

9. Site Control

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Introduction

The purpose of site control is to minimize potential contamination of workers, protect the public from the site's hazards, and prevent vandalism. Site control is especially important in emergency situations. This chapter describes the basic components of a program to control the activities and movements of people and equipment at a hazardous waste site.

Several site control procedures can be implemented to reduce worker and public exposure to chemical, physical, biologic, and safety hazards:

- Compile a site map.
- Prepare the site for subsequent activities.
- Establish work zones.
- Use the buddy system when necessary.
- Establish and strictly enforce decontamination procedures for both personnel and equipment (see Chapter 10, *Decontamination*).
- Establish site security measures.
- Set up communication networks.
- Enforce safe work practices.

This chapter, based on EPA's *Standard Operating Safety Guides* [1], discusses general aspects of these eight control measures.

The degree of site control necessary depends on site characteristics, site size, and the surrounding community. The site control program should be established in the planning stages of a project and modified based on new information and site assessments (see Chapter 6, *Site Characterization*). The appropriate sequence for implementing these measures should be determined on a site specific basis. In many cases, it will be necessary to implement several measures simultaneously.

Site Map

A site map showing topographic features, prevailing wind direction, drainage, and the location of buildings, containers, impoundments, pits, ponds, and tanks is helpful in:

- Planning activities.
- Assigning personnel.
- Identifying access routes, evacuation routes, and problem areas.
- Identifying areas of the site that require use of personal protective equipment.
- Supplementing the daily safety and health briefings of the field teams.

The map should be prepared prior to site entry and updated throughout the course of site operations to reflect:

- Accidents.
- Changes in site activities.
- Emergencies.
- Hazards not previously identified.
- New materials introduced on site.
- Vandalism.
- Weather conditions.

Overlays can be used to help portray information without cluttering the map.

Site Preparation

Time and effort must be spent in preparing a site for the cleanup activity to ensure that response operations go smoothly and that worker safety is protected. Site preparation can be as hazardous as site cleanup. Therefore, safety measures should be afforded the same level of care at this stage as during actual cleanup. Table 9-1 presents the major steps in site preparation prior to any cleanup activities.

Site Work Zones

To reduce the accidental spread of hazardous substances by workers from the contaminated area to the clean area, zones should be delineated on the site where different types of operations will occur, and the flow of personnel among the zones should be controlled. The establishment of work zones will help ensure that: personnel are properly protected against the hazards present where they are working, work activities and contamination are confined to the appropriate areas, and personnel can be located and evacuated in an emergency.

Hazardous waste sites should be divided into as many different zones as needed to meet operational and safety objectives. For illustration, this manual describes three frequently used zones:

- *Exclusion Zone*, the contaminated area.
- *Contamination Reduction Zone (CRZ)*, the area where decontamination takes place.
- *Support Zone*, the uncontaminated area where workers should not be exposed to hazardous conditions.

Delineation of these three zones should be based on sampling and monitoring results and on an evaluation of potential routes and amount of contaminant dispersion in the event of a release. Movement

of personnel and equipment among these zones should be minimized and restricted to specific Access Control Points to prevent cross-contamination from contaminated areas to clean areas. A schematic representation of the layout of work zones is given in Figure 9-1.

Table 9-1. Site Preparation

- Construct roadways to provide ease of access and a sound roadbed for heavy equipment and vehicles.
- Arrange traffic flow patterns to ensure safe and efficient operations.
- Eliminate physical hazards from the work area as much as possible, including:
 - ignition sources in flammable hazard areas.
 - exposed or ungrounded electrical wiring, and low overhead wiring that may entangle equipment.
 - sharp or protruding edges, such as glass, nails, and torn metal, which can puncture protective clothing and equipment and inflict puncture wounds.
 - debris, holes, loose steps or flooring, protruding objects, slippery surfaces, or unsecured railings, which can cause falls, slips, and trips.
 - unsecured objects, such as bricks and gas cylinders, near the edges of elevated surfaces, such as catwalks, roof tops, and scaffolding, which may dislodge and fall on workers.
 - debris and weeds that obstruct visibility.
- Install skid-resistant strips and other anti-skid devices on slippery surfaces.
- Construct operation pads for mobile facilities and temporary structures.
- Construct loading docks, processing and staging areas, and decontamination pads.
- Provide adequate illumination for work activities. Equip temporary lights with guards to prevent accidental contact.
- Install all wiring and electrical equipment in accordance with the National Electric Code.

Exclusion Zone

The Exclusion Zone is the area where contamination does or could occur. The primary activities performed in the Exclusion Zone are:

- Site characterization, such as mapping, photographing, and sampling.
 - Installation of wells for groundwater monitoring.
- Cleanup work, such as drum movement, drum staging, and materials bulking.

The outer boundary of the Exclusion Zone, called the Hotline, should be established according to the criteria listed in Table 9-2. It should be clearly marked by lines, placards, hazard tape and/or signs; or enclosed by physical barriers, such as chains, fences, or ropes. Access Control Points should be established at the periphery of the Exclusion Zone to regulate the flow of personnel and equipment into and out of the zone and to help verify that proper procedures for entering and exiting are followed. If feasible, separate entrances and exits should be established to separate personnel and equipment movement into and out of the Exclusion Zone.

The Exclusion Zone can be subdivided into different areas of contamination based on the known or expected type and degree of hazard or on the incompatibility of waste streams. This allows more flexibility in safety requirements, operations, decontamination procedures, and use of resources.

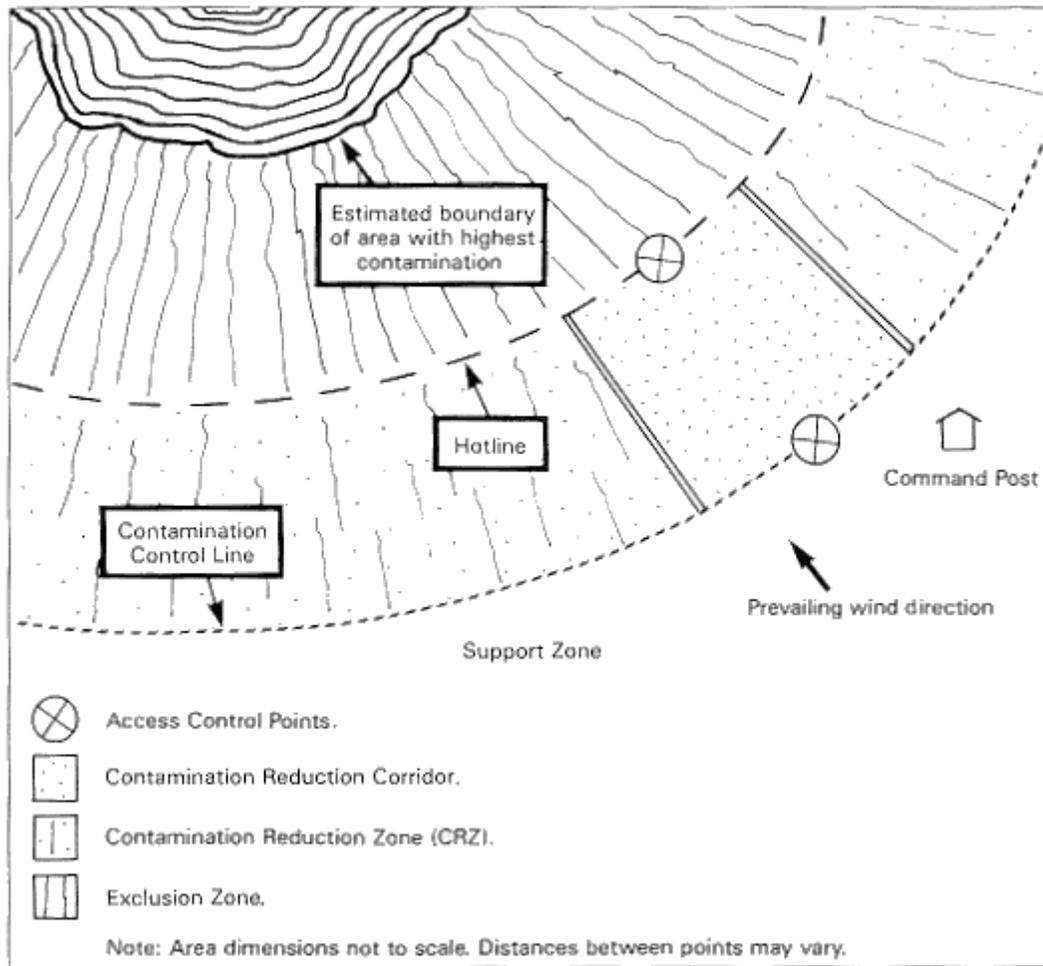


Figure 9-1. Site Work Zones. (Note that decontamination facilities are located in the Contamination Reduction Zone.)

The personnel working in the Exclusion Zone may include the Field Team Leader, the work parties, and specialized personnel such as heavy equipment operators. All personnel within the Exclusion Zone should wear the level of protection required by the Site Safety Plan. Within the zone, different levels of protection may be justified based on the degree of hazard presented. The level of personal protection required in each subarea (see Chapter 8, *Personal Protective Equipment*) should be specified and marked.

The required level of protection in the Exclusion Zone varies according to job assignment. For example, a worker who collects samples from open containers might require Level B protection, while one that performs walk-through ambient air monitoring might only need Level C protection. When appropriate, different levels of protection within the Exclusion Zone should be assigned to promote a more flexible, effective, and less costly operation, while still maintaining a high degree of safety.

Contamination Reduction Zone

The Contamination Reduction Zone (CRZ) is the transition area between the contaminated area and the clean area. This zone is designed to reduce the probability that the clean Support Zone will become contaminated or affected by other site hazards. The distance between the Exclusion and Support Zones provided by the CRZ, together with decontamination of workers and equipment, limits the physical

transfer of hazardous substances into clean areas. The boundary between the CRZ and the Exclusion Zone is called the Hotline. The degree of contamination in the CRZ decreases as one moves from the Hotline to the Support Zone, due both to the distance and the decontamination procedures.

Decontamination procedures take place in a designated area within the CRZ called the Contamination Reduction Corridor (CRC). They begin at the Hotline. At least two lines of decontamination stations should be set up within the CRC: one for personnel and one for heavy equipment. A large operation may require more than two lines. Access into and out of the CRZ from the Exclusion Zone is through Access Control Points: one each for personnel and equipment entrance, one each for personnel and equipment exit, if feasible.

Table 9-2. Establishing the Hotline

- Visually survey the immediate site environs.
- Determine the locations of:
 - hazardous substances
 - drainage, leachate, and spilled material
 - visible discolorations
- Evaluate data from the initial site survey indicating the presence of:
 - combustible gases
 - organic and inorganic gases, particulates, or vapors
 - ionizing radiation
- Evaluate the results of soil and water sampling.
- Consider the distances needed to prevent an explosion or fire from affecting personnel outside the Exclusion Zone.
- Consider the physical area necessary for site operations.
- Consider meteorological conditions and the potential for contaminants to be blown from the area.
- Secure or mark the Hotline.
- Modify its location, if necessary, as more information becomes available.

The boundary between the Support Zone and the CRZ, called the Contamination Control Line, separates the possibly low contamination area from the clean Support Zone. Access to the CRZ from the Support Zone is through two Access Control Points if feasible: one each for personnel and equipment. Personnel entering the CRZ should be required to wear the personal protective clothing and equipment prescribed for working in the CRZ. To reenter the Support Zone, workers should remove any protective clothing and equipment worn in the CRZ, and leave through the personnel exit Access Control Point.

The personnel stationed in the CRZ are usually the Site Safety Officer, a Personnel Decontamination Station (PDS) Operator, and the emergency response personnel. Additional personnel may assist the PDS Operator by conducting abbreviated decontamination procedures for sample containers.

The CRZ must be well designed to facilitate:

- Decontamination of equipment, PDS operators, personnel, and samples.
- Emergency response: transport for injured personnel (safety harness, stretcher), first-aid equipment (such as bandages, blankets, eye wash, splints, and water), containment equipment (absorbent, fire extinguisher).
- Equipment resupply: air tank changes, personal protective clothing and equipment (such as booties and gloves), sampling equipment (such as bottles and glass rods), and tools.
- Sample packaging and preparation for onsite or offsite laboratories.
- Worker temporary rest area: toilet facilities, bench, chair, liquids, and shade. Water and other potable liquids should be clearly marked and stored properly to ensure that all glasses and cups

are clean. Wash facilities should be located near drinking facilities to allow employees to wash before drinking. Drinking, washing, and toilet facilities should be located in a safe area where protective clothing can be removed. Facilities should be cleaned and inspected regularly. Appropriate protective measures should be taken by maintenance workers.

- Drainage of water and other liquids that are used during decontamination.

Personnel within the CRZ should be required to maintain internal communications, line-of-sight contact with work parties, work party monitoring (e.g., for air time left, fatigue, heat stress, hypothermia), and site security.

Support Zone

The Support Zone is the location of the administrative and other support functions needed to keep the operations in the Exclusion and Contamination Reduction Zones running smoothly. Any function that need not or cannot be performed in a hazardous or potentially hazardous area is performed here. The Command Post Supervisor should be present in the Support Zone. Other personnel present will depend on the functions being performed, and may include the Project Team Leader and field team members who are preparing to enter or who have returned from the Exclusion Zone.

Personnel may wear normal work clothes within this zone. Any potentially contaminated clothing, equipment, and samples must remain in the CRZ until decontaminated.

Support Zone personnel are responsible for alerting the proper agency in the event of an emergency. All emergency telephone numbers, change for the telephone (if necessary), evacuation route maps, and vehicle keys should be kept in the Support Zone.

Support facilities, listed in Table 9-3, are located in the Support Zone. To place these facilities, consider factors such as:

- Accessibility. Topography, open space available, locations of highways and railroad tracks, ease of access for emergency vehicles.
- Resources. Adequate roads, power lines, telephones, shelter, and water.
- Visibility. Line-of-sight to all activities in the Exclusion Zone.
- Wind direction. Upwind of the Exclusion Zone, if possible.
- Distance. As far from the Exclusion Zone as practicable.

Table 9-3. Support Zone Activities

FACILITY	FUNCTION
Command Post	<p>Supervision of all field operations and field teams. Maintenance of communications, including emergency lines of communication. Recordkeeping, including:</p> <ul style="list-style-type: none"> - accident reports - chain-of-custody records - daily logbooks - manifest directories and orders - medical records - personnel training records - site inventories - site safety map - up-to-date Site Safety Plans <p>Providing access to up-to-date safety and health manuals and other reference materials. Interfacing with the public: government agencies, local politicians, medical personnel, the media, and other interested parties. Monitoring work schedules and weather changes. Maintaining site security. Sanitary facilities.</p>
Medical Station	<p>First-aid administration. Medical emergency response. Medical monitoring activities. Sanitary facilities.</p>
Equipment and Supply Centers	<p>Supply, maintenance, and repair of communications, respiratory, and sampling equipment. Maintenance and repair of vehicles. Replacement of expendable supplies. Storage of monitoring equipment and supplies. Storage may be here or in an onsite field laboratory.</p>
Administration	<p>Sample shipment.. Interface with home office. Maintenance of emergency telephone numbers, evacuation route maps, and vehicle keys. Coordination with transporters, disposal sites, and appropriate federal, state, and local regulatory agencies.</p>
Field Laboratory	<p>Coordination and processing of environmental and hazardous waste samples. Copies of the sampling plans and procedures should be available for quick reference in the laboratory. Packaging of materials for analysis following the decontamination of the outsides of the sample containers which should be done in the CRZ. This packaging can also be done in ad designated location in the CRZ. Shipping papers and chain-of-custody files should be kept in the Command Post.. Maintenance and storage of laboratory notebooks in designated locations in the laboratory while in use, and in the Command Post when not in use.</p>

The Buddy System

Most activities in contaminated or otherwise hazardous areas should be conducted with a buddy who is able to:

- Provide his or her partner with assistance.
- Observe his or her partner for signs of chemical or heat exposure.
- Periodically check the integrity of his or her partner's protective clothing.
- Notify the Command Post Supervisor or others if emergency help is needed.

The Access Control Point for personnel entrance to the Exclusion Zone is a convenient location for enforcing the buddy system for two reasons: enforcement is the responsibility of the Project Team Leader, who is stationed in the CRZ, and all personnel who enter the contaminated area must pass through the control point.

The buddy system alone may not be sufficient to ensure that help will be provided in an emergency. At all times, workers in the Exclusion Zone should be in line-of-sight contact or communications contact with the Command Post Supervisor or backup person in the Support Zone.

Site Security

Site security is necessary to:

- Prevent the exposure of unauthorized, unprotected people to site hazards.
- Avoid the increased hazards from vandals or persons seeking to abandon other wastes on the site.
- Prevent theft.
- Avoid interference with safe working procedures.

To maintain site security during working hours:

- Maintain security in the Support Zone and at Access Control Points.
- Establish an identification system to identify authorized persons and limitations to their approved activities.
- Assign responsibility for enforcing authority for entry and exit requirements.
- Erect a fence or other physical barrier around the site.
- If the site is not fenced, post signs around the perimeter and use guards to patrol the perimeter. Guards must be fully apprised of the hazards involved and trained in emergency procedures.



Warning signs and fences help to prevent exposure of unauthorized and unprotected people to site hazards.

Have the Project Team Leader approve all visitors to the site. Make sure they have a valid purpose for entering the site. Have trained site personnel accompany visitors at all times and provide them with the appropriate protective equipment. To maintain site security during off-duty hours:

- If possible, assign trained, in-house technicians for site surveillance. They will be familiar with the site, the nature of the work, the site's hazards, and respiratory protection techniques.

- If necessary, use security guards to patrol the site boundary. Such personnel may be less expensive than trained technicians, but will be more difficult to train in safety procedures and will be less confident in reacting to problems around hazardous substances.
- Enlist public enforcement agencies, such as the local police department, if the site presents a significant risk to local health and safety.
- Secure the equipment.

Communication Systems

Two sets of communication systems should be established: internal communication among personnel on site, and external communication between onsite and offsite personnel.

Internal communication is used to:

- Alert team members to emergencies.
- Pass along safety information, such as the amount of air time left before the next rest period, air change, heat stress check, etc.
- Communicate changes in the work to be accomplished.
- Maintain site control.

Verbal communication at a site can be impeded by onsite background noise and the use of personal protective equipment. For example, speech transmission through a respirator can be poor, and hearing can be impaired by protective hoods and respirator air flow. For effective communication, commands must be pre-arranged. In addition, audio or visual cues can help convey the message. The most important thing is that signals are agreed to in advance.

Table 9-4 lists common internal communication devices. Both a primary and backup system are necessary. A set of signals should be established for use only during emergencies (see Table 12-4 in Chapter 12 for examples).

Effective internal communication also requires the identification of individual workers so that commands can be addressed to the right worker. The worker's name should be marked on the suit and, for long-distance identification, color coding, numbers, or symbols can be added. Flags may be used to help locate personnel in areas where visibility is poor due to obstructions such as accumulated drums, equipment, and waste piles.

All communication devices used in a potentially explosive atmosphere must be intrinsically safe (see footnote in Table 9-4) and not capable of sparking, and should be checked daily to ensure that they are operating.

An external communication system between onsite and offsite personnel is necessary to:

- Coordinate emergency response.
- Report to management.
- Maintain contact with essential offsite personnel.

The primary means of external communication are telephone and radio. If telephone lines are not installed at a site, all team members should know the location of the nearest telephone, and the correct change and necessary telephone numbers should be readily available in the Support Zone.

Table 9-4. Internal Communication Devices

Radio^a.

- Citizen's band
- FM

Noisemakers, including:

- Bell
- Compressed air horn
- Megaphone
- Siren
- Whistle

Visual signals, including:

- Flag
- Flares or smoke^b
- Hand signals
- Lights
- Signal board
- Whole body movements

^aAll radios used in the Exclusion and Contamination Reduction Zones must be certified as intrinsically safe for the situation of intended use [2,3].

^bOnly from the Support Zone.

Safe Work Practices

To maintain a strong safety awareness and enforce safe procedures at a site, a list of standing orders should be developed which state the practices that must always be followed and those that must never occur in the contaminated areas on site. Separate standing orders should be developed for the Contamination Reduction Zone and the Exclusion Zone if the hazards are sufficiently different. Sample standing orders are given in Table 9-5. To ensure that everyone who enters the site is aware of these orders and that a high degree of familiarity with their content is maintained, the list should be:

- Distributed to everyone who enters the site.
- Posted conspicuously at the Command Post.
- Posted conspicuously at the entrance Access Control Points into the Contamination Reduction Zone and/or the Exclusion Zone.
- Reviewed by the Field Team Leader or Project Team Leader with the field crew at the beginning of each workday. In this way, personnel are immediately informed of any new standing orders resulting from a change in site conditions or work activities.

In addition to the standing orders, a hazardous substance information form that lists the names and properties of chemicals present on site should be prepared and posted conspicuously. Employees should be briefed on the chemical information at the beginning of the project or whenever they first join the work team. Daily safety meetings should be held for all employees.

Table 9-5. Sample Standing Orders

For Personnel Entering the Contamination Reduction Zone:

- No smoking, eating, drinking, or application of cosmetics in this zone.
- No matches or lighters in this zone.
- Check in at the entrance Access Control Point before you enter this zone.
- Check out at the exit Access Control Point before you enter this zone.

For Personnel Entering the Exclusion Zone:

- No smoking, eating, drinking, or application of cosmetics in this zone.
- No matches or lighters in this zone.
- Check in at the entrance Access Control Point before you enter this zone.
- Check out at the exit Access Control Point before you enter this zone.
- Always have your buddy with you in this zone.
- Wear an SCBA in this zone.
- If you discover any signs of radioactivity, explosivity, or unusual conditions such as dead animals at the site, exit immediately and report this finding to your supervisor.

Working with tools and heavy equipment is a major hazard at sites. Injuries can result from equipment hitting or running over personnel, impacts from flying objects, burns from hot objects, and damage to protective equipment such as supplied-air respirator systems (see Chapter 8). The following precautions will help preclude injuries due to such hazards:

- Train personnel in proper operating procedures.
- Install adequate onsite roads, signs, lights, and devices.
- Install appropriate equipment guards and engineering controls on tools and equipment. These include rollover protective structures, seat belts, emergency shutoff in case of rollover, and backup warning lights and signals.
- Provide equipment such as cranes, derricks, and power shovels with signs saying "Unlawful to operate this equipment within 10 feet of all power lines."
- Use equipment and tools that are intrinsically safe (see footnote in Table 9-4) and not capable of sparking, and pneumatically and hydraulically driven equipment.
- Where portable electric tools and appliances can be used, (i.e., where there is no potential for flammable or explosive conditions), use three-wire grounded extension cords to prevent electric shocks.
- In hydraulic power tools, use fire-resistant fluid that is capable of retaining its operating characteristics at the most extreme temperatures.
- At the start of each workday, inspect brakes, hydraulic lines, light signals, fire extinguishers, fluid levels, steering, and splash protection.
- Keep all non-essential people out of the work area.
- Prohibit loose-fitting clothing or loose long hair around moving machinery.
- Keep cabs free of all non-essential items and secure all loose items.
- Do *not* exceed the rated load capacity of a vehicle.
- Instruct equipment operators to report to their supervisor(s) any abnormalities such as equipment failure, oozing liquids, unusual odors, etc.
- When an equipment operator must negotiate in tight quarters, provide a second person to ensure adequate clearance.
- Have a signalman direct backing as necessary.

- All onsite internal combustion engines should have spark arrestors that meet requirements for hazardous atmospheres. Refuel in safe areas. Do *not* fuel engines while vehicle is running. Prohibit ignition sources near a fuel area.
- Lower all blades and buckets to the ground and set parking brakes before shutting off the vehicle.
- Implement an ongoing maintenance program for all tools and equipment. Inspect all tools and moving equipment regularly to ensure that parts are secured and intact with no evidence of cracks or areas of weakness, that the equipment turns smoothly with no evidence of wobble, and that it is operating according to manufacturer's specifications. Promptly repair or replace any defective items. Keep maintenance and repair logs.
- Store tools in clean, secure areas so that they will not be damaged, lost, or stolen.
- Keep all heavy equipment that is used in the Exclusion Zone in that zone until the job is done. Completely decontaminate such equipment before moving it into the clean zone.

References

1. U.S. EPA. 1984. Standard Operating Safety Guides. EPA Office of Emergency and Remedial Response, Hazardous Response Support Division, Edison, NJ.
2. National Fire Protection Association. National Electrical Code, Chapter 5. Articles 500-503. National Fire Codes, NFPA 70.
3. National Fire Protection Association. Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous Classified Locations. National Fire Codes, NFPA 497M.

10. Decontamination

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Introduction

Decontamination - the process of removing or neutralizing contaminants that have accumulated on personnel and equipment - is critical to health and safety at hazardous waste sites. Decontamination protects workers from hazardous substances that may contaminate and eventually permeate the protective clothing, respiratory equipment, tools, vehicles, and other equipment used on site; it protects all site personnel by minimizing the transfer of harmful materials into clean areas; it helps prevent mixing of incompatible chemicals; and it protects the community by preventing uncontrolled transportation of contaminants from the site.

This chapter describes the types of contamination that workers may encounter at a waste site, the factors that influence the extent of contamination, and methods for preventing or reducing contamination. In addition, this chapter provides general guidelines for designing and selecting decontamination procedures at a site, and it presents a decision aid for evaluating the health and safety aspects of decontamination methods. The chapter does not cover decontamination of radioactively contaminated personnel or equipment. A health physicist should be consulted if this situation arises.

Decontamination Plan

A decontamination plan should be developed (as part of the Site Safety Plan) and set up before any personnel or equipment may enter areas where the potential for exposure to hazardous substances exists. The decontamination plan should:

- Determine the number and layout of decontamination stations.

- Determine the decontamination equipment needed.
- Determine appropriate decontamination methods.
- Establish procedures to prevent contamination of clean areas.
- Establish methods and procedures to minimize worker contact with contaminants during removal of personal protective clothing and equipment (PPE).
- Establish methods for disposing of clothing and equipment that are not completely decontaminated.

The plan should be revised whenever the type of personal protective clothing or equipment changes, the site conditions change, or the site hazards are reassessed based on new information.

Prevention of Contamination

The first step in decontamination is to establish Standard Operating Procedures that minimize contact with waste and thus the potential for contamination. For example:

- Stress work practices that minimize contact with hazardous substances (e.g., do not walk through areas of obvious contamination, do not directly touch potentially hazardous substances).
- Use remote sampling, handling, and container opening techniques (e.g., drum grapplers, pneumatic impact wrenches).
- Protect monitoring and sampling instruments by bagging. Make openings in the bags for sample ports and sensors that must contact site materials.
- Wear disposable outer garments and use disposable equipment where appropriate.
- Cover equipment and tools with a strippable coating which can be removed during decontamination.
- Encase the source of contaminants, e.g., with plastic sheeting or overpacks.

In addition, Standard Operating Procedures should be established that maximize worker protection. For example, proper procedures for dressing prior to entering the Exclusion Zone will minimize the potential for contaminants to bypass the protective clothing and escape decontamination. In general, all fasteners should be used (i.e., zippers fully closed, all buttons used, all snaps closed, etc.). Gloves and boots should be tucked under the sleeves and legs of outer clothing, and hoods (if not attached) should be worn outside the collar. Another pair of tough outer gloves is often worn over the sleeves. All junctures should be taped to prevent contaminants from running inside the gloves, boots, and jackets (or suits, if one-piece construction).

Prior to each use, the personal protective equipment (PPE) should be checked to ensure that it contains no cuts or punctures that could expose workers to wastes. Similarly, any injuries to the skin surface, such as cuts and scratches, may enhance the potential for chemicals or infectious agents that directly contact the worker's skin to penetrate into the body. Particular care should be taken to protect these areas. Workers with large areas of damaged skin should be kept from working on site until the skin heals.

All personnel should be trained in the Standard Operating Procedures for minimizing contact and maximizing worker protection, and these procedures should be enforced throughout site operations.

Types of Contamination

Contaminants can be located either on the surface of personal protective equipment or permeated into the PPE material. Surface contaminants may be easy to detect and remove; however, contaminants that have permeated a material are difficult or impossible to detect and remove. If contaminants that have permeated a material are not removed by decontamination, they may continue to permeate to either surface of the material where they can cause an unexpected exposure.

Five major factors affect the extent of permeation:

- **Contact time.** The longer a contaminant is in contact with an object, the greater the probability and extent of permeation. For this reason, minimizing contact time is one of the most important objectives of a decontamination program.
- **Concentration.** Molecules flow from areas of high concentration to areas of low concentration. As concentrations of wastes increase, the potential for permeation of personal protective clothing increases.
- **Temperature.** An increase in temperature generally increases the permeation rate of contaminants.
- **Size of contaminant molecules and pore space.** Permeation increases as the contaminant molecule becomes smaller, and as the pore space of the material to be permeated increases.
- **Physical state of wastes.** As a rule, gases, vapors, and low-viscosity liquids tend to permeate more readily than high-viscosity liquids or solids.

Decontamination Methods

All personnel, clothing, equipment, and samples leaving the contaminated area of a site (generally referred to as the Exclusion Zone) must be decontaminated to remove any harmful chemicals or infectious organisms that may have adhered to them.

Decontamination methods either (1) physically remove contaminants, (2) inactivate contaminants by chemical detoxification or disinfection/sterilization, or (3) remove contaminants by a combination of both physical and chemical means. Various decontamination methods are listed in Table 10-1.

Physical Removal

In many cases, gross contamination can be removed by physical means involving dislodging/displacement, rinsing, wiping off, and evaporation. Physical methods involving high pressure and/or heat should be used only as necessary and with caution since they can spread contamination and cause burns. Contaminants that can be removed by physical means can be categorized as follows:

- **Loose contaminants.** Dusts and vapors that cling to equipment and workers or become trapped in small openings, such as the weave of the clothing fabrics, can be removed with water or a liquid rinse (see photograph). Removal of electrostatically attached materials can be enhanced by coating the clothing or equipment with anti-static solutions. These are available commercially as wash additives or anti-static sprays.
- **Adhering contaminants.** Some contaminants adhere by forces other than electrostatic attraction. Adhesive qualities vary greatly with the specific contaminants and the temperature. For example, contaminants such as glues, cements, resins, and muds

have much greater adhesive properties than elemental mercury and, consequently, are difficult to remove by physical means. Physical removal methods for gross contaminants include scraping, brushing, and wiping. Removal of adhesive contaminants can be enhanced through certain methods such as solidifying, freezing (e.g., using dry ice or ice water), adsorption or absorption (e.g., with powdered lime or kitty litter), or melting.

- Volatile liquids. Volatile liquid contaminants can be removed from protective clothing or equipment by evaporation followed by a water rinse. Evaporation of volatile liquids can be enhanced by using steam jets. With any evaporation or vaporization process, care must be taken to prevent worker inhalation of the vaporized chemicals.

Table 10-1. Some Decontamination Methods

REMOVAL:

- **Contaminant Removal**

- Water rinse, using pressurized or gravity flow.
- Chemical leaching and extraction.
- Evaporation/vaporization.
- Pressurized air jets.
- Scrubbing/scraping. Commonly done using brushes, scrapers, or sponges and water-compatible solvent cleaning solutions.
- Steam jets.

- **Removal of Contaminated Surfaces**

- Disposal of deeply permeated materials, e.g., clothing, floor mats, and seats.
- Disposal of protective coverings/coatings.

INACTIVATION

- **Chemical Detoxification**

- Halogen stripping.
- Neutralization.
- Oxidation/reduction.
- Thermal degradation.

- **Disinfection/Sterilization**

- Chemical disinfection.
- Dry heat sterilization.
- Gas/vapor sterilization.
- Irradiation.
- Steam sterilization.

Chemical Removal

Physical removal of gross contamination should be followed by a wash/rinse process using cleaning solutions. These cleaning solutions normally utilize one or more of the following methods:

- Dissolving contaminants. Chemical removal of surface contaminants can be accomplished by dissolving them in a solvent. The solvent must be chemically compatible with the equipment being cleaned. This is particularly important when decontaminating personal protective clothing constructed of organic materials that could be damaged or dissolved by organic solvents. In addition, care must be taken in selecting, using, and disposing of any organic solvents that may be flammable or potentially toxic. Organic solvents include alcohols, ethers, ketones, aromatics, straight-chain alkanes, and common petroleum products.

- Halogenated solvents generally are incompatible with personal protective equipment and are toxic. They should only be used for decontamination in extreme cases where other cleaning agents will not remove the contaminant.
- Table 10-2 provides a general guide to the solubility of several contaminant categories in four types of solvents: water, dilute acids, dilute bases, and organic solvents. Because of the potential hazards, decontamination using chemicals should be done only if recommended by an industrial hygienist or other qualified health professional.
- Surfactants. Surfactants augment physical cleaning methods by reducing adhesion forces between contaminants and the surface being cleaned, and by preventing redeposit of the contaminants. Household detergents are among the most common surfactants. Some detergents can be used with organic solvents to improve the dissolving and dispersal of contaminants into the solvent [1].
- Solidification. Solidifying liquid or gel contaminants can enhance their physical removal. The mechanisms of solidification are: (1) moisture removal through the use of absorbents such as grounded clay or powdered lime; (2) chemical reactions via polymerization catalysts and chemical reagents; and (3) freezing using ice water.
- Rinsing. Rinsing removes contaminants through dilution, physical attraction, and solubilization. Multiple rinses with clean solutions remove more contaminants than a single rinse with the same volume of solution. Continuous rinsing with large volumes will remove even more contaminants than multiple rinsings with a lesser total volume.
- Disinfection/Sterilization. Chemical disinfectants are a practical means of inactivating infectious agents. Unfortunately, standard sterilization techniques are generally impractical for large equipment and for personal protective clothing and equipment. For this reason, disposable PPE is recommended for use with infectious agents.



Gross contaminants can be removed with water or a liquid rinse. Here, a member of the decontamination team rinses and scrubs the boots of a worker with a soft-bristled brush. Both individuals are wearing Level C personal protective equipment.

Many factors, such as cost, availability, and ease of implementation, influence the selection of a decontamination method. From a health and safety standpoint, two key questions must be addressed:

- Is the decontamination method effective for the specific substances present?
- Does the method itself pose any health or safety hazards?

Table 10-2. General Guide to Solubility of Contaminants in Four Solvent Types

SOLVENT	SOLUBLE CONTAMINANTS
Water	Low-chain hydrocarbons. Inorganic compounds. Salts. Some organic acids and other polar compounds.
Dilute Acids	Basic (caustic) compounds. Amines. Hydrazines.
Dilute Bases For example - detergent - soap	Acidic compounds. Phenols. Thiols. Some nitro and sulfonic compounds.
Organic Solvents^a For example: - alcohols - ethers - ketones - aromatics - straight-chain alkalines (e.g., hexane) - common petroleum products (e.g., fuel oil, kerosene)	Nonpolar compounds (e.g., some organic compounds).

^aWARNING: Some organic solvents can permeate and/or degrade the protective clothing.

Testing for the Effectiveness of Decontamination

Decontamination methods vary in their effectiveness for removing different substances. The effectiveness of any decontamination method should be assessed at the beginning of a program and periodically throughout the lifetime of the program. If contaminated materials are not being removed or are penetrating protective clothing, the decontamination program must be revised. The following methods may be useful in assessing the effectiveness of decontamination.

Visual Observation

There is no reliable test to immediately determine how effective decontamination is. In some cases, effectiveness can be estimated by visual observation.

- Natural light. Discolorations, stains, corrosive effects, visible dirt, or alterations in clothing fabric may indicate that contaminants have not been removed. However, not all contaminants leave visible traces; many contaminants can permeate clothing and are not easily observed.

- Ultraviolet light. Certain contaminants, such as polycyclic aromatic hydrocarbons, which are common in many refined oils and solvent wastes, fluoresce and can be visually detected when exposed to ultraviolet light. Ultraviolet light can be used to observe contamination of skin, clothing, and equipment; however, certain areas of the skin may fluoresce naturally, thereby introducing an uncertainty into the test [2,3,4]. In addition, use of ultraviolet light can increase the risk of skin cancer and eye damage; therefore, a qualified health professional should assess the benefits and risks associated with ultraviolet light prior to its use at a waste site.

Wipe Sampling

Wipe testing provides after-the-fact information on the effectiveness of decontamination. In this procedure, a dry or wet cloth, glass fiber filter paper, or swab is wiped over the surface of the potentially contaminated object and then analyzed in a laboratory. Both the inner and outer surfaces of protective clothing should be tested. Skin may also be tested using wipe samples.

Cleaning Solution Analysis

Another way to test the effectiveness of decontamination procedures is to analyze for contaminants left in the cleaning solutions. Elevated levels of contaminants in the final rinse solution may suggest that additional cleaning and rinsing are needed.

Testing for Permeation

Testing for the presence of permeated chemical contaminants requires that pieces of the protective garments be sent to a laboratory for analysis.

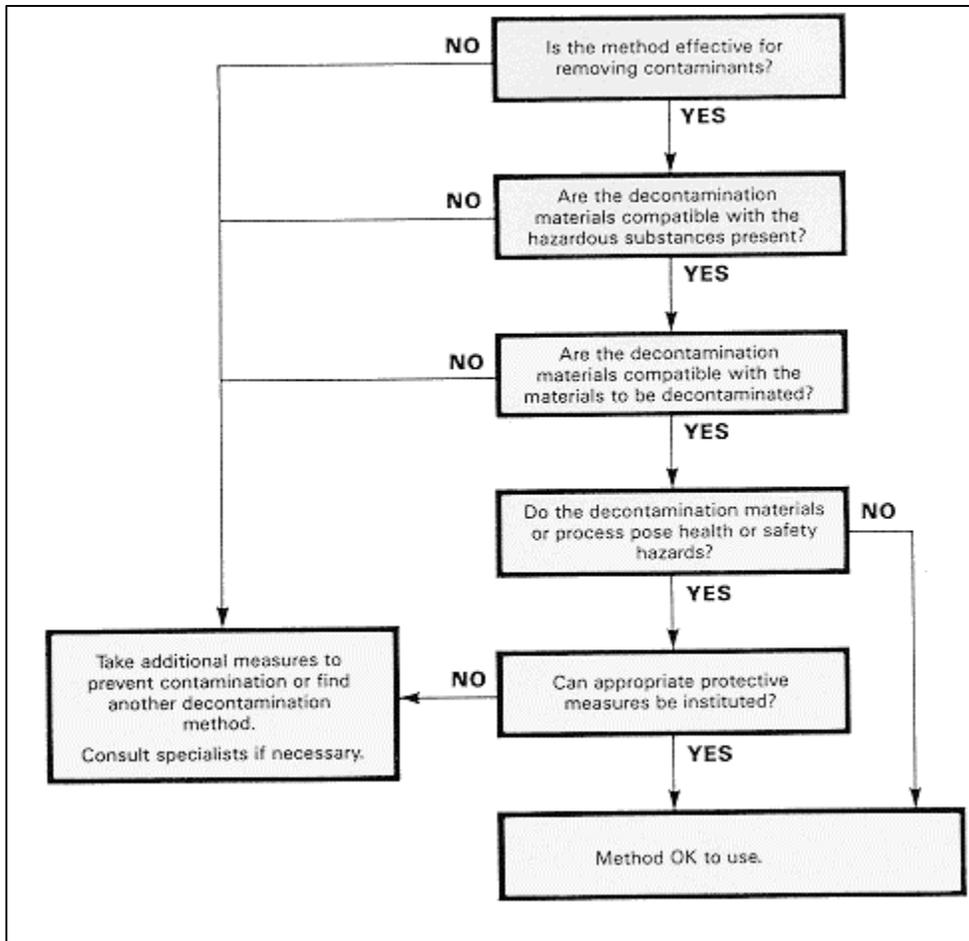
Health and Safety Hazards

While decontamination is performed to protect health and safety, it can pose hazards under certain circumstances. Decontamination methods may:

- Be incompatible with the hazardous substances being removed (i.e., a decontamination method may react with contaminants to produce an explosion, heat, or toxic products).
- Be incompatible with the clothing or equipment being decontaminated (e.g., some organic solvents can permeate and/or degrade protective clothing).
- Pose a direct health hazard to workers (e.g., vapors from chemical decontamination solutions may be hazardous if inhaled, or they may be flammable).

The chemical and physical compatibility of the decontamination solutions or other decontamination materials must be determined before they are used. Any decontamination method that permeates, degrades, damages, or otherwise impairs the safe functioning of the PPE is incompatible with such PPE and should not be used. If a decontamination method does pose a direct health hazard, measures must be taken to protect both decontamination personnel and the workers being decontaminated. Figure 10-1 presents a decision aid for evaluating the health and safety aspects of decontamination methods.

Figure 10-1. Decision Aid for Evaluating Health and Safety Aspects of Decontamination Methods.



Decontamination Facility Design

At a hazardous waste site, decontamination facilities should be located in the Contamination Reduction Zone (CRZ), i.e., the area between the Exclusion Zone (the contaminated area) and the Support Zone (the clean area) as shown in Figure 9-1 in Chapter 9.

The level and types of decontamination procedures required depend on several site-specific factors including:

- The chemical, physical, and toxicological properties of the wastes.
- The pathogenicity of infectious wastes.
- The amount, location, and containment of contaminants.
- The potential for, and location of, exposure based on assigned worker duties, activities, and functions.
- The potential for wastes to permeate, degrade, or penetrate materials used for personal protective clothing and equipment, vehicles, tools, buildings, and structures.
- The proximity of incompatible wastes.
- The movement of personnel and/or equipment among different zones.
- Emergencies.
- The methods available for protecting workers during decontamination.
- The impact of the decontamination process and compounds on worker safety and health.

Decontamination procedures must provide an organized process by which levels of contamination are reduced. The decontamination process should consist of a series of procedures performed in a specific sequence. For example, outer, more heavily contaminated items (e.g., outer boots and gloves) should be decontaminated and removed first, followed by decontamination and removal of inner, less contaminated items (e.g., jackets and pants). Each procedure should be performed at a separate station in order to prevent cross contamination. The sequence of stations is called the decontamination line.

Stations should be separated physically to prevent cross contamination and should be arranged in order of decreasing contamination, preferably in a straight line. Separate flow patterns and stations should be provided to isolate workers from different contamination zones containing incompatible wastes. Entry and exit points should be conspicuously marked, and the entry to the Contamination Reduction Zone (CRZ) from the Exclusion Zone should be separate from the entry to the Exclusion Zone from the CRZ. Dressing stations for entry to the CRZ should be separate from redressing areas for exit from the CRZ. Personnel who wish to enter clean areas of the decontamination facility, such as locker rooms, should be completely decontaminated.

Examples of decontamination lines and procedures for personnel wearing various levels of protection are provided in Appendix D.



A member of the decontamination team suited in Level B personal protective equipment stands by to scrub down a worker after an initial rinse down in the decontamination shower

Decontamination Equipment Selection

Table 10-3 lists recommended equipment for decontamination of personnel, personal protective clothing, and equipment. In selecting decontamination equipment, consider whether the equipment itself can be decontaminated for reuse or can be easily disposed of. Table 10-4 lists recommended equipment for decontamination of large equipment and vehicles. Note that other types of equipment Table 10-3. Note that other types of equipment not listed in Tables 10-3 and 10-4 may be appropriate in certain situations.

Table 10-3. Some Recommended Equipment for Decontamination of Personnel and Personal Protective Clothing and Equipment

- 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.
- Lined 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, soft-bristled 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.

Table 10-4. Some Recommended Equipment for Heavy Equipment and Vehicle Decontamination

- Storage tanks of appropriate treatment systems for temporary storage and/or treatment of contaminated wash and rinse solutions.
- Drains 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 operator 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.

Disposal Methods

All equipment used for decontamination must be decontaminated and/or disposed of properly. Buckets, brushes, clothing, tools, and other contaminated equipment should be collected, placed in containers, and labeled. Also, all spent solutions and wash water should be collected and disposed of properly. Clothing that is not completely decontaminated should be placed in plastic bags, pending further decontamination and/or disposal.

Personal Protection

Decontamination workers who initially come in contact with personnel and equipment leaving the Exclusion Zone will require more protection from contaminants than decontamination workers who are assigned to the last station in the decontamination line. In some cases, decontamination personnel should wear the same levels of PPE as workers in the Exclusion Zone. In other cases, decontamination personnel may be sufficiently protected by wearing one level lower protection (e.g., wearing Level C protection while decontaminating workers who are wearing Level B).

The level of protection required will vary with the type of decontamination equipment used. For example, workers using a steam jet may need a different type of respiratory protection than other decontamination personnel because of the high moisture levels produced by steam jets. In some situations, the cleaning solutions used and wastes removed during decontamination may generate harmful vapors. Appropriate equipment and clothing for protecting decontamination personnel should be selected by a qualified health and safety expert.

All decontamination workers are in a contaminated area and must themselves be decontaminated before entering the clean Support Zone. The extent of their decontamination should be determined by the types of contaminants they may have contacted and the type of work they performed.

Emergency Decontamination

In addition to routine decontamination procedures, emergency decontamination procedures must be established. In an emergency, the primary concern is to prevent the loss of life or severe injury to site personnel. If immediate medical treatment is required to save a life, decontamination should be delayed until the victim is stabilized. If decontamination can be performed without interfering with essential life-saving techniques or first aid, or if a worker has been contaminated with an extremely toxic or corrosive material that could cause severe injury or loss of life, decontamination must be performed immediately. If an emergency due to a heat-related illness develops, protective clothing should be removed from the victim as soon as possible to reduce the heat stress. During an emergency, provisions must also be made for protecting medical personnel and disposing of contaminated clothing and equipment. See Chapter 12 for further information on decontamination during emergencies.

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