CHAPTER 11

DECONTAMINATION

INTRODUCTION

Decontamination is the safe removal or inactivation of any hazardous contaminant that adheres to or is otherwise in contact with personnel, protective clothing, protective equipment, and any other incident-related equipment, vehicles, materials, or debris. Potential contaminants include physical (e.g., asbestos, radioactive substance), chemical (e.g., pesticide), or biological agents (e.g., bacteria, viruses, other parasites) . There are several basic objectives to decontamination procedures:

1. *To protect on-site response personnel from direct bodily exposure to contaminants adhering to or absorbed into protective clothing or equipment*—The presumption is that personal protective clothing (PPC) and equipment (PPE) are appropriately selected to prevent bodily exposure to contaminants. However, unnoticed tears, rips, punctures, and other malfunctions may in fact result in actual exposure (especially during particularly rigorous response activity), in which case timely decontamination can effective minimize the duration of exposure. Of course, in the absence of malfunction of properly selected PPC and PPE, decontamination prevents personal exposure during donning and doffing procedures.

2. *To prevent the mixing of incompatible or synergistic chemical contaminants derived from different response activities involving exposure of the same personnel and/or equipment to different chemical hazards*—During a particular incident, it may be necessary to use the same PPC, PPE, and other equipment (e.g., hand tools, vehicles, extrication equipment) for a variety of different tasks and also in different locations, with subsequent contamination by different chemical materials that may be incompatible. Chemical incompatibilities or synergies may in turn exacerbate existing hazards as well as result in completely different hazards, such as when a

relatively innocuous powder becomes highly skin-absorbable and toxic when mixed with water.

3. *To protect off-site personnel (e.g., hospital personnel) from exposure in the process of treating victims, servicing equipment, or handling and transporting incident-related debris or other materials*—While much of the concern regarding decontamination typically focuses on on-site incident-related activities, decontamination procedures play a vital role in the attempt to confine hazardous contaminants to the incident site where they can be better controlled. Transported off-site via victims, response personnel, and response-related equipment and debris, such contaminants readily place off-site response personnel as well as the unsuspecting and unprepared public-at-large in danger.

4. *To protect the families of response personnel from "carry-home contamination" (i.e., contamination carried off site on the body, in clothing, and/or in personal vehicles)*—A particularly vulnerable subset of the off-site public at risk due to improper decontamination procedures is composed of the families of response personnel. Even if not personally involved in tasks requiring direct exposure to physical, chemical, or biological contaminants, on-site response personnel can become contaminated indirectly simply by being present at the incident site. Also, in many situations involving volunteer responders, personnel arrive on-site in personal vehicles and wearing personal clothes. Personal vehicles can become contaminated either by on-site conditions (e.g., wind, rain, runoff) or by the owners themselves, with subsequent risk to family members and friends; contaminated personal clothes can also transport dangerous chemicals directly into the home.

5. *To protect environmental resources (e.g., water, soil, air) and, subsequently, the general public from the incident-related release of contaminants*—Another major risk to the public-at-large is the environmental release of contaminants into water, soil, and air not solely as a result of the incident, but also from emergency response operations themselves. Runoff water from fire fighting operations, for example, must not only be contained but collected and finally decontaminated prior to final disposal. Similarly, construction debris from the incident as well as runoff and debris from postincident decontamination operations (e.g., dirt from vehicle tires, equipment wash water) must be decontaminated prior to release to environmental resources that can serve as hazard transport vectors into the general community.

SCOPE OF DECONTAMINATION PLAN

The meet the objective of decontamination, the decontamination plan must include SOPs pertaining to each of the following:

- minimization of personnel contact with hazardous substances
- maximization of responder protection
- determination of number and layout of decontamination stations
- determination of decontamination methods and equipment
- prevention of contamination of clean areas
- minimization of contact with contaminants during removal of PPC and PPE
- disposal of materials and equipment that cannot be completely decontaminated and/or that become contaminated as a result of decontamination operations

While there is typically no time to develop SOPs for a specific incident, generic guidelines and checklists should be developed that can be modified and applied as appropriate on a site-specific basis. However, it should also be understood that the appropriateness of any decontamination method is ultimately determined by the specific nature of the hazardous substance of concern and the on-site conditions encountered during the incident. Therefore, all decontamination plans, guidelines, and checklists must be carefully reviewed and tested against the actual field situation before implementation.

Minimization of Personnel Contact

Typically viewed as the first step in any comprehensive decontamination program, the minimization of personnel contact with hazardous substances (Fig. 11.1) depends upon not only proper clothing, equipment, policies, and procedures, but also (and perhaps most importantly) attitudes. Personnel must understand that there is nothing heroic about exposing themselves (and, thereby, co-workers and family) to hazardous substances; that potentially lethal agents are typically not visible, nor do they necessarily advertise their presence with strong odors; and that, depending upon the nature of the contaminant and its concentration, a contaminant may cause irreversible acute and chronic affects. The only acceptable professional attitude is, therefore, that attitude of seasoned caution which must inform all response behavior and which is encapsulated in the dictum: *The first responsibility of every emergency response provider is to protect himself.*

Certain behavioral constraints necessarily follow from this dictum and must be stringently enforced, including :

- limited access to operational areas, based on functional need, and strict adherence to precautionary measures
- except as required by job function or assigned task and directed by operational SOPs and operational orders, prohibition of any

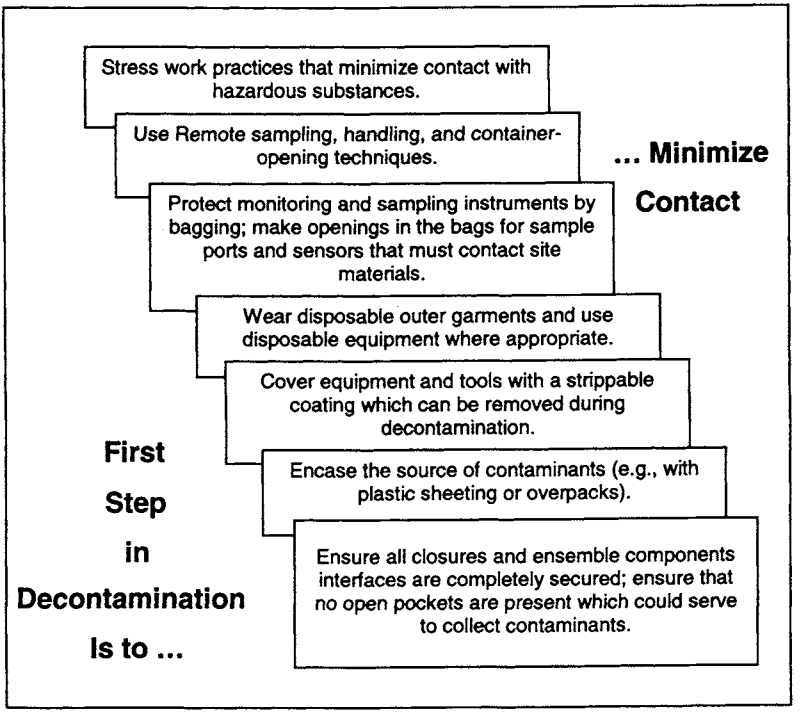

FIGURE 11.1 Examples of standard operating procedures that minimize contact with chemicals (adapted from OSHA, OSHA Technical Manual, Section 7. OSHA Electronic Library).

casual investigation of structures, containers, or substances that may result in release of or contact with hazardous agents

- strict adherence to site control constraints regarding both prescribed and proscribed behavior, activities and clothing, such as eating, drinking, smoking, washing, sleeping, use of sanitary facilities, use of designated footwear, and other clothing as well as personal protective equipment

In no circumstances shall any response personnel ignore or otherwise acquiesce to any infringement by any person of any rule or practice implemented to control exposure. This is particularly important with regard to site visits by governmental and other VIPs—a stricture that, unfortunately, is too often ignored for the sake of political grandstanding before the TV audience.

Incompatible and Synergistic Chemical Contaminants

Incompatible chemicals (Table 11.1) are those that react with one another with the release of dangerous energy and other products, such as heat, explosion, fire, and toxic gases. Synergistic chemicals are those that, when introduced into the human body simultaneously (e.g., inhalation of certain pesticide particulates as well as petrochemical vapors), result in an unpredictable enhancement of the toxic or other harmful effects of one or more of the components of the mixture.

In any incident involving chemicals, there is always the possibility that response personnel will be exposed to both incompatible and synergistic chemicals. It is this possibility that informs the on-site implementation of risk management practices and the selection of appropriate PPC and PPE. However, the use of any PPC, PPE, and other incident-related equipment itself defines the need for subsequent decontamination so as to (a) avoid hazards other than those immediately presented by the incident, and/or (b) avoid additional hazards derived from response operations, and/or (c) manage chemical risks to personnel regardless of the source of risk.

The importance of decontamination as the means of avoiding incompatible and synergistic reactions beyond those immediately presented by the incident is twofold:

1. decontamination minimizes the probability that incompatible chemicals will be mixed as a direct result of response operations and, therefore, the likelihood that the risks associated with the incident will not be compounded by additional risks (either in kind or degree), and
2. decontamination minimizes the probability that response personnel will be unknowingly exposed to chemicals that could result in health and safety risks beyond those routinely expected by virtue of task assignment.

Decontamination Stations and Facilities

The location and layout of on-site decontamination stations must be based on site-specific conditions of the actual incident, including:

1. precise nature of physical, chemical, and/or biological contaminants
2. specific resources that must undergo decontamination, including victims, response personnel, equipment and supplies, response vehicles, and any other site-related or incident-related materials (e.g., construction debris)
3. number and type of activities and associated equipment necessary to implement proper decontamination procedures (Fig. 11.2)
4. isolation from clean areas

TABLE 11.1 Examples of Chemical Incompatibilities (Adapted from the Dangerous Chemical Code, Bureau of Fire Prevention, City of Los Angeles Fire Department)

Chemical	Avoid Contact with ...
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkaline metals	Water, chlorinated hydrocarbons, carbon dioxide, halogens
Ammonia (anhydrous)	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid (anhydrous)
Ammonium nitrate	Acids, metallic powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide
Bromine	Ammonia, acetylene, butadiene, butane, methane, propane, hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Carbon (activated)	Calcium hypochlorite, all oxidizing agents
Chlorates	Ammonium salts, acids, metallic powders, sulfur, finely divided organic or combustible materials
Chromic acid	Acetic acid, naphthalene, camphor, glycerin, turpentine, alcohol, flammable liquids
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane, hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide

continues

TABLE 11.1—*continued*

Chemical	Avoid Contact with ...
Cumene hydroperoxide	Acids (organic and inorganic)
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Fluorine	Isolate from all other chemicals
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkaline chemicals
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, Iron, alcohols, acetone, aniline, nitromethane, flammable liquids, combustible materials, most other organic materials
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Iodine	Acetylene, ammonia, hydrogen
Mercury	Acetylene, fulminic acid, ammonia
Nitric acid (concentrated)	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases and liquids
Oxalic acid	Silver, mercury
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood
Potassium	Carbon tetrachloride, carbon dioxide, water

Note. The list of chemicals is not complete, nor are all incompatible substances for each chemical shown.

5. required protection of decontamination processes from the ongoing incident, response-operations, and weather conditions
6. ease of containing and otherwise managing decontamination wastes (e.g., runoff from washing contaminated vehicles) prior to their final treatment and disposal

Depending upon constraints of time, personnel, and/or the availability of proper equipment, decontamination cannot be completed on the site

- Drop cloths of plastic or other suitable materials on which heavily contaminated equipment and outer protective clothing may be deposited
- Collection containers, such as drums or suitably lined trash cans, for storing disposable clothing and heavily contaminated personal protective clothing or equipment that must be discarded
- Line box with absorbents for wiping or rinsing off gross contaminants and liquid contaminants
- Large galvanized tubs, stock tanks, or children's wading pools to hold wash and rinse solutions. These should be at least large enough for a worker to place a booted foot in and should have either no drain or a drain connected to a collection tank or appropriate treatment system
- Wash solutions selected to wash off and reduce the hazards associated with the contaminants
- Rinse solutions selected to remove contaminants and contaminated wash solutions
- Long-handled, softbristled brushes to help wash and rinse off contaminants
- Paper or cloth towels for drying protective clothing and equipment
- Lockers and cabinets for storage of decontaminated clothing and equipment
- Metal or plastic cans or drums for contaminated wash and rinse solutions
- Plastic sheeting, sealed pads with drains, or other appropriate methods for containing and collecting contaminated wash and rinse solutions spilled during decontamination
- Shower facilities for full body wash or, at a minimum, personal wash sinks (with drains connected to a collection tank or appropriate treatment system)
- Soap or wash solution, wash cloths, and towels for personnel
- Lockers or closets for clean clothing and personal item storage

FIGURE 11.2 Equipment used for decontamination of personnel and personal protective clothing (adapted from NIOSH, USCG, and EPA, 1985: Occupational Safety and Health Guidance Manual for Hazardous Waste Activities).

of the incident. In fact, it is generally most advisable that on-site field decontamination be restricted (wherever possible) to:

- persons (including victims and response personnel) who will not realize increased risk to life or health due to any delay of access to off-site professional medical services
- personal protective clothing and equipment that must be readily available for subsequent use in response operations
- any other materials or items that cannot be moved off-site without endangerment of the general public or environmental resources

Where materials are removed to off-site locations and facilities for subsequent decontamination, it is necessary, of course, that suitable precautionary measures be taken at those locations and facilities to assure the effec-

- Design disinfecting facilities in stations with proper lighting, separate ventilation to the outside environment, fitted with floor drains connected to a sanitary sewer system, and to prevent contamination of other station areas.
- Within disinfecting facilities, install a minimum of 2 sinks with hot and cold water faucets and a sprayer attachment, and with drains connected to a sanitary sewer system. Sink faucets should not require the user to grasp, with hands, to turn on or off. All surfaces should be nonporous material with continuous molded counter top and splash panel surfaces
- Equip disinfecting facilities with rack shelving of nonporous materials. Shelving should be provided above sinks for drip-drying of cleaned equipment. All drainage from shelving should either go into a sink or drain directly into a sanitary sewer system.
- If possible, select front loading industrial laundry machines designed for the type of cleaning required for protective clothing.
- When exposure occurs, clean the equipment and store the waste water from this process in a double wall tank where it can then be pumped to waste transfer vehicles for appropriate disposal
- Provide a designated cleaning area in each station for the cleaning and disinfection of protective clothing, protective equipment, portable equipment, and other clothing. This cleaning area should have proper ventilation, lighting, and drainage connected to a sanitary sewer system.
- Physically separate the designated cleaning area from areas used for food preparation, cleaning of food and cooking utensils, personal hygiene, sleeping, and living areas; also physically separate the designated cleaning area from the emergency medical disinfecting facility.
- Store station emergency medical supplies/equipment, other than that stored on vehicles, in a dedicated, enclosed room protected from the outside environment.
- Store protective clothing and protective equipment in a dedicated, well-ventilated area or room
- Do not store reusable emergency medical supplies and equipment, protective clothing, and protective equipment in a kitchen, living, sleeping, or personal hygiene areas, nor shall it be stored in personal clothing lockers

FIGURE 11.3 Precautionary measures for disinfecting facilities in fire and EMS facilities (adapted from U.S. Fire Administration, 1997: Safety and Health Considerations for the Design of Fire and Emergency Medical Services Stations [FA 168]).

tive containment and management of contaminants prior to ultimate disposal (Fig. 11.3).

Decontamination Methods and Equipment

Basic decontamination methods involve physical and/or chemical removal, detoxification, and disinfection/sterilization of contaminants.

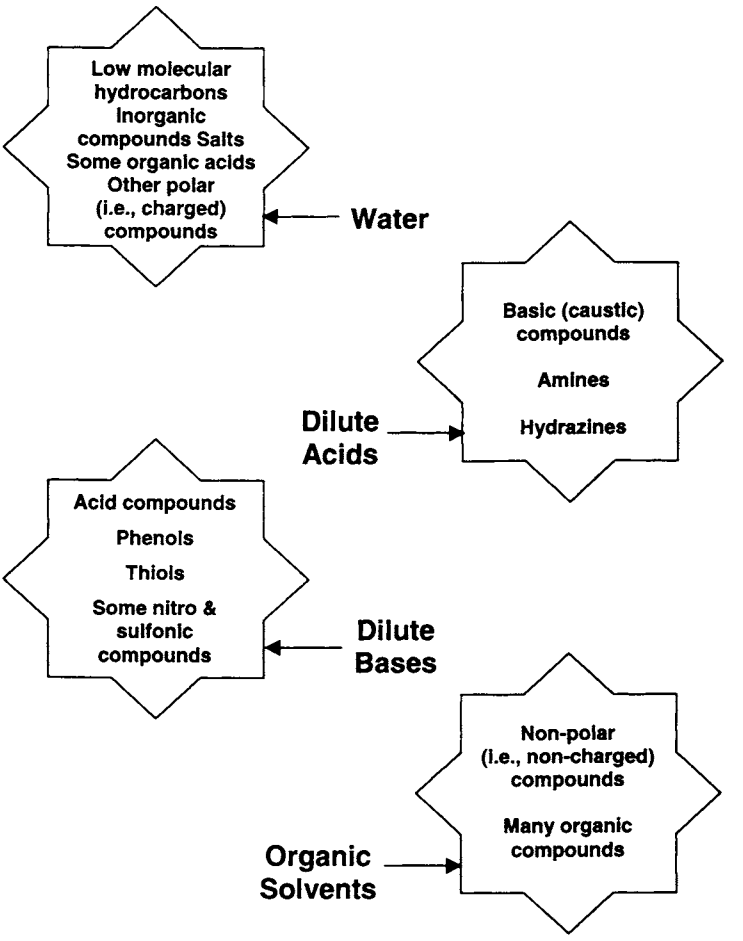

FIGURE 11.4 Examples of contaminants solubilized by each of four solvent types (adapted from NIOSH, USCG, and EPA, 1985: Occupational Safety and Health Guidance Manual for Hazardous Waste Activities).

1. Physical/Chemical Removal

Gross dirt and caked muds (e.g., lodged in tire treads) containing nonadhesive contaminants can be physically dislodged by brushing, scraping, and pounding, followed by either simple flushing or pressurized air or rinse water. Adhesive contaminants may require more stringent physical treatment prior to physical dislodgment, including freezing (e.g., by dry ice or ice water), melting, adsorption onto other surfaces(e.g., sand) , and ab-

sorption into inert materials such as kitty litter or powdered lime. Various ultrasound devices may be useful for dislodging small amounts of either adhesive and nonadhesive materials. Steam jets are useful for cleaning many types of adhesive contaminants.

Dusts and vapors of contaminants that collect in small openings in clothing and equipment may simply be washed free with water or blown free with an air jet. Contaminants that cling more tenaciously to materials by virtue of electrostatic forces may be more easily removed by water or air from materials that have been treated with commercially available antistatic solutions and sprays.

Liquid contaminants may be wiped off, absorbed into inert substances, and/or, in the case of volatile liquids, air dried, followed by water rinse. Warm air or steam jets may be used to facilitate evaporation. The physical removal of liquefied contaminants may also be facilitated by solidification, which may involve the use of absorbents (e.g., clay, powdered lime) to remove moisture, dry ice, or water to cause freezing, or the addition of chemical catalysts that effect polymerization (i.e., chemical joining together of similar molecules into long chains).

Regardless of the type of the type of process employed, the physical removal of gross contaminants should be followed by appropriate wash and rinse of contaminated materials.

Primary wash solutions typically contain cleaners that depend upon the action of a variety of solvents (which dissolve contaminants) and surfactants (which, like household detergents, reduce the forces of adhesion between the contaminant and the material contaminated). Cleaners should therefore be selected on the basis of the compatibility of solvent types (Fig. 11.4) with the structural materials of items to be decontaminated. Manufacturers of PPC, PPE, and other types of response equipment typically supply information on solvent compatibility with the engineering specifications of manufactured items.

Types of equipment needed for each type of physical/chemical removal (Fig. 11.5) are essentially containers (including storage tanks for wash and rinse solutions), sprayers, brooms, and brushes, as well as items used for containment of contaminants (e.g., curtains, booths) during the decontamination process. All equipment used for decontamination must be dedicated equipment (i.e., not to be used for any other purpose) that is also compatible with cleaning and solvent solutions.

Physical decontamination also includes removal of contaminated surfaces as opposed to the removal of contaminants from surfaces. This process involves the disposal of materials and items (clothing, protective coverings, floor mats). However, before their final disposal, such items typically must undergo either chemical deactivation or disinfection to ensure that they do not contaminate environmental resources. No materials can be finally disposed

- Storage tanks of appropriate treatment systems for temporary storage and/or treatment of contaminated wash and rinse solutions
- Drain or pumps for collection of contaminated wash and rinse solutions
- Long-handled brushes for general exterior cleaning
- Wash solutions selected to remove and reduce the hazards associated with the contamination
- Rinse solutions selected to remove contaminants and contaminated wash solutions
- Pressurized sprayers for washing and rinsing, particularly hard-to-reach areas
- Curtains, enclosures, or spray booths to contain splashes from pressurized sprays
- Long-handled brushes, rods, and shovels for dislodging contaminants and contaminated soil caught in tires and the undersides of vehicles and equipment
- Containers to hold contaminants and contaminated soil removed from tires and the undersides of vehicles and equipment
- Wash and rinse buckets for use in the decontamination of operation areas inside vehicles and equipment
- Brooms and brushes for cleaning operator areas inside vehicles and equipment
- Containers for storage and disposal of contaminated wash and rinse solutions, damaged or heavily contaminated parts, and equipment to be discarded

FIGURE 11.5 Equipment used for decontamination of heavy equipment and vehicles (adapted from NIOSH, USCG, and EPA, 1985: Occupational Safety and Health Guidance Manual for Hazardous Waste Activities).

except in conformance with applicable hazardous waste regulations. It is therefore necessary to coordinate directly with hazardous waste authorities and RCRA permitted transporters and treatment, storage, and disposal (TSD) facilities to determine appropriate disposal requirements and constraints.

Any means of physical/chemical removal (especially those involving heat or pressurized steam) may result in vapors, particles, and liquids that may present risk to the person employing them through inhalation or through eye or skin contact. Physical removal methods typically do not alter the chemical attributes of contaminants, nor affect the viability of pathogenic organisms. Caution must therefore be used with all methods, with appropriate attention paid to (a) personal protective clothing and equipment (e.g., gloves, goggles, respiratory protection) to be used by the person performing the decontamination procedure, (b) containment of all dislodged contaminants to prevent entry into environmental resources or contact with other persons, and (c) additional treatment (as may be required) to deactivate or disinfect dislodge materials prior to final disposal.

2. Detoxification

Detoxification is essentially a chemically, physically, or biologically mediated change in (a) the molecular structure of a contaminant molecule,

or (b) the chemical dynamics of a contaminant mixture or solution to achieve a less hazardous substance or material.

Commonly used chemical detoxification procedures involve the removal of halogen atoms (e.g., chlorine, bromine, fluorine, iodine) from a contaminant molecule (e.g., carbon tetrachloride, trichloroethane), which is known as *halogen stripping;* the addition or removal of electrons (or hydrogen) from the contaminant molecule (e.g., transformation of an alcohol to organic acid), which is known as *oxidation* (when electrons are added) or reduction (when electrons or hydrogen atoms are removed); and the addition of acids or bases to a contaminant solution to adjust either the acidic or the alkaline nature of the solution toward a less corrosive state, which is called *neutralization.* The most commonly used physical detoxification procedure is *thermal degradation,* in which heat is used to transform a contaminant molecule into a less hazardous molecule.

Other chemical and physical processes may be used (or are under ongoing investigation and development) to effect changes in the structure and/or chemical dynamics of contaminant molecules, such as *chelation,* which involves the addition of chemicals that tightly bind to contaminant molecules, thereby facilitating their removal or otherwise reducing their chemical reactivity. Biological agents may also be used to degrade contaminants to less hazardous substances, as in the use of selected species of bacteria and yeasts to degrade certain types of petrochemicals and pesticides—a rapidly expanding technology known as *bioremediation.*

Emergency response services are well advised to be extremely cautious with regard to the use of any detoxification method. There are several reasons for this caution:

- Even standard detoxification methods (e.g., neutralization, halogen stripping) are typically employed only when there is detailed chemical knowledge and understanding of the chemical dynamics involved
- The effectiveness and safety of detoxification methods is dependent on a large number of factors, including the concentration of target contaminants, the concentrations of potentially interfering chemical species in a contaminant mixture, and the ambient conditions under which the procedure is performed
- The treatment of any hazardous or potentially hazardous waste can be legally undertaken only by U.S.EPA permitted facilities that conform to strict procedural and technical requirements

In light of these considerations, response services should rely on the advice of regulatory authority and, as necessary, seek out the professional services of properly licensed contractors who are legally, scientifically, and technically competent to undertake detoxification.

TABLE 11.2 Decontamination Methods for Equipment Used in the pre-Hospital Health-Care Setting (Adapted from the U.S. Fire Administration, 1992: Guide to Developing and Managing an Emergency Service Infection Control Program [FA-112])

Process	Application	Details
Sterilization	**Target**	All forms of microbial life, including high numbers of bacterial spores
	Method(s)	Steam under pressure (autoclave), gas (ethylene oxide), dry heat, or immersion in EPA-approved chemical sterilant for prolonged period of time (e.g., 6-10 hours or according to manufacturers' instructions). Liquid chemical sterilants should be used only on those instruments that are impossible to sterilize or disinfect with heat.
	Use	For those instruments or devices that penetrate skin or contact normally sterile areas of the body (e.g., scalpels, needles). Disposable invasive equipment eliminates the need to reprocess these types of items. When indicated, however, arrangements should be made with a health-care facility for reprocessing of reusable invasive instruments
High-Level Disinfection	**Target**	All forms of microbial life except high numbers of bacterial spores.
	Method(s)	Hot water pasteurization (80-100°C for 30 minutes) or exposure to an EPA-registered sterilant chemical (as above), except for a short exposure time (10-45 minutes, or as directed by the manufacturer).
	Use	For reusable instruments or devices that come into contact with mucous membranes (e.g., laryngoscope blades, endotracheal tubes).

continues

3. Disinfection/Sterilization

Both disinfection and sterilization involve the killing of microorganisms, but differ with respect to the range of microbes actually killed. As shown in Table 11.2, disinfection may be carried out at various levels of efficacy as defined by the types of microbes (e.g., bacteria, viruses, fungi) affected and whether or not the disinfecting agent (e.g., heat, germicide) destroys bacterial spores (i.e., reproductive structures of bacteria). Only sterilization, which involves the use of an autoclave, a sterilant gas, a liquid sterilant, or dry heat, can destroy all forms of microbial life as well as a large proportion of bacterial spores. It should be noted, however, that even sterilization techniques do not necessarily kill all bacterial spores.

TABLE 11.2—*continued*

Process	Application	Details
Intermediate-Level Disinfection	**Target**	*Mycobacterium tuberculosis*, vegetative bacteria, most viruses, and most fungi; does not kill bacterial spores.
	Method(s)	EPA-registered "hospital disinfectant" chemical germicides that have a label claim for tuberculocidal activity; commercially available hard-surface germicides or solutions containing at least 500 ppm free available chlorine (a 1:100 dilution of common household bleach; approximately ¼ cup bleach per gallon of tap water).
	Use	For those surfaces that come into contact only with intact skin (e.g., stethoscopes, blood pressure cuffs; splints), and which have been visibly contaminated with blood or bloody body fluids. Surfaces must be pre-cleaned of visible material before the germicidal chemical is applied for disinfection.
Low-Level Disinfection	**Target**	Most bacteria, some viruses, some fungi, but not *Mycobacterium tuberculosis* or bacterial spores.
	Method(s)	EPA-registered "hospital disinfectant" (no label claim for tuberculocidal activity).
	Use	These agents are excellent cleaners and can be used for routine housekeeping or removal of soiling in the absence of visible blood contamination.
Environmental Disinfection		Environmental surfaces that have become soiled should be cleaned and disinfected using any cleaner or disinfectant agent which is intended for environmental use. Such surfaces include floors, woodwork, ambulance seats, countertops, etc.
Important: To assure the effectiveness of any sterilization or disinfection process, equipment and instruments must first be thoroughly cleaned of all visible soil.		

With the exception of certain emergency medical service organizations, very few emergency response services possess the equipment to carry out effective sterilization. Even where appropriate sterilization equipment is available, it is impractical (if not impossible) to sterilize large equipment or PPC and PPE. Wherever possible, therefore, disposable clothing and equipment should be used, with appropriate planning for safe disposal through incineration. No infected clothing or equipment should be deposited in a landfill unless it has been sterilized.

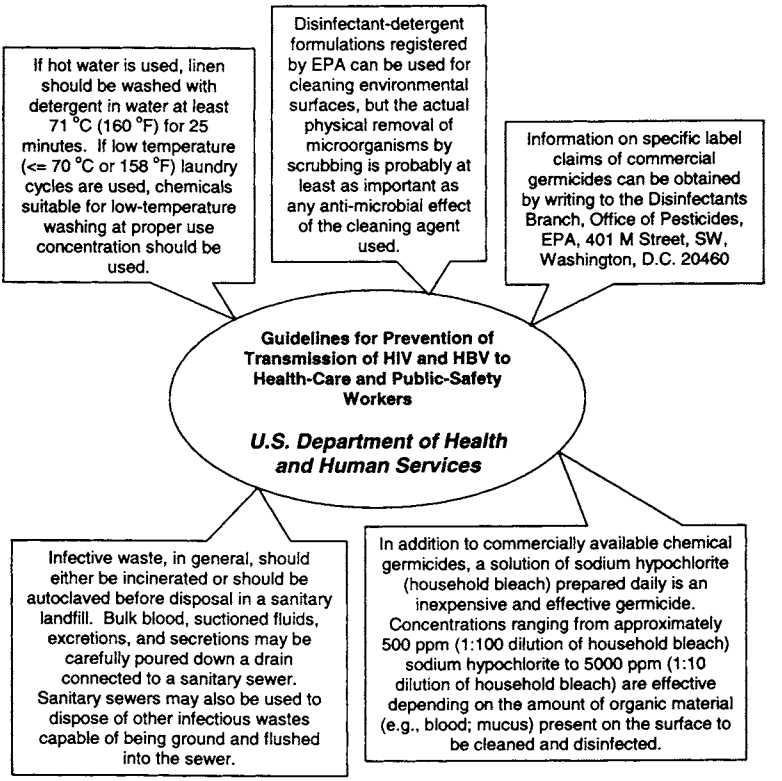

FIGURE 11.6 Selected guidelines regarding proper cleaning, disinfection, and/or disposal of infected materials (based on information provided by U.S. Department of Health and Human Services, 1989: A Curriculum Guide for Public-Safety and Emergency-Response Workers: Prevention of Transmission of Human Immunodeficiency Virus and Hepatitis B Virus [89–108]).

Disinfection by means of commercially available and U.S. EPA registered germicides, household bleach, and cleaning agents (Fig. 11.6) is effective only when proper attention is given to the prior removal of gross dirt and grime. This is because a disinfectant must come into direct contact with a microbe in order to kill it, and dirt, grime, and other materials prevent direct contact between the disinfectant and the target organism. The duration of contact between the disinfectant and the target organism is also important—the longer the contact, the greater the probability the microbe will be killed. Detailed information concerning the precleaning of infected items required for the effective use of germicides, as well as recommended contact times, is printed on germicide labels. Additional information concerning germicide labels can also be obtained directly from the U.S. EPA.

Prevention of Contamination of Clean Areas

During an actual incident, the most important means of preventing the contamination of clean areas is the establishment of *work zones*. Depending upon the nature of the incident, any number of clearly demarcated work zones may be designated. In most incidents involving hazardous waste sites, three zones are typically used:

1. Exclusion Zone

This is the contaminated area or an area that is likely to become contaminated in the process of the incident. The outer boundary of this zone is the *hotline*, which must be clearly marked. The precise location of the hotline is determined on the basis of various considerations, including: (a) known or possible routes of dispersion of contaminants (including surface runoff and wind dispersion), (b) the amount of contaminants, (c) the relationship of site topography to the actual and potential area of contamination, (d) distances necessary to prevent any possible explosion or fire within the exclusion zone from affecting personnel outside of the exclusion area, (e) area necessary to conduct response operations, including the use of response vehicles and heavy equipment, (f) on-site meteorological conditions, including both current and projected conditions, and (as time may permit), (g) field monitoring data (including data derived from air, water, soil, and contaminant sampling).

As the incident develops and more information becomes available about the nature of contaminants and other potential risks (e.g., underground tanks, subsurface transformer stations, underground electrical cables), it may become necessary or advisable to adjust the delimitation of the hotline to better protect personnel.

Access control points must be established on the hotline to manage the movement of response personnel and equipment into and out of the exclusion zone.

The exclusion zone itself may be subdivided on the basis of different types of hazards and/or degree of risk encountered or expected. The type of personal protective clothing and equipment required within the exclusion zone must be clearly indicated at access points and, as appropriate, within each subdivision.

2. Contaminant Reduction Zone

This is the zone where decontamination occurs; it is essentially a buffer area between the highly contaminated exclusion zone and the contaminant-free area of the site (Fig. 11.7).

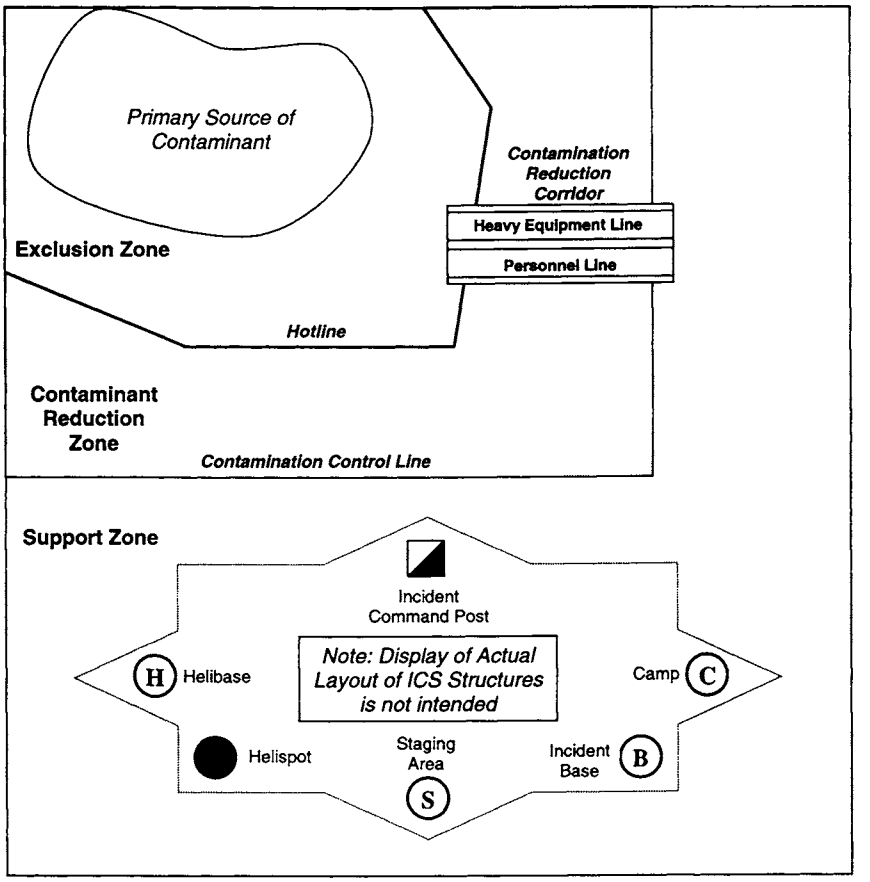

FIGURE 11.7 Schematic example of layout of various work zones and ICS-related facilities (note standard ICS symbols used for these facilities).

All access to and through the contaminant reduction zone is through the *contamination reduction corridor,* which extends from the contaminant-free area of the site through the hotline. Access points must be established on the "clean side" of this corridor to control entry and exit. Within the contamination reduction corridor, at least two lines of decontamination should be established—one for personnel, and one for equipment. As personnel and equipment move from work assignments in the exclusion line toward the clean area, decontamination takes place and, therefore, the risk of contaminating the clear area diminishes.

While the essential layout of the contamination reduction zone is based on the need to decontaminate personnel and equipment (in the con-

tamination reduction corridor), it must also accommodate other important functions, including:

- Emergency response, including the transport of injured response personnel and emergency first aid
- Emergency containment equipment and operations
- Resupply of operational equipment, including PPC and PPE, sampling equipment, and tools
- Packaging and preparation of samples (e.g., soil, debris, hazardous wastes) for subsequent analysis
- Rest and recovery areas for response personnel, including toilet facilities, potable water, washing facilities
- Safe containment of all liquids and other materials used in the decontamination process

3. Support Zone

This is the clean area in which all response-related administrative duties and all other operations that need not be performed in either the exclusion or contaminant reduction zones are performed. While the support zone is operationally protected by the contamination control line, it should be noted that, as the emergency develops, necessary adjustments to the location of the contamination control line could result in adjustments to the location of support zone facilities, with consequent interference in overall incident management. The location of support zone facilities must therefore be based as much as possible on a worst-case analysis of the developing incident , while still maintaining practical administrative control of all on-site activities. Other factors in locating specific support zone facilities (e.g., incident command post, staging area, incident base, camps, helibase, and helispot) include:

- Accessibility for emergency vehicles and equipment
- Availability of electrical power, telephones, shelter, potable water, and roads
- Line-of-site visibility of incident-site operations (while still locating facilities as far away from the exclusion zone as possible)
- Wind direction and topography (which could influence intrusion of wind-blown or runoff-entrained contaminants into the support zone)

Removal of PPC and PPE

Depending on the nature of an actual incident and types and degrees of risk, the incident safety officer will establish (a) requirements for protec-

tive ensembles and equipment to be used by response personnel in the exposure zone, and (b) specific steps for removing and disinfecting each article in the process of moving from work areas within the exposure zone to the support zone.

As depicted in the example in Fig. 11.8, decontamination procedures extend (via the contamination reduction corridor) into both exclusion and support zones, even though they are most vigorous in the contamination reduction zone. Decontamination procedures designated for the exclusion zone are intended to prevent gross contamination of the contamination reduction zone; those designated for the contamination reduction corridor, to remove all remaining contamination prior to entry to the support zone.

The number and sequence of steps along the decontamination line depend upon actual site conditions, becoming more numerous and stringent with increasing hazards and risks associated with the exclusion zone. In some instances, it may be necessary to establish resting/cooling stations along the decontamination line—as when response operations must be undertaken under ambient conditions of high heat and humidity.

While typical layouts of decontamination stations (such as those included in Fig. 11.8) have long been established for incidents that involve hazardous waste, similar configurations (adaptations thereof) may be employed for incidents involving nonhazardous waste sites but which nonetheless present the hazard of contamination with physical, chemical, or biological agents. Of course, depending upon the nature of the contaminant hazard, different types of decontamination activities at the various stations of the decontamination line may have to be implemented.

Disposal of Contaminated Materials

A key consideration with regard to any decontamination line is the waste that is generated as a consequence of performing the various decontamination procedures, including:

- neutralization spray solution
- detergent wash solution
- disinfectant rinse solution
- rag and paper wipes
- clumps and scrapings of contaminated mud
- disposable PPC and PPE

The decontamination program must specify how these various wastes are to be packaged and disposed in compliance with applicable federal, state, and local regulations. It is important to distinguish between contaminated

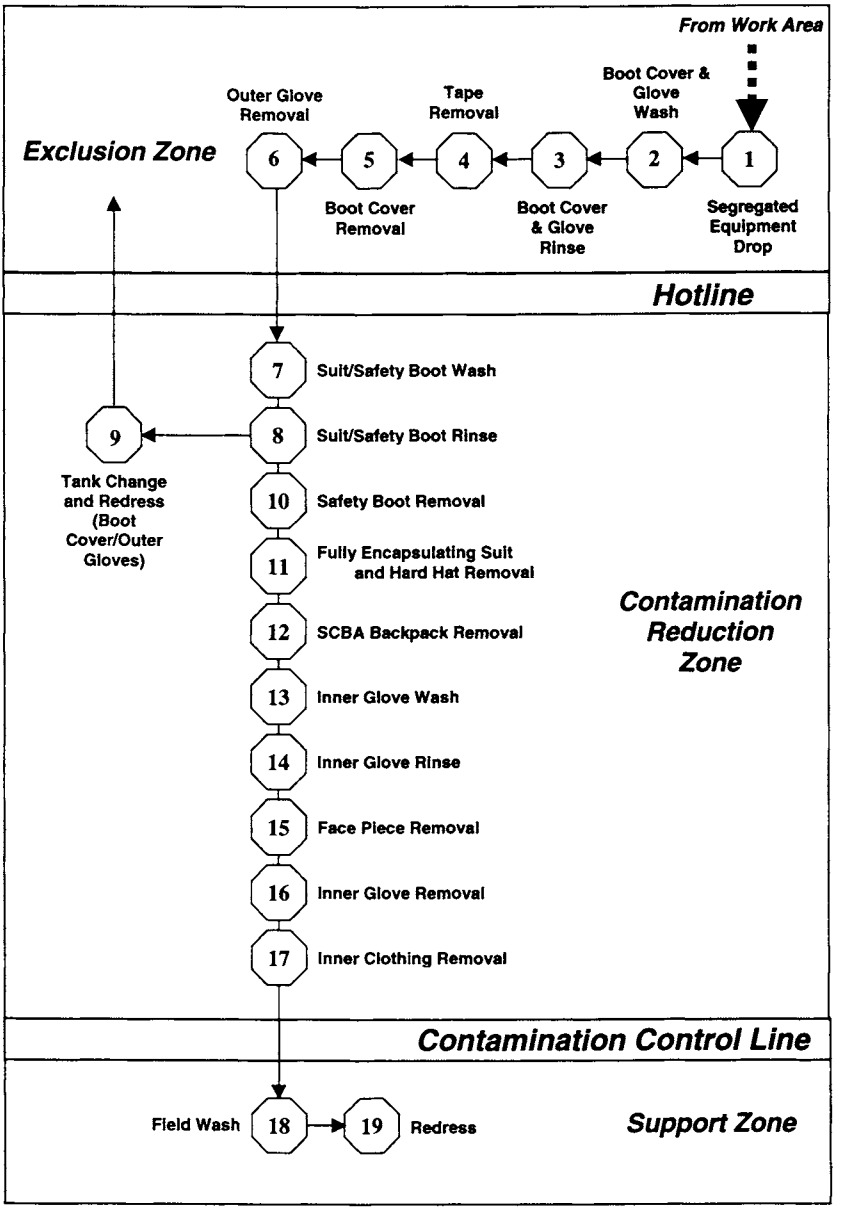

FIGURE 11.8 Maximum decontamination layout: level A protection (adapted from NIOSH, USCG, and EPA, 1985: Occupational Safety and Health Guidance Manual for Hazardous Waste Activities).

waste generated by the incident and that generated by on-site decontamination procedures designed for response personnel and equipment.

In many instances, for example, contaminated construction debris (e.g., from a collapsed building or other structure) presents a major obstacle to the primary response effort (e.g., search and rescue) and must be moved out of the way as quickly as possible. In such a situation, it is very unlikely that there will be time or resources to decontaminate debris; on-site storage, with provision for containment, must then be implemented. Once the primary response effort has been concluded by the lead responding agency, the management of bulk contaminated debris (including decontamination and disposal) typically becomes the responsibility of another agency having appropriate jurisdictional authority.

In some instances, contaminated PPC, PPE, and other response equipment are wrapped or placed in secure bulk containers for subsequent decontamination at the home-base of the response service.

EMERGENCY DECONTAMINATION

Emergency decontamination may have to be undertaken as a result of any on-site accident involving response personnel, whether that accident results in relatively minor or major injury to personnel. Figure 11.9 includes a standard decision guide for determining the steps to take in such a situation. While the various steps included in this guide are designed to maximize the administration of appropriate on- and/or off-site medical response to such an emergency, it is also important that the medical response not result in the contamination of on-site "clean areas" or of off-site medical personnel, facilities, or ambulance services.

Of course, in a life-threatening situation, it is the health of the injured worker that must be given priority, which sometimes requires a highly abbreviated on-site decontamination effort, consisting primarily of wrapping the victim in a protective covering (e.g., blanket, plastic) that can contain gross contamination and which can be later decontaminated and disposed. However, before wrapping the contaminated victim in a blanket or plastic sheet, it is vitally important to remove or cut off as much grossly contaminated clothing as possible in order to minimize contact of contaminants with the victim's body.

Any clothing gives some degree of protection against contamination and, of course, the protective clothing worn by response personnel is specifically selected to maximize protection. However, all clothing is subject to permeation by contaminants, the degree of permeation being subject to various factors (Fig. 11.10), including (a) the time interval in which contaminants are in contact with the clothing, (b) the physical state and chemical

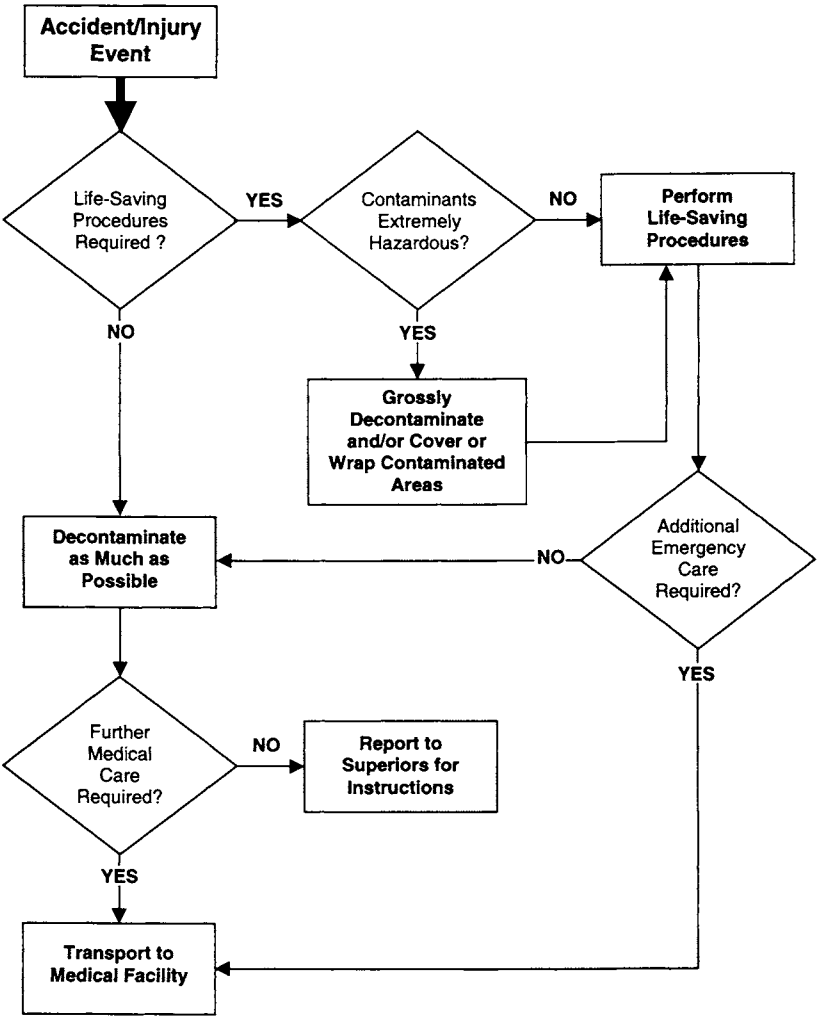

FIGURE 11.9 Decision guide for emergency decontamination (adapted from NIOSH, USCG, and EPA, 1985: Occupational Safety and Health Guidance Manual for Hazardous Waste Activities).

nature of the contaminant, (c) the concentration of the contaminant, and (d) the ambient temperature. In an emergency situation, it is therefore most advisable to strip the victim of any obvious contaminated clothing or equipment as quickly as possible. No attempt should be made to wash or rinse gross contamination off of the victim's clothing because this would most

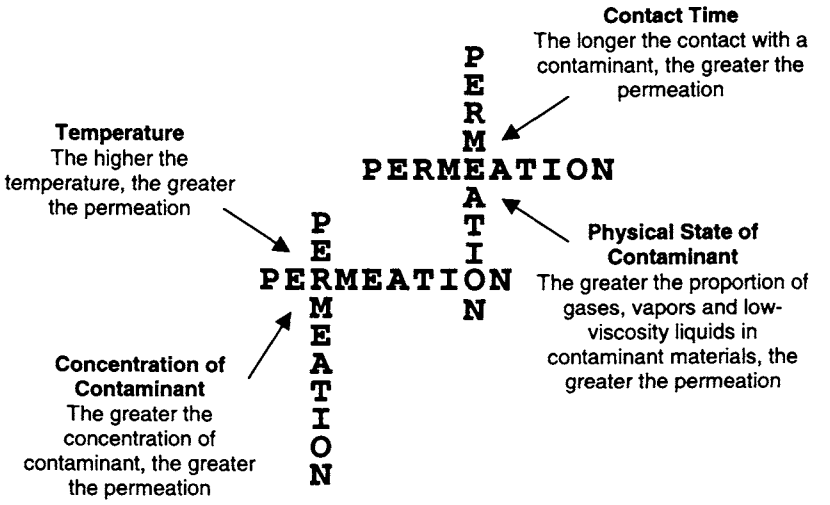

FIGURE 11.10 Four key factors that influence the permeation of contaminant chemicals into protective clothing and equipment (adapted from information provided by OSHA, OSHA Technical Manual, Section 7, OSHA Electronic Library).

likely increase the rate of permeation of the contaminant through that clothing. Depending on the nature of the contaminant, a wash or rinse solution could also result in enhanced risk due to unsuspected chemical or physical reactions of the contaminant with rinse solutions—a situation that usually cannot be reliably assessed in the press of an emergency.

In all situations involving the spillage of blood or the release of body fluids, appropriate decontamination (Fig. 11.11) should be implemented to minimize the potential for the spread of bloodborne diseases. This procedure, including the *universal precautions* always to be associated with handling blood and body fluids, is as applicable (and necessary) in an emergency situation as in any nonemergency situation and need not in any way interfere with the timely emergency treatment of the victim.

Where it is impossible to decontaminate the victim properly prior to off-site transport, it is important that the victim be accompanied to the off-site medical facility by a person who is fully knowledgeable of (a) the type of contaminant to which the victim has been exposed, (b) the nature of emergency decontamination that was performed on the victim while on-site , and (c) the appropriate types of decontamination and other precautions that medical, rescue, and other emergency personnel should employ during and subsequent to transporting, handling, and treating the victim.

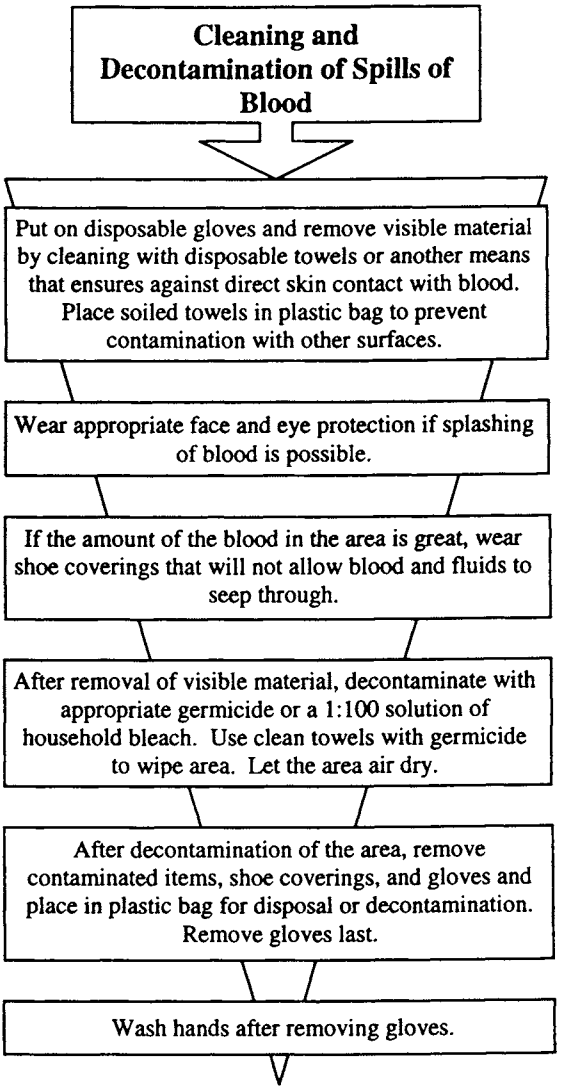

FIGURE 11.11 Directions for cleaning and decontaminating spills of blood (adapted from U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, 1989: A Curriculum Guide for Public-Safety and Emergency-Response Workers [89–108]).

Because the potential for injury of response personnel is always high, emergency decontamination and all associated activities (e.g., rescue), procedures (e.g., emergency first aid), and equipment (e.g., ventilation equipment in ambulances) must be viewed as an integral component of the site safety plan. The site safety officer must therefore ensure that all possible needs for decontamination as a result of response operations and contingencies be thoroughly examined and appropriate proactive policies and SOPs established. Moreover, because the need for emergency decontamination may (depending upon the nature of the incident) instantaneously escalate due to uncontrollable exposure of the general public, extensive planning is required to deal effectively with the decontamination of not only individual response personnel but also large community populations.

Given the potential scope of emergency decontamination in any incident (and, especially, in terrorist incidents), effective proactive planning depends heavily upon effective coordination with local, state, and Federal rescue, response, and support resources (Table 11.3) that are available to provide a wide range of services, including on-site emergency treatment of victims, the control and stabilization of hazardous conditions that could result in increased instances of exposure to contaminants, and the provision of technical assistance and equipment.

While it is typically the responsibility of the safety officer of the lead response organization to provide for the basic on-site equipment needed to control potential contaminants and to implement emergency decontamination (Table 11.4), no local response agency or organization can be expected to maintain sufficient equipment to meet the potential decontamination needs of large off-site populations. This situation underscores the importance of interagency and interorganizational liaison to ensure the regional stockpiling (e.g., in civil defense and state repositories) or other timely availability (e.g., Federal Emergency Management Agency, regional response team stockpiles) of equipment, materials, and supplies that can be used both to control the spread of contaminants into the general population and to effect, as needed, decontamination of large numbers of persons and vital community resources.

With regard to the local availability of equipment and supplies required proactively and reactively for the control of contaminants and incident-related decontamination, municipal managers should consider the use of municipal-wide inventories of potential industrial contaminants to identify potential equipment and supply needs, including not only the types and amounts of equipment and supplies that should be stockpiled or made available via requisition, but also needs regarding (a) the maintenance, upkeep, and replacement of identified equipment and supplies, (b) the timely transport of supplies under worst-case conditions, and (c) back-up supplies that may be needed in the event of simultaneous incidents.

TABLE 11.3 Types of Support Services Typically Available through Federal, State, and Local Support Services

Agency or Organization	Rescue	Response	Support
Federal			
Army Corps of Engineers			☐
Coast Guard		☐	☐
Department of Defense (DOD)		☐	☐
Department of Transportation			☐
Environmental Protection Agency (EPA)		☐	☐
Federal Aviation Administration (FAA)			☐
Federal Emergency Management Agency (FEMA)			☐
National Institute for Occupational Safety and Health (NIOSH)			☐
Occupational Safety and Health Administration (OSHA)			☐
State			
Civil defense			☐
Department of Health			☐
Department of Labor			☐
Environmental Agency		☐	☐
Office of the Attorney General			☐
State Police	☐		☐
Local			
Ambulance and rescue services	☐	☐	☐
Cleanup contractor	☐	☐	☐
Disposal companies	☐	☐	
Fire department	☐	☐	☐
Hospital			☐
Police	☐		☐
Red Cross			☐
Salvation Army			☐
Transporters			☐
Utility companies			☐

TABLE 11.4 Basic On-Site Equipment Used to Control Exposure to Contaminants and to Implement Emergency Decontamination Procedures

Personal Protection

- **Escape SCBA or SCBA, which can be brought to the victim to replace or supplement his or her SCBA**
- **Personal protective equipment and clothing specialized for known site hazards**

Medical

- **Air splints**
- **Decontamination solutions appropriate to onsite hazards**
- **Reference books containing basic first-aid procedures and information on treatment of specific injuries**
- **Antiseptics**
- **Emergency eye wash**
- **Resuscitator**
- **Safety Harness**
- **Stretchers**
- **Water, in potable containers**
- **Blankets**
- **Emergency showers or wash stations**
- **Wire basket litter (Stokes litter) which can be used to carry victim in bad weather and on difficult terrain, and is itself easy to decontaminate**

Hazard Mitigation

- **Fire-fighting equipment and supplies**
- **Spill-containment equipment, such as absorbents and oil booms**
- **Special hazardous-use tools, such as remote pneumatic impact wrenches, non-sparking wrenches and picks**
- **Containers to hold contaminated materials**

Toward the same objective, industrial managers should explore the potential for mutual assistance programs among industrial partners, with particular emphasis given to mock-incidents as a means of training multi-facility personnel to ensure the rapid delivery of fully operational contamination control equipment, supplies, and, as appropriate, personnel to the incident scene.