United States
Environmental Protection
Agency

Hazardous Waste Engineering
Research Laboratory
Cincinnati, OH 45268

Research and Development

EPA/600/S2-85/028 June 1985

EPA

Project Summary

Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites

M. P. Esposito, J. L. McArdle, A. H. Crone, J. S. Greber, R. Clark, S. Brown, J. B. Hallowell, A. Langham, and C. D. McCandlish

This study produced a general decontamination guide for use by those responsible for decontamination activities at Superfund sites. It contains stepwise guidance for developing a cost-effective decontamination strategy, descriptions of methods for treating or removing contaminants from structural materials, case studies illustrating field use of many decontamination methods, cost analyses for the application of each method to a model building, a discussion of worker health and safety precautions, and a summary of available sampling techniques for measuring contamination levels both before and after cleanup. Additional research is recommended to 1) verify the effectiveness of existing decontamination methods for a range of contaminants and structural materials, 2) develop and demonstrate new cleanup techniques, and 3) improve sampling techniques for determining structural contamination.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), otherwise known as Superfund, established a dual-phase program for responding to environmental problems caused by hazardous substances. The removal program involves cleanup or other actions taken in response to emergency conditions or on a short-term or temporary basis. The remedial program involves long-term responses that permanently remedy problem sites.

To be eligible for cleanup under Superfund, a site must be included on the National Priorities List (NPL). As of this writing, 538 sites appear on the NPL, which was first promugated by the U.S. Environmental Protection Agency (EPA) on September 8, 1983. Currently, the EPA is proposing the addition of 248 new sites to the list.

As the number of sites on the NPL grows and as removal and remedial activities at Superfund sites accelerate, the task of decontaminating buildings, structures, and construction equipment will become increasingly important. These items often represent large capital investments, and the costs of dismantling and disposing of such structures in a secure landfill can be very expensive. The objective of an effective decontamination program, therefore, is to return contaminated buildings, structures, and equipment to active, productive status.

The goal of this study was the development of a general guide for government personnel, cleanup contractors, and other individuals responsible for planning and executing decontamination activities at Superfund sites.

Procedures

Initially a survey was conducted of decontamination activities at 50 Superfund sites across the country. These sites were thought to have contaminated buildings, structures, and equipment, and the survey gathered information on 1) the types of contaminants of most concern and 2) the methods currently proposed or used for decontamination of the buildings, structures, and equipment in place at these sites. This survey revealed that the methods used to remove contaminants from buildings, structures, and equipment are few and rarely documented in detail. For example, it is common practice to steam clean equipment such as backhoes, bulldozers, and drilling augers, but testing to verify that the contaminants of concern have been adequately removed is generally not performed. Contaminated buildings and structures are seldom cleaned and returned to active use. More often, they are closed and barricaded to prevent further entry and exposure, or they are torn down and buried in secure landfills. Contaminated underground structures such as tanks, sumps, and sewers are sometimes filled in place with concrete to prevent their reuse. These and other survey findings clearly pointed to the need for basic guidance dealing with the identification and selection of appropriate decontamination methods, as well as their application to contaminants and structural materials.

The remainder of the project focused on development of a decontamination data base containing current information on specific cleanup methods and their application, as well as guidelines for developing site-specific cleanup strategies. Those with direct experience in programs involving decontamination of dioxins, explosives, PCBs, and other toxic wastes from buildings and equipment were contacted. In addition, the literature was thoroughly searched for information on decontamination methods.

Discussion

Figure 1 summarizes the strategy for dealing with building decontamination, including guidance and information for selecting the least costly method(s) that are technologically feasible and that will effectively reduce comtamination to predetermined levels. Step 1, determining the nature and extent of contamination, consists of querying former employees; searching old business records, inspection reports, and news stories; conducting a visual site inspection; and collecting and analyzing samples from the contaminated surfaces or structures. Step 2, developing a site-specific decontamination plan, is further broken down into the following activities: evaluating hazards; identifying the future intended use of buildings, structures, and equipment; establishing decontamination target levels for the contaminants present; identifying and evaluating potential decontamination methods; selecting the most cost-effective method(s) for achieving the decontamination target levels; determining worker health and safety requirements (training, medical surveillance, personal protective equipment, site safety); writing the site decontamination plan; estimating costs; and hiring the contractor and initiating cleanup. Step 3, evaluating decontamination effectiveness, involves reinspecting the site for evidence of residual contamination; collecting and analyzing samples from the decontaminated area; determining whether the target levels for residual contamination have been reached; repeating, and if necessary, modifying the decontamination procedures until satisfactory results are obtained; and determining the need for long-term monitoring.

The document also describes several traditional and developmental decontamination methodologies and discusses their potential applicability to various combinations of contaminants and structural materials. Method descriptions include a general discussion of the procedure, contaminant and surface applicability, engineering considerations (including building preparation, process description, and equipment needs), safety requirements, waste disposal, and costs. The following paragraphs briefly describe each example method:

Absorption is widely used in industrial settings to clean up chemical and other liquid spills. It is also commonly used by emergency response teams such as fire departments. This method is most applicable immediately following liquid contaminant spills. Contaminants rapidly penetrate most surfaces, and absorbents act to contain them. Depending on the surface and time elapsed since the spill, further decontamination procedures may have to be employed.

Acid etching of a contaminated surface is used to promote corrosion and removal of the surface layer. Muriatic acid (hydrochloric acid) is used to remove dirt and grime from brick building surfaces in urban areas and to clean metal parts (e.g., pickle liquors from metal finishing operations). The resulting contaminated debris is then neutralized and disposed of. Thermal or chemical treatment of the removed material may be required to destroy the contaminant before disposal. Although this technique is not known to have been applied to chemically con-

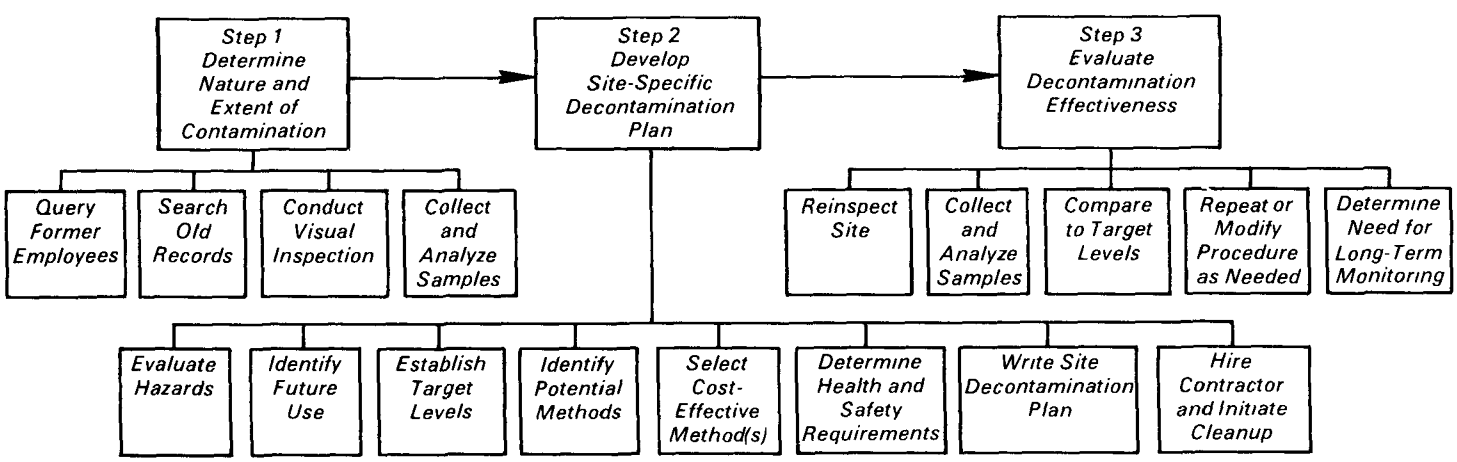

Figure 1. *Flow diagram of steps for developing a decontamination strategy*

taminated building surfaces, it is believed to have good potential.

Asbestos abatement consists of four techniques: removal, encapsulation, enclosure, and special operations (e.g., maintenance and monitoring). In removal operations, all friable asbestos-containing building materials are completely removed to eliminate the release of asbestos fibers into the air. The other techniques leave the asbestos fibers in place but limit potential exposure levels through various treatment, maintenance, and inspection procedures.

Bleaching formulations are applied to a contaminated surface, allowed to react with contaminants, and removed. Application usually occurs in conjunction with other decontamination efforts, such as the use of absorbents and/or waterwashing. Bleach has been used as a decontaminant against mustard, G and V chemical agents, and (experimentally) organophosphorous pesticides.

Demolition of a building, structure, or piece of equipment includes complete burndown, controlled blasting, wrecking with balls or backhoe-mounted rams, rock splitting, sawing, drilling, and crushing. Many of these techniques have been employed for nuclear facility decontamination and for the cleanup of military arsenals.

Dismantling refers to the physical removal of selected structures (such as contaminated pipes, tanks, and other process equipment) from buildings or other areas. It can be the sole decontamination activity (e.g., removal of contaminated structures from an otherwise clean building), or it can be used in the initial stage of a more complex building decontamination effort (e.g., removal of structures prior to flaming, hydroblasting, or other cleanup techniques).

Drilling and spalling can remove up to 5 cm of contaminated surface material from concrete or similar materials. This technique consists of drilling holes (2.5 to 4 cm diameter) approximately 7.5 cm deep. The spalling tool bit is inserted into the hole and hydraulically spreads to spall off the contaminated concrete. The technique can achieve deeper penetration (removal) of surfaces than other surface-removal techniques, and it is good for large-scale applications. The treated surface is very rough and coarse, however, and may require resurfacing (i.e., capping with concrete). The drilling and spalling method has been used in the decommissioning of nuclear facilities.

Dusting/vacuuming/wiping is simply the physical removal of hazardous dust and particles from building and equipment surfaces by common cleaning techniques. Variations include vacuuming with a commercial or industrial-type vaccum; dusting off surfaces such as ledges, sills, pipes, etc., with a moist cloth or wipe; and brushing or sweeping up hazardous debris. Dusting and vacuuming are applicable to all types of particulate contaminants, including dioxin, lead, PCB's, and asbestos fibers, and to all types of surfaces. Dusting/vacuuming/wiping is the state-of-the-art method for removing dioxin-contaminated dust from the interior of homes and buildings.

Encapsulation/enclosure physically separates contaminants or contaminated structures from building occupants and the ambient environment by means of a barrier. An encapsulating or enclosing physical barrier may take different forms; among them are plaster epoxy, and concrete casts and walls. Acting as an impenetrable shield, a barrier keeps contaminants inside and away from clean areas, thereby alleviating the hazard. As a result, contamination of part of a structure will not result in the contamination of adjacent areas. Encapsulation has been used on damaged asbestos insulation, leaky PCB-contaminated electrical transformers, and open maintenance pits and sumps contaminated by heavy metals.

Flaming refers to the application of controlled high temperature flames to contaminated noncombustible surfaces, providing complete and rapid destruction of all residues contacted. The flaming process has been used by the Army to destroy explosive and low-level radioactive contaminants on building surfaces. Its applicability to other contaminants is not well known. This surface decontamination technique is applicable to painted and unpainted concrete, cement, brick, and metals. Subsurface decontamination of building materials may be possible, but extensive damage to the material would probably result. This technique can involve high fuel costs.

Fluorocarbon extraction of contaminants from building materials involves the pressure-spraying of a fluorocarbon solvent onto the contaminated surface followed by collection and purification of the solvent. RadKleen is an example of a commercial process that uses Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane or $C_2Cl_3F_3$) as the solvent. The RadKleen process is currently used for cleaning radioactive material from various surfaces. It has been applied to chemical agents on small objects, and thus field capability has been demonstrated. Studies have been conducted for agent-contaminated clothing materials, such as polyester-cotton, Nomex, butyl rubber gloves, and charcoal-impregnated cloth. Although this method has not been demonstrated for removing contaminants from building surfaces, it looks very promising.

Gritblasting is a removal technique in which abrasive materials (such as sand, alumina, steel pellets, or glass beads) are used for uniform removal of contaminated surfaces from a structure. Gritblasting has been used since 1870 to remove surface layers from metallic and ceramic objects and is currently used extensively. For example, sandblasting is commonly used to clean the surfaces of old brick and stone buildings. Gritblasting is applicable to all surface contaminants except some highly sensitive explosives such as lead azide and lead styphnate. This method is applicable to all surface materials except glass, transite, and Plexiglas.

Hydroblasting/waterwashing refers to the use of a high-pressure (3500 to 350,000 kPa) water jet to remove contaminated debris from surfaces. The debris and water are then collected and thermally, physically, or chemically decontaminated. Hydroblasting has been used to remove explosives from projectiles, to decontaminate military vehicles, and to decontaminate nuclear facilities. Hydroblasting also has been employed commercially to clean bridges, buildings, heavy machinery, highways, ships, metal coatings, railroad cars, heat exchanger tubes, reactors, piping, etc. Off-the-shelf equipment is available from many manufacturers and distributors.

Microbial degradation is a developing process whereby contaminants are biologically decomposed by microbes capable of utilizing the contaminant as a nutrient source. Conceptually, microbes are applied to the contaminated area in an aqueous medium and allowed to digest the contaminant over time; the microbes are then destroyed chemically or thermally and washed away. Microbial degradation as a building decontamination technique has not been demonstrated.

Painting/coating includes the removal of old layers of paint containing high levels of toxic metals such as lead, the use of fixative/stabilizer paint coatings, and the use of adhesive-backed strippable coatings. In the first technique, paint containing lead in excess of 0.06 percent is removed from building surfaces by commercially available paint removers and/or physical means (scraping, scrubbing, waterwashing). Resurfacing or further decontamination efforts may be necessary. The second technique involves the use of various agents as coatings on contaminated surfaces to fix or stabilize the contaminant in place, thereby decreasing or eliminating exposure hazards. Potentially useful stabilizing agents include molten and solid waxes, carbo-waxes (polyoxyethylene glycol), saligenin (α, 2-dihydroxytoluene), organic dyes, epoxy paint films, and polyester resins. The stabilized contaminants can be left in place or removed later by a secondary treatment. In some cases, the stabilizer/fixative coating is applied in situ to desensitize a contaminant such as an explosive residue and prevent its reaction or ignition during some other phase of the decontamination process. In the third technique, the contaminated surface is coated with a polymeric mixture. As the coating polymerizes, the contaminant becomes entrained in the lattice of or attached to the polymer molecules. As the polymer layer is peeled off, the residue is removed with it. It may be possible, in some cases, to add chemicals to the mixture to inactivate the contaminants.

Photochemical degradation refers to the process of applying intense ultraviolet light to a contaminated surface for some period of time. Photo-degradation of the contaminant follows. In recent years, attention has been focused on this method because of its usefulness in degrading chlorinated dioxins (TCDD in particular). Three conditions have been found to be essential for the process to proceed: 1) the ability of the compound to absorb light energy, 2) the availability of light at appropriate wavelengths and intensity, 3) the presence of a hydrogen donor.

Scarification is a method that can be used to remove up to an inch of surface material from contaminated concrete or similar materials. The scarifier tool consists of pneumatically operated piston heads that strike the surface, causing concrete to chip off. This technique has been used in the decommissioning of nuclear facilities and in the cleanup of military arsenals.

Sealing is the application of a material that penetrates a porous surface and immobilizes contaminants in place. One example is K-20, a newly-developed commercial product. The effectiveness of this product is not fully known. Although it acts more as a barrier than a detoxifier, K-20 may facilitate chemical degradation as well as physical separation of some contaminants.

Solvent washing refers to the application of an organic solvent (e.g., acetone) to the surface of a building to solubilize contaminants. This technique has not yet achieved widespread use in building decontamination, although it is beginning to be used in the decommissioning of nuclear facilities. The method needs further development in application, recovery, collection, and efficiency. The hot solvent soaking process has been shown to be effective in decontamination of PCB-contaminated transformers.

Steam cleaning physically extracts contaminants from building walls and floors, and from equipment. The steam is applied through hand-held wands or automated systems, and the condensate is collected in a sump or containment area for treatment. This method is currently used by explosives handling and manufacturing facilities. It has also been used to remove dioxin-contaminated soil from vehicles and drilling equipment in Times Beach, Missouri.

Vapor-phase solvent extraction is a method in which an organic solvent with a relatively low boiling point (such as methyl chloride or acetone) is heated to vaporization and allowed to circulate in a contaminated piece of equipment or an enclosed area. The vapors permeate the contaminated materials, where they condense, solubilize contaminants, and diffuse outward. The contaminant-laden liquid solvent is collected in a sump and treated to allow recycling of the solvent. This method has not yet been applied to building decontamination, although it is believed to have good potential.

In addition to the guidance on developing a cost-effective cleanup strategy and the information on various decontamination methods, the document also includes several case studies illustrating the actual application of many decontamination methods. Table 1 summarizes these case studies, indicating the contaminants present and the decontamination methods used in each case. Finally, the handbook includes cost analyses for the application of each method to a model building, a discussion of worker health and safety precautions, and information on available sampling methods.

Conclusions and Recommendations

As a result of this study, one can conclude that there will often be considerable merit in assuring that future owners of decontaminated buildings and structures on Superfund sites are made aware of the nature and levels of any residual contamination and of the cleanup methods used. Ensuring the transfer of such information from one site owner to the next will require a method for permanently recording this information. Regulations requiring the addition of such information to the property deed, as is required in the deed of all RCRA-permitted facilities, may be a workable solution.

Additional research is needed to bridge gaps in the state of the art in the following three key information areas:

Sampling Methods

First, and perhaps most important, sampling methods for determining the type and degree of contamination existing on building/structure/equipment surfaces, both before and after cleanup efforts, are poorly developed, documented, and verified. Similarly, subsurface sampling techniques (such as corings) for determining the depth of contamination in porous substances (such as concrete or wood floors) have not been adequately developed and documented. Although "wipe tests" are often referred to in site records, the actual methodology used is rarely described in enough detail to allow simulation or reproduction by others, and the technique itself is known to be inadequate for quantitatively transferring contaminants from surfaces to wipes or swabs.

Decontamination Techniques

Second, the applicability and effectivenes of the decontamination techniques described in the handbook for treating various contaminant/structural material combinations encountered at Superfund sites have not been fully explored. For example, the degree to which steam cleaning removes dioxin-contaminated soil particles from drilling augers has not been established, even though this method is routinely used to clean equipment at dioxin-contaminated sites. Additional research to verify/demonstrate the effectiveness of currently available and newly developing techniques under various conditions is badly needed. Also, decontamination methods that have not previously been applied to specific contaminant/substrate combinations but show a strong potential applicability should be tested in pilot investigations. In the meantime, it is recommended that the individual method descriptions presented in the handbook be used as a general guide in evaluating the potential of each technique on a site-specific basis for efficiency, wastes generated, equipment and support facilities needed, time and safety requirements, structural effects, and costs. Also, each method or combination of methods should be pretested in the laboratory or at the site before full-scale implementation to determine the effectiveness of the strategy.

Table 1. *Summary of Case Studies*

Site	*Contaminants present*	*Decontamination methods*
Homes and other buildings Seveso, Italy	*TCDD*	*Dusting/vacuuming/wiping Painting/coating Dismantling Demolition*
State Office Building Binghamton, New York	*PCBs, TCDD, TCDF*	*Dusting/vacuuming/wiping Dismantling*
Sontag Road area[a] *St. Louis County, Missouri*	*TCDD*	*Dusting/vacuuming/wiping Insulation removal Scrubbing (equipment only) Steam cleaning (equipment only)*
One Mark Plaza Office Complex San Francisco, California	*PCBs, PCDD, PCDF*	*Insulation removal Dusting/vacuuming/wiping Solvent washing Scraping Painting/coating K-20 Gritblasting Scarification/jackhammering Dismantling Hydroblasting/waterwashing (equipment only)*
Frankford Arsenal Philadelphia, Pennsylvania	*Explosives*	*Flaming Demolition*
	Asbestos	*Asbestos removal*
	Radiological residues	*Dusting/vacuuming/wiping Hydroblasting/waterwashing Scarification Gritblasting Dismantling*
	Heavy metals	*Painting/coating*
Office building New England	*Asbestos*	*Asbestos encapsulation*
Luminous Processes, Inc.[a] *Athens, Georgia*	*Low-level radiation*	*Paint stripping/sanding Hydroblasting/waterwashing Dismantling*
Chemical Metals Industries, Inc.[a] *Baltimore, Maryland*	*Heavy metals, acids, alkalis, cynaide- and ammonia-bearing compounds, salts, and solids and sludges of unknown composition*	*Gritblasting Dismantling*

[a]*Superfund site.*

Methodologies for Determining Acceptable Contaminant Levels

Third, a formal, systematic approach for determining acceptable levels of contaminants remaining in and on building and equipment surfaces does not currently exist. As a result, guidance on how clean is clean and the establishment of target levels could not be included in this handbook and must continue be be addressed case by case.

M.P. Esposito, J.L. McArdle, A.H. Crone and J.S. Greber are with PEI Associates, Inc., Cincinnati, OH 45246. R. Clark, S. Brown, J.B. Hallowell, A. Langham and C.D. McCandlish are with Battelle Columbus Laboratories, Columbus, OH 43201.

☆U.S.Government Printing Office: 1985 — 559-111/10859

M. P. Esposito, J. L. McArdle, A. H. Crone, and J. S. Greber are with PEI Associates, Inc., Cincinnati, OH 45246; R. Clark, S. Brown, J. B. Hallowell, A. Langham, and C. D. McCandlish are with Battelle Columbus Laboratories, Columbus, OH 43201.
***Naomi P. Barkely** is the EPA Project Officer (see below).*
The complete report, entitled "Guide for Decontaminating Buildings, Structures, and Equipment at Superfund Sites," (Order No. PB 85-201 234/AS; Cost: $22.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268