CHAPTER 19

SITE RESTORATION

19-1 GENERAL

a. Development of a site restoration plan to return the accident area to a technically achievable/acceptable condition begins early in the nuclear weapon accident response effort. However, site restoration becomes the dominant task only after classified weapons, weapon debris, classified components, and other hazards are removed, or more precisely, when the National Defense Area (NDA) or National Security Area (NSA) is disestablished, or when overseas the Security Area is dissolved.

b. Several factors have significant influence on site restoration decisions and procedures. Some of the more prominent factors are: size of the contaminated area, its topography/ demographics, and the civil authority and prerogatives once the NDA is disestablished, or overseas, the Security Area is dissolved.

c. Some actions otherwise performed in support of the basic response effort are vital in site restoration. One example would be determining the extent of contamination. Such actions should be recognized, therefore, during development of the site restoration plan and the results incorporated into the plan.

19-2 PURPOSE AND SCOPE

This chapter provides guidance for accomplishing the restoration of a nuclear weapon accident site contaminated with radioactive materials. In this section, several decontamination considerations are discussed as well as the reoccupation of contaminated areas and follow-up activities.

19-3 SPECIFIC REQUIREMENTS

The accidents at Thule, Greenland, and Palomares, Spain, taught us that site restoration of an area contaminated with radioactive materials, though not easy, can be accomplished. The following actions will. be required:

a. Coordination between responsible civil and military organizations.

b. Determination of agreed-upon cleanup and technically achievable/ financially acceptable levels.

c. Determination and plotting of contaminated areas.

d. Completion of environmental assessment(s).

e. Completion of decontamination, fixing, reducing the concentration, or removing the contaminant.

f. Restoring the contaminated area to normal use.

g. Development of plans for post restoration radiation monitoring “and assessment.

19-4 RESOURCES

a. Material resources necessary for site restoration will range from heavy equipment for soil and vegetation removal, to materials such as soaps and detergents for scrubbing lesser amounts of contamination from surface areas. These resources are, for the most part, available both commercially and within DoD. A specific list of all possible resources at this juncture could be misleading and is, therefore, not included. The precise resources required will depend on the specific contamination problem and the decontamination method(s) selected.

b. As described in other sections, each response force. staff element will contribute to the site restoration effort. However, four response force elements are the key to the On-Scene Commander’s (OSCs) effort to plan and execute site restoration. The four elements are the Radiological Safety, Logistics, Legal, and Engineer response elements. In addition to site restoration, the Radiological Safety, Logistics, and Legal officers each have extensive responsibilities described in Chapters 5, 17, and 18, respectively. Specifically, the Staff Engineer provides expert advice on the, capabilities of various pieces of heavy equipment to accomplish specific types

of decontamination, recommend procedures, determine support requirements for restoration tasks, and coordinate the conduct of engineering surveys discussed later in this chapter. Supporting Staff Engineers responsibilities in this area, DNA provides the model site restoration computer program which operates in an interactive mode on an IBM PC or IBM compatible and requires 256K RAM. This program was designed to address a radiological contamination problem providing information ranging from methods/costs to efficiencies. The primacy and rights of civil authorities/ officials concerning site restoration cannot be overemphasized. Accordingly, the Senior FEMA Official (SFO), a Department of Energy (DoE) representative, and State and local authorities or foreign government officials are critical in planning site restoration as well as to the accomplishment of site restoration.

19-5 CONCEPT OF OPERATIONS

The OSC's responsibilities do not end with disestablishment of the NDA or overseas the dissolution of the Security Area. Specifically, the OSC must continue to assist in protecting the public from radiological hazards and support the DoD contribution to returning the area to an acceptable condition.

a. Coordinated Activities. Site restoration activities are undertaken in coordination with the Federal Emergency Management Agency (FEMA), State, and local authorities or foreign government officials. There are no guidelines, national or international, for restoration of areas contaminated with radioactive nuclear materials, which means technically achievable/ acceptable cleanup levels vary from locale to locale.

(1) The OSC will develop various restoration strategy options. These options should be derived from his staff and advisors. Consideration is given to request the DNA Advisory Team to assist in preparing these options. The team will use data from the Joint Hazard Evaluation Center (JHEC), Federal Radiological Monitoring and Assessment Center (FRMAC), and local demographics with a Site Restoration computer Program (S RP) to develop restoration options. Once these options are developed on-site, they should be forwarded for national-level review. Specifically, to utilize the SRP mentioned above, the advisory team must be provided extensive information in the foilowing area:

(a) RADIOLOGICAL.

1. Detailed mapping of the contaminated area (Aerial Measurement System (AMS), Ground Surveys).
2. Listing of any fixatives used to minimize resuspension.
3. Established cleanup level.

(b) DEMOGRAPHIC/TOPOGRAPHIC.

1. Size of affected area (m2).
2. Population/ Household size.
3. Land use.
4. Land value.

(c) The information provided by the computer includes

1. DECON method used on each surface.
2. Rate at which the DECON method is applied.
3. Type of labor used in the method.
4. Type of equipment used in the method.
5. Major materials required.
6. Efficiency of the method in reducing inhalation and external dose.
7. Dose to radiation workers.
8. Dose commitment from surface exposure.

(2) An ad hoc committee at the national level is established which includes representatives from DoD, FEMA, DoE, DoS, state and local governments, EPA, and other Federal agencies and representatives which may have statutory responsibilities with regard to site restoration. This committee will formulate the scope, policies, and concepts to be included in site restoration. The OSC should provide the committee through the SFO the strategy options along with radiological map data for negotiations and final governmental resolution/ approval.

(3) The final set of strategy options will be used by the OSC and staff to build the final site restoration plan.

b. Radiological Safety Standards. In the absence of Federal guidance, DoD has adopted the policy that radiological contamination resulting from accidents involving U.S. nuclear weapons or devices posing an actual or potential threat to populations, or to the environment, shall be reduced to a minimal practical level or at least to a level which recognized scientific practice and knowledge indicates is safe for current and reasonable projected use.

c. Procedures. The procedural recommendations in the following paragraphs are limited to site restoration actions dealing with the locating, handling, and disposing of radioactive contamination. Because site restoration depends heavily on civil engineering procedures, the staff engineer plays a major role in development of the site restoration plan.

(1) Identifying the Contaminated Area. The first step in site restoration identifies the contaminated or affected area. This step is accomplished by conducting systematic radiological surveys and engineering studies. Data used in determining the contaminated area may be obtained during initial ground monitoring, aerial measurement surveys, follow-on ground monitoring, and air sampling.

(a) The outer perimeter of the contaminated area is determined by measuring either low energy gamma radiation, or alpha radiation, and corroborated by laboratory radioanalysis. Initial techniques employed may involve both ground monitoring and aerial measurement survey to determine the main areas of contamination. All initial measurements should be completed in the first few days of the response operation before contamination migrates into the soil or surfaces and becomes difficult to measure. Control measures should be implemented immediately if there is any possibility that the contaminants may be spread, or as soon as the initial radiological survey has been completed. As additional information becomes available, re-evaluation must be made of the situation for possible modification of control measures in effect.

(b) Soon after the perimeter of the contaminated area has been established, detailed surveys should be conducted to accurately determine the location of various intensities of radiation. Such surveys may involvecollecting samples of air, soil, water, plants, and animals for laboratory analysis, as well as obtaining detailed ground radiation measurements. These detailed surveys provide additional data from which site restoration planning can be initiated. Further surveys, including collection of samples and radiation measurements, should continue to be made until site restoration has been completed.

(2) Environmental Assessment. The principal objectives of the environmental assessment are to identify the effects on the ecosystems at the accident site and to identify various decontamination techniques used in restoring the accident site. Radiological surveys are key. to the environmental assessment because they establish the level and extent of contamination and are the basis for determination of possible decontamination techniques.

(3) Decontamination Considerations. A substantial portion of the site restoration effort will be to remove or reduce the level of contamination to return the affected area to an achievable/acceptable condition. If the contamination is contained exclusively on government property, the decontamination effort is planned and supported solely by military assets. If, however, the contamination is on public or private property, the decontamination effort must be planned jointly by the OSC, local and/or State officials and the Federal agencies or foreign government officials concerned. In all situations, the SRF can expect to be involved in the initiation of site restoration.

(a) In accidents, the bulk of the contamination is contained normally in the upper stratum (within one inch of the surface); therefore, immobilizing or “fixing” contamination may be necessary to prevent spreading and/ or to facilitate removal. Specifically, immobilizing the contamination in heavily contaminated areas, (for example, craters) will decrease significantly the subsequent spread of contamination. Other methods may be used such as spraying with water or fixative and/ or covering the concentration with plastic sheeting. Covering the concentration with fresh earth could provide a temporary fixative. Advice should be obtained from the Radiological Safety Officer and Staff Engineer about using a particular fixative and its impact on both the environment and on subsequent site restoration operations. Constructing physical containment features may be necessary, such as dams, dikes, or ditches, to prevent the contaminants from spreading or being eroded.

(b) Decontamination methods used to cleanup an accident area may vary widely. Some factors that will influence the method chosen are type and use of the soil, type and amount of vegetation in the area, type and level of contamination present. Other factors are type and number of buildings. Effective decontamination begins with the use of the simplest method. For example, when high levels of contamination are present, repetitive use of a simple method may be effective, or a more sophisticated technique may be required to remove the contamination. Normally, lower levels of contamination are removed first, but under certain environmental considerations, removing the highest level first may be advisable to reduce the spread of contamination.

1. Vegetation in the area should be washed or removed. Decomposition of plant material can be accelerated by shredding and using quicklime. If shredders are used, care must be taken to control resuspension.

2. Scraping is probably the most effective method for removing contamination from land surfaces. This method should be used when high contamination levels will not permit use of other methods. Contaminated soil removed by this method should be processed through a mechanical and/or chemical separator for removal of the contaminant to achievable/ acceptable levels. The soil may then be returned to the location from which removed; however, if difficulty is encountered in removing the contaminant, it must be transported from the site to an acceptable radiological disposal facility. The quantity of material packaged and shipped may also create a large scale logistic problem. The logistics officer and/ or DoE personnel assist in identifying and locating suitable shipping containers.

3. In areas with lesser contamination levels, plowing may be an effective method of achieving permissible levels of contamination in the proximate surface. The depth of the proximate surface varies even within similar environments. The proximate surface may be within one or two inches of the surface in a forest or field, not planned for development, while the proximate surface for agricultural land generally is generally defined by the depth of agricultural plowing. If dilution within the proximate surface is contemplated, burial action of plowing is enhanced further if the area is wetted before plowing as surface dust will be kept from rising and collecting on previously turned furrows. Wetting and plowing will also tend to mix the contaminant in depth so that it is not left in a single stratum.

4. Contaminated buildings and other structures should be decontaminated and, in severe cases, removed and re-built.

5. Table 19-1 provides guidelines on the permissible levels of fixed and removable contamination. The fixation and/ or decontamination efficiency of the methods discussed above, when used singly or in combination, are contained in Tables 19-2. Methods to decontaminate various surfaces are contained in Table 19-3.

(4) Contaminated Waste Disposal. The methods and procedures for disposing of contaminated waste material will require coordination between the OSC, the SFO and appropriate civilian authorities/ officials.

(a) Early identification of a waste disposal site and its acceptance criteria are necessary to determine packaging and transportation requirements.

(b) Contaminated soil and building materials may require packaging in containers. The type of container selected depends on the material to be packaged and the mode of transportation. Containers used must meet the requirements of applicable DoD, DoE, and Department of Transportation (DoT) regulations and/ or country involved. Containers varying in size from 55-gallon drums to large containers, for example, 5,000-gallon fuel tanks, have been used in previous restoration efforts. Because the shipments will consist of contaminated materials, advice must be obtained from transportation specialists. Moreover, the method of shipment selected should ensure that the materials are moved in a safe and efficient manner and that all regulations/ requirements are followed.

(5) Reoccupation of Evacuated Areas. Levels of surface and airborne contamination remaining in an area will be factors determining when the area is safe for reoccupation.

(a) Resuspension, and resuspension factors, will be major considerations. In light of this, the Nuclear Regulatory Commission guidance states that airborne activity may be averaged over all of the air inhaled for a whole year to determine the annual dose to the lung. Recognizing that cleanup will continue, and that the magnitude of resuspension will decrease with time, reoccupation may be possible at a time when airborne activity is still two to three times the maximum permissible steady state concentration.

(b) Surface contamination on objects with which people come in contact must be at acceptable levels before the items can be released for unrestricted use, or before reoccupation can be permitted. Surface contamination is divided into two categories: “fixed” and “removable,” when determining if personal possessions may be released to their owners. Fixed contamination is that which has settled into a surface and cannot be wiped off, removable is that which can be expunged if the surface is rubbed.

(6) Follow-Up Activities. After site restoration is complete, the site should be inspected to ensure that all aspects of the site restoration plan have been accomplished. Continued monitoring and analysis of material, such as soil and vegetation, and people is necessary for long periods to ensure that radiation, environmental, and health standards have been permanently and successfully achieved. Normally, a civil agency will be responsible for long term radiological monitoring.

19-6 ACCIDENT RESPONSE PLAN ANNEX

A separate Site Restoration Plan (SRP) will be developed in coordination with representatives from Federal, State, and local agencies, or the host country, government officials/representatives. The Site Restoration annex of the accident response plan should identify possible methods to restore an accident site and contaminated areas..lnformation and procedures which may be appropriate for the Site Restoration annex to the accident response plan include:

a. Procedures for collection of environmental samples required to support restoration operations.

b. Procedures for decontamination and/or fixation of contaminated areas.

c. Procedures for the disposal of contaminated material.

d. Identification of requirements for site restoration planning with State, Federal, and civil authorities and host government officials.

TABLE 19-1. Radioactive Contamination Guides.

Contaminated Items and Indications for Actions	Fixed or Removable	Contamination Level				Method of Measurement
		Alpha		Beta-gamma 1 /		
		dpm per I 00 cm²	dpm per 100 cm²	mrad/hr @I in.	dpm per 100 cm²	
1. Containers. Prior to nonradioactive use, should be	F	200		0.2		Probe
decontaminated if above:	R		None		100	Smear 2/
2. Facilities and Equipment 3/4/						
a. Uncontrolled. Requires decontamination	F	I 000		0.2		Probe
If above:	R		100		100	Smear 2/
b. Controlled:						
(I) Facilities	F	I 000		.05		Probe
	R		200		400	Smear 2/
(2) Equipment Items:	F	1000		2.0		Probe
	R		200		2000	Smear 2/

I / Measured through not more than 7 milligrams per square centimeter of total absorber and averaged not more than 1 square meter
2/ Smears analyzed with a calibrated counting system.
3/ For U-natural, U-depleted, and U-238; levels for alpha contamination should be increased by factors of 5.
(In accordance wih NRC guidelines
4/ If Radium 226 is a contaminant, levels for alpha contamination should be reduced by a factor of 2.

F—Fixed
R—Removed

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources

The table includes decontamination efficiencies for the following land areas and resources.

Vacant Land
Agricultural Fields
“ Wooded Land/ Lawns
Orchards
Asphalt Streets/ Parking and Other Paved Asphalt
Concrete Streets/ Parking and Other Paved Concrete

Exterior Wood Walls/ Brick Walls
Concrete/ Wood Floors
Interior Concrete Walls and Wood/ Plaster Walls
Carpeted and Linoleum Floors
Roofs
‘Automobiles, Auto Tires, Engine Drive Train, and Interior

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources (Continued)

DECONTAMINATION OF VACANT LAND

DECONTAMINATION METHOD	EFFICIENCY INHALATION	EFFICIENCY EXTERNAL
Clear; Harvest	30	40
Surface Sealer/ Fixative-Clear; Harvest	40	40
Surface Sealer/ Fixative-Clear; Harvest-Scrape 4“ to 6“	96	96
Low Pressure Water	55	25
Low Pressure Water (x2)	79.8	43.8
Low Pressure Water (x3)	90.9	57.8
Low Pressure Water (x4)	95.96	68.4
Surface Sealer/ Fixative, Plow	92	55
Surface Sealer/ Fixative, Deep Plow	98.5	65
Surface Sealer/ Fixative, Clear; Harvest Double Scrape	99.44	99.44
Surface Sealer/ Fixative, Clear; Harvest Double Scrape, Scrape 4“ to 6”	99.92	99.92
3“ Asphalt & Cover with 6“ Soil	60	40
Surface Sealer/ Fixative, 3“ Asphalt& Cover with 6“ Soil	86	42
Low Pressure Water, 3” Asphalt& Cover with 6“ Soil	82	55
Clear; Harvest, 3“ Asphalt & Cover with 6“ Soil	72	58
Surface Sealer/ Fixative, Clear; Harvest 3“ Asphalt& Cover with 6“ Soil	76	64
Low Pressure Water (x2), 3“ Asphalt & Cover with 6“ Soil	91.9	66.3
Low Pressure Water (x3), 3” Asphalt& Cover with 6“ Soil	96.4	74.7
Surface Sealer/ Fixative, Plow 3“ Asphalt& Cover with 6“ Soil	96.8	73
Surface Sealer/ Fixative, Deep Plow, 3” Asphalt& Cover with 6“ Soil	99.4	79
Surface Sealer/ Fixative, Clear; Harvest, Double Scrape 3“ Asphalt & Cover with 6” Soil	99.78	99.66
3“ Asphalt& Cover with 6” Soil (x2)	84	64
Surface Sealer/ Fixative	65	00
Plow	98	95
Surface Sealer/ Fixative, Clear; Harvest, Double Scrape (x2)	99.99	99.99

DECONTAMINATION OF AGRICULTURE FIELDS

Low Pressure Water	55	25
Low Pressure Water (x2)	79.8	43.75
Low Pressure Water (x3)	90.9	57.8
Low Pressure Water (x4)	95.9 “	68.4
Surface Sealer/ Fixative	65	00
Leaching, EDTA	92	35
Clear; Harvest	3 0	30
Scrape 4“ to 6“	86	86
Plow	90	50
Deep Plow “	98	60
Surface Sealer/ Fixative-Clear; Harvest	40	40
Surface Sealer/ Fixative-Clear; Harvest-Double Scrape	99.44	99.44
Surface Sealer/ Fixative-Clear; Harvest-Double Scrape-Scrape 4“ to 6“	99.92	99.92
Three-Inch Asphalt and Cover with 6“ Soil (No Trees)	60	40
Low Pressure Water-Three Inch Asphalt and Cover with 6” Soil (No Trees)	84.7	55
Surface Sealer/ Fixative-Three Inch Asphalt and Cover with 6” Soil (No Trees)	89.5	42
Leaching, $FeCl^3$-Three Inch Asphalt and Cover with 6“ Soil (No Trees)	97.6	70
Scrape 4“ to 6”-Three Inch Asphalt and Cover with 6“ Soil (No Trees)	94.4	91.6
Plow-Three Inch Asphalt and Cover with 6“ Soil (No Trees)	97	91
Deep Plow-Three Inch Asphalt and Cover with 6“ Soil (No Trees)	99.4	97
Clear; Harvest-Three Inch Asphalt and Cover with 6“ Soil (No Trees)	72	58

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources (Continued)

DECONTAMINATION OF VACANT LAND

DECONTAMINATION METHOD	EFFICIENCY INHALATION	EXTERNAL
Three Inch Asphalt and Cover with 6“ Soil(No Trees) (x2)	88	64
Three inch Asphalt and Cover with 6“ Soil (No Trees) (x3)	96.4	78.4
Low Pressure Water (x2)-Three Inch Asphalt and Cover with 6“ Soil (No Trees)	93.9	66.3
Surface Sealer/ Fixative-Scrape 4“ to 6“	96	96
Surface Sealer/ Fixative-Double Scrape	99.44	99.44
Surface Sealer/ Fixative, Double Scrape, Scrape 4“ to 6“	99.92	99.92
Surface Sealer/ Fixative-Plow	92	55
Surface Sealer/ Fixative-Deep Plow	98.5	65

DECONTAMINATION OF ORCHARDS

Low Pressure Water	33	15
Low Pressure Water (x2)	47.9	26.3
Low Pressure Water (x3)	54.5	34.7
Low Pressure Water (x4)	57.5	41
Scrape 4“ to 6“	48	48
Plow	51	27
Surface Sealer/ Fixative-Defoliate-Scrape 4“ to 6“	80	68
Surface Sealer/ Fixative-Defoliate-Double Scrape	90.32	78
Surface Sealer/ Fixative-Scrape 4“ to 6“	75	51
Surface Sealer/ Fixative-Defoliate-Scrape 4“ to 6“ - Low Pressure Water	77.3	71
Surface Sealer/ Fixative-Remove and Replace-Scrape 4“ to 6“	93.6	93.6
Surface Sealer/ Fixative-Plane, Scarify; Radical Prune	72.5	18
Surface Sealer/ Fixative-Plane, Scarify; Radical Prune-Plow	93.3	45
Surface Sealer/ Fixative-Remove and Replace-Scrape 4“ to 6“ - Three Inch Asphalt and Cover with 6” Soil (No Trees)	95	94.56
Cover with 6“ Soil (Trees in Place)	30	24
Surface Sealer/ Fixative-Cover with 6“ Soil Trees in Place	33	25.2
Low Pressure Water, Cover with 6“ Soil (Trees in Place)	47.9	33
Surface Sealer/ Fixative, Remove & Replace Scrape 4“ to 6“, P1OW	95.7	95.1
Surface Sealer/ Fixative	50	0
Surface Sealer/ Fixative-Plane, Scarify; Radical Prune-Plow	93.3	45

DECONTAMINATION OF WOODED LAND

Surface Sealer/ Fixative, Defoliate	48	00
Surface Sealer/ Fixative, Clear; Harvest	65	40
Surface Sealer/ Fixative, Clear; Harvest Scrape 4“ to 6“	85	85
Surface Sealer/ Fixative, Clear; Harvest Double Scrape	89.25	89.25
Surface Sealer/ Fixative, High Pressure Water	67.5	42.5
Surface Sealer/ Fixative, Defoliate, High Pressure Water	77.5	69.5
Surface Sealer/ Fixative, Clear; Harvest, 3“ Asphalt & Cover with 6“ Soil	70	60
Surface Sealer/ Fixative, High Pressure Water, 3“ Asphalt & Cover with 6“ Soil	72	45.5
Surface Sealer/ Fixative	50	00
Surface Sealer) Fixative, Scrape 4“ to 6”	67.5	42.5
Surface Sealer/ Fixative, Clear; Harvest High Pressure Water	85	85

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources (Continued)

DECONTAMINATION OF EXTERIOR WOOD WALLS

DECONTAMINATION METHOD	EFFICIENCY INHALATION	EXTERNAL
Low Pressure Water	90	85
Wash and Scrub	95	90
Low Pressure Water, Wash and Scrub	94	90.25
Vacuum	99	94
Vacuum, Low Pressure Water	99.3	94
Vacuum, Wash and Scrub	99.6	95.5
High Pressure Water	98	93
Vacuum, High Pressure Water	99.7	97.9
Surface Sealer/ Fixative, Remove and Replace	99.9	99.9
Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.98	99.98
Double Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.99	99.99
Vacuum, Foam	99.8	98.5
Strippable Coating	85	84
Double Vacuum, Foam	99.83	98,65
Double Vacuum, Foam, Remove and Replace	99.94	99.6
Surface Sealer/ Fixative, Remove Structure	99.99	“99.99
Vacuum, Strippable Coating	99.6	97.3
Surface Sealer/ Fixative	65	00
Vacuum, Surface Sealer/ Fixative	99.5	

DECONTAMINATION OF EXTERIOR BRICK WALLS

Vacuum	29	25
Double Vacuum	36.1	30.25
Low Pressure Water	90	85
Vacuum, Low Pressure Water	91.48	86,5
Vacuum, Foam	92.9	88.75
Double Vacuum, Foam	92.97	88.84
Double Vacuum, Low Pressure Water	91.69	86.75
Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.72	99.7
Double Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.74	99.72
Double Vacuum, Foam, Remove and Replace	99.86	99.93
Vacuum, High Pressure Water	91.48	87.25
Double Vacuum, High Pressure Water	91.69	87.45
Double Vacuum, Foam, High Pressure Water	95.78	92.75
Strippable Coating	40	35
Vacuum, Hydroblasting	96.45	92.5
Double Vacuum, Hydroblasting	96.49	92.67
Vacuum, Wash and Scrub	92.19	88.38
Double Vacuum, Wash and Scrub	92.33	88.49
Vacuum, Plane, Scarify	99.29	99.25
Double Vacuum, Place, Scarify	99.30	99.26
Vacuum, Surface Sealer/ Fixative, Remove Structure	99.72	99.7
Surface Sealer/ Fixative	65	00
Foam	92	87

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources (Continued)

DECONTAMINATION METHOD	EFFICIENCY INHALATION	EXTERNAL
DECONTAMINATION OF LINOLEUM FLOORS		
Vacuum	99	95
Double Vacuum	99.3	96.25
Wash & Scrub	97	95
Vacuum, Wash & Scrub	99.85	99
Vacuum, Foam	99.9	99.25
Double Vacuum, Foam	99.9	99.25
Double Vacuum, Wash and Scrub	99.86	99.06
Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.99	99.99
Double Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.99	99.99
Double Vacuum, Foam, Surface Sealer/ Fixative, Remove and Replace	99.99	99,99
Strippable Coating	98	97
Vacuum, Strippable Coating	99.6	97,85
Surface Sealer/ Fixative	80	**00**
DECONTAMINATION OF WOOD FLOORS		
Vacuum	**90**	85
Double Vacuum	**94.5**	" 91
Wash and Scrub	**92**	87
Vacuum, Wash and Scrub	**95**	91
Vacuum, Foam	**97.5**	95.5
Double Vacuum, Foam	**98.08**	96.4
Double Vacuum, Wash and Scrub	**95.9**	92.8
Vacuum, Surface Sealer/ Fixative, Remove and Replace	**99.97**	99.96
Double Vacuum, Surface Sealer/ Fixative, Remove and Replace	**99.98**	99.97
Double Vacuum, Foam, Surface Sealer/Fixative, Remove and Replace	**99.99**	99.99
Vacuum, Surface Sealer/ Fixative, Resurface	**99.96**	99.94
Double Vacuum, Surface Sealer/ Fixative, Resurface	**99.98**	99.96
Double Vacuum, Foam, Surface Sealer/ Fixative, Resurface	**99.99**	99.98
Strippable Coating	**80**	75
Vacuum, Strippable Coating	**97**	94.5
Surface Sealer/ Fixative	**85**	**00.**
High Pressure Water	**95**	**90**
DECONTAMINATION OF CARPETED FLOORS		
Vacuum	60	55
Double Vacuum	72	66.25
Vacuum, Foam	80	75.25
Double Vacuum, Foam	83.2	78.06
Double Vacuum, Foam (x2)	86.56	81.35
Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.52	99.46
Double Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.63	99.56
Vacuum, Steam Clean	72.8	67.2
Vacuum, Wash and Scrub	76	70.8
Double Vacuum, Steam Clean	78.16	72
Double Vacuum. Wash and Scrub	79.9	73

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources (Continued)

DECONTAMINATION OF CONCRETE FLOORS

DECONTAMINATION METHOD	EFFICIENCY INHALATION	EFFICIENCY EXTERNAL
Vacuum	74	69
Double Vacuum	83.1	78.61
Wash and Scrub	85	80
Vacuum, Wash and Scrub	94.8	92.56
Vacuum, Foam	97.4	95.66
Double Vacuum, Foam	97.63	96.15
Double Vacuum, Wash and Scrub	95.78	94.01
Vacuum, Surface Sealer/ Fixative, Resurface	99.79	99.75
Double Vacuum, Surface Sealer/ Fixative, Resurface	99.86	88,83
Double Vacuum, Foam, Surface Sealer/ Fixative, Resurface	99.97	99.96
Strippable Coating	95	90
Vacuum, Hydroblasting	98.96	97.52
Double Vacuum, Hydroblasting	98.99	97.65
Vacuum, High Pressure Water	96. I	94.11
Double Vacuum, High Pressure Water	96.79	95.29
Vacuum, Strippable Coating	96.62	94.42
Double Vacuum, Strippable Coating	97.30	95.5

DECONTAMINATION OF 1NTER1OR WOOD/PLASTER WALLS

Vacuum	99	95
Double Vacuum	99.3	96.25
Wash and Scrub	97	95
Vacuum, Wash and Scrub	99.85	99
Vacuum, Foam	99.9	99.25
Double Vacuum, Foam	99.9	99.25
Double Vacuum, Wash and Scrub	99.86	99.06
Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.99	99.99
Double Vacuum, Surface Sealer/ Fixative, Remove and Replace	99.99	99.99
Strippable Coating	98	97
Vacuum, Strippable Coating	99.6	97.85
Surface Sealer/ Fixative	80	

DECONTAMINATION OF INTERIOR CONCRETE WALLS

Vacuum	**70**	65
Double Vacuum	**79**	74.1
Wash and Scrub	**80**	75
Vacuum, Wash and Scrub	**92.5**	89.95
Vacuum, Foam	**95.5**	93.35
Double Vacuum, Foam	**95.8**	94.04
Double Vacuum, Wash and Scrub	**93.7**	91.43
Vacuum, Surface Sealer/ Fixative, Remove and Replace	**99.76**	99.41
Double Vacuum, Surface Sealer/ Fixative, Remove and Replace	**99.83**	99.79
Double Vacuum, Foam, Surface Sealer/ Fixative, Remove and Replace	**99.96**	99.94
Strippable Coating	**90**	85
Vacuum, High Pressure Water	**94**	91.6
Double Vacuum, High Pressure Water	**94.96**	93.0 I
Vacuum, Hydroblasting	**97.3**	95.45
Double Vacuum, Hydroblasting	**97.69**	95.61
Vacuum, Strippable Coating	**91.3**	88.45
Double Vacuum, Strippable Coating	**93.28**	90.6

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources (Continued)

DECONTAMINATION METHOD	EFFICIENCY	
	INHALATION	EXTERNAL
DECONTAMINATION OF ASPHALT STREETS/PARKING		
Vacuum	**50**	45
Double Vacuum	**67.5**	61.5
Low Pressure Water	**95**	85
Vacuum, Low Pressure Water	**95.5**	86.25
Vacuum, Foam	**97.5**	91.75
Double Vacuum, Foam	**98.05**	91.92
Double Vacuum, Low Pressure Water	**95.78**	86.53
Vacuum, Remove and Replace	**99.5**	99.45
Double Vacuum, Remove and Replace	**99.68**	99.62
Double Vacuum, Foam, Remove and Replace	**99.98**	99.92
Vacuum, Resurface	**99.25**	98.9
Double Vacuum, Resurface	**99.51**	99.23
Double Vacuum, Foam, Resurface	**99.97**	99.84
Strippable Coating	**97.5**	93
Vacuum, Thin Asphalt/ Concrete Layer	**99**	49.4
Double Vacuum, Thin Asphalt/ Concrete Layer	**99.35**	64.58
Vacuum, 3“ Asphalt with Cover with 6“ Soil	**99.25**	71.4
Double Vacuum, 3” Asphalt and Cover with 6“ Soil	**99.51**	79.98
Vacuum, Strippable Coating	**98**	96.15
Surface Sealer/ Fixative	**97.75**	**02**
Double Vacuum, Strippable Coating	**98.38**	**93.46**
Foam	**97**	**90**
Double Vacuum, Strippable Coating, Foam	**99.84**	**98.36**
DECONTAMINATION OF CONCRETE STREETS/PARKING		
Vacuum	**50**	45
Double Vacuum	**67.5**	61.5
Low Pressure Water	**95**	85
Vacuum, Low Pressure Water	**95.5**	86.25
Vacuum, Foam	**97.5**	91.75
Double Vacuum, Foam	**98.05**	91.92
Double Vacuum, Low Pressure Water	**95.78**	86.53
Vacuum, Remove and Replace	**99.5**	99.45
Double Vacuum, Remove and Replace	**99.68**	99.62
Double Vacuum, Foam, Remove and Replace	**99.98**	99.92
Vacuum, Resurface	**99.25**	98.9
Double Vacuum, Resurface	**99.51**	99.23
Double Vacuum, Foam, Resurface	**99.97**	99.84
Strippable Coating	**97.5**	93
Vacuum, Thin Asphalt/ Concrete Layer	**99**	53.8
Double Vacuum, Thin Asphalt/ Concrete Layer	**99.35**	67.66
Vacuum, 3“ Asphalt and Cover with 6“ Soil	**99.25**	71.4
Double Vacuum, 3“ Asphalt and Cover with 6“ Soil	**99.51**	79.98
Vacuum, Strippable Coating	**98**	96.15
Surface Sealer/ Fixative	**97.75**	**02**
Double Vacuum, Strippable Coating	**98.38**	**93.46**
Foam	**97**	**90**
Double Vacuum, Strippable Coating, Foam	**99.84**	**98.36**

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources (Continued)

DECONTAMINATION METHOD	EFFICIENCY INHALATION	EFFICIENCY EXTERNAL
DECONTAMINATION OF ROOFS		
Vacuum	60	**50**
Sandblasting	99	**96**
High Pressure Water	97	**93**
Foam	93	**90**
Strippable Coating	85	**80**
Low Pressure Water	**90**	**85**
Low Pressure Water (x2)	98	**96.25**
Remove and Replace	99.9	**99**
Vacuum, High Pressure Water	98	**95**
Vacuum, Low Pressure Water	92	**87.5**
Surface Sealer/ Fixative, Remove and Replace	99.94	**99.81**
DECONTAMINATION OF LAWNS		
Double Vacuum	**30**	**20**
Low Pressure Water	**85**	75
Low Pressure Water (x2)	**91**	84
Low Pressure Water (x3)	**93**	86.88
Low Pressure Water (x4)	**94**	88.06
Close Mowing	**65**	65
Remove and Replace	**98**	98
Leaching, $FeCl^3$	**85**	80
Surface Sealer/ Fixative, Remove and Replace, Low Pressure Water	**99.9**	99.7
Surface Sealer/ Fixative, Remove and Replace, Leaching, $FeCl^3$	**99,92**	99.9
Surface Sealer/ Fixative, Remove and Replace	**99**	99
DECONTAMINATION OF OTHER PAVED ASPHALT		
Vacuum	**50**	45
Double Vacuum	**67.5**	61.5
Low Pressure Water	**95**	85
Vacuum, Low Pressure Water	**95.5**	86.25
Vacuum, Foam	**97.5**	91.75
Double Vacuum, Foam	**98.05**	91.92
Double Vacuum, Low Pressure Water	**95.78**	86.53
Vacuum, Remove and Replace	**99.5**	99.45
Double Vacuum, Remove and Replace	**99.68**	99.62
Double Vacuum, Foam, Remove and Replace	**99.98**	99.92
Vacuum, Resurface	**99.25**	98.9
Double Vacuum, Resurface	99.51	99.23
Double Vacuum, Foam, Resurface	**99.97**	99.84
Strippable Coating	**97.5**	93
Vacuum, Thin Asphalt/ Concrete Layer “	**99**	49.4
Double Vacuum, Thin Asphalt/ Concrete Layer	**99.35**	64.58
Vacuum, Strippable Coating	**98**	96.15
Surface Sealer/ Fixative	**97.75**	02
Double Vacuum, Strippable Coating	**98.38**	93.46
Foam	**97**	90
Double Vacuum, Strippable Coating, Foam	**99.84**	98.36

TABLE 19-2. Efficiencies for Decontamination of Land Areas and Selected Resources (Continued)

ENGINE-DRIVE TRAIN AND INTERIORS AUTO EXTERIORS

DECONTAMINATION METHOD	EFFICIENCY INHALATION	EXTERNAL
Water Wash	85	80
Water Wash (x2)	96.25	93
Wash & Scrub	95	94
Wash and Scrub (x2)	99.5	99.28
Repaint	99.9	99.8
ENGINE-DRIVE TRAIN		
Steam Clean	75	65
Steam Clean (x2)	92.5	86
Clean Engine with Solvent	95	90
Steam Clean, Clean Engine with Solvent	97.5	94.75
Steam Clean, Clean Engine with 4 Solvent (x2)	99.63	98.95
INTERIORS		
Vacuum	75	70
Double Vacuum	92.5	89.5
Detailed Auto Cleaning	95	90
Detailed Auto Cleaning (x2)	96	92
Replace/ Reupholster	99	99
Vacuum, Remove Interior/ Clean/ Replace	98	97
TIRES		
Water Wash	80	50
Wash and Scrub	90	85
Replace	99.9	99.9
Sandblasting	95.9	88

TABLE 19-3. Decontamination Methods

METHOD	SURFACE	ACTION	TECHNIQUE	ADVANTAGES	DISADVANTAGES
CAUSTICS: Lye (sodium hydroxide) Calcium hydroxide Potassium hydroxide	Painted surfaces (horizontal)	Softens paint (harsh method)	Lye paint removal solution: 10 gal. water, 4 lb lye, 6 lb boiler compound, 0.75 lb cornstarch. Allow lye paint remover solution to remain on surface until paint is softened to the point where it may be washed off with water. Remove remaining paint with longhandled scrapers.	Minimum contact with contaminated surfaces. Easily stored.	Personnel hazard (will cause burns). Reaction slow; thus, it is not efficient on vertical or overhead surfaces. Should not be used on aluminum or magnesium.
Trisodium phosphate	Painted surfaces (vertical, overhead)	Softens paint (mild method)	Apply hot 10% solution by rubbing and wiping procedure (see DETERGENTS)	Contamination may be reduced to tolerance in one or two applications.	Destructive effect on paint. Should not be used on aluminum or magnesium.
ABRASION	Nonporous surfaces	Removes surface	Use conventional procedures, such as sanding, filing, and chipping; keep surface damp to avoid dust hazard.	Contamination may be reduced to as low a level as desired.	Impractible for porous surfaces because of penetration by moisture.
SANDBLASTING	Nonporous surfaces	Removes surface	Keep sand wet to lessen spread of contamination. Collect used abrasive or flush away with water.	Practical for large surface areas.	Contamination spread over area must be recovered. Contaminated dust is personnel hazard,
VACUUM BLASTING	Porous and nonporous surfaces	Removes surface; traps and controls contaminated waste.	Hold tool flush to surface to prevent escape of contamination.	Contaminated waste ready for disposal. Safest abrasion method.	Contamination of equipment.
VACUUM CLEANING	Dry surfaces -----	Removes contaminated dust by suction	Use conventional vacuum technique with efficient filter	Good on dry porous surfaces. Avoids water reactions.	All dust must be filtered out of exhaust. Machine is contaminated.
WATER	All nonporous surfaces (metal, painted, plastics, etc.)	Dissolves and erodes	Hose with high pressure water at an optimum distance of 15 to 20 feet. Spray vertical surfaces at	All water equipment may be utilized. Allows operation to be carried out from a distance.	Drainage must be controlled, Not suitable for porous materials. Oiled surfaces cannot

TABLE 19-3. Decontamination Methods (Continued)

METHOD	SURFACE	" ACTION	TECHNIQUE	ADVANTAGES	DISADVANTAGES
WATER (Continued)			an angle of incidence of 300 to 45"; **work from top to bottom to avoid recontamination. Work from upwind to avoid spray. Determine cleaning rate, experimentally, if possible; otherwise, use a rate of4 square** feet per minute.	**Contamination may be reduced by 50%. Water equipment may be used for solutions of other decontaminating agents.**	be decontaminated. Not applicable on dry contaminated surfaces (use vacuum). Not applicable on porous surfaces **such as wood, concrete, canvas. Spray will be contaminated.**
STEAM	Nonporous surfaces **(especially painted or oiled surfaces)**	**Dissolves and erodes**	Work from top to bottom and from upwind. Clean surface at a rate of 4 square feet per minute. **The cleaning efficiency of steam will be greatly increased by using detergents.**	**Contamination may be reduced by approximately 90% on painted surfaces**	**Steam subject to same limitations as** water. Spray hazard makes **the wearing of** waterproof outfits necessary.
DETERGENTS	**Nonporous surfaces (metal, painted, glass, plastic, etc.)**	Emulsifies contaminant **and increases wetting power of water and cleaning efficiency of steam**	**Rub surface 1 minute with a rag moistened with detergent solution; then wipe with dry rag. Use clean surface of the rag for each application.** **Use a** power rotary brush with pressure **feed for more efficient cleaning.** **Apply solution from a distance with a pressure proportioned,** **Do not allow solution to drip onto other surfaces.** Moist application is all that is necessary,	Dissolves industrial film **and other materials which hold con tamination. Contamination may be reduced by 90%.**	May **require personnel contact with surface. May not be efficient on long-standing contamination.**

TABLE 19-3. Decontamination Methods (Continued)

METHOD	SURFACE	ACTION	TECHNIQUE	ADVANTAGES	DISADVANTAGES
COMPLETING AGENTS Oxalates Carbonates Citrates	Nonporous surfaces (especially unweathered surfaces, i.e., no rust or calcareous growth).	Form soluble complexes with-contaminated material	Completing agent solution should contain 3% (by weight) of agent. Spray surface with solution. Keep surface moist for 30 min. utes by spraying with solution periodically. After 30 minutes, flush material off with water. Completing agents may be used on vertical and overhead surfaces by adding chemical foam (sodium carbonate or aluminum sulfate).	Holds contamination in solution. Contamination may be reduced by 75% in 4 minutes on unweathered surfaces. Easily stored. Carbonates and citrates are nontoxic, noncorrosive.	Requires application for 5 to 30 minutes. Little penetrating power; of small value on weathered surfaces.
ORGANIC SOLVENTS	Nonporous surfaces (greasy or waxed surfaces, paint or plastic finishes, etc.)	Dissolves organic materials (oil, paint, etc.)	Immerse entire unit in solvent or apply by wiping procedure (see DETERGENTS).	Quick dissolving action. Recovery of solvent possible by distillation.	Requires good ventilation and tire precautions. Toxic to personnel. Material bulky.
INORGANIC ACIDS	Metal surfaces (especially with porous deposits, i.e.. rust or calcareous growth); circulatory pipe systems.	Dissolves porous deposits	Use dip-bath procedure for movable items, Acid should be kept at a concentration of from 1 to 2 normal (9 to 18% hydrochloric, 3 to 6% sulfuric acid). Leave on weathered surfaces for 1 hour. Flush surface with water, scrub with a water-detergent solution, and rinse. Leave in pipe circulatory systems 2 to 4 hours; flush with plain water, a water-detergent solution, then again with plain water.	Corrosive action on metal and porous deposits. Corrosive action may be moderate by addition of corrosion inhibitors to solution.	Personnel hazard. Wear goggles, rubber boots, gloves, and aprons. Good ventilation required because of toxicity and explosive gases. Acid mixtures should not be heated. Possibility of excessive corrosion if used without inhibitors. Sulfuric acid not effective on calcareous deposits.
ACID MIXTURES: Hydrochloric Sulfuric Acetic Acid Citric Acid Acetates Citrates	Nonporous surfaces (especially with porous deposits); circulatory pipe systems.	Dissolves porous deposits	Same as for inorganic acids. Mixture consists of 0.1 gal. hydrochloric acid, 0.2 lb sodium acetate, and 1 gal. water.	Contamination may be reduced by 90% in 1 hour (unweathered surfaces). More easily handled than inorganic acid solutions.	Weathered surfaces may require prolonged treatment. Same safety precautions as required for inorganic acids.