistence of liquid agent.
- Adding carriers to improve dispersion characteristics.
- Inserting the agent into the appropriate munitions.

Common military munitions may be used, including aerial bombs, artillery shells, rockets, missiles, grenades, and mines. They can be designed in the form of a stationary bomb on the ground, an aerial bomb (exploding while still airborne so as to disperse the agent in the air for inhalation, or exploding on impact), or a land mine. With the increasing possibility of military supplies reaching the hands of terrorists through theft, seizure, or sale, use of such munitions for chemical terrorism is a growing possibility.

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

Other Explosive/Bursting Devices

In addition to military munitions, a variety of other explosive devices may be used to spread the chemical agent. Such devices would ordinarily include a small burster charge surrounded by the agent and activated by a fuse, timer, or other device. When the burster charge goes off, it ruptures the device and disseminates the chemical agent. Examples include:

- Packaging the agent with a small explosive charge (e.g., a package bomb or suitcase bomb).
- Crashing and exploding a truck loaded with large amounts of a nerve agent
- Packaging chemical agents as a contaminant in a shrapnel weapon (e.g., a nail bomb).

Note: After dissemination by explosive force, part of the agent will remain liquid, part will be aerosolized, and part will evaporate to form a vapor. This usually results in a significant loss of the chemical agent. The primary objective of using an explosive device is to scatter the agent in a vapor cloud and/or to heavily contaminate an area.

Commercial Delivery Systems

Because a small quantity of chemical agent can inflict a large number of casualties, commercial delivery systems can effectively be used to deliver the agent. Many such systems are dual-purpose, easy to obtain, and easy to adapt for terrorist purposes. They therefore pose a significant threat—even though they are less efficient and less reliable than munitions delivery systems. Examples of such systems include:

- Crop-dusting aircraft.
- Weather balloons.
- Small aerosol generators (e.g., a pesticide generator used to spray orchards from a pick-up truck). Such generators can be air-, ground-, or watercraft-based.
- Suitcase generators (able to contaminate rooms or buildings).
- Pump-type pressure sprayers (e.g., garden chemical or paint sprayers available at hardware stores).
- Hand-held aerosol generators (e.g., deodorant spray cans).
- Hand-held liquid spray gun similar to a tear gas dispenser.
- Placement of a remotely activated sprayer in an air ventilation system.

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

Breaking Devices

Breaking devices include:

- Encapsulating a chemical agent in a breakable object (e.g., light bulb, thermos bottle).
- Microencapsulating a chemical agent to be activated by direct contact. (e.g., similar to "scratch-and-sniff").

Dumping or Placing

Dumping or placement methods include:

- Placement of an open gas cylinder, using the wind or a fan to carry a gas cloud toward victims.
- Dropping an open container of a liquid agent from a high place (e.g., a balcony, an airplane or helicopter) into a crowded area, such as an open stadium or hotel atrium.
- Placement of an agent in a closed public space (e.g., airport terminal, shopping mall, convention center, arena, subway station) to evaporate. The rate of evaporation may be quite slow, however, resulting in few exposures to high concentrations.
- Creating a pool of liquid agent using a hose and pump system.
- Insertion of chemical agents in foodstuffs (e.g., on production lines at packaged food factories, dairies, meat processing plants, bottlers). Poisoning an entire water supply is considered unlikely, because of the large amounts of agent it would require. However, a private water supply (e.g., for a building) could be effectively targeted.

Binary Devices

In binary devices, two chemical precursors are kept separate until the last moment, when they are mixed and allowed to form the harmful chemical agent. Binary munitions (i.e., artillery shells, bombs, etc.) have been developed for several nerve agents. The 1995 Tokyo sarin incident used a simple binary device—packages containing plastic pouches of chemicals which, when punctured with a needle-tipped umbrella, released their contents and formed the deadly sarin gas. Casualties included 12 dead and 1,100 injured, some permanently scarred.

These examples illustrate the flexibility of chemical agents as weapons of terrorism, and other methods are certainly possible. Although feasible delivery methods would seemingly be limited by the terrorists' concern for personal safety (i.e., whether they could effectively protect themselves from the effects of their own attack), terrorists willing to sacrifice themselves in the process of harming others would have many more options.

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

PHYSICAL PROPERTIES THAT AFFECT EFFECTIVENESS AND METHODS OF DISSEMINATION

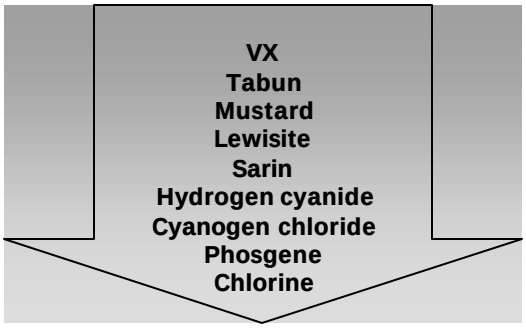
In addition to the agent's physical form (vapor, gas, aerosol, spray, liquid, solid), other physical properties of a particular chemical agent will affect its effectiveness as a weapon, the ways it can best be disseminated, and the severity of the effects it produces in victims.

Physical Properties

PROPERTY	DESCRIPTION
Flow Characteristics	Dissolving solid and viscous (thick) liquids gives them better flow characteristics (that is, makes them flow more smoothly). The flow characteristics of an agent affect the ease with which it can be dispersed through an aerosol nozzle and whether it forms a fine mist that can remain airborne a long time (as opposed to merging into heavy droplets that fall quickly to the ground).
Corrosiveness	Some chemical agents are highly corrosive. For these agents, the production equipment, storage containers, and dissemination devices must be able to withstand the corrosive effects of the agent.
Volatility	Volatility is the ease with which an agent forms a vapor as it evaporates. Because vapor clouds produced by toxic chemicals are hazardous, a highly volatile chemical agent might be an attractive choice for a terrorist weapon. (A volatile agent that is lighter than air—e.g., hydrogen cyanide—would quickly dissipate outdoors, make it less effective, but it would be effective in confined spaces.) Volatility is related to several other factors: ▪ Volatility relates to ***temperature:*** the higher the temperature, the higher the volatility. ▪ Volatility is commonly expressed as the ***equilibrium concentration*** of the material in the air—the concentration that does not change over time for a given temperature. This concentration is stated as weight of agent per volume of atmosphere (e.g., mg/1 or mg/m^3). The larger the equilibrium concentration, the more easily the agent evaporates. ▪ Volatility is related to ***vapor pressure***, expressed as units of pressure at a given temperature. The larger the vapor pressure, the easier the material becomes a vapor. ▪ Volatility is inversely related to ***persistence*****:** the higher the volatility, the lower the persistence.

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

PHYSICAL PROPERTIES THAT AFFECT EFFECTIVENESS AND METHODS OF DISSEMINATION (CONTINUED)

PROPERTY	DESCRIPTION
Persistence	Persistence is the length of time an agent remains effective after delivery. Generally speaking, chemical agents tend to degrade or disperse quickly. However, persistence depends on environmental conditions, the agent used, and the amount used. For example, some agents are gone within a few hours in wet conditions. Others evaporate in the heat. Evaporation rates also differ with the type of surface on which the agent lies. Three levels of persistence have been described: *non-persistent, semi-persistent,* and *persistent*. These terms are variously defined and depend heavily on environmental conditions. FEMA uses the following definitions: ▪ **Non-persistent:** Minutes to hours ▪ **Semi-persistent:** Less than 12 hours ▪ **Persistent**: More than 12 hours Persistence may also be expressed in terms of the speed at which the agent will evaporate relative to the speed at which water will evaporate at 15°C, sometimes known as an S value. For example, an agent with a persistence of 6 would evaporate 6 times faster than water at 15°. S values are useful primarily for comparisons. It may be possible to increase the persistence of an agent by mixing it with other more persistent agents or thickeners or by particulation (rendering it into powder form). The relative persistence of several chemical agents is shown below. **Most Persistent**  **VX** **Tabun** **Mustard** **Lewisite** **Sarin** **Hydrogen cyanide** **Cyanogen chloride** **Phosgene** **Chlorine** **Least Persistent**

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

PHYSICAL PROPERTIES THAT AFFECT EFFECTIVENESS AND METHODS OF DISSEMINATION (CONTINUED)

PROPERTY	DESCRIPTION
Contamination Density	Contamination density is the amount of agent applied to a given area, measured in mass of agent per unit of area (e.g., grams per square meter).
Concentration	Concentration is the relative content of the chemical agent in the mixture, or its strength. This property is described in several different ways. ▪ ***Theoretical concentration*** is how much of the agent has been placed in a given volume (e.g., 5 grams per liter). ▪ ***Effective concentration*** begins with amount of the agent and reduces that amount by how much is left in the container, absorbed in carpeting, etc. This is also referred to as ***true concentration, actual concentration,*** or ***real concentration***. ▪ ***Effective concentration*** is also used to mean the concentration needed to desired effect (e.g., "the effective concentration for producing 50 percent casualties in unprotected personnel").
Toxicity	Toxicity is the relative severity of the illness or incapacitation cause by the agent. Common indicators of toxicity, expressed as a single number or a range, include: ▪ ID_{50}: Median incapacitating dose (the dose that will disable 50 percent of those exposed to it). ▪ ICt_{50}: Median incapacitating exposure. ▪ ECt_{50}: Median exposure at which an effect is observed. ▪ NOEL: The No-Observed-Effect Level (below this dose no effects are seen). ▪ NOAEL: The No-Observed-Adverse-Effect Level (like NOEL, but used when good effects are possible). ▪ LOEL: Lowest-Observed-Effect Level (lowest level at which an effect is observed).

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

PHYSICAL PROPERTIES THAT AFFECT EFFECTIVENESS AND METHODS OF DISSEMINATION (CONTINUED)

PROPERTY	DESCRIPTION
Lethality	Lethality is the ease with which it causes death. A measure of lethality is Lethal Dose for 50 Percent, or LD_{50}. This is the size of the dose for an individual that will kill half of all the people receiving it. For chemical agents, LD50 is usually expressed as mass of the agent per kilogram of the victim's body weight (e.g., mg/kg). The exposure route should be given along with LD_{50}, because the effects of an agent may vary greatly depending on how the agent enters the body. Another measure, used primarily for vapors, is the median lethal exposure, or LCt_{50}. In this measure, exposure is derived from concentration of agent multiplied by time of exposure). A common rule of thumb is to assume that a dose ten times the LD_{50} or LCt_{50} will result in total loss of life among the exposed.
Rate of Action	Rate of action refers to how quickly symptoms appear after exposure. The rate of action depends on several factors, including the specific agent, its concentration, whether the victim is protected, and the individual's characteristics. The following categories are used to classify rate of action, although they are only loosely defined: ▪ **Precipitous:** Within a few minutes ▪ **Rapid:** A few minutes to tens of minutes ▪ **Delayed:** 10 minutes to several hours

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

METEOROLOGICAL CONDITIONS AND OTHER FACTORS

The effects of a chemical attack are affected by meteorological conditions and other environmental factors, including:

- Temperature (air and ground).
- Humidity.
- Precipitation.
- Wind speed and direction.
- Surrounding or nearby buildings and terrain.

The table gives examples of the possible effects of these conditions and factors.

CONDITION/FACTOR	POSSIBLE EFFECTS
Temperature	▪ Higher air temperatures may cause evaporation of aerosol particles, decreasing their size and improving their inhalability. ▪ Ground temperature can either increase or decrease evaporation rates and persistence.
Humidity	▪ High relative humidity may enlarge aerosol particles, lessening their inhalability. ▪ High humidity plus high temperature causes people to sweat more, and moisture intensifies the effects of mustard agents on skin.
Precipitation	▪ Light rain disperses and spreads chemical agents, causing faster evaporation. ▪ Heavy rain dilutes and disperses chemical agents, allowing it to penetrate the ground more easily. It can also spread contamination to other areas. ▪ Snow slows evaporation and increases persistence of contamination.

CHEMICAL AGENTS: METHODS OF DISSEMINATION (CONTINUED)

METEOROLOGICAL CONDITIONS AND OTHER FACTORS (CONTINUED)

CONDITION/FACTOR	POSSIBLE EFFECTS
Wind Speed and Direction	▪ Wind speed determines how fast a primary cloud moves. ▪ Wind direction dictates which areas will be downwind of the release and subject to contamination. ▪ High winds can disperse vapors, aerosols, and liquids rapidly, shrinking the contamination area and reducing exposure to the agent.
Buildings and Terrain	▪ Soil and surface type affect evaporation, absorption, persistence, and rate of vapor movement across the ground. ▪ Forestation and hills can interfere with vapor movement and increase exposure in the area where the agent is trapped.

CHEMICAL AGENTS OF INTEREST

The Centers for Disease Control and Prevention (CDC) focuses its preparedness efforts on the following priority agents:

- Military nerve agents
- Sulfur and nitrogen mustards
- Lewisites
- Ricin and saxitoxin (discussed in these course materials as biological agents—see Appendix A)
- BZ
- Hydrogen cyanide
- Cyanogen chloride

There are, however, many other chemical agents that are of potential interest to emergency planners. The following table lists chemical agents of interest as potential terrorist weapons, grouped within six major types and listed by code and common name. The codes are those commonly used in the United States. In many cases they are Standard NATO Agreement (STANAG) codes used by the NATO countries as well. However, other designations may also be used for these agents.

TYPE	CODE	COMMON NAME
Nerve Agents	GA	Tabun, Le-100
	GB	Sarin
	GD	Soman
	GF	CMPF; cyclosin
	GV	2-dimethylaminoethyl-(dimethylamido)-phosphonofluoridate
	VE	(VE)
	VG	(VG)
	VM	(VM)
	(VR)	(VR)
	VR55	(VR55)
	VS	(VS)
	VX	(VX)
	V_x	(V_x)

CHEMICAL AGENTS OF INTEREST (CONTINUED)

TYPE	CODE	COMMON NAME
Blister Agents	CX	Phosgene oxime
	ED	Ethyldichloroarsine
	H	Sulfur mustard
	HD	Distilled mustard
	HL	MX mix
	HN-1	Nitrogen mustard one
	HN-2	Nitrogen mustard two
	HN-3	Nitrogen mustard three, TO
	HT	HT mix
	L	Lewisite
	MD	Methyldichloroarsine
	PD	Phenyldichloroarsine
	Q	Sesquimustard
	T	Bi(2-chloroethyl sulfide) monoxide
	THD	Thickened HD
Choking Agents	CG	Phosgene
	CL	Chlorine
	DP	Diphosgene
	PS	Chloropicrin, NC, G8
Blood Agents	AC	Hydrogen cyanide
	CK	Cyanogen chloride
	SA	Arsenic trihydride, or arsine
Vomiting Agents	DA	Diphenylchloroarsine
	DC	Diphenylcyanoarsine
	DM	Adamsite
Incapacitants (Psychochemical)	BZ	QNB, 3-quinuclidinyl benzilate
Incapacitants (Tearing)	BA	Bromacetone
	CA	Bromobenzenecyanide
	CN	Chloroacetophenone
	CNB	CNB mix
	CNC	CNC mix
	CNS	CNS mix
	CR	Dibenz [b,f] [1,4] oxazepine
	CS	Pepper gas
	CS1	CS powder 95, silica aerogel 5
	CS2	CS powder blend with silicone-treated aerogel
	CSX	CS solution 1 gram in triocytlphosphite 99 grams

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS

The effects of exposure to chemical agents are similar within types of agents.

NERVE AGENTS

Effects of nerve agents appear almost immediately and may include the following:

- Miosis (pupils constricted to pin-point size and dimmed vision), a long-lasting symptom
- Runny nose and drooling
- Shortness of breath
- Sweating
- Muscular twitching
- Nausea and vomiting
- Changes in heart rate
- Convulsions or seizures, loss of consciousness, paralysis
- Cramps and diarrhea
- Respiratory failure and death by suffocation

Types of Symptoms. Symptoms differ with the particular agent, the concentration, length of exposure, and form of the agent (vapor vs. liquid), as shown in the table on the next page.

Even exposure to low levels of nerve agents can cause serious effects. The effects of low levels of an agent appear to be the same whether or not drugs that act to protect victims from the lethal effects are administered before exposure.

Onset of Effects. Effects from vapor occur within seconds. Effects from liquids begin within 30 minutes (large amount of agent) or up to 18 hours (small amount). At high concentrations, nerve agents can cause death within as little as 2 minutes of exposure. In those who survive, nerve agents may cause permanent changes in brain function.

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS (CONTINUED)

Severity of Effects

The following table compares toxicity and lethality of various nerve agents, as well as their effects. In comparing toxicity and lethality, remember that a lower number indicates higher toxicity/lethality (i.e., it takes less of the agent to produce effects).

	EFFECTS																			
Agent/ Concentration or Exposure	Local Sweating	Nausea	Vomiting	Weakness	Tearing	Urination	Diarrhea	Gasping	Seizures	Miosis	Runny Nose/Drool	Difficulty Breathing	Headache	Tightened Chest	Cramps	Heavy Sweating	Muscular Twitch	Cough	Death	**Toxicity: ID_{50}**	**Lethality: LD_{50}**
Tabun low conc.										x	x		x	x						300 mg-min/m^3 *#	400 mg-min/m^3 #°
high conc.		x	x				x					x			x	x	x	x	x		
Sarin low conc.										x	x		x	x						75 mg-min/m^3 *#	100 mg-min/m^3 #
high conc.		x	x				x					x			x	x	x	x	x		
Soman low conc.										x	x		x	x						75-300 mg-min/m^3 *#	100-400 mg-min/m^3 # ^
high conc.		x	x				x					x			x	x	x	x	x		
VX liquid – small to moderate exp.	x	x	x	x																50 mg-min/m^3	100 mg-min/m^3
large exp.					x	x	x	x	x							x					
VX vapor – small to moderate exp.										x	x	x									
large exp.					x	x	x	x	x	x						x					

* Unmasked.
# Resting personnel
°Respiratory lethal doses kill in 1-10 min.
^ Onset of toxicity within several minutes to a few hours depending on concentration of agent.

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS (CONTINUED)

BLISTER AGENTS

All blister agents cause painful blistering of the skin and other surfaces exposed to the agent. The three main families of blister agents (mustards, organoarsenic, and halogenated oximes) differ somewhat in specific effects and toxicity.

Mustard Agents

Mustard agents produce painful fluid-filled blisters on exposed skin, damage the eyes, and kill cells in affected areas. If inhaled, mustard agents can do considerable damage to the lungs; most deaths caused by exposure to mustard agents result from lung damage.

Early symptoms include throat irritation and scratchy eyes. Blistering may occur 4 to 6 hours, or as long as 48 hours, after exposure. Delayed effects include eye pain, breathing difficulties, and (for ingested mustard) nausea, vomiting, and diarrhea. Because of the delayed onset of obvious symptoms, victims may be unaware of exposure until severe effects have occurred.

Large amounts of mustard agent absorbed in the blood can affect the bone marrow, damaging the ability to produce new blood cells and fight infection. The effects of mustard agents are summarized in the following table.

Effects of Mustard Agents:
Distilled Mustard (HD), Nitrogen Mustard (HN), Sulfur Mustard (H)

AGENTS	ORGAN/SYSTEM AFFECTED	EFFECTS
HD, HN, H	Skin	Reddened skin in 2-24 hours; large blisters
HD, HN, H	Eyes	Low dose vapor exposure: Reddening of the eyes High dose vapor exposure: Severe reddening, light sensitivity, twitching of eye muscles, pain, corneal damage
HD, HN, H	Pulmonary	Hoarseness, loss of voice, productive cough, fever, difficulty breathing, wheezing and rattling
HD, HN, H	Gastrointestinal	Nausea, vomiting, pain, diarrhea, prostration
HD, H	Central Nervous System	Apathy, depression, intellectual dullness
HD, H	Metabolism	Death in 5-10 days, pulmonary insufficiency, compromised immune response

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS (CONTINUED)

Organoarsenic Compounds

Organoarsenic compounds cause effects similar to those of mustard agents (redness, blistering), but much more quickly. These agents cause immediate pain and serious damage to the eyes—permanent blindness if decontamination doesn't occur within 1 minute. The effects do not improve with fresh air, and they worsen with time. These agents also can act as systemic poisons, although they do not damage bone marrow. Effects of three chemicals in this group are listed in the following table.

Effects of Selected Organoarsenic Blister Agents

AGENT	EFFECTS			
	SKIN	EYES	PULMONARY	SYSTEMIC
Lewisite (L)				
Systemic poison			Pulmonary edema	Diarrhea, restlessness, weakness, subnormal temperature, low blood pressure
Liquid	Immediate skin pain, reddening in <30 min., blistering in 13 hrs.	Immediate eye pain, loss of sight if not decontaminated in < 1 min.		
Phenyldichloro-arsine (PD) **Ethyldichloro-arsine** (ED)	Reddening, blisters	Instant pain and eye muscle twitch, swelling	Pumonary edema	Systemic poisoning; acute poisoning resulting in shock

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS (CONTINUED)

Halogenated Oximes

This group of agents irritates the eyes and respiratory tract, progressing to pulmonary edema. Exposed skin immediately develops wheel-like patterns of irritation, forming angry welts within an hour, dead tissue within a few days, and ulcerated wounds thereafter. Damage to eyes can cause permanent blindness. The effects do not improve with fresh air, and they worsen with time. The effects of phosgene oxime are shown below.

Effects of Halogenated Oximes

	EFFECTS			
AGENT	SKIN	EYES	PULMONARY	GASTROINTESTINAL
Phosgene Oxime (CX)	30 sec.: blanching, reddened rings. 30 min.: welts. Later: dead tissue, ulcerated wounds.	Extreme pain, permanent blindness if not decontaminated	Respiratory irritation, pulmonary edema	Hemorrhagic inflammation

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS (CONTINUED)

Toxicity and Lethality of Blister Agents

The toxicity and lethality of blister agents vary with the route of exposure, as shown in the following table.

Toxicity/Lethality of Blister Agents

AGENT/EXPOSURE ROUTE	ID50*	LD50*
Distilled Mustard (HD)		
Eye	200	
Skin**	2,000	10,000
Inhalation		1,500
Nitrogen Mustard (HN)		
Eye	200	
Skin (masked)	9,000	20,000
Inhalation		1,500
Sulfur Mustard (H)		
Eye	200	
Skin**	2,000	10,000
Inhalation		1,500
Lewisite (L)		
Eye (from vapor)	<300	
Skin (masked)	>1500	100,000
Inhalation		1200-1500
Phenyldichloroarsine (PD)	1,800	2,600
Ethyldichloroarsine (ED)		
Skin		100,000
Inhalation	5-10	3,000-5,000

* $mg\text{-}min/m^3$

** Wet skin absorbs more mustard than dry. Exerts casualty effect at lower concentration in hot humid weather. Repeated exposures are cumulative.

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS (CONTINUED)

CHOKING AGENTS

Initially, choking agents cause symptoms of an irritated respiratory tract (sore throat, coughing), similar to the effects of tear gases. Severe effects begin 2 to 24 hours after exposure. Although these effects may subside for as long as a day, more serious effects erupt later from the corrosive effects on the lungs. The lungs fill with fluid, causing chest tightness, difficulty breathing, and possibly death.

Effects may differ with the route of exposure and the form of the agent. For example, phosgene evaporates very quickly. Liquid phosgene is not hazardous except as a source of vapor.

The effects, toxicity, and lethality of two choking agents are compared in the following table.

	EFFECTS				TOX.	LETH.
AGENT	EYES	PULMONARY	GASTRO-INTESTINAL	SYSTEMIC	ID50*	LD50*
Phosgene (CG)	Tearing	Coughing, choking, chest tightness, shortness of breath, wheezing and rattles, delayed pulmonary edema (4 hrs), hypoxia		Low blood pressure	1,600	3,200
Chlorine (CL)					1,800	19,000
Ingestion		Severe mouth and throat pain, throat swelling, inability to breathe	Severe abdominal pain, vomiting	Fever, rapid drop in blood pressure		
Inhalation	Eye pain	Tight chest, feeling of suffocation, coughing, shortness of breath, choking, coughing up blood		Weakness, cyanosis (turning blue-gray), low blood pressure, dizziness		

* $mg\text{-}min/m^3$

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS (CONTINUED)

BLOOD AGENTS

Blood agents containing cyanides interfere with the body's ability to use oxygen. Victims have a sense of suffocating, causing them to breathe rapidly and take in more contaminated air.

Small amounts may cause little or no effect. High concentrations of vapor are quickly lethal. Other blood agents (e.g., arsine) can cause damage to organs.

The effects at various exposure levels, toxicity, and lethality of three blood agents are compared in the following table.

Effects of Blood Agents

		TOXICITY	LETHALITY
AGENT/EXPOSURE LEVEL	EFFECTS	ID_{50}*	LD_{50}*
Hydrogen Cyanide (AC)			
Moderate (low concentration of vapor)	Increase in breathing rate/depth, dizziness, nausea, vomiting, headache. Progresses to severe with continued exposure.	Varies with dosage	4,500 (at 150 mg/m^3 concentration)
Severe (high concentration of vapor)	15 sec.: increase in breathing rate/depth. 30 sec.: convulsions. 2-4 min.: breathing stops 4-8 min: heartbeat stops		2,000 (at 200 mg/m^3 concentration)
Cyanogen Chloride (CK)			
Moderate (low concentration of vapor)	Increase in breathing rate/depth, dizziness, nausea, vomiting, headache. Progresses to severe with continued exposure.	7,000	11,000
Severe (high concentration of vapor)	15 sec.: increase in breathing rate/depth. 30 sec.: convulsions. 2-4 min.: breathing stops 4-8 min. heartbeat stops		
Arsine (SA)			
Slight exposure	Headache, uneasiness	2,500	5,000
Increased exposure	Chills, nausea, vomiting		
Severe exposure	Damage to blood, liver, kidneys; anemia		

* $mg\text{-}min/m^3$

EFFECTS OF EXPOSURE TO CHEMICAL AGENTS (CONTINUED)

INCAPACITANTS

Vomiting Agents

The effects of vomiting agents are temporary and seldom lethal (although exposure to extremely high levels is potentially dangerous). These agents work quickly but, after the victim is removed from exposure, the symptoms go away on their own. In moderate concentrations, effects last 30 minutes; in high concentrations, effects may last 3 hours.

Symptoms and toxicity/lethality levels for Adamsite, a common vomiting agent, are listed in the following table.

Effects of Vomiting Agents

AGENT	SYMPTOMS (IN PROGRESSIVE ORDER)	ID_{50}*	LD_{50}*
Adamsite (DM)	Irritation of eyes and mucous membranes Runny nose Sneezing and cough Severe headache Acute pain and tightness in chest Nausea Vomiting	22 (1-min. exposure) 8 (60-min. exposure)	15,000

* $mg\text{-}min/m^3$

Irritants

The effects of irritants (riot control agents) are almost immediate, temporary, and rarely produce serious effects. Breathing clean air decreases the effects, which may include:

- Eye pain, tearing, and redness.
- Painful airways.
- Coughing.
- Breathing difficulty.
- Skin irritation.

SOURCES OF CHEMICAL AGENTS

Chemical agents suitable for use as instruments of terrorism can either be obtained from existing supplies or synthesized.

EXISTING SUPPLIES

Existing supplies of chemical agents are potential sources of chemical agents for terrorist activity. Many could be purchased, stolen, or otherwise obtained from such sources as military installations, industrial suppliers, research facilities, or foreign state sponsors. Most chemical agents are relatively simple compounds made from even simpler compounds. Many hazardous substances are commercially available with minimal, if any, restrictions. So if the agent itself cannot be obtained, its precursors often can. (Precursors are simpler compounds, or chemical ingredients, used to create the agent.)

While some precursor chemicals are difficult to obtain,[2] there are a multitude of precursor chemicals that have legitimate civil uses and could be obtained fairly easily. To illustrate, the following table lists some of the precursors used to produce sarin (GB) and the civil uses of those precursors.

Civil Uses of Sarin (GB) Precursors

PRECURSOR	CIVIL USES
Ammonium bifluoride 1341-49-7	Ceramics, disinfectant for food equipment, electroplating, etching glass
Diethylphosphite 762-59-2	Organic synthesis, paint solvent, lubricant additive
Dimethyl methylphosphonate (DMMP) 756-79-6	Flame retardants
Dimethylphosphite 868-85-9	Organic synthesis, lubricant additive
Hydrogen fluroide	Fluorinating agent in chemical reactions, uranium refining
Methylphosphonous difluoride 753-59-3	Organic synthesis
Potassium bifluoride 7789-29-9	Fluorine production

[2] Precursor chemicals necessary for the production of some chemical agents are controlled by the 1993 Chemical Weapons Convention (CWC), in force since April 1997. Experts feel that illegal acquisition of such chemicals would raise suspicions and attention.

SOURCES OF CHEMICAL AGENTS (CONTINUED)

EXISTING SUPPLIES (CONTINUED)

PRECURSOR	CIVIL USES
Potassium fluoride 7789-23-3	Fluorination of organic compounds
Sodium bifluoride 1333-83-1	Antiseptic
Sodium fluoride 7681-49-4	Pesticide
Thionyl chloride 7719-09-7	Organic synthesis

Chlorine, phosgene, and hydrogen cyanide are examples of toxic industrial chemicals that can be bought on the commercial market or stolen, thus avoiding the need to manufacture them. Blister agents such as sulfur mustard, nitrogen mustard, and lewisite can be synthesized easily or with only moderate difficulty, although obtaining large amounts of the precursors for these agents would be difficult.

SYNTHESIS OF CHEMICAL AGENTS

Most chemical agents can be synthesized in small amounts fairly easily. Methods for preparing chemical agents have been available in chemical literature for decades. To produce larger amounts, or if the chemicals need to be stored for any significant amount of time, the process is more complex and may require sophisticated facilities, equipment, and expertise.

There are a number of issues involved in production of chemical agents:

- **Heat:** Heat may be needed to produce the reaction, or heat may be produced by an exothermic chemical reaction, and the heat must be controlled. While it may not be difficult to refrigerate small amounts of agent, controlling the heat for large amounts may present an problem.
- **Mixing:** Again, mixing the ingredients may be simple with small amounts but difficult with large amounts. Mixing is especially problematic for nerve agents. Agents that have corrosive ingredients must be mixed and stored in vessels made of special alloys.
- **Handling:** There is risk involved in handling both the reactants (i.e., ingredient chemical compounds that, when mixed with other ingredients, form a new compound) and the resulting compound. The risk is magnified when the amounts are large.
- **Managing the reaction:** Although many chemical reactions appear simple, they may be difficult to control. Side reactions may cause a low yield of the desired product, and conditions (e.g., temperature, pressure, reactant concentrations) will affect how the ingredients react. The result can be that very little of the desired agent is produced or that unwanted reactions occur.

SOURCES OF CHEMICAL AGENTS (CONTINUED)

SYNTHESIS OF CHEMICAL AGENTS (CONTINUED)

- **Purification:** After the reaction is complete, the chemicals usually have to be purified—especially if the agent will be stored for any length of time. Purification methods depend on the compounds involved but may require sophisticated procedures.
- **Formulation:** After an agent has been purified, it may need to be mixed with other materials, such as stabilizers (to extend storage life), thickeners (to enhance persistence), or agents to provide desired physical properties without reducing lethality.
- **Storage:** The length of time a chemical agent can be stored and still remain effective depends on the agent. When properly purified, formulated, and stored, some agents can remain useful for up to 50–100 years. An impure or improperly stored agent may have a shelf life of only a few months.

That said, a sizable terrorist incident could be created with a small amount of chemical agent. This degree of toxicity helps reduce the complexity of production or acquisition and eliminates the need for a large infrastructure of facilities and personnel. This, in turn, eases problems of security and transport. Therefore, the capability to produce sufficient amounts of chemical agents to do considerable damage is within the reach of some terrorist organizations.

The following table describes the ease of manufacture and precursor availability for selected chemical agents.

SOURCES OF CHEMICAL AGENTS (CONTINUED)

SYNTHESIS OF CHEMICAL AGENTS (CONTINUED)

Sources and Ease of Manufacture for Selected Chemicals[3]

CHEMICAL AGENT	PRECURSOR AVAILABILITY	EASE OF MANUFACTURE
Nerve Agents		
Tabun (GA)	Precursors available. Manufacturing instructions not readily available.	Relatively easy to manufacture
Sarin (GB)	Precursor chemical covered by CWC	Moderately difficult to manufacture
Soman (GD)	Precursor chemical covered by CWC	Difficult to manufacture
GF	Precursor chemical covered by CWC	Moderately difficult to manufacture
VX	Precursor chemical covered by CWC	Difficult to manufacture
Blister Agents		
Sulfur mustard (HD)	Large quantity buys of precursor chemicals without detection difficult. Precursor chemicals covered by CWC.	Easy to synthesize
Nitrogen mustard (HN-2)	Large quantity buys of precursor chemicals without detection difficult. Precursor chemicals covered by CWC.	Easy to synthesize
Nitrogen mustard (HN-3)	Large quantity buys of precursor chemicals without detection difficult, but available.	Easy to synthesize
Lewisite (L, HL)	Moderately difficult to acquire precursor chemicals	Moderately difficult to manufacture

[3] Adapted from "Combating Terrorism: Need for Comprehensive Threat, and Risk Assessments of Chemical and Biological Attacks," U.S. General Accounting Office Report to Congressional Requesters, September 1999. Published at http://cryptome.org/ns99163.htm.

SOURCES OF CHEMICAL AGENTS (CONTINUED)

SYNTHESIS OF CHEMICAL AGENTS (CONTINUED)

CHEMICAL AGENT	PRECURSOR AVAILABILITY	EASE OF MANUFACTURE
Blood Agents		
Hydrogen cyanide (AC)	Industrial product. Precursor chemicals covered by CWC.	N/A
Cyanogen chloride (CK)	Available as commercial product	Not easily produced
Choking Agents		
Chlorine (CL)	Industrial product. No precursors required.	N/A
Phosgene (CG)	Industrial product. No precursors required.	N/A

CHEMICAL AGENTS: DETECTION AND DIAGNOSIS

The symptoms of exposure to chemical agents can serve as warning signs that a chemical attack has occurred (although, with agents whose effects are delayed, these signs may become apparent after severe exposure and damaging effects have occurred). Small animals, birds, and insects may show the effects of exposure before humans, which may provide another indicator. The overview at the beginning of this appendix listed a number of additional indicators of a possible chemical terrorist incident.

HEALTH SURVEILLANCE

The critical on-scene assessments and patient examinations provided by emergency responders potentially may serve as an informal passive surveillance system. In some cases, these nationwide monitors may report potential events in a fashion timely enough to allow for rapid intervention. However, in a chemical event, surveillance is most useful for tracking exposed individuals for long-term physiological difficulties, chronic illnesses, cancers, etc.

In conducting surveillance activities, it is important not to immediately discount chemicals as the source of an unexplained syndrome. Contaminating a water or food supply with a hazardous chemical could sicken many people, and prematurely eliminating chemicals as a potential cause could delay effective treatment.

DIAGNOSIS

CDC focuses its preparedness efforts on a prioritized list of hazardous chemicals, including:

- Military nerve agents
- Sulfur and nitrogen mustards
- Lewisites
- Ricin[4]
- Saxitoxin[1]
- BZ
- Hydrogen cyanide
- Cyanogen chloride

[4] In these course materials, ricin and saxitoxin are treated as biological agents. See Appendix __.

CHEMICAL AGENTS: DETECTION AND DIAGNOSIS (CONTINUED)

DIAGNOSIS

CDC has the capacity to monitor for chemicals mainly at the Federal level. It does not advocate that State labs test potential chemical terrorism samples before shipping them to CDC. Most State public health chemical labs are not equipped to rule out the presence of a Level 4 biological agent that potentially could be present in a human sample collected from a suspected victim of a chemical attack. They also do not have the irradiators necessary to neutralize the hardiest of the biological agents if they were present.

The first 30 samples from the most contaminated (exposed) people must be sent to CDC as rapidly as possible, to speed identification of the causative agent and determination of whether or not a second chemical agent is involved. As many additional samples as possible should be collected and sent to CDC.

DETECTION SYSTEMS

Several detection systems have been developed for use by military and civil defense organizations to detect the presence of specific types of chemicals. Detection systems are useful for identifying proper protection methods after an event. However, they may have little impact on casualty care because (1) they are not on site when the release occurs, and (2) many agents act so quickly that casualties will have occurred before the detectors arrive at the scene.

The following systems, which have different advantages in terms of accuracy and speed of detection, are some of the approaches that may be used:

- **Colorimetric Devices (Indicator Papers and Cards):** These are papers impregnated with materials that change color in reaction to specific chemical agents (similar to litmus paper). Test kits include a set of chemicals (either on cards or in vials). After exposure to a chemical agent, the chemical card or vial can be treated with a second set of chemicals which, if positive, causes a distinctive color change. This method can be very sensitive and specific but may be time consuming and can cause false positives. M8 and M9 test papers and the M256A1 kit are colorimetric devices.
- **Ionization Detectors:** These devices pull air through a unit which ionizes the molecules in the air (i.e., the molecules become electrically charged ions or they attach to a charged particle). The ions pass through baffles that only allow specific ions (the kind that the suspected chemical agent produces) to pass through. When those ions pass through and reach a collector, they produce an electrical current, signaling the possible presence of the chemical agent.

  This type of device is both sensitive and fast-acting. However, fairly common substances produce false positives in some ionization detectors. M43A1 is an example of an ionization detector.

CHEMICAL AGENTS: DETECTION AND DIAGNOSIS (CONTINUED)

DETECTION SYSTEMS (CONTINUED)

- **Ion Mobility Detectors:** These devices produce ions, then measure how long the ions take to move from one place to another. The Chemical Agent Monitor (CAM) is such a device.
- **Mass Spectrometers:** These are highly accurate devices that produce ionized fragments from a chemical sample. Specific chemical agents are identified by the pattern of fragment weights and charges generated by the sample.

  This type of device is used in the gas chromatograph-mass spectrometer (GC-MS)—a chemical analysis system that separates the chemicals present in a sample and sends them to a mass spectrometer for analysis.

- **Remote-Sensing Techniques:** Systems have been developed that allow the detection of agents without actual sampling of or contact with the chemical agent. The systems are based on sending a beam of light into the potentially contaminated area and measuring light emissions. (Different chemicals reflect or absorb light differently.) These systems tend to be less sensitive than direct-contact methods.

  The following table compares sensitivity and time required for several detection systems to identify the nerve agent sarin (GB).

Comparison of Detection Systems Identifying Sarin[5]

SYSTEM	METHOD	SENSITIVITY	TIME REQUIRED	COMMENTS
M9 Test Paper	Colorimetric	0.1 mm droplet	20 sec. or less	Requires direct contact with liquid agent. Sensitivity to airborne droplets cannot be estimated for meaninful comparison.
M256A1 Kit	Colorimetric	0.005 mg/m^3	15 min.	
M43A1	Ionization	0.1-0.2 mg/m^3	< 2 min.	
Chemical Agent Monitor (CAM)	Ion Mobility	< 0.1 mg/m^3	< 1 min.	This is the U.S. CAM system.
MM-1	Mass Spectrometry	62 mg/m^3	< 45 sec.	

[5] Adapted from *Chem-Bio: Frequently Asked Questions.* Alexandria, VA: Tempest Publishing, 1998, p. 124.

CHEMICAL AGENTS: DETECTION AND DIAGNOSIS (CONTINUED)

DETECTION SYSTEM APPLICATIONS

The following table identifies detection devices and systems that can be used to detect specific chemical agents.

AGENTS	DETECTION SYSTEMS					
	M8 PAPER	M9 PAPER	M8A1	M256A1	CAM	ICAD
Nerve Agents (Vapor): Tabun, sarin, soman, VX			x	x	x	x
Nerve Agents (Liquid): Tabun, sarin, soman, VX	x	x				
Blister Agents						
Sulfur mustard (liquid)	x					
Sulfur mustard (vapor)					x	
Distilled mustard (liquid)	x					
Distilled mustard (vapor)				x	x	
Lewisite (vapor)				x		x
Phosgene oxime				x		x
Blood Agents						
Hydrogen cyanide				x		x
Cyanogen chloride				x		

SITE SET-UP FOR A CHEMICAL RELEASE

Following a chemical incident, law enforcement personnel must set up the incident site, including:

- Designation of zones and boundaries.
- Crime scene designation and security.
- Ingress and egress.
- Access and staging points.
- Personnel accountability of all who enter the site.

ZONES

Incident sites will include the following zones, each upwind and uphill from the previous one:

- **Hot zone** (exclusion zone)—the area immediately around the release site. This area requires full protective gear and strict entry/exit control at least 25 meters from the source. Only minimal medical care (antidotes and emergency life-saving measures) occurs here, and contaminated emergency vehicles do not cross over the boundary to the warm zone.
- **Warm zone** (contamination reduction zone)—where warm (i.e., rapid) triage, limited medical care (enough to get the victim through decontamination), and decontamination take place. (See the Decontamination fact sheet for more information on decontamination facilities.) This area requires full protective gear and controlled access.
- **Cold zone** (support zone)—an evaluation and support area for monitoring casualties following decontamination and transporting patients to hospitals as needed. Protective gear must be at hand for workers in this area in case it becomes necessary.

  A "hot line" separating the contaminated area from the agent-free zone should be visibly marked (e.g., using yellow crime scene tape).

SITE SET-UP FOR A CHEMICAL RELEASE (CONTINUED)

PLANNING FACTORS

In determining the location of site zones and boundaries and the best location(s) for field decontamination, consider the following factors:

Siting Considerations

Type of Delivery

- Blast
  - Cloud
  - Circular
- Air Delivery
  - Wind direction
  - Height above ground

Wind Direction and Speed

- Stronger winds carry contamination farther.
- Winds > 20 mph can cause the agent to break up.

Terrain

- Open (allows for wider dispersal)
- Enclosed (forestation limits dispersal)

Population Centers

- Near highly populated areas, plan for wide dispersal.

Waterways

- Presence of bodies of water (lake, river, stream) in exclusion contributes to waterborne delivery downstream.

Site Traffic

- Ingress/egress for emergency vehicles
- Access to zones (entry/exit control points) by rescue and decontamination personnel
- Staging points
- Personnel accountability (all who enter Hot Zone)
- Patient transfer point
- Crowd control

Need for Flexibility

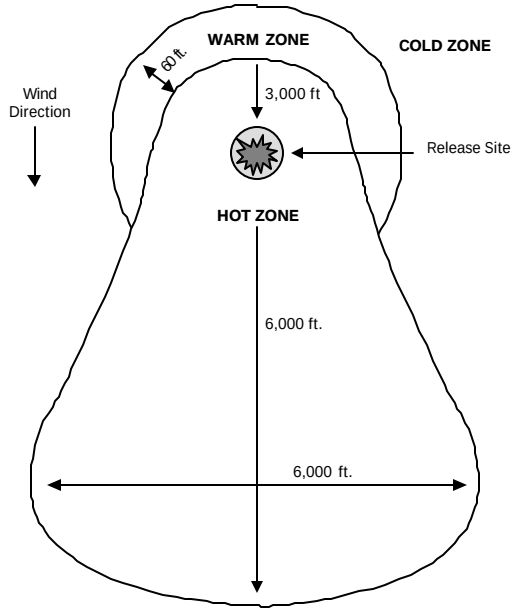
- Change boundaries if conditions change (e.g., change in wind direction).
- Change boundaries (shrink/expand) when new information is available about agent.
- Maintain diagram with boundaries and reasons for their locations to facilitate change.

SITE SET-UP FOR A CHEMICAL RELEASE (CONTINUED)

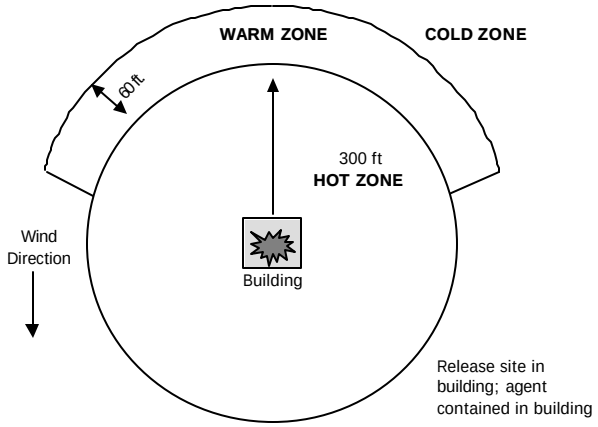
SETTING BOUNDARIES

The following diagrams illustrate site boundaries for open and closed areas.

Site Boundaries ¾ Open Area[6]



Site Boundaries ¾ Closed Area[12]



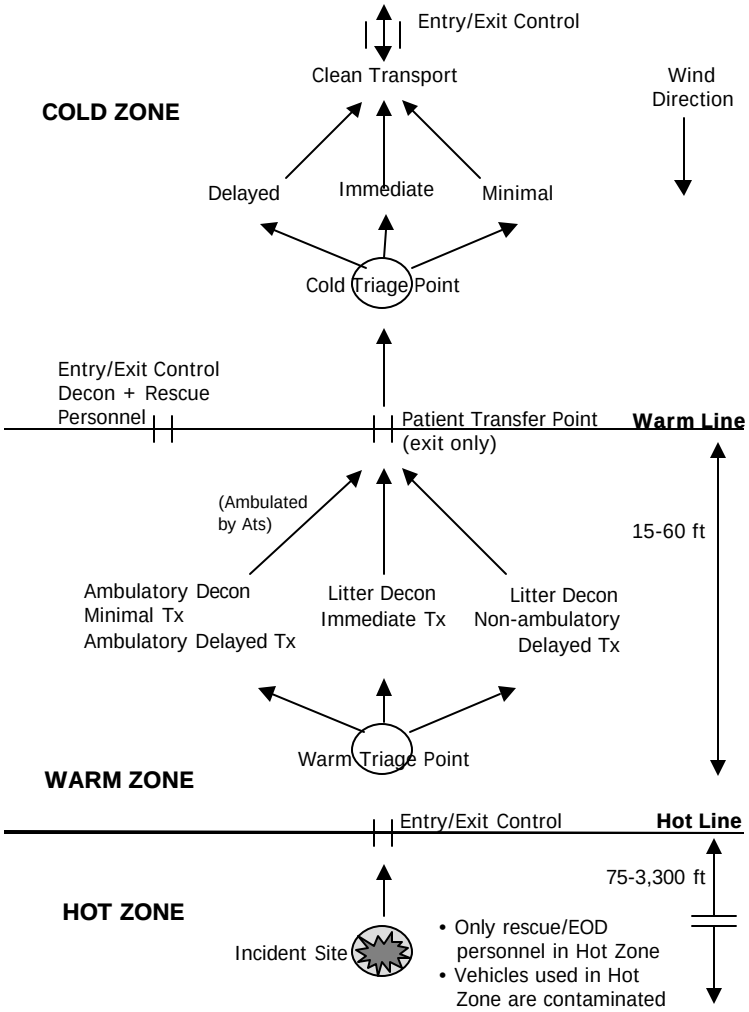
[6] Source: *Jane's Chem-Bio Handbook.* Jane's Information Group, Alexandria, VA: 2000, pp. 25-26.

SITE SET-UP FOR A CHEMICAL RELEASE (CONTINUED)

SITE SET-UP

The following diagram illustrates a site set-up that includes the zones, control lines, and key features discussed above. This set-up assumes that the release site is still hot and that there are multiple casualties with a mix of major, minor, and critical injuries. A slightly simpler set-up for decontamination is illustrated in the Decontamination fact sheet.

Set-Up of a Site[7]



[7] Adapted from *Jane's Chem-Bio Handbook.* Jane's Information Group, Alexandria, VA: 2000, p. 27.

WORKER PROTECTION FOR CHEMICAL AGENTS

Chemical agents can variously enter the body through the lungs, skin, eyes, and by ingestion. When responders enter a known or suspected chemically contaminated area, they should rely on personal protective equipment (PPE) and respiratory protection described in the codes 29 CFR 1910.120(q) and 29 CFR 1910.134.

PPE for use against chemical agents consists of respiratory and dermal protection. The level of protection that is required will depend on the specific agent, the conditions under which the equipment is worn, and the activities and exposure level of the personnel.

RESPIRATORY PROTECTION

Two types of respiratory protection include air-purifying respirators and self-contained breathing apparatus (SCBA gear).

Air-Purifying Respirators

Air-purifying respirators (also called gas masks) cover the face and pass contaminated air through a filter which removes the chemical agent or renders it harmless. Different filters are used for different agents. Some filters are designed to trap contaminants as they pass through a series of absorbent/adsorbent materials (absorbent materials trap the contaminant within the material; adsorbent materials trap the contaminant on the surface). Other filters are designed to react with certain agents and neutralize them. Eventually, filters become saturated (this is called "breakthrough") and lose their protective quality.

Powered Air-Purifying Respirators (PAPRs) use a power source—usually a battery pack—to pull air across a gas-particulate canister into the facepiece. The positive pressure created by this action helps protect against leaks in the facepiece.

SCBA Gear

SCBA gear includes a face mask that is connected to its own supply of clean air—an air tank. Although it is heavier, it provides greater protection than a gas mask. However, the air supply is limited to an hour or less.

WORKER PROTECTION FOR CHEMICAL AGENTS (CONTINUED)

DERMAL PROTECTION

Protective suits provide dermal protection. They may include an overgarment (permeable or impermeable suit), boots, and gloves. The best choice of suit often depends on the specific chemical agent. Some agents will react with the suit material and degrade it, leading to tears that will allow entry of contaminants.

Impermeable Suits

Impermeable suits form a physical barrier between the wearer and the chemical agent. They have very long breakthrough times and are less vulnerable to mask breakers (chemical agents that quickly pass through a filter) than permeable suits are. These suits can become very hot if worn for extended periods.

Permeable Suits

Permeable suits allow air to move through the suit and let the wearer's perspiration to evaporate, so they are cooler. They use an absorbent lining (similar to a mask filter) to trap the chemical agent. Permeable suits can be permeated by mask breakers and by dusty agents.

WORKER PROTECTION FOR CHEMICAL AGENTS (CONTINUED)

INTEGRATED PROTECTION

Respiratory and dermal protection ensembles are used to protect first responders against vapor or liquid chemical agent environments. The Occupational Safety and Health Administration (OSHA) has designated four levels of protection, outlined in the following table.

Levels of Protection[8]

LEVEL	GEAR DESCRIPTION	RECOMMENDED USES
Level A	"Moon suit": Greatest level of skin, respiratory, and eye protection. Includes: ▪ Pressure-demand, full face-piece SCBA or supplied-air respirator with escape cylinder. ▪ Fully encapsulating vapor protection suit: • Suit covers full torso, head, arms, legs. • Chemical-resistant steel-toed boots. • Outer and inner chemical resistant gloves. • Suit completely covers user, SCBA, gloves, and boots. • Two-way radio equipment is contained within the suit.	Used when any of the following conditions exist: ▪ Material requires the highest level of protection for skin, eyes, respiratory system based on measured or potential high concentration of vapors, gases, or particles. ▪ High risk of splash potential, immersion, or exposure to unexpected vapors, gases, or particles. ▪ Substances highly hazardous to skin are known or present and skin contact is possible. ▪ Operations will be conducted in a confined, poorly ventilated area. ▪ Required level of equipment has not yet been determined.

[8] Adapted from *First Responder Chem-Bio Handbook: Practical Manual for First Responders*. Alexandria, VA: Tempest Publishing, 1998.

WORKER PROTECTION FOR CHEMICAL AGENTS (CONTINUED)

INTEGRATED PROTECTION (CONTINUED)

LEVEL	GEAR DESCRIPTION	RECOMMENDED USES
Level B	Highest level of respiratory protection and lesser level of skin protection. Includes: ▪ Same respiratory protection as Level A. ▪ Hooded chemical-resistant clothing, including: • Coveralls. • Gloves (inner and outer). • Boots. • Hard-hat. • Face shield (optional). • Two-way radios.	Recommended when: ▪ Type and concentration of agent has been identified and requires a high level of respiratory protection but less skin protection. ▪ Atmosphere contains less than 19.5% oxygen. ▪ Identified vapors or gases are indicated by detection methods and are known not to contain high levels of chemicals harmful to the skin or capable of absorption through intact skin. ▪ Liquids or particles are present and are known not to contain high levels of chemicals harmful to the skin or capable of absorption through intact skin.
Level C	Provides an adequate level of protection when concentrations and types of airborne substances are known and the criteria for using air-purifying respirators are met. Includes: ▪ Full-face shield or half-mask. ▪ Air-purifying respirator or SCBA. ▪ Same hooded chemical-resistant clothing as for Level B.	Recommended when: ▪ Levels of contaminant, liquid splashes, or other direct contact will not adversely affect or be absorbed through any exposed skin. ▪ Types of chemicals have been identified, concentrations have been measured, and an air-purifying respirator is available that can remove them. ▪ Atmosphere contains at least 19.5% oxygen. Not appropriate for initial entry and response at a chemical incident.
Level D	Work uniform providing minimal protection.	▪ Atmosphere contains no known hazards. ▪ Work functions preclude splashes, immersion, or potential for unexpected inhalation of any chemicals. Not appropriate for initial entry and response at a chemical incident.

WORKER PROTECTION FOR CHEMICAL AGENTS (CONTINUED)

WORKER PROTECTION FOR SPECIFIC CHEMICAL AGENTS

The following table lists the levels of protection appropriate for vapor and liquid forms of selected chemical agents.

Protective Levels for Specific Agents[9]

CHEMICAL AGENT	PROTECTIVE LEVELS					
	VAPOR			LIQUID		
	Level A	Level B	Level C	Level A	Level B	Level C*
Nerve Agents: Tabun (GA), Sarin (GB), Soman (GD), VX	x			x	x	*
Blister Agents: Distilled Mustard (HD), Nitrogen Mustard (HN), Sulfur Mustard (H), Phosgene Oxime (CX), Lewisite (L), Phenyldichloroarsine (PD), Ethyldichloroarsine (ED)	x			x	x	*
Choking Agents:						
Phosgene (CG)	x				x	*
Chlorine (CL)		x	x		x	*
Blood Agents:						
Hydrogen Cyanide (AC)	x				x	*
Cyanogen Chloride (CK)		x	x		x	*
Vomiting Agent: Adamsite (DM)		x	x		x	*

*Level C protection level depends on the operational assignment (not appropriate for initial entry and response at a chemical incident).

[9] Adapted from: *First Responder Chem-Bio Handbook: Practical Manual for First Responders*. Alexandria, VA: Tempest Publishing, 1998, pages A-4-23.

WORKER PROTECTION FOR CHEMICAL AGENTS (CONTINUED)

PROTECTION FOR HEALTH AND MEDICAL PERSONNEL

Health and medical personnel are at risk when treating chemically contaminated patients. Strategies such as the following should be employed to ensure that these personnel avoid becoming victims of toxicity from secondary contamination:

- Patient decontamination.
- Using PPE while decontaminating patients or treating patients who require care before decontamination.

DECONTAMINATION

VICTIM DECONTAMINATION

Liquid or aerosolized chemicals can pose an ongoing threat to the victim because of the risk of continued absorption. For many chemical agents, rapid decontamination is critical because the agents (especially nerve agents) can cause injury in a matter of minutes. (Vapor exposures do not require decontamination.)

Separating People from the Hazard

The first step is to separate the victims from the chemical agent. If the agent is released indoors, two different approaches may be possible:

- Removing the agent from the building by shutting off the intake ducts and vents and setting the exhaust system to maximum to vent the fumes to the outside.
- Removing the people from the building.

If the agent is released outdoors, victims need to be moved to a location that is upwind and uphill from the release.

The victims' clothing must be removed, to allow thorough decontamination and avoid recontamination, and the chemical must be removed from the victim as quickly as possible, using appropriate methods for the type of agent.

Decontamination methods may be either physical removal or chemical removal (deactivation). Often, physical removal is used for gross decontamination, followed by chemical removal. Special kits for specific agents may be available for skin decontamination.

DECONTAMINATION (CONTINUED)

Physical Removal of Chemical Agents

The following methods are used to physically remove contaminants. In each case, the removed contaminant or wash water and the removed clothing must be collected for proper disposal. Materials for all of these methods are easily obtained.

- **Aeration:** For vapor contamination, placing the victim outside, in a breeze if possible, and removing outer clothing. (This may be sufficient decontamination for vapor-only exposure.)
- **Scraping, sweeping, brushing, or vacuuming:** Removing the bulk of the chemical agent by physical means (e.g., using a tongue depressor to scrape most of the agent off the skin).
- **Hosing:** Flushing the victim's body with large amounts of water (e.g., using a fire hose and spray nozzle). Water temperature is an issue because cold water can cause hypothermia in victims and personnel, even in warm weather.
- **Absorbent material:** Using absorbent material (e.g., flour, earth, dry soap powder, Fuller's Earth, Dutch Powder) to absorb the chemical, then wiping it off with wet tissue.
- **Soap and water:** Washing the victim with large amounts of soapy water (either fresh water or sea water).

Chemical Removal of Contaminants

In some cases, a particular chemical preparation can be applied to the contaminant which will react with it and convert it into something less toxic. Using the wrong chemicals, however, may cause dangerous interactions.

The most common chemical removal method used on people (as opposed to equipment and surfaces) is to wash the skin with a 0.5% hypochlorite solution (i.e., diluted bleach). Caution should be taken if decontamination occurs indoors because bleach solutions can cause off-gassing of chlorine gas.

WORKER DECONTAMINATION

First responders and decontamination personnel may become exposed to the chemical agent in the course of their duties. Self- and buddy-decontamination procedures should be set up to allow for rapid decontamination of personnel.

DECONTAMINATION (CONTINUED)

EQUIPMENT AND SURFACE DECONTAMINATION

Equipment exposed to the chemical agent (e.g., workers' personal protective equipment (PPE) and equipment used by decontamination personnel) must be decontaminated. The following methods are used.

METHOD	USED FOR	DESCRIPTION
Chemical	Equipment (e.g., scissors, aprons, gloves) used by decontamination personnel	Washing in 5% chlorine solution.
Aeration	Light contamination or contamination caused by vapor	Airing outdoors for several days in wind and sunlight.
Soap and Water	Heavily contaminated articles	Immersion in hot soapy water for an hour, rinsing, draining, and hanging.
Slurry	Impregnated items worn by personnel	Spraying or applying slurry, then rinsing with water (may be done while the clothing is being worn).

Residual contamination (e.g., chemical agents absorbed in porous materials) can emerge later as vapors, endangering patients and workers. Decontaminated equipment should be checked with chemical agent monitors before being returned to use.

MOST PATIENT LITTERS ABSORB CONTAMINATION AND CANNOT BE COMPLETELY DECONTAMINATED. IF A LITTER CANNOT BE SUCCESSFULLY DECONTAMINATED, IT MUST BE REMOVED FROM SERVICE AND DESTROYED. HOWEVER, THERE ARE A FEW NEW COMMERCIALLY AVAILABLE LITTERS THAT ARE COMPLETELY DECONTAMINABLE.

DECONTAMINATION (CONTINUED)

Decontamination Facilities

In most cases, the ability to decontaminate victims immediately will be essential in reducing the extent of injuries and deaths caused by exposure. Provisions should be made for establishing a field decontamination operation for this purpose. Field decontamination of casualties also helps prevent contamination of medical transport and hospital personnel and equipment.

Field Decontamination

The field decontamination operation must be upwind/uphill from the release site, and provisions must be made to change location if wind direction changes. (It is suggested that two decontamination sites be planned about 75 meters apart.)

In addition to the actual decontamination system, materials, and personnel, provisions should be made for the following:

- Establishment and marking of zones, including:
  - Hot zone (exclusion zone).
  - Warm zone (contamination reduction zone)—the "decon" zone, where decontamination takes place. A transition area (e.g., a "shuffle pit") should be provided for movement from this area to the support/treatment areas.
  - Cold zone (support zone)—an evaluation and support area for monitoring casualties following decontamination (medical monitoring and chemical monitoring to confirm decontamination).
  - A visible "hot line" separating the contaminated area from the agent-free zone.
- Site security to prevent the spread of contamination to and from the decontamination area.
- A clean area within the decon zone where workers can rest without masks and equipment.
- Concurrent decontamination and life-saving measures.
- Dealing with walking wounded, incapacitated victims (litter victims), infants, handicapped persons, the elderly, and animals (e.g., search and rescue dogs, guide dogs). Separate corridors for walking wounded and litter patients are recommended.
- Separate facilities for male and female victims (for privacy reasons) if possible without delaying decontamination procedures.
- Providing victims with uncontaminated paper gowns, clothing, and/or blankets after decontamination.
- Triage and victim tagging (i.e., identifying the contaminant and the decontamination procedures used, time, etc.).
- Transport of decontaminated casualties to medical facilities.
- Handling of property.
- Preservation of chain of evidence.

DECONTAMINATION (CONTINUED)

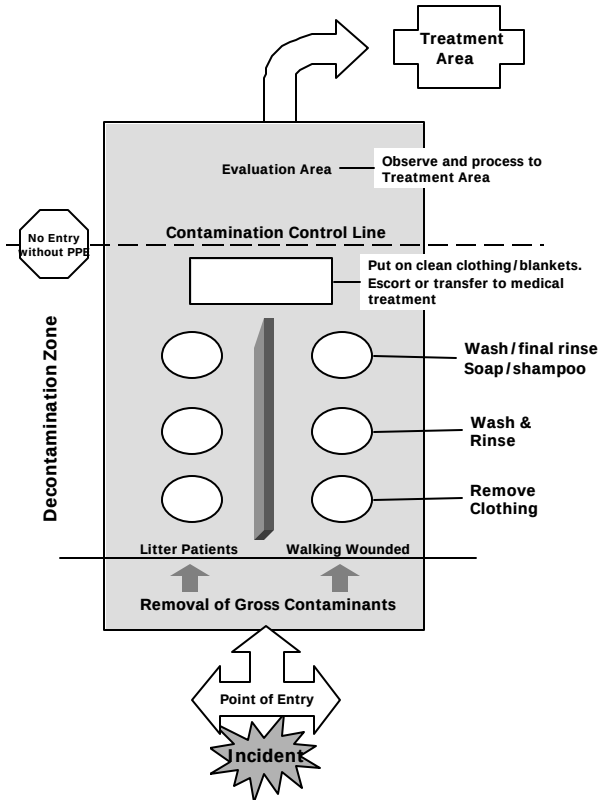
Field Decontamination (Continued)

- Collection of contaminated water, materials, and clothing. Runoff can cause further contamination.
- Recordkeeping.

Some jurisdictions have found it expedient to set up decontamination operations at locations such as swimming pools or car washes.

The following diagram illustrates a decontamination site with the zones and facilities described above. For more information on setting up the incident site (including an alternate decontamination set-up), see the Site Set-up fact sheet in this appendix.

Decontamination Operations[10]



[10] Source: *First Responder Chem-Bio Handbook: A Practical Manual for First Responders.* Tempest Publishing

DECONTAMINATION (CONTINUED)

Transport of Victims

Casualties should be decontaminated before being transported to medical facilities, if possible, to avoid contamination of transport personnel and equipment. If contaminated victims must be transported, the transport personnel must wear PPE and equipment should be used that can be easily decontaminated. The ambulance and equipment must be decontaminated before reuse.

Hospital Decontamination Facilities

Hospitals and other medical facilities must have provisions and facilities for decontaminating victims (including those not decontaminated at the scene and walk-ins) before they enter the hospital.

Decontamination at Mass Care Facilities

Arrivals at mass care facilities must be screened to ensure that contaminated people are identified and effectively decontaminated before entering. Isolation of bodily fluids is required to prevent secondary illness from off-gassing after the ingestion of some chemicals.

DISPOSAL OF CONTAMINATED CLOTHING AND EQUIPMENT

A clothing dump should be established at least 73 meters downwind of the decontamination facility. Contaminated clothing and equipment (except impermeable chemical protective overgarments and rubber gloves) should be deposited there. If possible the discarded items should be placed in plastic bags, airtight containers, or buried to prevent toxic vapors from escaping.

DISPOSAL OF CONTAMINATED DEAD

Additional arrangements may be needed for the decontamination, storage, and removal of contaminated cadavers.

ENVIRONMENTAL DECONTAMINATION

The need to perform environmental decontamination for chemical agents depends on the chemical involved. Persistent chemicals can remain in the environment for long periods and must (if found in unsafe levels) be actively removed through decontamination. More volatile chemicals will evaporate without outside intervention, eliminating the need for decontamination.

DECONTAMINATION (CONTINUED)

DECONTAMINATION METHODS FOR SPECIFIC CHEMICAL AGENTS

The following table lists decontamination suggested methods and products for specific chemical agents.

CHEMICAL AGENT	DECONTAMINATION METHODS
Nerve Agents	
Tabun (GA)	Bleach slurry; alkali solutions; hot soapy water; M258A1; M291 kit
Sarin (GB)	Bleach, large amounts of water; M258A1; M291 kit. Alkaline solutions to speed up decomposition. If left alone, self-decontamination will occur within a few days.
Soman (GD)	Solids, powders, and solutions containing bleach; decon wipes (moistened with NaOH dissolved in water, phenol, ethanol, and ammonia); M258A1; M291 kit
VX	Bleach, large amounts of water; M258A1; M291 kit
BLISTER AGENTS	
Distilled mustard (HD), sulfur mustard (H)	Sodium hypochlorite solution, large amounts of water; M258A1; M291 kit
Nitrogen mustard (HN)	Supertropical bleach (STB); large amounts of water; fire
Phosgene oxime (CX)	Large amounts of water
Lewisite (L)	Hypochlorite solution; caustic soda; large amounts of water
Phenyldichloroarsine (PD), Ethyldichloroarsine (ED)	Bleach; caustic soda
CHOKING AGENTS	
Phosgene (CG)	Vapor: Fresh air Liquid: Large amounts of water
Chlorine (CL)	Lots of water. Flush skin or eyes with water 15 min.
BLOOD AGENTS	
Hydrogen Cyanide (AC), Cyanogen Chloride (CK),	Skin decontamination usually not necessary; soap and water may be used. Remove wet, contaminated clothing and rinse underlying skin with water.
Arsine (SA)	None
VOMITING AGENTS	
Adamsite (DM)	In open area, none. In enclosed places, bleaching powder for gross contamination

TREATMENT OF CHEMICAL EXPOSURE VICTIMS

Despite the fact that severe exposure to chemical agents can be quite lethal, there are treatments for exposure to all of the chemical agents that have been discussed. For some agents there are antidotes (preparations that specifically counteract the effects of the agent). For a few there are prophylactics (drugs that can be taken pre-exposure for protection).

In most cases, the first step is to move contaminated and exposed victims to a restricted area away from the chemical for immediate decontamination. See the Decontamination fact sheet for more information.

GENERAL TREATMENT REGIMES

For public health and emergency medical response planning, it may be useful to discuss treatment in terms of clinical syndrome rather than specific chemical—for example, the neurological toxicity of nerve agents; the burns and trauma associated with blister agents; the respiratory failure effects of blister agents, blood agents, and choking agents; and cardiovascular shock that may follow severe exposure to many of the agents.

The following table lists clinical syndromes typically associated with chemical agents, agents that may cause them, and medical therapies that are used.

TREATMENT OF CHEMICAL EXPOSURE VICTIMS (CONTINUED)

GENERAL TREATMENT REGIMES (CONTINUED)

Medical Therapies for Chemical-Caused Syndromes

SYNDROME	CAUSATIVE AGENTS												MEDICAL THERAPEUTIC NEEDS
	Corrosives	Blister Agents	Explosives	Oxidants	Incendiaries	Radiologicals	Military agents (nerve agents)	Asphyxiants (choking agents)	Irritants	Pharmaceuticals	Metals	Pesticides	
Burns and Trauma	x	x	x	x	x	x							Intravenous fluid and supplies Pain medications Pulmonary products Splints and bandages
Respiratory Failure	x		x	x	x		x	x	x	x	x		Pulmonary products Ventilators and supplies Antidotes (when available) Tranquilizing medications
Cardio-vascular Shock							x	x		x		x	Intravenous fluid and supplies Cardiovascular products Antidotes (when available)
Neurological Toxicity						x	x			x		x	Antidotes (when available)

TREATMENT OF CHEMICAL EXPOSURE VICTIMS (CONTINUED)

MEDICAL MANAGEMENT FOR SPECIFIC TYPES OF AGENTS

The following table lists medical management practices for specific types of chemical agents.

TYPE OF AGENT	MEDICAL MANAGEMENT
Nerve Agents	▪ Antidote: Atropine plus a pyridinium oxime appropriate for the specific agent. Available as MARK I autoinjector system. ▪ Anticonvulsants (e.g., Diazepam) ▪ Ventilation and supportive therapy ▪ Prophylaxis: Atropine or other pharmaceuticals
Blister Agents (Mustards)	▪ Immediate decontamination (removal of the agent) ▪ No specific antidotes ▪ Burn therapy ▪ Eye irrigation ▪ Antibiotics ▪ Breathing support (oxygen, anti-inflammatories, humidity control)
Blister Agents (Organoarsenics)	▪ Immediate decontamination ▪ Symptomatic relief, including treatment of lesions ▪ Antidote: British Anti-Lewisite (BAL) to prevent blistering, to treat eyes, and as therapy for systemic arsenic poisoning ▪ Pain management ▪ If inhaled, pulmonary support
Blister Agents (Halogenated Oximes)	▪ Immediate decontamination ▪ Symptomatic treatment of lesions ▪ Pain relief ▪ If inhaled, pulmonary support

TREATMENT OF CHEMICAL EXPOSURE VICTIMS (CONTINUED)

MEDICAL MANAGEMENT FOR SPECIFIC TYPES OF AGENTS

TYPE OF AGENT	MEDICAL MANAGEMENT
Blood Agents	▪ Decontaminate if liquid exposure ▪ Antidote (standard treatment for cyanide poisoning) ▪ Supportive therapy, symptomatic relief
Choking Agents	▪ Removal from exposure site. A victim who survives 48 hours has a good chance for recovery ▪ Respiratory/cardiopulmonary support ▪ No specific antidotes ▪ Antibiotics ▪ Intravenous fluids
Vomiting Agents	▪ Symptomatic relief
Irritants	▪ Flushing of eyes ▪ Ventilation ▪ Symptomatic relief (skin preparations)
Psychochemicals	▪ Protection from harm until effects wear off ▪ Long-term monitoring and psychiatric counseling

MENTAL HEALTH ISSUES

Exposure to hazardous chemicals can lead to psychosocial responses different from, and in some instances greater than, other emergency situations. Unique mental health concerns may relate to:

- The inability to quantify exposure.
- Concerns about developing illnesses well into the future.
- Resulting feelings of vulnerability and loss of control.

These concerns must be considered during the planning process.

SUMMARIES: SELECTED CHEMICAL AGENTS

	Persistence			Rate of Action			Route of Entry			PPE		Effects	Decontamination
Agents	Non-persistent	Semi-persistent	Persistent	Precipitous	Rapid	Delayed	Respiratory	Skin	Eyes	Respiratory	Skin		
Nerve Agents												Headache, runny nose, salivation, miosis, difficulty breathing, tight chest, seizures, convulsions. Rate of action and effects vary with form (vapor/liquid) and amount of agent.	Remove agent, flush with warm water/soap.
Tabun (GA)		x		x[1]	x[2]		x			x	x		
Sarin (GB)		x		x[1]	x[2]		x			x	x		
Soman (GD)		x		x[1]	x[2]		x			x	x		
VX			x	x[1]	x[2]		x			x	x		
Blister Agents												Red, burning skin, blisters, sore throat, dry cough. Pulmonary edema, memory loss, coma, seizures. Some symptoms delayed 2-24 hrs.	Remove from area. Flush with warm water/soap.
Mustard (H)			x			x	x	x	x	x	x		
Lewisite (L)			x		x		x	x	x	x	x		
Phosgene Oxime (CX)			x		x		x	x	x	x	x		
Blood Agents												Red skin/lips, rapid breathing, dizziness, nausea, vomiting, convulsions, miosis, salivation, GI hemorrhage, pulmonary edema, respiratory arrest	Remove from area, remove wet clothing, flush w/ soap/water, aerate.
Hydrogen Cyanide (AC)	x				x		x	x	x	x	x		
Cyanogen Chloride (CK)	x				x		x	x	x	x	x		
Arsine (SA)	x				x		x	x	x	x	x		
Choking Agents												Eye/airway irritation, dizziness, tightness in chest, pulmonary edema, painful cough, nausea, headache	Wash with copious amounts of water, aerate.
Chlorine (CL)	x				x[3]	x[4]	x	x		x	x		
Phosgene (CG)	x				x[3]	x[4]	x	x		x	x		
Diphosgene (DP)	x				x[3]	x[4]	x	x		x	x		
Irritants												Tearing eyes, nose/throat irritation, coughing, shortness of breath, vomiting	Brush off material, use decon wipes, water, remove contaminated clothing
Tear Gas (CS, CR)	x[5]	x[5]	x[5]	x			x	x		x	x		
Mace (CN)	x				x		x	x		x	x		
Pepper Spray (OC)		x[6]					x	x		x	x		

[1] In vapor form
[2] In liquid form
[3] In high concentration
[4] Up to 3 hours in low concentrations
[5] Low to high, >60 days on porous material
[6] Varies depending on surface