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Project Summary

Reference Manual of Countermeasures for Hazardous Substance Releases

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When a release of hazardous substances has occurred or threatens to occur, federal, state, local government, or industrial personnel may have to assume responsibility for immediate and planned removal, which is the principal cleanup and treatment phase. They must select treatment and disposal processes, or countermeasures, which are effective for the particular hazardous substances and circumstances of the release.

The manual described in this Project Summary contains procedures to assist response personnel in selecting optimum countermeasures. The procedures make up a rational methodology which consist of four decision-making steps in series, starting with identification of the substance(s) involved and site-specific parameters, and ending with an optimization of technically feasible counter-measures in the light of economic, logistic, and other criteria. The methodology uses comprehensive tables, or matrices, which provide technical guidance for almost 700 hazardous substances designated by the Comprehensive Environmental Response, Compensation and Liability Act of 1980, otherwise known as CERCLA or Superfund (PL96-510). Remedial action of a long-term nature, which follows removal, is not addressed here.

The manual is designed as a reference for use in field or office and stands alone. It is based on available, sometimes incomplete, sources. Its purpose is to provide persons with a limited background a fast, workable guide to plausible removal countermeasures, given a reasonable amount of knowledge about the release. The user should be cognizant of federal, state and local regulations that may impact the decision to select specific countermeasures, and of the fact that these regulations may be amended from time to time. An example of the application of the manual to a real situation is included.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, 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).

Objectives and Background

The manual described in this Project Summary is designed to assist federal, state, and local government and industry personnel who may find it necessary to respond to a release (or threat of a release) of hazardous substances designated in the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). Approximately 700 hazardous substances have been designated pursuant to CERCLA Section 101(14). The manual applies to many types of releases, including transportation and non-transportation related ones as well as those from hazardous waste sites.

The manual guides the responder through a series of decisions and actions to be taken at the site of the release or potential release. Actions such as these are mandated by the National Contin-

gency Plan (NCP) (40 CFR Part 300).

Note that regulations may be amended from time to time, as may lists of regulated chemicals. Check to see that your information is up-to-date.

Manual Contents

The entire manual is summarized in Figure 1, which shows how Sections 2 to 5 are used in the selection of countermeasures for a given release situation.

Section 2 of the manual provides guidelines for situation assessment. This provides for the identification of the hazardous substance and determination of the proper response procedures dependent on the medium (atmosphere, surface water, ground) receiving the release. Discussions on site assessment, guidelines for protective clothing selection, and equipment decontamination at the affected sites are offered in Appendices A, B, and C.

Section 3 addresses the selection of countermeasures. The information generated in Section 2 is utilized in three steps: The "A" Tables disclose the physical nature of the hazardous substances involved and the associated hazards; the "B" tables establish various technically feasible countermeasures based on Tables A; and the "C" Tables give the optimal countermeasures in light of applicable criteria and parameters. Samples of all three tables are provided in this Project Summary. Note that the number-letter combination identifying each table is based both on the nature of the spilled substance and on the type of receiving medium. The term countermeasure includes physical, chemical, and biological cleanup; treatment; and disposal processes to be carried out on-site or off-site. Countermeasure selection criteria include considerations of the degree of cleanup achievable, environmental factors, logistics, safety, and cost. One possible alternative is to take no immediate action and rely on isolation alone until such time as the hazards have lessened and suitable countermeasures can be applied.

Section 4 lists all countermeasures in Section 3. The countermeasures are categorized and defined in terms of their characteristics, advantages, and disadvantages. Having been presented at the conclusion of Section 3 with at least one optimal countermeasure, the responder may make the final choices by referring to this listing. An important use of the listing occurs when a release consists of two or more hazardous substances. It is crucial that synergistic effects be considered. The application of different countermeasures in parallel or in series must then be closely examined.

Section 5 lists the bibliography which underlies the entire manual. A total of 285 sources were accessed; of these, 235 were reviewed and 203 distinct sources extracted. The cut-off publication date for bibliography sources was 1983. The bibliography is categorized with major headings similar to those used in Sections 3 and 4 and arranged alphabetically by author within each category. Section 4 references the original sources so that the responder may obtain more detailed information, if desired. The final subsection, "General Sources," contains a list of references, each of which may address a number of different countermeasures.

Three appendices conclude the manual. All three are devoted to safety aspects necessary in the approach, entry, and decontamination of a hazardous spill or waste site. Appendix A presents suggested guidelines for site assessment, entry, and control. Appendix B provides

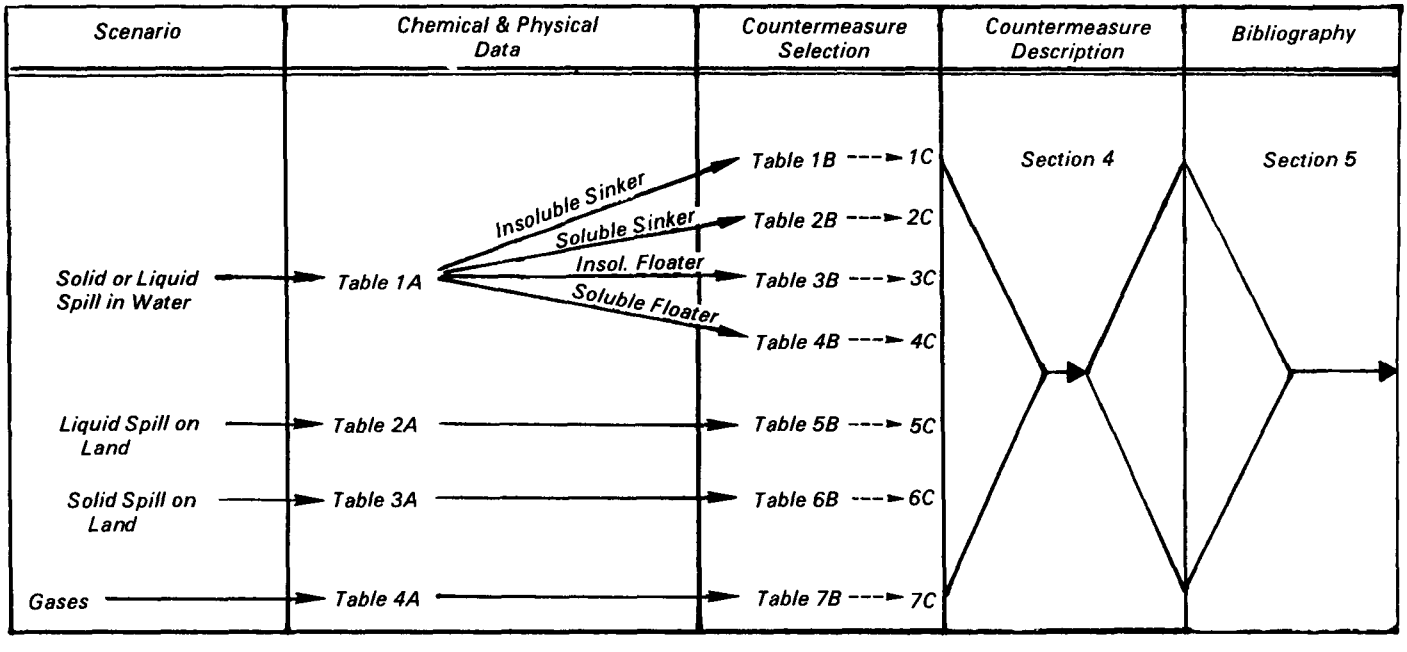

Table	# of Pages	Table	# of Pages	Table	# of Pages	Table	# of Pages	Table	# of Pages
1A	40	1B	2	5B	2	1C	4	5C	4
2A	14	2B	2	6B	2	2C	4	6C	3
3A	23	3B	1	7B	1	3C	5	7C	1
4A	2	4B	1			4C	5		

Figure 1. Pathways in the use of the manual.

details on suggested guidelines for selection of chemical resistant clothing. Appendix C discusses decontamination protocols in terms of work zones, safety clothing, and equipment.

Use of the Manual — Brief Overview

The selection of countermeasures for a given release situation is illustrated in Figure 1. Briefly, four steps are carried out in series:

1. *The Spill Scenario* is obtained from Section 2:
   The Hazardous Substance and its state (liquid, solid, gas); and the medium (water, land, atmosphere) into which it is released.
2. *Chemical and Physical Data* of the released substance are obtained from the "A" Tables in Section 3:
   Releases in water — Table 1A; Liquids released on land — Table 2A; Particulate solids released on land — Table 3A; Compressed gases released into air — Table 4A.
3. *Technically Feasible Countermeasures* are obtained from the "B" Tables in Section 3:
   Spills on water: Insoluble sinkers — Table 1B; Soluble sinkers — Table 2B; Insoluble floaters — Table 3B; Soluble floaters — Table 4B; Liquid spills on land — Table 5B; Particulate solid spills on land — Table 6B; Compressed gases released into air — Table 7B.
4. Optimum Countermeasures are selected from among the *Technically Feasible Countermeasures* by using the "C" Tables in Section 3 (Tables 1C through 7C correspond to Tables 1B through 7B).

For more details about items 1 to 4 above, the manual presents:

- *Descriptions of the Countermeasures* and their characteristics (for better understanding of the Optimum Countermeasures) in Section 4, and a
- *Listing of the Original Sources* from which Descriptions of the Countermeasures were taken (including both specific and general references) in Section 5.

The preceding decision-making methodology has related to one hazardous substance release into one environmental medium. The correlating parameter in steps 2 and 3 is the chemical class to which the substance of interest has been assigned. The countermeasures then depend on the chemical class. Actual spill situations may involve (a) hazardous substance(s) belonging to more than one chemical class and (b) scenarios of more than one hazardous substance being released into more than one environmental medium.

For eventualities (a) and (b), the following procedure is suggested. The responder should carry out steps 2, 3, and 4 for all alternative chemical classes, hazardous substances, and media pertaining to the incident. The result will be a multiplicity of feasible and optimum countermeasures, usually a choice of several for any one set of inputs. The responder should select countermeasures which are common to the chemical classes and substances released into each medium. Also, a judgment must be made about the cleanup priority of each medium, e.g., should countermeasures for different media be performed in series or in parallel, or in some other time relationship? To help the user with such decisions, the material in Sections 4 and 5 emphasizes logistics, speed of deployment, cost of different countermeasures, etc.

Sample page from "A" Table:

Table 1A. *Releases in Water*

★ *"B" Table Reference*

Hazardous Substance	*Chemical Class/ CAS No.*	*Hazard(s) In Addition To Toxicity*	★ *Behavior in Water*
Acenaphthene	*Aromatics CAS 83-32-9*	*Combustible*	*1B Insoluble Sinker*
Acenaphthylene	*Aromatics CAS 208-96-8*	*Combustible*	*3B Insoluble Floater*
Acetaldehyde	*Aldehydes CAS 75-07-0*	*Flammable Polymerizable*	*4B Soluble*
Acetic acid	*Acidic compounds, organic CAS 64-19-7*	*Combustible Corrosive*	*2B Soluble*
Acetic anhydride	*Acidic compounds, organic CAS 108-24-7*	*Combustible Corrosive*	*2B Soluble, decomposes*
Acetone	*Ketones CAS 67-64-1*	*Flammable*	*4B Soluble*
Acetone cyanohydrin	*Cyanides and nitriles CAS 75-86-5*	*Combustible w/toxic products Poison*	*4B Soluble*
Acetonitrile	*Cyanides and nitriles CAS 75-05-8*	*Flammable w/toxic products*	*4B Soluble*
Acetophenone	*Ketones CAS 98-86-2*	*Combustible*	*1B Insoluble Sinker*
Acetyl bromide	*Aliphatics, halogenated CAS 506-96-7*	*Flammable w/toxic products Corrosive Reactive*	*2B Decomposes (Sinker)*
Acetyl chloride	*Aliphatics, halogenated CAS 75-36-5*	*Flammable w/toxic products Corrosive Reactive*	*2B Decomposes (Sinker)*
2-Acetylamino fluorene	*Amines, aryl CAS 53-96-3*	*Potential carcinogen*	*1B Insoluble Sinker*
1-Acetyl-2-thiourea	*Ureas CAS 591-0802*		*2B Soluble*

Countermeasure Considerations

The many techniques for containment, treatment, and disposal (listed in Table 8 of the manual) need to be considered in their basic, practical aspects. Depending on the location of the treatment and any interference with the environment, three types of countermeasures are possible:

1. *In Situ:* The spill site is not significantly disturbed by the treatment method carried out on the site, e.g., radio-frequency heating of ground surface using implanted electrodes (removed after treatment) to distill off organic pollutants.
2. On Site: The spill site is disturbed by the treatment method which is carried out on the site, e.g., contaminated soil is excavated, incinerated on the site in mobile incinerators, and the clean soil is replaced on the site.
3. Off Site: The spill site is disturbed, and the contaminated material transported off the site is either (a) treated in a

Table 1B. *Insoluble Sinkers in Water*

Applicable Countermeasures / Chemical Class	Containment					Displacement			Treatment											Disposal			
	Dams, Berms and Dikes	Trenches	Curtain Barriers (1)	Stream Diversion	Synthetic Membrane Covers	Dredging (2)	Pumping	Dispersion/Dilution (3)	Activated Carbon	Synthetic Sorbents	Granular Media Filtration	Gravity Separation	Coagulation/Flocculation	Ion Exchange — Anionic	Ion Exchange — Cationic	Neutralize w/acid (4)	Neutralize w/base	Oxidation	Precipitation	Biological Treatment (7)	Incineration	Wet Air Oxidation	Landfill	Deep Well Injection
Acidic compounds, organic	√	√	√	√	√	√	√	√	√		√	√					√				√		√	√
Aliphatics, halogenated	√	√	√	√	√	√	√	√	√	√	√	√						√			√		√	√
Amides, anilides and imides	√	√	√	√	√	√	√	√			√	√									√		√	√
Amines, alkyl	√	√	√	√	√	√	√	√	√		√	√						√			√		√	√
Amines, aryl	√	√	√	√	√	√	√	√	√		√	√						√			√		√	√
Aromatics	√	√	√	√	√	√	√	√	√		√	√						√			√		√	√
Aromatics, halogenated	√	√	√	√	√	√	√	√	√	√	√	√					√	√			√		√	√
Asbestos	√	√	√	√	√	√	√	√			√	√									√		√	√
Azo compounds	√	√	√	√	√	√	√	√			√	√									√		√	√
Basic compounds	√	√	√	√	√	√	√	√	√		√	√				√					√		√	√
Chromates	√	√	√	√	√	√	√	√	√		√	√		√					√		√		√	√
Cyanates	√	√	√	√	√	√	√	√	√		√	√		√	√						√		√	√
Cyanides and nitriles	√	√	√	√	√	√	√	√	√		√	√		√	√		√	√	(5)		√	√	√	√
Epoxides	√	√	√	√	√	√	√	√	√		√	√						√			√		√	√
Esters	√	√	√	√	√	√	√	√	√		√	√									√		√	√
Ethers	√	√	√	√	√	√	√	√	√		√	√									√		√	√
Halides, alkyl	√	√	√	√	√	√	√	√	√		√	√									√		√	√
Halides, inorganic	√	√	√	√	√	√	√	√	√		√	√		√	√		√		√		√		√	√
Heavy metals	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√				√		√		√	√
Ketones	√	√	√	√	√	√	√	√	√		√	√									√		√	√
Nitro compounds	√	√	√	√	√	√	√	√	√	√	√	√						√			√	√	√	√
Nitroso compounds	√	√	√	√	√	√	√	√	√		√	√									√		√	√
Olefins	√	√	√	√	√	√	√	√	√		√	√									√		√	√
Organometallics	√	√	√	√	√	√	√	√	√		√	√		√	√				√		√		√	√
Organophosphates	√	√	√	√	√	√	√	√	√		√	√									√		√	√
Oxides	√	√	√			√	√	√	√		√	√			√			√			√		√	√
Peroxides	√	√	√			√	√	√			√	√					√	(6)			√		√	√
Phenols and cresols	√	√	√			√	√	√	√	√	√	√	√					√		√	√	√	√	√
Phosphorous and compounds	√	√	√			√	√	√			√	√		√	√						√		√	√
Phosphates and phosphonates	√	√	√			√	√	√			√	√									√		√	√
Strychnine and salts	√	√	√			√	√	√	√		√	√									√		√	√
Sulfates	√	√	√			√	√	√			√	√			√						√		√	√
Sulfides and mercaptans	√	√	√			√	√	√	√		√	√		√	√			√			√	√	√	√
Sulfites	√	√	√			√	√	√			√	√									√		√	√
Sulfones, sulfoxides, & sulfonates	√	√	√			√	√	√	√		√	√		√							√		√	√
Ureas	√	√	√			√	√	√			√	√									√		√	√

(1) Use during dredging operations
(2) Mechanical dredging applicable to particulates only
(3) Reduce contaminant levels below toxic level through flow augmentation and mechanical mixing. Applicable to small spills in remote areas only!
(4) Treat with dilute and/or removable acids
(5) Treat with sodium hypochlorite or calcium hypochlorite
(6) Treat with hydrogen peroxide or ozone
(7) Potentially biodegradable

Table 1C. *Insoluble Sinkers*

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Limitations: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Requirements: Special Equipment	Power	Monitoring	Off-site Disposal/Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Curtain Barriers	C	In-situ	NA	Neat Diss	<1 day	X	X		X	X			X					TEC		$200-300/ft	1.1.3.2	Max. current — 1-2 knots Max. depth — 2-5 feet Max. waves — 6 feet
Dams, Berms, Dikes	C	In-situ	NA	Neat Diss	varies		X	X	X	X	X							HEO CE		$4/cu yd	1.1.1	Earth moving equipment may require special access
Stream Diversion	C	In-situ	NA	Neat Diss	varies		X		X		X		X	X				HEO CE			1.1.5	Earth moving equipment may require special access. Power required for pumps. Mobile unit available.
Synthetic Membrane Cover	C	In-situ	NA	Neat Diss	varies	X			X	X	X		X					TEC PRO		3-4¢/sq. ft. (1972)	1.2.3	Material must be chemically compatible with hazardous substance Navigable water only
Trenches	C	In-situ	NA	Neat Diss	varies		X	X	X	X	X		X					HEO CE			1.1.2	Underwater trenches may require special equipment
Dispersion	D	In-situ	Gross	Neat Diss	>1 day							X							X		1.3.5	Bad weather and rough water may enhance dispersion. Type of HS dictates whether dispersion usable in populated acreas
Dredging	D	In-situ	Gross	Neat	>1 day				X	X	X					X		TEC CE	X	$5-15/yd³	1.3.1	Parimeter of spill must be known. Requires large boat/barge
Pumping	D	In-situ	NA	Neat Diss	varies								X	X		X		TEC		$50-60/hr	1.3.4	~32' height limit for vacuum pumping. May need corrosion/ explosion proof pumps.
Activated Carbon Column	T	On-site	Moderate Polish	Diss	>1 day						X		X	X	X	X		TEC PRO		2-23¢/gal 50-55¢/lb	2.1.1	Spent carbon must be regenerated or disposed of.
Biological Treatment	T	Off-Site	Moderate Polish	Neat Diss	Varies								X					STE	X		4.0	May require special bacteria.

Table 1C. *(continued)*

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Limitations: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Requirements: Special Equipment	Power	Monitoring	Off-site Disposal/Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Biological Treatment	T	In-situ	Moderate Polish	Diss	>1 day			X	X	X								STE			4.0	May require special bacteria.
Coagulation/ Flocculation	T	On-Site	Moderate	Diss	< ½ day								X	X		X		CHE CH TEC			3.1	1 stage of treatment process. Usually followed by filtration or gravity separation.
Granular Media Filtration	T	On-Site	Gross	Neat	>1 day								X	X		X		STE TEC			2 3	1 stage of treatment process. Follows flocculation/coagulation & precedes polishing.
Gravity Separation	T	On-Site	Gross	Neat	<1 day								X			X		TEC			2.4	1 stage of treatment process. Follows flocculation/coagulation & precedes polishing, May require special equipment.
Incineration		On-Site	Moderate Polish (Disposal)	Neat Diss	<1 day	X					X	X	X		X	X	X	PRO	X		5.2	May require stack monitoring. May produce toxic gases/ashes.
Incineration		Off-site	Moderate Polish (Disposal)	Neat Diss	<1 day								X		X	X	X	PRO	X	$395-791/ton solid $53-237/ton liq.	5.2	May require stack monitoring. May produce toxic gases/ashes
Ion Exchange (Anionic/ Cationic)	T	On-site	Moderate Polish	Diss	>1 day						X		X	X	X	X		CHE TEC			3.4	Proper selection of resin is very important.
Neutralization	T	On-site	Moderate Polish	Diss Neat	>1 day						X		X	X	X		X	TEC CHE			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.

Table 1C. *(continued)*

Counter-measures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Limitations: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Requirements: Special Equipment	Power	Monitoring	Off-site Disposal/Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Neutralization	T	In-situ	Moderate Polish	Neat Diss	<1 day	X	X		X	X					X		X	CH TEC			3.6	Neutralizer itself may be hazardous. May cause violent exothermic reaction.
Oxidation	T	On-site	Moderate Polish	Diss	>1 day						X		X	X	X		X	CH CHE TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction.
Oxidation	T	In-situ	Moderate Polish	Diss	<1 day	X	X		X	X					X		X	CH TEC			3.7.1	Oxidants and/or reaction products may cause environmental damage. May require pH adjustment before & after reaction. Main cost is chemicals.
Precipitation	T	On-site	Gross Polish	Diss	>1 day						X		X	X	X	X	X	CH CHE TEC			3.9	Precipitating chemicals may be hazardous.
Precipitation	T	In-situ	Gross Polish	Diss	<1 day	X	X		X	X					X	X	X	CH TEC			3.9	Precipitation chemicals may be hazardous. Toxic precipitates should be removed and disposed of.
Synthetic Sorbents	T	In-situ	Gross	Neat	<1 day	X			X	X						X		TEC			2.1.4	
Synthetic Sorbent Column	T	On-site	Moderate Polish	Diss	>1 day						X		X	X	X	X		CH TEC			2.1.4	
Wet Air Oxidation	T	Off-site	Moderate Polish (disposal)	Diss	<1 day								X					TEC	X		5.3	Typically used for industrial waste water treatment.

Table 1C. *(continued)*

Countermeasures	Containment, Dispersement or Treatment	Mode	Potential Extent of Cleanup	Form of HS	Dependent Time	Limitations: Environmental: Wind	Precipitation	Temperature	Water Velocity	Water Surface Conditions	Special Access	Unusable in Populated Areas	Requirements: Special Equipment	Power	Monitoring	Off-site Disposal/Recycling	Special Safety Precautions	Manpower	Permits	Unit Cost	Text Section	Comments
Landfill		*Off-site (Disposal)*		*Neat Diss*	*Varies*													*TEC*	*X*	*$55-240/ ton*	*5.5*	*Requires containerization or dewatering. May require pretreatment and/or solidification.*
Deep Well Injection		*Off-site (Disposal)*		*Neat Diss*	*Varies*													*TEC*	*X*	*$.06-$1/ gal*	*5.6*	*Service generally contracted. Extensive geologic study to determine adequate well location.*

Legend:
STE = Sanitary Engineer
CHE = Chemical Engineer
CH = Chemist
HEO = Heavy Equipment Operator
PRO = Professional
TEC = Technician
NA = Not Applicable
CE = Civil Engineer

(central) facility with the clean material either returned back to the site or disposed of in the vicinity of the treatment facility or (b) disposed of with minimal if any treatment in a proper disposal site.

These three basic categories determine the cost structure (treatment and disposal vs. transportation costs) of the countermeasure, and also the regulatory requirements. The responder should be conversant with or at least aware of the federal, state, and local environmental regulations which may make some countermeasures, otherwise preferred, unsuitable. Typical examples are the need to obtain permits for treatment methods (such as incineration, which could change a solid or liquid pollution problem into an air pollution problem) or transportation of hazardous wastes across certain cities or states. Regulations change with time and location and are not covered in this manual.

Example of Manual Use

To illustrate how a responder would use the manual, the following typical spill scenario is given. A train has derailed. Several tank cars carrying various chemicals are off the tracks. One car containing acrylonitrile has ruptured, and the contents are leaking from the car and running into a nearby stream. The stream is slow moving and quite small. It serves neither as a source of domestic water nor as a recreation area. However, it does flow into a major waterway approximately five miles downstream from the spill. The major waterway is a source of both potable water and recreation for a large metropolitan area.

The responders in this situation are actually presented with two spill scenarios: one involving a liquid spill on land and the other a liquid spill in water. Containment procedures, probably different for each situation, must be initiated simultaneously. Once containment of the spilled material has been achieved, displacement, treatment and/or disposal countermeasures can be applied to the contaminated soil and water. Treatment countermeasures need not be conducted simultaneously for each situation. Indeed, the spill of acrylonitrile in the stream presents a much more immediate and serious threat to the environment and nearby populace than does the material spilled on land. The responder, in all likelihood, will concentrate on treating the contaminated stream first and the soil second.

The Countermeasures Manual addresses four specific and individual spill scenarios; and not multi-media events, as given in this example. When confronted with a multi-media spill, the responder must separate it into two (or more) single medium spills, consult this manual for feasibility countermeasures for each single medium spill, and then determine

the best combination of countermeasures to apply.

The manual was submitted in partial fulfillment of Contract No. 68-03-3014 by Combustion Engineering Corporation under the sponsorship of the U.S. Environmental Protection Agency. It covers the period September, 1982 to July, 1984, and work was completed as of December, 1984.

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The complete report, entitled "Reference Manual of Countermeasures for Hazardous Substance Releases," (Order No. PB 87-232 252/AS; Cost: $24.95, subject to change) will be available only from:

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