PROJECT SUMMARY

DUST AND VAPOR SUPPRESSION TECHNOLOGIES FOR EXCAVATING CONTAMINATED SOIL

by

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ABSTRACT

This report presents typical requirements for dust and vapor suppression during the excavation of contaminated soil, sludges, and sediments and analyzes the ability of currently available technologies to meet these requirements. To define typical suppression requirements, the study reviews records of remedial actions at Superfund sites, contaminants, modes of emission transport, and environmental impacts from emissions. To help removal/response planners, the report discusses the information needed to specify control measures for dust and vapor emissions from excavation activities.

In performing the study, current dust and vapor control practices were reviewed at over 150 NPL sites. Analysis of 100 sites where dust and vapor emissions were a potential problem revealed that 59 percent of the sites employed no specific controls. Water sprays were used at 18.1 percent, and covers were utilized at 13.3 percent of the sites surveyed. Chemical suppressants and containment structures were each employed at 4.8 percent of the 100 sites. In some instances, site managers utilized more than one method of dust and vapor control.

The study identifies 13 categories of commercial suppression technologies available for use by on-scene coordinators, cleanup contractors, and design engineers. Each technology is described and reviewed for its applicability, effectiveness, implementability, cost, and relative advantages and disadvantages. Application and utilization guidelines are also presented.

Three case histories are described in some detail. These involve 1) utilization of an air-supported structure on the Nyanza Chemical Superfund Site to control both dust and vapor emissions; 2) drilling and mud additives to neutralize acid gas emissions during well installations at Bruin Lagoon; and 3) a research project employing water sprays and water curtains to control dust emissions from excavation and truck loading with a front-end loader.

This Project Summary was developed by EPA's Risk Reduction Engineering 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

As the number of Superfund sites undergoing remediation increases, the need for dust and vapor suppression measures to protect the health and safety of on-site workers and the public also increases. Activities that particularly require control include excavation, soil loading and unloading, and transport prior to treatment or disposal of the hazardous material. Although personnel protective equipment has successfully reduced on-site worker exposure to dust and vapor, it cannot feasibly be used to mitigate off-site exposures. As a result, there is an increased interest in research, commercial development, and applications of dust and vapor control technologies that are more effective than conventional construction dust control measures.

This study was commissioned to provide individuals assigned to design remedial programs with current information on suppression technology availability and applications. Areas where further research is necessary to develop technologies and/or to provide better performance data are also identified in the report.

APPROACH

This study identified materials, pollutants, unit operations, and environments commonly associated with Superfund sites by reviewing EPA Record of Decision (ROD) files for 250 Superfund sites. The survey indicated which dust/vapor control requirements are most likely to arise in the future. It also provided information about technologies currently in use.

In parallel with this ROD survey, information on conventional and newly available technologies was obtained using computer-assisted literature searches and personal contacts with EPA personnel, remediation contractors, consultants, and other persons working in the remediation design/implementation area. Three case histories provided additional insight into how suppression techniques are used during an active excavation.

TECHNOLOGIES

The 13 categories of commercially available dust and vapor suppression technologies identified in this report are summarized below.

1. Water - The addition of water to soils and excavations that need dust control continues to be one of the most common suppression techniques for dust and chemically-contaminated dust particles. Water is applied topically to increase the density and cohesion of soils, thus preventing release to the atmosphere.

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2. Water Additives - Water additives are typically surfactants and other water extenders that increase the penetration and staying power of topical applications in order to lower labor costs by reducing the frequency of application. Adhesive type polymers such as latexes, acrylics, and the waste-derived lignosulfonates are typical examples of this class of dust suppressant.

3. Inorganics - Hydroscopic inorganic salts such as calcium chloride have long been used to control dust on unpaved roads. These salts absorb and chemically bind moisture. When integrated into a roadway with the proper soil particle size distribution, the salt retains moisture over a long period of time. Alternatively, pozzolanic material such as cement and lime can be incorporated into the soil to provide higher soil cohesion and strength.

4. Organics - Oils, waste oils, bitumens, and vegetable gums have historically been used to wet and bind particles together to resist entrainment by blowing winds and drafts created by earth-moving equipment. These materials have an affinity for soils and a lower vapor pressure and thus remain effective longer than water.

5. Foams - Vapor and dust suppression has been demonstrated by foams produced by air entrapping water additives. Several available products are modifications of fire-fighting foams. Blankets of these foam products suppress the evolution of particles and vapors by physically blocking escape routes and insulating the soil from the effects of the sun and wind. Stabilizers are commercially available to extend the life of these foams to several days.

6. Air-Supported Structures - Commercially available air-supported membranes have been applied to enclose areas undergoing excavation. In conjunction with air lock entrances and exhaust stream dust and vapor pollution control equipment, these structures have the capability for relatively high effectiveness.

7. Acid Gas Neutralization Additives - Drilling technologies adapted from the natural gas and oil industry have been used with some success in working with contaminated soils. Specifically, ferrous compounds used in the drilling mud have proven effective in reacting with and retaining sulfurous gases below the surface in the bore hole.

8. In Situ Volatilization - Several technologies are available for in situ treatment of volatile organic compounds which could be applied to reduce vapors prior to excavation. These include in situ volatilization, biodegradation, soil flushing, and steam stripping.

9. Self-Supporting Enclosures - A variety of relatively inexpensive enclosures have potential application for containing dust and vapor during excavations. Unlike air-supported structures, the building can be operated at or slightly below atmospheric pressure for the purpose of directing purge air to air pollution control devices. Dual radius arch frames supporting corrugated steel or textile covers, geodesic domes, and construction equipment hangers may find successful application during excavations. One reported application included a moving self-supported structure that advanced on rails beside the excavation as the work proceeded.

10. Vacuum Trucks - Commercially available vacuum trucks with liquid and/or dust separation and control equipment can be used to remove soils and sludges that are fluid enough to flow to the pickup nozzle.

11. Covers, Mats, Membranes - Various systems are available for covering soil or lagoon surfaces with physical barriers. These include thin (4-6 mil) plastic sheets, thicker (30-40 mil) covers, mats, and geotextiles, and bulk materials such as straw, wood chips, and sludges. Some barriers are applied from rolls, held in place, and later removed during excavation. Others which are applied in bulk, such as paper mill sludges, straw, aged manure or other adsorbent materials, can be removed for disposal along with the soil.

12. Windscreens - Windscreens to reduce windshear over soils, can be used in controlling emissions from excavations and temporary waste storage piles. Design guidelines and effectiveness measurements are currently available in the literature.

13. Work Scheduling - Planning excavations according to the seasons can reduce the overall potential for emissions by taking advantage of reduced emissions due to lower temperatures, wind speeds, and humidity. In addition, monitoring the emissions downwind during remediation activities can be used to reduce releases. Work schedules and dust or vapor controls can be adjusted as meteorological conditions and observed emission levels vary.

APPLICATIONS

A survey of current practices at 100 sites where dust and vapor emissions were considered a potential problem was performed. Most sites surveyed either practiced no overt dust and vapor control or relied on some form of natural dispersion in the atmosphere. Water spraying, daily or seasonal scheduling, and covers of various types were the technologies most commonly used. Fifteen sites utilized water spray to control dust. Relatively few sites reported use of chemical additives to enhance water spraying or the enclosure of the remediation in a temporary building or structure. Eleven sites utilized chemical suppressants to aid in vapor control. Four sites specifically utilized containment structures to control dust.

DUST AND VAPOR EMISSION POTENTIAL

The remedial program designer must consider the site conditions, soil/sediment/waste characteristics, and planned remedial activities to specify dust and vapor emission controls. The following parameters should be considered when planning control measures:

- Distance to nearest residence or other receptors.
- Relative volatility of the potential vapors.
- Threshold Limit Value (TLV) or other relevant standards for contaminants of concern.
- Odor threshold of the potential vapors.
- Temperature, wind direction and speed, humidity, time of year, and other meteorological parameters prevailing during the time of the planned excavation.
- Particle size distribution and moisture content of the soils, sludges, and sediments.
- Square footage of area to be excavated and the planned depth of excavation quantities to be removed.
- Method of removal.

- Soil/waste physical/chemical characterizations.
- Effect of dust/vapor control technologies on treatment technologies (e.g., foam on soil washing).

Generally, given contaminants of moderate mobility and toxicity at moderate concentrations, the designer should utilize readily implementable conventional technologies (i.e. water, water additives, organics, inorganics, covers, and seasonal scheduling) in conjunction with site perimeter monitoring for contaminants of concern or representative indicator parameters. As a contingency, more aggressive techniques (i.e. foams, windscreens, scheduling in response to meteorological conditions) should be called for whenever monitoring detects elevated concentrations of dust and vapor.

If contaminants of concern are present at higher concentrations or have relatively high toxicity and mobility, a more rigorous projection of off-site impacts during remediation may be warranted. This may consist of a focused risk assessment, including dust/vapor generation and dispersion modeling in conjunction with the identification of appropriate short-term exposure risk action levels.

If the assessment indicates that significant off-site exposures could potentially result, more rigorous emission control technologies should be applied, such as planned programmed use of windscreens, foams, or the construction of enclosures which can exert positive control of emissions.

APPLICATIONS GUIDELINES

The applicability of each technology to vapor or dust control was evaluated in this study. The advantages, disadvantages, and constraints in applying each technology are summarized in Table 1. Several technologies, including water additives, inorganics, organics, and forms, require the purchase of raw materials from one of a large number of potential suppliers. These materials are available in numerous formulations and have a wide range of raw costs as well as a wide range of application rates. Table 2 summarizes the material costs for these technologies in dollars per acre using typical formulations and application rates.

Costs for other vapor suppression technologies and installed costs per square yard were estimated by using material costs and a generic application concept. These estimated costs were developed solely for comparative purposes. The relative costs are presented in Table 3. In order to assess relative site-specific costs on a preliminary basis, the designer must consider what areas and operations will be conducted, whether reapplications will be necessary, and whether point source air pollution control devices may be necessary, as well as site-specific cost factors such as regional labor rate differences and the impact of working with health and safety equipment.

CASE STUDIES

Nyanza Chemical, Ashland, Massachusetts, and Bruin Lagoon, Butler County, Pennsylvania, both Superfund sites, and test work at Cincinnati, Ohio, were the three cases selected for further study. Each of these cases had special features which should assist the reader in understanding how control technologies would work under specific field conditions.

NYANZA CHEMICAL, ASHLAND, MASSACHUSETTS, is noteworthy for its use of a leached inflatable building to reduce costs. An area approximately 80 feet wide by 105 feet long was enclosed. Some effort was required to find a vendor who would accept the building decontamination procedures. The vendor indicated manual installation of the anchors would suffice; however, unplanned expenses were incurred when it was found necessary to bring in a drilling subcontractor to set the anchors for the building. Even so, the leased building was less expensive to install and use than a comparably sized self-supporting structure. The inflatable building was leased at a rate of $14,000 for four months; a cost of $120,000 was estimated for a comparable self-supporting structure. Building permits were required for the inflatable structure even though it was a temporary installation. Ventilation was provided with two blowers controlled by a differential pressure switch which maintained an inside air pressure of 3/4 to 1 1/4 feet above atmospheric pressure. Two 7,500 CFM fans supplied approximately four to five air changes per hour. An air lock entrance supplied with the building was used to admit and remove earth-moving equipment without significant loss of air pressure. The spent air was filtered through a radial flow carbon adsorption unit with a relatively low pressure drop. Work inside the building was carried out in level B protective gear because of the carbon monoxide levels resulting from operation of the earth-moving equipment inside the building. The excavated soils were incinerated on-site to destroy volatile organic compounds and then returned to the ground. The inflatable building assisted this treatment by excluding precipitation from the contaminated soils.

This case history demonstrated that commercially available inflatable buildings can be practical field solutions for sites where excavations need to be enclosed.

BRUIN LAGOON, BUTLER COUNTY, PENNSYLVANIA, began operations in the 1930s and for over 40 years was used as a disposal site for mineral oil production sludges, acidic and oily wastes, coal fines, fly ash, and waste sludges from the reclamation of used motor oil.

The initially selected remediation consisted of on-site stabilization and containment. After a substantial amount of this remedial work was completed, hydrogen sulfide and other related acidic gases were encountered. Analytical results from test borings showed hydrogen sulfide emissions approaching 1,000 ppm by volume in the air.

To circumvent this problem, previously stabilized sludge was used to form a cover over the remaining lagoon surfaces. This cover was penetrated with monitor/vent wells using specialized drilling mud and special well head construction. A Calgon carbon adsorption system was used to clean the vented acidic gases.

The drilling subcontract cost of installing 10 shallow wells, 10 deep wells, and 6 soil borings was approximately $150,000.

TEST SITE, CINCINNATI, OHIO. Tests performed at a small farm near Cincinnati, Ohio, with a front-end loader and a dump truck were analyzed in an effort to quantify the effectiveness of conventional dust control measures.

Three instrument towers were used, one upwind, one downwind, and one between the excavation site and the dump truck loading station. These locations could distinguish dust emissions from the active excavation and dust emissions from the dump truck loading operation.

Spray treatments of the excavation with water and with water and water-extender solutions achieved dust suppression efficiencies of 60 to 70 percent of particles less than 2.5 microns. Water curtains and foam treatments at the dump truck loading station were less effective and suffered operational problems.

CONCLUSIONS AND RECOMMENDATIONS

Remedial action designers can select an effective dust or vapor suppression technology or combination of technologies for the site conditions most likely to be encountered in the United States. There are dust or vapor suppression options for even the highest risk scenarios for emissions from soil or sludge excavation.

There are a limited number of quantitative data correlations for accurately predicting performance of most dust and vapor suppression technologies. This is especially true for the newer technologies. Thus, most suppression systems cannot be designed with confidence, and designers will tend to be overly conservative. A database on the effectiveness and reliability of the partial control technologies needs to be developed so that available methods can be designed with confidence in moderate to high risk emission situations.

For many dust and vapor suppression technologies, little or no quantitative data are available on 1) the potential for accelerating contamination migration, 2) problems of control technology residue treatment/disposal, and 3) the possible formation of additional toxic materials on-site due to reactions of waste with dust and vapor suppression.

This survey indicates that to date the application of dust and vapor technologies has been predominately ad hoc without correlation of operating parameters with cost and effectiveness. Predictive conditions and field applications data useful for design of control systems and site operations are inadequate for most technologies. It is recommended, therefore, that a program of additional studies be undertaken to design and develop a dust and vapor control information base that can, for a given set of site conditions, be used to select a control technology, design an effective control system, and estimate costs sufficiently to identify lowest minimum cost systems. This information base should be drawn from an integrated set of controlled laboratory and field tests and measurements from current or past field operations. Efforts should be made to model and present the information in ways useful to remedial action planners.

TABLE 1. APPLICATION GUIDELINES FOR DUST AND VAPOR TECHNOLOGIES

Technology	Application In Dust Control	Application In Vapor Control	Constraints In Use	Benefits Of Use
Water	Yes	Low Effectiveness	Runoff Reaction with pollutants Costly repeat applications Time consuming Low effectiveness with vapors	Cost-effective method widely available.
Water Additives	Yes	Low Effectiveness	Reaction with pollutants Limited availability Low effectiveness with vapors	Extended benefits of water by reducing costs of repeated application.
Inorganics	Yes	Low Effectiveness	Reaction with pollutants Effective only on relatively non-disturbed soils Low effectiveness with vapors	Cost-effective method that requires infrequent application.
Organics	Yes	Yes	Specialized applicators Reaction with pollutants Material handling constraints Application temperature dependent	Effective in dust suppression. May add BTU value to soil. May provide tough dimensionally stable continuous membrane. May be used with geotextiles.
Foam	Yes	Yes	Reaction with pollutants Specialized applicators Material handling constraints Relatively short life Some toxic decomposition Products upon heating	Existing marketing towards HW site use for overnight vapor suppression. May produce stable blankets. Slow drainage rate. May resist product pickup.
Air-Supported Enclosures	Yes	Yes	Cost may restrict use to smaller sites Potential greenhouse effect	Available nationwide for lease/purchase no chemicals introduced into system.
Acid GAS Neutralization Additives	Yes	Yes	Reaction with pollutants untested in this application	Demonstrated technology for same contaminants in drilling applications.

(continued)

TABLE 1. (continued)

Technology	Application In Dust Control	Application In Vapor Control	Constraints In Use	Benefits Of Use
In Situ Treatment	No	Yes	Effective on highly permeable soil use on limited group of compounds Effectiveness dependent on soil character	Removes vapors before excavation may obviate need for excavation.
Self-Supporting Enclosures	Yes	Yes	Cost may restrict use to small sites Construction may disturb site Potential greenhouse effect	Effective containment of dust and vapor.
Vacuum Trailers	Yes	Yes	Requires control of airborne pollutants Limited to applicable materi- also (e.g., sludges, loose granular material)	No additional chemicals used.
Covers, Mats and Membranes	Yes	Yes	Must be removed during active material handling Mat/liner failure Potential greenhouse effect	Ease of application. Effective control in many situations.
Windscreens	Yes	No	Subject to wind direction Marginally effective	
Scheduling	Yes	Yes	Stockpiles Dependent on weather conditions Rigorous timing constraints	Seasonal scheduling - least costly method. Can be applied on contingency basis.

TABLE 2. REPRESENTATIVE SUMMARY OF DUST AND VAPOR SUPPRESSANT PRODUCTS

Product Type	Typical Material Cost ($/Acre)[A]	Form
Calcium Lignosulfonates	67	Organic Binder
Calcium Chloride	230	Inorganic Binder
Sodium Silicate	340	Inorganic Binder
Vinyl Acetate Resins	480	Water Additive
Acrylic Emulsions	840	Water Additive
Ammonium Lignosulfonates	620	Organic Binder
Asphalt Emulsion	1,180	Organic Binder
Soil Enzyme	1,400	In Situ Injectable
Wood Fibers with Plastic Netting	1,700	Covers, Mats, Membranes
Polyurethane-Polyurea Foam	8,400	Foam
Sodium Bentonite Clay	16,500	Covers, Mats, Membranes
Sodium Bentonite and Geotextile Fabric	26,100	Covers, Mats, Membranes

[A]Costs updated to August 1988 dollars by vendor information.

TABLE 3. APPLICATION AND COST GUIDELINES FOR DUST AND VAPOR TECHNOLOGIES

Technology	Dust Control Application	Vapor Control Application Effectiveness	Relative Costs
Water	Yes	Low effectiveness	Low
Water Additives	Yes	Low effectiveness	Low
Inorganics	Yes	Low effectiveness	Low
Organics	Yes	Yes	Low - Moderate
Foam	Yes	Yes	High
Air-Supported Enclosures	Yes	Yes	High
Drilling Mud Additives	Yes	Yes	Low - Moderate
In Situ Volatilization	No	Yes	Moderate - High
Geodesic Domes/Semi-Permanent Structures	Yes	Yes	High
Vacuum Trailers	Yes	Yes	High
Mats and Liners	Yes	Yes	High
Windscreens	Yes	No	Low - Moderate
Scheduling	Yes	Yes	Very Low

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Mary K. Stinson is the EPA Project Office (see below).

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DISCLAIMER

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Contract No. 68-03-3450 to Roy F. Weston, Inc. It has been subject to the Agency's peer review and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

This report provides a review of current technologies for suppressing dust and vapor emissions arising from the excavation and treatment of contaminated soils, sludges, and sediments. In addition, areas for further research and development in dust and vapor suppression are identified.

For further information, please contact the Superfund Technology Demonstration Division at the Risk Reduction Engineering Laboratory.

E. Timothy Oppelt, Director

Risk Reduction Engineering Laboratory

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ABSTRACT

The excavation of contaminated materials during remedial investigations, removal actions, and remedial action activities can result in the release of fugitive dust and vapor emissions. A review of currently available dust and vapor suppression technologies for use during the excavation of contaminated soil, sludges, and sediments was conducted.

Thirteen types of commercially available suppression technologies were identified and evaluated for potential utilization by on-scene coordinators, cleanup contractors, and design engineers. Each technology is described and reviewed for its applications, effectiveness, implementability, cost, advantages, and disadvantages. Three case histories are also discussed.

This report was submitted in partial fulfillment of Contract No. 68-03-3450 by Roy F. Weston, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from September 1, 1987, to September 30, 1988.

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TABLES

LIST OF ABBREVIATIONS

ABBREVIATIONS

ACFM	Actual Cubic Feet per Minute
EPA	Environmental Protection Agency
ROD	Record of Decision
TAT	Technical Assistance Team
RI	Remedial Investigation
ISV	In Situ Volatilization
OSC	On-Scene Coordinator
NPL	National Priorities List
RI/FS	Remedial Investigation/ Feasibility Study
TPD	Tons per Day
W.C.	Water Column
OVA	Organic Vapor Analyses
PID	Photo Ionization Detector
hp	Horse Power
I.D.	Induced Draft

UNIT CONVERSION TABLE

	English (U.S.)	Metric (SI)
Area:	1 ft^2	9.2903 x 10^{-3} m^2
	1 $in.^2$	6.4516 $cm2^2$
Flow Rate:	1 gal/min	6.3090 x 10^{-5} m^3/s
	1 gal/min	6.3090 x 10^{-2} m L/s
	1 Mgal/d	43.8126 L/s
	1 Mgal/d	3.7854 x 10^3 m^3/d
	1 Mgal/d	4.3813 x 10^{-2} m^3/s
Length:	1 ft	0.3048 m
	1 in.	2.54 cm
	1 yd	0.9144 m
Mass:	1 lb	4.5359 x 10^2g
	1 lb	0.4536 kg
Volume:	1 ft^3	28.3168 L
	1 ft^3	2.8317 x 10^{-2} m^3
	1 gal	3.7854 L
	1 gal	3.7854 x 10^{-3} m^3

ft = foot, ft^2 = square foot, ft^3 = cubic foot
in. = inch, in^2 = square inch
yd = yard
lb - pound
gal = gallon
gal/min = gallons per minute
Mgal/d = million gallons per day
m = meter, m^2 = square meter, m^3 = cubic meter
cm = centimeter, cm^2 = square centimeter
L = liter
g = gram
kg = kilogram
m^3/s = cubic meters per second
L/s = liters/sec
m^3/d = cubic meters per day

SECTION 1

INTRODUCTION

OBJECTIVES

The purpose of this report is to identify commercially available transportable equipment and methods for suppressing vapor and dust emissions during excavation and related activities in handling contaminated soils, sludges, and sediments at Superfund sites. The report is more than a state-of-the-art review. In addition to surveying current practices, it also contains guidance, by use of examples and decision points, for dealing with potential emissions. The suggested technologies utilize commercially available transportable equipment, but their application for suppressing vapor and dust emissions at Superfund sites may not have been tested in all cases.

In each case the technologies discussed in this report are intended to assist the project officer or the remedial/removal action designer who must address the potential for vapor and/or dust emissions during excavation. There is a need for this type of information as more and more sites are subject to final design considerations. Thus, the information provided here is intended to assist at a site where a potential for dust or vapor emissions has been identifed in a Record of Decision (ROD), but little or no guidance has been provided as to how to deal with that potential.

The equipment and methods that are available for vapor and dust suppression during excavation of contaminated soils are being developed at a rapid pace as new situations are encountered in a variety of environmental, institutional, public health, and economic settings. As a result, our principal method of gathering information in this field of endeavor was to interview people who have seen or tried a particular method at a particular site. Those interviewed include EPA's Technical Assistance Team (TAT) personnel, EPA Project Officers in the regional offices, EPA On-Scene Coordinators (OSC), personnel within the Army Corps of Engineers, and vendors of equipment and services.

Little if any documentation of this rapidly changing experience appears to have been recorded. For example, a computer-assisted literature search disclosed many dust suppression methods and, to a lesser extent, vapor suppression methods, but few applications to hazardous waste sites, and more particularly, fewer references to excavation at hazardous waste sites.

The computer-assisted search for material on dust and vapor suppression technologies was conducted by using the following databases on the DIALOG System:

1. Compendex (Engineering Index)
2. NTIS (National Technical Information Service)
3. Environline
4. Pollution Abstracts
5. Water Resources Abstracts
6. E.I. Engineering Meetings
7. Conference Papers Index
8. Chemical Industry Notes
9. Occupational Safety and Health
10. Agricola (National Aricultural Library)
11. CA Search (Chemical Abstracts)
12. Georef

A summary of this computer-assisted literature search is presented in the bibliography provided at the end of this report. A thorough review of this bibliography was conducted, and selected reports and documents were obtained and studied. These were reviewed and analyzed and used as references where appropriate in the text of this report.

In addition to the interviews, information was gathered by a letter survey mailed to potential vendors of dust and vapor suppression equipment and services. The respondents to this mailing are included in Appendix A.

A manual search of current journals known to carry articles and advertising related to this field of endeavor was also performed.

A review was also made of the RODs available in the legal library of EPA Region III in order to identify those sites where dust and vapor control is required and to identify the types of dust and vapor problems that are confronting designers. This review covered RODs that were prepared for sites throughout the United States from roughly 1983 to the present. Where possible, this review was followed by interviews with appropriate EPA project officers.

APPROACH

The arrangement of this current survey report is essentially as follows: Section 4 discusses the types of vapor and dust problems that are likely to confront a project officer or remediation/removal designer. Section 5 provides a survey of the equipment and methods that have been identified through our literature search and discussions with those active and experienced in Superfund cleanup efforts involving the excavation of soil and sediments. In Section 6, three case histories are presented illustrating the use of the previously identified methods. Section 7 discusses application and utilization guidelines. Section 8 discusses the cost and performance data that were developed during the course of this survey.

Conclusions and recommendations are presented in Sections 2 and 3, respectively, for the convenience of the reader who may wish to evaluate our findings before delving into the detailed discussions of the latter sections.

SECTION 2

CONCLUSIONS

1. On the basis of existing information, remedial action designers can select an appropriate dust or vapor suppression technology or combination of technologies for application to most site conditions likely to be encountered in the United States.

2. There are dust or vapor suppression options for even the highest risk scenarios for emissions from soil or sludge excavation.

3. There are a very limited number of quantitative data correlations for accurately predicting performance for most partial control dust and vapor suppression technologies. This is especially true for the newer technologies. This may result in insufficient performance on particular sites, or in an overly conservative design.

4. The database on the effectiveness and reliability of the partial control technologies needs to be improved so that these technologies can be used with confidence in the moderate to high risk emission situations.

5. For many of the dust and vapor suppression technologies, little or no chemical compatibility data are available so that direct use/no use decisions for a particular contaminant site are difficult to make.

6. There is limited current information which quantifies the potential for accelerating environmental contamination migration, control technology residue treatment/disposal

problems, and the possible formulation of additional toxic materials on-site due to technology/waste reactions from the utilization of dust and vapor suppression controls.

SECTION 3

RECOMMENDATIONS

This survey report indicates that dust and vapor technologies have been predominantly applied without a rigorous programmatic approach. Techniques exist to control dust and vapor emissions under all site conditions normally encountered, but predictive conditions and field applications data useful for the design of control systems and site operations are inadequate for most technologies. It is recommended that a dust and vapor information base be designed and developed that can, for a given set of site conditions, be used to select a control technology, design an effective control system, and estimate costs sufficiently to reliably select minimum cost emission controls. This information base should be drawn from an integrated set of controlled laboratory and field tests and measurements taken from current field operations. Effort should be made to model the information in ways useful to remedial action planners.

Specific recommendations are:

1. Empirical correlations should be developed to estimate dust and vapor impacts on receptors. These risk estimations can be used as preliminary screening devices to decide how severe the emission problems are and what level of control is justified.

2. Quantitative performance data should be acquired on the range of applicability and effectiveness of relatively new technologies (forms, enclosures) as a function of site, operating, and control system parameters. These data should be further correlated with cost estimation information to provide methods for forecasting control system costs for given site conditions.

3. Effort should be given to developing a systems approach to dust and vapor control which integrates use of scheduling, site operations, excavation methods, and other control technologies to minimize dust and vapor emissions.

4. An independent study should be made of dust and vapor control under emergency response conditions where a rapid response is required with minimal time to plan and set up a control system. This study should test applicability, speed of implementation, and performance of off-the-shelf available equipment and materials.

5. Research in the area of treatment and disposal of any dust and vapor suppressant residuals on a site is needed.

SECTION 4

CHARACTERISTICS OF DUST AND VAPOR EMISSIONS DURING EXCAVATION OF CONTAMINATED SOILS

In planning response and remedial actions, the sources, characteristics, and mobility of potential fugitive dust and vapor emissions must be considered. When soil, sludges, and sediments are excavated, the contaminants are exposed to the wind during the excavation, transport, and materials handling processes. Contaminant mobility depends on the equipment employed, the properties of the contaminants and the soil matrix, the local topography, and ambient weather conditions. The degree of potential hazard to the off-site community also depends on the toxicity and/or carcinogenicity of mobile contaminants, the pathways to off-site communities, and the proximity of off-site receptors.

The remediation/removal planner must first project the potential off-site hazards based on these considerations before considering which, if any, dust or vapor suppression technologies should be employed on the site and whether to apply them full time during excavation or on a contingency basis.

ACTIVITIES REQUIRING DUST AND VAPOR CONTROL

There are many types of site remediation activities related to excavation that result in fugitive dust and vapor emissions. Every unit process that is applied to the contaminated materials on a removal/remediation site may be a potential source of these emissions. These activities include:

- Soil, sludge, or sediment excavation and liquid transfer.
- Sludge/sediment dredging.
- Soil, sludge, or sediment loading.
- On-site/off-site transport.
- On-site staging/stockpiling.
- General site vehicular traffic.
- Inactive face of an excavation.
- Long-term stockpiling/storage on-site.
- Processing of soil for on-site treatment.
- Intrusive site/remedial investigation or design phase sampling activities.

Unit operations that may require dust and vapor controls are discussed in the following subsections.

Soil, Sludge, or Sediment Excavation

Soil, sludge, or sediment is typically excavated using heavy equipment such as:

- Backhoe.
- Front-end loader.
- Bulldozer.
- Crane with dragline or clamshell.

Dust and vapor emission points include:

- Equipment tracks/tires.
- Newly exposed excavation face.
- Newly excavated soil equipment bucket.

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No studies have been identified that quantitatively predict fugitive emissions associated with each type of equipment. However, the specific sources of potential emissions can be identified and the relative magnitude of emissions can be projected based on observed mechanisms of dust and vapor transport phenomena.

The use of a bulldozer is expected to result in a high rate of fugitive emission generation because it typically scrapes a thin layer of soil and pushes it a greater distance than the other equipment available. It is typically used to push soil toward a loading point where a front-end loader is used to load trucks. The use of a bulldozer maximizes newly exposed surfaces, and its tracks churn a large area of newly exposed soil as it moves.

A crane equipped with a dragline has the reach to excavate a large area while the crane cab remains stationary, thus eliminating the effects of churning tracks. The bucket is typically dragged across a long, shallow cutting face, exposing large, newly exposed surfaces. Unlike the bulldozer, the tracks will not create fugitive emissions. Emission points are limited to the soil cutting face, soil contained in the bucket, and spillage from the bucket.

The crane and clamshell combination is typically used only for excavating sludges, dredging, or excavating pliable materials. When used for solids, it should result in lower emissions than a dragline because the surface area of newly exposed soil is approximately the size of one clamshell bucket. When used for dredging of sludges and sediments, dusting does not occur due to the high moisture content. Volatilization is minimized because the surface minimization tendency of free liquids limits the exposed surface area. In the latter case, however, a source of fugitive emissions is the liquid leakage from the clamshell that commonly occurs as it is moved to the unloading point.

The front-end loader can be used for excavation in place of a bulldozer. It can be operated in a manner that would result in a reduced potential for excavation-related emissions. A loader can be operated at the face of a deeper excavation to limit newly exposed surfaces to little more than the size of the loader bucket. To reduce emissions, rubber tire loaders can be used on firm level soils instead of track crawler loaders. Fugitive emission points for loaders include the excavation face, loader bucket, and to a lesser extent, the loader tracks or tires.

The backhoe can be established in a stationary position to reach into an excavation and withdraw a bucket-load of soil, while limiting the newly exposed surface to little more than the size of the backhoe bucket. The bucket can typically be unloaded without repositioning the base of the backhoe. Emission points include only the excavation face, backhoe bucket, and excavated material staging area, the discharge point of the backhoe.

In summary, the selection of excavating equipment and the choice of operational technique clearly affect the fugitive emission generation source points, the rates of emissions, and the surface areas that might have to be controlled by suppression technologies.

Sludge or Sediment Dredging

Sludge or sediment being excavated under water typically present no dust emission problem and offer a lower surface area for the vaporization of volatile constituents than unsaturated soil. Dredging will result in the entrainment of contaminated fines in the water column which can now spread great distances downstream. However, vapor emissions may be a significant problem in cases where high organic content sludges are being dredged. Equipment used in dredging contaminated sludges and sediments typically includes:

- Clamshell, dragline, and backhoe.
- Hydraulic dredges.

As discussed above, emission sources for clamshell, dragline, and backhoe applications in sludges and sediments excavated below water are the bucket itself and spillage from the bucket. Hydraulic dredges typically employ underwater mechanical cutting devices or hydraulic agitation coupled with suction pumps. The slurried material is then conveyed by pipeline to a spoils area or directly to a tank truck or processing unit. The pipeline transfer effectively reduces the potential for emissions during dredging and may be preferable to mechanical excavation where the off-site emissions from mechanical dredging may be a problem (assuming that the hydraulic dredge can be used effectively). Emissions may occur at the pipeline discharge point unless the filling operation is properly controlled.

Soil, Sludge, or Sediment Loading

Excavated soil is typically loaded onto a dump truck or dump trailer with a backhoe, front-end loader, clamshell, or dragline bucket. Each of these typically drops the soil several feet through the air, resulting in air/soil contact and emissions from fresh soil surfaces saturated with contaminants. This activity can constitute a significant dust and/or vapor emission source.

The loading of saturated sediments and sludges onto trucks from mechanical dredging equipment presents a potential vapor emission point. Emissions are less likely than for equally contaminated unsaturated soils due to the higher cohesion and lower surface area of viscose, saturated materials. Emissions from a hydraulic dredge pipeline will increase with turbulence and splashing at the discharge point. This can be reduced by using tank trucks to receive the materials.

On-Site Transport

A common unit operation used in cleanup location is the transport of soil on-site to a central staging point. Dust and vapor emissions may be enhanced from the surface of the loaded soil during transport due to air currents and load shifting on roads. Such emissions will be high when the truck is loaded above the top of the bed. Dust emissions may also result from tire contact with the soil and turbulent wakes from passing trucks.

If the soil is unloaded on-site, emissions will occur at the dump truck unloading point due to high air/soil contact and surface renewal, as discussed in the subsection on loading.

On-Site Staging/Stockpiling

Contaminated soil is often staged on-site in stockpiles prior to sampling/analysis and treatment/disposal on-site or off-site. Such stockpiles are typically used for short-term storage. Emissions may occur due to the effects of wind and diffusion of contaminant vapors to the surface of the stockpile. The emission rate is likely to be higher than that for the original in-place soils because it has been recently disturbed and would be more loosely compacted.

General Site Vehicular Traffic

Site vehicular traffic, other than from soil excavation vehicles, will result from various maintenance and supervisory activities. Dust emissions may result from such traffic, and traffic in contaminated areas would contribute to potential off-site exposure hazards. Emissions caused by traffic in uncontaminated areas would be limited to nuisance dust. Although nuisance dust is not typically as hazardous as dust-containing contaminants, often it cannot be differentiated from contaminated dust in the total particulate measurements commonly employed to obtain real-time air quality measurements. Thus, vehicular dust may represent a problem in achieving fenceline particulate limitations.

Inactive Face of an Excavation

During active excavation of soils, the newly exposed face of the excavation is briefly inactive while the excavator loads trucks or moves to adjacent areas to conduct the excavation. At completion of the working day, the face of the excavation will typically remain exposed overnight. Since these surfaces contain newly exposed contaminants, the face of the excavation during inactive periods also represents a fugitive emission source. In addition, there is the potential for off-site, onsite migration of contaminants in stormwater runoff during precipitation events.

Long-Term Stockpiling/Storage On-Site

At times, it may be necessary to stockpile contaminated soil on-site for extended periods of time. An uncovered soil stockpile represents a potential dust and vapor emission source due to the action of wind and diffusion of vapors to the surface of the stockpile. The emission rate is likely to be initially higher than that for the original in-place soils because it has been recently disturbed and is likely to be more loosely compacted.

Processing of Soil For On-Site Treatment

While this operation is not directly associated with excavation, greater emphasis is now being placed on on-site treatment. Many on-site treatment technologies, such as rotary kiln incineration, require some preliminary treatment and handling steps, known as feedstock preparation, before treatment. These operations may include:

- Soil screening.
- Rock crushing.
- Conveyor belts.
- Feed/storage hoppers.
- Shredding.
- Dewatering.

In the planning stage, it is important to be aware that unit operations unrelated to excavation are also sources of potential dust and vapor emissions.

For example, in the case of the Denny Farm Site in southwest Missouri, there was a potential for fugitive emissions of dioxin-contaminated soils resulting from the conveyor belt and shredder operations at the mobile onsite incinerator.

Intrusive Site Remedial Investigation (RI)/Design Phase Sampling Activities

Many site investigation activities -- whether prior to a removal action, during an RI, or in the design phase of work prior to a remedial action -- require disturbing contaminated soils, sludges, and sediments. These include:

- Drilling borings or wells.
- Test pit samples.
- Sludge/sediment sampling.

In some cases, such as in the Bruin Lagoon case study presented in Section 6, significant emissions can result from such activities. However, these activities are usually limited in area and, in most cases, are not cause for concern regarding off-site hazards resulting from fugitive emissions. A review of on-site monitoring data during these investigation activities may be indicative of the propensity of the waste/soil materials to release fugitive emissions. Such data may be useful to the removal/remediation planner.

TYPES OF DUST AND VAPOR CONTAMINANTS

Superfund sites that require emergency or remedial action typically contain a number of hazardous constituents that may exhibit a wide range of toxicity characteristics, migration mechanisms, and potential off-site hazards. The mechanism of concern for this report is transport of vapors and dusts via the air to potential off-site receptors.

Volatile compounds whose pure form is usually in the liquid or solid state (e.g., perchloroethylene, dichlorobenzene) may pose a vapor emission problem upon excavation. Even gases, such as methane and hydrogen sulfide, may be trapped in soils or sludges below the surface or weakly bound to the liquid phase by ionic equilibrium (e.g., $NaHS/H_2S$) and released upon exposure to the air.

Contaminants with low vapor pressures (e.g., dioxins, metals) may be bound to soil or present in waste particles and may be released to the atmosphere in particulate form during excavation-related activities.

Based on an extensive review of over 250 Superfund RODS, a list of contaminants and contaminant types that are likely to be encountered has been compiled. This list, presented in Table 1, provides the principal type of emission expected (i.e., dust or vapor) and summarizes the associated migration and control concerns.

ASSESSING THE POTENTIAL FOR EMISSIONS

The removal/response planner must assess the potential for uncontrolled fugitive emissions and determine the potential off-site hazards that may result. The available information may include a Site Assessment, Remedial Investigation, Endangerment Assessment, Feasibility Study, and/or Record of Decision (ROD).

The ROD is typically a brief report documenting the remedial action selection. It often mentions that dust and vapor emissions could potentially occur during the excavation

TABLE 1. TYPES OF CONTAMINANTS AND MODES OF TRANSPORT

Contaminant/Type	Mode of Transport (Vapor or Dust)	Migration Concerns
Landfill Gases Methane Hydrogen Sulfide	Vapor	Difficult to contain, highly mobile, ignitable at high concentrations, toxic at high to moderate concentrations, malodorous at low concentrations.
Inorganic Acid Vapors Hydrogen Sulfide Hydrogen Cyanide Hydrogen Chloride Sulfuric Acid	Vapor	Difficult to contain, highly mobile, corrosive, toxic at high to low concentrations, malodorous at low concentrations.
Volatile Organic Compounds A variety of chlorinated and nonchlorinated organic compounds ranging in volatility from methylene chloride to chlorobenzene.	Vapor	Typically contained in soil moisture or adsorbed onto soil organic fraction and is readily stripped from the soil when in contact with fresh air not already saturated with organics. A wide range of toxicity, carcinogenicity, and odor characteristics.
Semivolatile Organic Compounds A variety of chlorinated and nonclorinated organic compounds ranging from dichlorobenzene to pyrene.	Vapor and Dust	Typically adsorbed onto soil organic fraction or present in separate liquid or solid phase. Transport to vapor phase generally lower. Transport via dust possible. A wide range of toxicity, carcinogenicity, and odor characteristics.
Polychlorinated Biphenyls	Dust (to a lesser extent vapor)	Typically adsorbed onto soil organic fraction. Relatively low volatility results in lower vapor phase transport rate. Transport via dust possible. A highly regulated carcinogen.

(continued)

TABLE 1. (continued)

Contaminant/Type	Mode of Transport (Vapor or Dust)	Migration Concerns
Dioxins, Furans	Dust	Typically adsorbed onto soil organic wastes. Low volatility limits vapor phase transport. Transport possible via dust. Highly regulated, highly toxic classes of organic compounds.
Pesticides (Organic) 2,4-D 2, 5-TP Silvex Lindane Pentachlorophenol	Dust (to a lesser extent vapor)	Typically adsorbed onto soil organic fraction or associated with organic wastes. Low volatility resulting in lower vapor phase transport. Transport via dust possible. Typically environmentally persistent with a range of toxicity and carcinogenicity characteristics. Typically low solubility results in little chemical binding to soil. Physically mixed with soil and/or battery casings. Transport via dust possible.
Metal Dusts Lead/Lead Oxides	Dust (to a lesser extent vapor)	
Dissolved/Adsorbed Metals Chromium Cadmium	Dust	Typically low to moderate solubility results in some migration at relatively low concentration and adsorption onto soils. Transport via dust possible, but metal fraction is low. Persistent and toxic.
Metal Vapors Mercury	Vapor	Mercury volatile in metalic form. Transport via vapor. Toxic.
Radiation	Dust and Vapor	May be present in gas (e.g. radon) or solid form. Exposure to radioactive dusts, particularly hazardous due to release of alpha particles and other ionizing radiation.

of contaminated soil and sediment but typically will not describe the specific counter measures to be taken or provide quantitative information to define the potential. Thus, the removal/remediation planner must review the information provided in the site assessment or RI/FS to define the potential for uncontrolled fugitive emissions.

In some cases, off-site atmospheric levels have already been measured during the RI phase, when some limited excavation must be carried out. When this occurs, it is possible to extrapolate this data to what might be expected during the remediation itself. Some assessment of the potential for release to atmosphere may have been made during the Endangerment Assessment; however, this analysis is usually limited to the effect of taking no remedial action. The FS remedial alternative evaluation should consider the off-site impacts of the excavation alternatives. This is typically a qualitative analysis, but if the potential impacts are identified as critically high, some risk analysis may have been conducted.

If quantitative analysis of the potential impacts of excavation has not been conducted, the removal/remediation planner should, at a minimum, conduct a qualitative assessment of potential off-site impacts. The following is a suggested list of parameters that would be needed to assess the potential for dust and vapor emission problems during an excavation of contaminated soils:

- Distance to nearest residence or other receptors.
- Relative volatility of the potential vapors constituents.

- Threshold Limit Value (TLV) or other relevant standards for contaminants of concern (e.g., Cancer Assessment Group values).

- Odor threshold of the potential vapors.

- Temperature, wind direction and speed, humidity, time of year, and other meteorological parameters that prevail during the time of the planned excavation.

- Particle size distribution and moisture content of the soils, sludges, and sediments.

- Square footage of area to be excavated and the planned depth of excavation.

- Method of removal; quantity to be removed.

- Soil/waste physical/chemical characteristics.

- Effect of dust/vapor control technologies or treatment technologies (e.g., foam on soil washing).

Given contaminants of moderate mobility and toxicity at moderate concentrations, the removal/remediation planner could approach the problem by utilizing readily implementable conventional technologies (i.e., water, water additives, organics, inorganics, covers, and seasonal scheduling) in conjunction with site perimeter monitoring for contaminants of concern or representative indicator parameters. Other more aggressive techniques (e.g., foams, windscreens, scheduling in response to meteorological conditions) can be specified as contingency measures for more dangerous situations or when monitoring detects elevated concentrations during remedial activities.

Often contaminants of concern are present at higher concentrations (i.e., waste materials), have relatively high toxicity and mobility, or excavation occurs adjacent to residential areas. In this case a more rigorous projection of off-site impacts during remediation may be warranted, if not already stated in the site assessment or RI/FS work. This may consist of a focused risk assessment including dust/vapor generation and dispersion modelling in conjunction with the identification of appropriate short-term exposure risk action levels.

Guidance for quantitative estimates of emissions from exposed and partially vegetated surfaces and from the excavation process itself can be found in Cowherd et al. (1985), Shen (1982), and EPA's Industrial Source Complex (ISC) dispersion model (EPA 1986). Atmospheric dispersion models are also available in this dispersion model publication. If the assessment indicates that significant off-site exposures could potentially result, more rigorous emission control technologies should be applied, such as planned programmed use of windscreens and foams, or the construction of enclosures that offer positive control of emissions.

CURRENT PRACTICES AT HAZARDOUS WASTE SITES

To provide an overview of current practice, a survey of approaches for dust and vapor control was made of approximately 120 hazardous waste sites throughout the 10 EPA regions. This inventory was prepared through telephone interviews with on-scene coordinators (OSC) at selected hazardous waste sites. The sites were identified by reviewing Record of Decision (ROD) files to find problems controlling dust or vapors during remediation. Sites were also selected from EPA and WESTON case histories and from the top 150 sites on the October 1987 NPL list that have completed remedial activities.

The majority of the approximately 120 sites examined in the survey employed no specific control for dust or vapor emissions. Fifteen sites utilized water sprays to control dust. Eleven sites utilized covers, mats, or membranes for dust or vapor suppression. Four sites utilized chemical suppressants to aid in vapor control. Five sites utilized buildings to control dust. Only six sites utilized separate techiques for dust and vapor suppression. Forty-one of the surveyed sites that utilized some form of dust and vapor controls are summarized in Table 2 and Figure 1.

On sites where dust or vapor suppression techniques were not utilized, the OSCs indicated that such controls were not necessary for the particular site. Low concentrations of vapor-forming volatile contaminants and of constituents bound to solid particles were most often cited as the reason for not using suppression technologies. These OSCs generally felt that the dispersion of fugitive vapors and dusts by the natural wind currents was sufficient to prevent significant impacts off-site.

The most commonly used practice for the active control observed in this survey, regardless of the pollutant, appears to be the application of a water spray. Water application techniques ranged in sophistication from the use of a garden sprinkler and hose to the application-specialized devices to produce a fine mist such as that found in the Del Norte Pesticides site. The majority of OSCs indicated that their experiences were limited to water application with garden hoses and sprinklers. Success was generally mixed. The most common concern experienced by the OSCs was that low water volume spray devices provided inadequate coverage of dust-generating activities. This was particularly evident during loading and unloading operations for dry materials. A few suggested that specialized equipment, beyond that available at a hardware store, was needed. Spray equipment with two switchable modes can be acquired to provide a fine mist and higher volume and wider coverage during loading/unloading operations.

TABLE 2. PREVIOUS APPLICATIONS OF DUST AND VAPOR CONTROL TECHNOLOGIES

Site Name	Vapor Control Technology	Dust Control Technology	Contaminants of Concern
Alvesio, San Jose, CA		Acrylics	Asbestos
American Creosote, Pensacola, FL		Chemical suppressant	Creosote
Bog Creek Farm, NJ		Water spraying	Volatile organics
Bossard Site, Utica, NY		Water spraying	Asbestos
Bunker Hill Mine, Kellog, ID		Cover/water spray	Lead dust
Chem Waste Management, Vickery, OH		Cover	Chlorobenzene
City Chemical, Winter Park, FL		Water spraying	Solvents
Crystal Chemical Co., Houston, TX			
D'Imperio Property, NJ		Water spraying	PCB
Dayton Walther, Portsmouth, OH		Cover	Lead dust
Del Norte Pesticide, Crescent City, CA		Water spraying	Pesticides
Denny Farm, McDowell, MO		Self-supporting structure with interior vacuum	Dioxin
Diamond Alkali/Shamrock, Newark, NJ		Geotextile	Dioxin
Fairchild Republic Co., Hagerstown, MD		Tarp	Chromium
GE Moreau	Clay	Plastic sheeting	PCB
Gallaway Pits, TN		Chemical suppressant	Pesticides
Gallup Site, CONN		Sealed trucks	Organics

(continued)

TABLE 2. (continued)

Site Name	Vapor Control Technology	Dust Control Technology	Contaminants of Concern
Gems Landfill, NJ	Active Interior Gas Collection, Carbon Adsorption, In Situ Volatilization (ISV)		Volatiles
Goose Farm, Ocean Co., NJ	Tarp	Wind screens	Organics
Hollingsworth Solderless Terminal, FL	In situ volatilization (ISV)		TCE
Howe Chemical Inc., Minneapolis, MN		Scheduling	Pesticides
Iron Bound Area Sites, Newark, NJ		Vacuum truck, silicates, water spraying	Dioxin
Keefe Envir Services, NH	Cover	Water spraying	Dust
Marty's GMC, Kingston, MA	Tarp, chemical sealant		Paint sludge
Newcome Bros. Site, MS		Water spraying	Dust
Ni-Chro Nicroplating, Louisville, KY	Scheduling		Cyanide
Norco Battery, Riverside, CA		Water spraying	Lead dust
Nyanza Chemical Waste	Air supported structure	Water spraying	Nitrobenzene VOCs
Old Beth Page Landfill, Bethpage, NY	Passive venting		
Plymouth Harbor/Cannon Eng., Plymouth, MA	Water spraying		Organics
Rohm & Haas Landfill, Bristol, PA	Tarp, scheduling		Dimethylphenol

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(continued)

TABLE 2. (continued)

Site Name	Vapor Control Technology	Dust Control Technology	Contaminants of Concern
Sol Lynn/Indust Transformers, Houston, TX		Water spraying	PCB
Spiegelberg Landfill, Livingston Co., MI		Water spraying, chemical suppressant	Paint/sludge
Standard Steel, Anchorage, Alaska		Water spraying cover	PCB
Sylvester, NH	In situ volatilization (ISV) incineration		Volatile Organics
Twin City Munitions Plant, MN	In situ volatilization		TCE
Unnamed, Cortland, NY	Scheduling		Gasoline
Upjohn, Barceloneta, PR	In situ volatilization (ISV) carbon adsorption		Carbon Tetrachloride
Vertac, Jacksonville, AR		Windscreen	Insecticide
Wide Beach Development, Lake Erie, NY		Water spraying	PCB

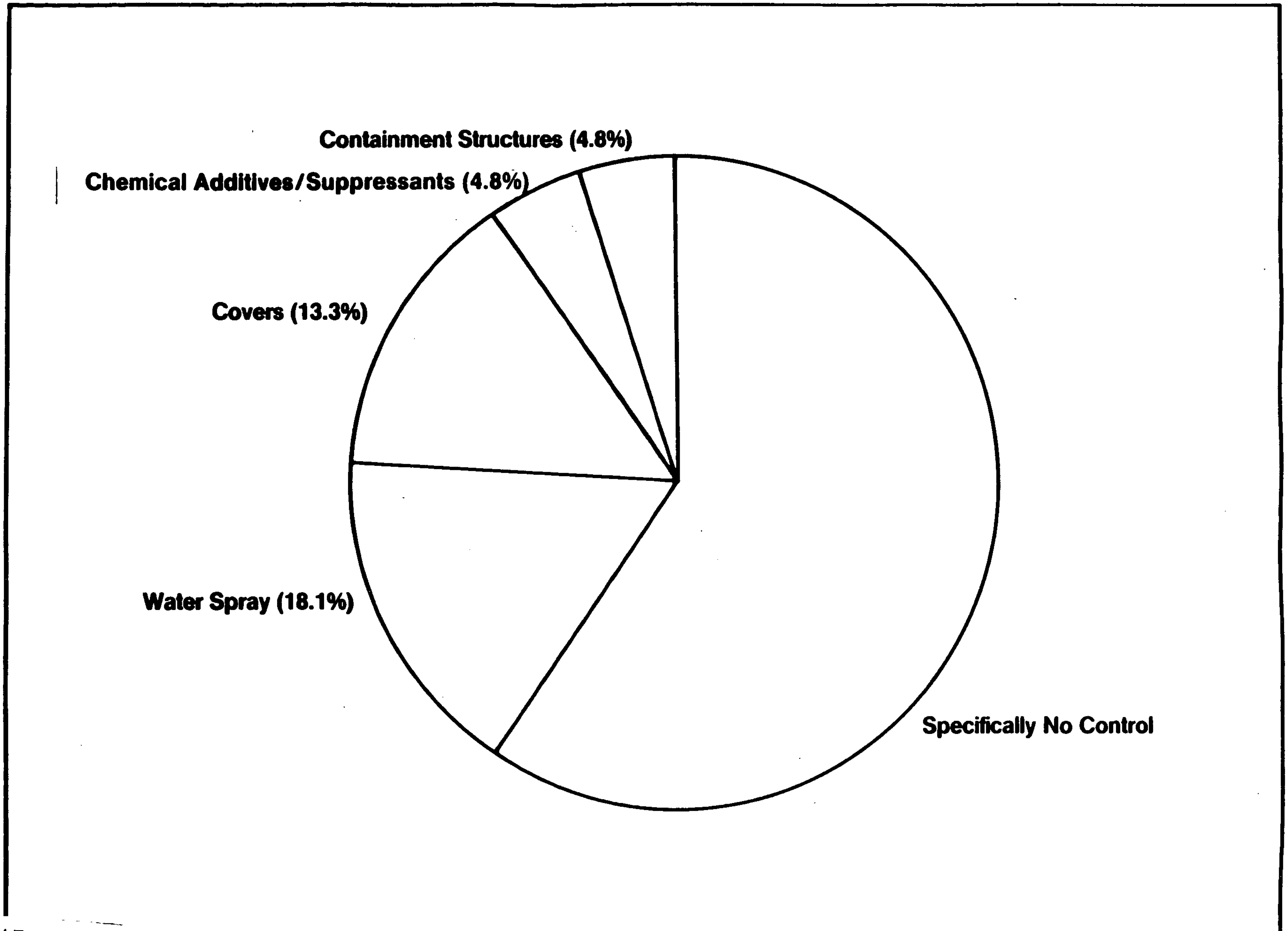

FIGURE 1 DUST/VAPOR CONTROL RESPONSES UTILIZED AT HAZARDOUS WASTE SITES

SECTION 5

COMMERCIALLY AVAILABLE DUST AND VAPOR SUPPRESSION TECHNOLOGIES

Methods used for dust control at Superfund sites were initially based on techniques developed for civil engineering projects. For example, water, because of its low cost, general availability, general or relative inertness, ease of handling, and effectiveness, has long been used to suppress dust during conventional construction excavations. Paving over dirt and gravel site access roads and the use of vegetation or other slope stabilizers (e.g., straw or hay mulches) are also recognized dust suppression methods applicable to Superfund sites. However, most methods for vapor suppression during excavation have been more recently developed for specific application to contaminated sites.

There is a relatively small experience base for application of new suppressant technologies to waste cleanup operations. To date, few vendors of commercially established preparations for dust suppression are experienced in applying their products in a chemically contaminated environment. Some vendors have decided not to offer their products to hazardous waste markets for fear of long-term liability. Others are discouraged by the special requirements for technologies suppressing dust and vapor emmissions from chemically contaminated soils. For example, more commercially established water extenders and wetting agents, roadway stabilizing inorganic salts and polymers, and slope stabilizing formulations based on pacifiers are physically incompatible or react adversely with chemically-

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contaminated soils. Because the wastes themselves are often a mixture of different substances, the question of chemical compatibility is a complex one. Little data on compatibility of suppressant chemicals with waste constituents are currently available.

The addition of another chemical or chemicals into an already chemically-contaminated site may require special handling techniques and equipment before, during, and after use. For example, some of the silicate pacifiers are highly caustic. Some of the foam vapor suppression formulations create a foam mat that may impede subsequent material handling and remedial treatment. Given the emphasis SARA places on on-site treatment and disposal techniques, this inhibition of post-excavation handling and treatment would be significantly detrimental to regulatory compliance at Superfund sites.

Increased employment of dust and vapor suppression methods is dependent upon finding solutions to these operational problems and communicating these solutions to user communities.

WATER APPLICATION

The water truck is a common piece of equipment at many active construction sites where fugitive dusts pose a problem. Water, along with water-based particulate suppressants, is applied to the site surface through a liquid pressure distributor, a gravity-flow water distributor, or by hand spraying. The applied water percolates into the soil and increases adhesion between the particles, thus reducing dusting due to truck and heavy equipment traffic. Water suppresses dust well, but its effect is relatively short because of evaporation. Because application of water is an added cost and is time consuming, its use is limited at construction sites. However, the reduction in health risk often justifies water application at hazardous waste sites.

At waste sites the application of water is often considered first due to the relatively successful experience in using water as a dust suppressant. Water sprinkling, although generally effective in the short-term, requires reapplications and careful monitoring of application rates to avoid creating additional site runoff.

Orleman et al. (1980), for instance, report that water applications at twice a day have lower initial and operating costs than other methods for controlling dust from paved and unpaved surfaces. Similarly, Bauer et al. (1972) indicate that air entrainment of soil and sediment particles is inversely proportional to the third power of the soil and sediment moisture content. Only wind speed is similarly weighted in importance.

At most sites the reaction hazards and risks of chemical incompatibility associated with water usage are low. The equipment is readily available, the cost is moderate, and performance can be good with appropriate reapplication. Water addition, therefore, will continue to be one of the most used methods of dust suppression. Its effectiveness in suppressing vapor emissions, however, is unexplored and may be low since the vapor emissions are frequently insoluble hydrocarbons with specific gravity less than one.

There are simple ways to increase the effectiveness of suppressant water. For example, applying water in proportion to the water truck speed would be a better application technique. Adjusting the application rate of the water to match the site evaporation rate should result in better operational effectiveness and would minimize contaminated water runoff. Practical guidelines on the application and effectiveness of water for dust control are comprehensively addressed in Orlemann et al., Chapter 2. Our survey has not disclosed any active research into improving water suppression by relating water application rate to truck speed and/or evaporation rate, soil properties, topography, etc.

WATER/ADDITIVE SUPPRESSANTS

Various water additives, such as resins, polymers, and surfactants, are available commercially. They are designed to reduce the rate of evaporation loss and to increase soil adhesion or penetration. In addition to the common practice of using water additives as a dust suppressant on haul roads, water additives may also be used to control dust from active work faces (e.g., excavation areas). However, work faces will require frequent reapplication as they are excavated. Water additives have been surveyed by others evaluating their applicability to hazardous waste sites. A good guide to vendor experience in the application of water additives for dust suppression is provided in Rosbury, 1985. Vendors in this study were contacted to determine their current use of water additives. The vendors are listed in Appendix A.

Water additives are typically surfactants and other water extenders that increase the penetration and residence time of topical applications in order to reduce the frequency of application and the attendant labor costs. Adhesive type polymers such as latexes, acrylics, and waste-derived lignosulfonates are typical examples of this class of dust suppressant. Numerous commercial formulations are available.

There are two categories of the adhesive products now used: lignosulfonates and acrylics. Lignosulfonates are a highly effective water soluble and nontoxic binding agent for the substrate that generates dust. Working face applications will prevent dust for a few days or weeks at less cost than untreated water because the lignosulfonate mixture has a far longer surface residency time.

The effectiveness of water for dust control can be improved by the use of a small amount of surfactants. Thus, the total volume of water required can often be reduced by a surface active compound. For example, lignosulfonates are incompatible with strong oxidizing agents. The prolonged and excessive heating of lignosulfonates as in incinerators can result in decomposition and release of toxic sulfur dioxide fumes. Some acrylic products may produce hydrogen cyanide gas when burned. The effectiveness of the additive is always subject to specific site characteristics. It may be necessary to apply some chemical suppressants in more than one application since many soils will not absorb amounts greater than 0.5 gal/yd^2 (PED Co., 1983). If site contaminants are water soluble, then leachate treatment may be required to treat the produced water as hazardous waste.

INORGANIC CONTROL AGENTS

Inorganic salts have been used for dust control because of their hygroscopic properties. The salts keep the surface damp and resist evaporation. They are less expensive to maintain than oils or emulsions. Some salt products can be applied in a liquid or solid form. The liquid application method provides ease of application and a relatively uniform application. The salts offer more binding capabilities than oils and emulsions, and they do not stick to shoes, clothes, or field equipment. Furthermore, the aggregate binding capability of salts prevents the surface from fragmenting under loads and leaving potholes on the site. For inorganic salt use, the site conditions must be compatible with the salt. Many, but not all salts, contain chloride and have a potential for adverse reactions with site soil contaminants. Also, the chloride ion is not held by the soil itself and can migrate freely after application. In addition, salts of magnesium, tin, zinc, copper, and lead are incompatible with some wastes such as sodium salts of arsenate, borate, phosphate, iodate, and sulfide. In addition, the degree of dust control from salt applications depends upon the compatibility of the site soils with the salts.

Hygroscopic inorganic salts such as calcium chloride have long been used to control dust on unpaved roads. These salts absorb and chemically bind moisture. When integrated into a roadway with the proper soil particle size distribution, the salt retains moisture over a long period of time and reduces the release of dust to the atmosphere. Alternatively, pozzolanic material such as cement and lime can be incorporated into the soil. These pozzolans react with water to provide higher soil cohesion and strength, thus reducing the release of dust. Ambient atmospheric moisture is retained on the stabilized surface.

Assuming there are no chemical incompatibilities with the wastes, salt application effectiveness at hazardous waste sites should be comparable to that at nonhazardous waste sites. Areas actively undergoing excavation, however, would likely not benefit from this technology because the salts need to be mixed in with the soils to be effective.

Lime addition, as a means of chemical stabilization of soils, can have beneficial effects beyond accomplishing dust control by raising the sediment pH, thus retarding heavy metal release. Materials such as fly ash have also been used in combination with lime for soils stabilization.

ORGANIC DUST CONTROL AGENTS

Oils, waste oils, bitumens, and vegetable gums have historically been used to wet and bind particles together to resist entrainment by blowing winds and drafts created by earth-moving equipment. These materials have an affinity for soils and have lower vapor pressures than water and, thus, they remain effective longer than water. Bitumens, unused oils, other mineral oil-derived materials and organic chemical derivatives can provide safe and effective dust suppression. Many of these oils and waste oils can generate vapor emission problems themselves when applied for dust control.

The BTU content may be beneficially reused if subsequent and immediate incineration is part of the remediation scheme. However, the user should always verify that there are no chemical incompatibilities with the wastes on the site. Waste oils contaminated with trace quantities of potent toxic compounds (i.e., PCBs and dioxin) have caused some of the worst cases of environmental pollution on record.

Other organic materials such as asphalt emulsions have been sprayed on prepared surfaces in liquid form and the material allowed to solidify to form a continuous membrane that suppresses dust (for example, Army Corps of Engineering Study EM 1110-2-505). Toughness and dimensional stability have been further increased by spraying onto supporting fabrics (Culpepper, 1972). Similar applications with polyvinyl acetate (latex) were reported by Anderson (1971). Due to high fluid viscosity, the use of asphalt or latex may incur higher equipment and energy costs. Initial heating of these organics before spray application is often necessary. Most work with these organic agents has been as dust suppressants. Organics such as these may also hold some promise of being able to suppress vapor emissions because of the possible solution of the soil contaminants in the organic binders. However, no testing has been conducted for vapor emission control. In addition, these agents are typically applied to roadways and other static surfaces.

FOAM SUPPRESSANTS

Vapor and dust suppression has been demonstrated with foams produced by air-entrapping water additives. This relatively new suppression technology was originally developed for fire fighting. Several available products are modifications of fire fighting foams. Blankets of these foam products suppress the mobility of particles and vapors by physically blocking escape routes and insulating the soil from the effects of the sun and wind. Commercially available stabilizers can extend the life of these foams to several days. Specialized nozzles or conventional fire fighting foam-producing nozzles are used depending on the commercial formulation. The different types of foams that may find use in hazardous waste applications have been surveyed recently (Evans, July 1986).

Foams have been utilized to contain vapor emissions from spills and, recently, to contain vapors at hazardous waste sites. Table 3 lists the names, addresses, and telephone numbers of some foam vendors.

Several foams used for the express purpose of suppressing hazardous vapors are commercially available for application at hazardous waste sites. Utilization of these foams is increasing fairly rapidly. Some vendors have conducted research and published extensive chemical compatibility charts (e.g., 3M Tech Paper 98-0211-2584-8) to support new applications. Through the use of this literature, the removal/remediation planner has a basis for evaluating the chemical compatibility of foams with the wastes at a site.

Temporary or short-term foams last for 20 minutes to one hour. These foams are used on spills, on active work faces, excavating buckets, and/or transportation vehicles at the site. Long-term foams contain stabilizers that maintain their effectiveness for 24 hours or longer. These are used on the work face for overnight suppression of vapors or on the loaded truck to control vapors during transportation.

Additional foam characteristics essential for vapor control at hazardous waste sites include the ability to produce stable blankets, resistance to product pickup, a slow drainage rate, and physical properties that do not impede subsequent material handling and treatment/disposal activities. For example, waste incineration might be impeded by agents that contain fluorocarbons that release hydrogen fluoride when heated. Some of the long-term foams may form a strong film that could interfere

TABLE 3. HAZARDOUS WASTE FOAM SUPPLIERS

1. National Foam
   150 Gordon Drive
   Lionville, Pennsylvania 19353

   Telephone: 215-363-1400

2. Environmental Security, Incorporated
   352 Abbeyville Road
   Lancaster, Pennsylvania 17603

   Telephone: 717-392-1251

3. 3M
   Hazardous Material
   Control Products Division
   8301 Greensboro Drive - Suite 300
   McLean, Virginia 22101-3689

   Telephone: 800-221-1454 (inside New Jersey)
   800-221-1455 (outside New Jersey)

with screw and belt conveyor transport. The effectiveness of foams on vapor suppression reported by manufacturers usually varies between 50 percent and 100 percent depending on the chemical nature of the vapors. There are certain chemicals, particularly highly water-reactive ones, on which water-based foams are ineffective. Likewise, a foam that is effective for use with acids is generally not effective on alkaline materials and vice versa. Some foams may actually react with the material and increase the rate of release of toxic vapors from the soil.

For best performance, foam-generating chemicals must be used according to vendor instructions. The quality of the foam, its performance, and its effectiveness may be affected by the storage procedures, site characteristics, and application equipment used. Preremoval/remediation planning must consider foam equipment and handling at the site and other applicable dust and vapor suppression technologies. Some foams need special application equipment that may not be readily available or interchangeable with foam application equipment from different vendors. Foam application personnel must be trained as to equipment use, maintenance, and foam application techniques. Properly handled, foams provide rapid and uniform coverage by conforming to site surfaces and can reduce health risks and hazards through vapor and dust suppression.

Before using a foam in the field there is a need to independently verify the effectiveness of the product. In addition, the removal/remediation planner must be aware that effectiveness claims typically apply to covered source material. Actual field effectiveness will also be impacted by the duration of uncontrolled operations (i.e., during each excavation/loading action that results in surface renewal).

AIR-SUPPORTED ENCLOSURES

Commercially available air-supported membranes have been used to enclose areas undergoing excavation. The membrane provides a barrier that prevents uncontrolled release to the atmosphere. In conjunction with air lock entrances and exhaust stream dust and vapor pollution control equipment, these structures are highly effective where site conditions permit their use.

Air-supported enclosures are fabric and/or plastic structures supported by air pressure. Centrifugal fans controlled by static pressure sensors are used to support the enclosure. Prefabricated air locks that contain the static pressure inside and prevent the escape of uncontrolled contaminants are also readily available.

Air-supported enclosures are subject to special building permit requirements. These structures are readily available throughout the country for purchase or for lease.

Reportedly, areas from 10,000 square feet to 10 acres can be covered, with height restrictions ranging from a maximum of one-half to a minimum of one-sixteenth of the width (Means, 1987).

These commercially available inflatable buildings offer the means to enclose small to moderately sized work spaces. Both dust and vapor suppression are possible since it is possible to direct the spent supporting air through such devices as bag-house filters and carbon adsorption units for dust and vapor control. If vapor concentrations in the exhaust stream are relatively high, a regenerative air system might be feasible.

Worker and equipment operator personnel protection measures must be carefully evaluated and addressed, however, because of the potential for accumulating dust, vapors, and exhaust products from the excavation equipment within the structure. If the buildup of organic vapors within the structure is high, the chemical compatibility between vapors and the structural fabric may also have to be considered.

Air-supported buildings can be purchased or rented. This decision will depend on availability and the vendor's acceptance criteria for used inflatable buildings. The vendor must approve the planned decommissioning/cleanup procedures as adequate to accept the return of the fabric and related air-supported structure equipment.

Nylon, woven polyethylene, vinyl film, and vinyl-coated dacron fabrics have a reported life span of two to ten years when used in air-supported structures (Means, 1987).

Our survey of removal remedial actions revealed that inflatable buildings have been successfully used to contain vapor emissions in at least one application. This application used low pressure drop carbon filters for air purification prior to discharge. The site, NYANZA Chemical, is discussed in detail in Section 6 of this report.

ACID GAS NEUTRALIZATION ADDITIVES FOR VAPOR CONTROL

Drilling muds are used to lubricate drilling bits and other drilling equipment. Various conditioners and additives can be introduced into these muds in order to give them specifically desired qualities. The modified drilling muds can be used under various downhole conditions.

Modified drilling muds have been employed with some success at Superfund sites having significant potential release of vapors during subsurface activity. For example, during the initial excavation of one site, hydrogen sulfide and related gases were released in large enough amounts to halt operations. An alternate excavation plan was developed in which several ventilation wells were drilled in and around the affected soils and subsequently purged with a blower. Toxic gas suppression was accomplished during drilling by a method used in the oil and gas exploration industry, wherein drilling muds are conditioned with ferrous compounds that will react with the sulfurous compounds in the bore hole. Hydrogen sulfide and related vapors that would otherwise be released during the drilling operations are thus retained in the bore hole by the reaction of the sulfurous compounds with the ferrous compounds in the drilling mud. Following installation of the wells, suction was applied and the off-gases were manifolded to conventional air pollution control devices. For additional details, see the discussion on Bruin Lagoon in Section 6 of this report.

The use of drilling mud additives is limited to contaminants for which suitable drilling mud additives have been identified. Mud suppression could be used for hydrogen sulfide and other acid gas contaminants such as hydrogen cyanide and sulfuric acid. Less reactive volatile organic compounds and some of the other contaminants encountered at waste sites may not be readily contained by this technique.

Although this technology has not been applied to soil excavation, such solutions could be topically applied to exposed soils during excavations to prevent the release of acid gases.

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IN SITU TREATMENT TECHNOLOGIES

With this approach, an effort is made to reduce the vapor concentrations before soil excavation begins. Gases and volatile compounds can be removed from contaminated soils by either passive or active vent systems. Passive vent systems rely on trenches, vents, and other installed conduits that allow unwanted gas and vapors to migrate to the surface under the influence of naturally occurring buoyancy (density) and concentration gradients. Existing municipal waste landfills contaminated with industrial wastes and needing excavation may already have passive vent systems. Active vent systems rely on positive displacement blowers or vacuum pumps to provide the motive power (Army Corps of Engineers, 2 September 1986).

Soils contaminated with solvents may need the installation of active systems to increase the rate of volatilization of the contaminants. Such active systems are called in situ volatilization (ISV) systems. ISV is an emerging technology for in-place soil treatment that is primarily applicable to treatment of unsaturated VOC-contaminated soils and has been applied to the control of vapor emissions at Superfund sites. ISV treatment removes VOCs by mechanically drawing air through the pore spaces in the soil and allowing VOCs to volatilize from the soil matrix into the air stream. An ISV system requires the installation of an array of vents in the contaminated portion of the unsaturated (vadose) zone. Typically, the vents are manifolded to the suction side of vacuum pumps to actively draw air from the soil. Depending upon the resulting concentration of VOCs in the vent system air, emissions controls such as vapor phase carbon adsorption may be required.

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ISV systems can be designed with a great deal of flexibility for operation over a wide range of VOC removal rates. Two important parameters that must be assessed when determining the viability of ISV technology for a particular site are the soil's permeability to air and the volatility of the contaminants. Other parameters that will affect the performance of ISV technologies include subsurface soil profile, the absorptive capacity of the soil, the natural organic content of the soil, the mixtures of contaminants, and the physical states of the contaminants in the soil. The types of soils and contaminants that ISV is applicable to and its treatment effectiveness are currently being investigated. Several limitations to ISV are: the contaminant must be volatile enough to transfer from the soil to the air; the soil must be permeable enough to allow sufficient air flow; and the resultant air plus volatiles may need scrubbing or treatment with activated carbon, incineration, or catalytic oxidation. Finally, the results of the treatment are uncertain because the treated soil is still in place and not readily analyzed for residual VOC compounds.

In addition to gas venting, other in situ techniques such as soil flushing, biodegradation, and steam stripping may be applied prior to, or possibly in lieu of, excavation. These innovative techniques are also in the development and early stages of full-scale implementation. The main advantage of in situ treatment is that it allows treatment of contaminated soil without excavation by a system that can be designed for site-specific soil and contaminant characteristics.

SELF-SUPPORTING ENCLOSURES

The use of self-supporting and/or semipermanent enclosures has been proposed for areas too large to enclose with an inflatable structure (see Subsection 5.7), and/or where the dust and vapor emissions present an extreme enough hazard to warrant the expense of a more permanent structure (SIBAS, 1987).

Geodesic domes represent one of the least expensive ways to enclose a relatively large area. Other enclosing structures are available with different installation and operating features. Dual radius hemispheres, prefabricated steel hangers, and other special constructions intended for warehousing are available (Means, 1987).

Geodesic domes are available in diameters up to 415 feet in aluminum and up to 60 feet in wood. Dual radius bulk storage domes are available in diameters up to 400 feet in both corrugated steel and wood. Tension structures with steel frames and fabric shells are available for areas up to 36,900 square feet with heights up to 124 feet.

One specialized construction technique for enclosing a remediation site employed an enclosing structure capable of following the planned excavation route by moving on rails as the work progressed. A movable cover 63 feet by 112 feet was applied to the excavation of low-level radioactive wastes at the Kema site in Arnhem, the Netherlands (Sibas, 1987).

Tents may be used, but they have the drawback of requiring supporting pillars within the enclosed space and are not usually appropriate for excavation activities.

These structures are usually inert to the wastes being excavated and they can be installed wherever suitable foundations can be provided. Usually some ventilation is required and the resulting spent air may need air pollution control measures similar to those required by air-supported enclosures. Within these structures, indoor pollution levels are likely to exacerbate hazardous conditions in the work area. These structures have an added advantage in that the air exhaust can be used to exert a negative pressure within the structures. This will prevent inadvertent leakage that could occur with structures supported by positive air pressure.

Self-supporting structures are generally more expensive than other control techniques, but they provide the most reliable and effective control of off-site migration of dusts and vapors.

VACUUM TRUCKS

Commercially available vacuum trucks can be used to remove soils and sludges fluid enough to flow to the pickup nozzle. In many cases suction transfer can provide a more controlled alternative to excavation and loading.

Some vendors of conventional industrial vacuum systems have modified their equipment to include air pollution control equipment within the mobile vacuum truck unit. Provisions have also been provided on some equipment for handling both wet and dry materials by bypassing the unneeded air pollution control equipment (Guzzler, 1986).

Where material characteristics allow their use, vacuum trucks with emission control devices should significantly reduce excavation, loading, and transportation related emissions versus conventional excavators and dump trailers. No studies were identified that quantified such vacuum truck fugitive emissions reduction. However, decreased air/waste contact and enclosure of the waste during transport should reduce the potential for emissions. The designer should work closely with the vendor, however, to ensure that only proper and effective applications are undertaken and that the air pollution control devices are appropriate and adequate.

COVERS, MATS, AND MEMBRANES

Various system are available for covering soil with physical barriers. These include: relatively thin plastic sheets (4-6 mils); thicker plastic covers (30-40 mils); mats; geotextiles that may be open mesh screens of jute or synthetic materials; and mulches of organic and inorganic materials supplied in bulk form.

Plastic and geotextile barriers are typically applied from rolls and are relatively easy to place and remove. Some experimental work with spray-applied fiberglas mats that are subsequently coated with polymeric binders has also been reported. Some experimentation was also done with fiberglas scrim and spraying of polyvinyl acetate or cationic asphalt-neoprene emulsion to bond the scrim and soil surface as a means of dust control (Culpepper, June 1972). Paper mill sludges, aged manure, and other absorbent waste materials have also been used. These barriers are effective in insulating the protected surface and physically containing dusts and vapors. Tears, loose edges, and penetration by vegetation are some of the observed failure modes for these covers.

A well-anchored mulch can be used as a physical barrier for soil stabilization (Army Corps of Engineers, September 19, 1986, Study EM 1110-2-505). The mulch usually consists of vegetative material such as straw, which is layered and anchored by woven paper products, natural or synthetic netting, or a combination of these. For example, during the summer of 1980 at the Caputo Site, near South Glen Falls, New York, a combination of topsoil, organic papermill sludges, and manure was used to adsorb fumes from PCB-contaminated soils (Shen, T.T.; Sewell, G.H.). The cover was nearly 100 percent effective at the time of application, but no further measurements were taken, so the effect of time on suppression efficiency is unknown.

Materials applied in bulk have a potential advantage over the roll-applied covers, and although they have not been used in this application, they could potentially be effective at the active face of the excavation. The organic bulk materials can be excavated with soils and readily processed through material handling or treatment process (e.g., incineration) equipment.

WINDSCREENS

Agricultural engineering practices have long included the use of windscreens to reduce dust emissions and limit the areal extent of dust and vapor migration by decreasing windshear over soils. Windscreens offer a low-cost method for reduction of fugitive dust emissions and are easily transported and assembled. The effectiveness of a windscreen depends upon its density, height, porosity, and placement with respect to prevailing winds at the site. Several types of windscreens have proven to be economical and effective wind erosion control measures (Bauer, 1972). Transportable windscreens are typically 4 to 10 feet high and are composed of polyester or other high-strength material. Horizontal protection from windshear at the working face typically extends up to 9 to 12 times the vertical height of the windscreen, with the maximum reduction of wind velocity at distances of 1 to 5 screen heights downwind. The optimal location was found by Sturder and Arya to depend on both the windscreen height and porosity (Sturder, 1988). The lower porosity windscreen causes lower wind speeds. Although low-porosity barriers result in more windspeed reduction, high-porosity barriers will give greater protection over longer downwind distances. The greatest decrease in windspeed on the downwind side of a given barrier is provided when the barrier is aligned at right angles to the wind. The application of windscreens can be effective only at reducing wind sheer at removal/remediation sites and will not eliminate the formation and transport of fugitive dust. Their effectiveness is lessened by changing wind conditions, and they have been observed to be only marginally effective when screening stockpiled material (Rosbury, June 1985). Further, many active excavation/material handling operations will potentially disperse dust above the effective height of wind speed reduction. Windscreens can be utilized where total control is not essential and can be combined with other techniques to enhance performance of the overall dust control program.

SCHEDULING

Prevailing weather conditions significantly affect the rate of both dust and vapor emissions during excavation projects. Generally, cool weather reduces vapor emissions by reducing the vapor pressure or partial pressure of the contaminants. Wet, low wind conditions reduce dust emissions. Thus, seasonal scheduling to take advantage of prevailing weather conditions could be used to help mitigate potential off-site hazards due to excavation at the site. While no studies quantifying the performance of seasonal scheduling have been identified, the advantages of working during winter conditions on organics-contaminated sites have been been widely observed. In cases where a higher degree of control is necessary, scheduling may be combined with other techniques to provide a greater effectiveness than either would achieve independently. However, seasonal scheduling may reduce the efficiency of excavation operations due to the effects of cold and rain on equipment, soil conditions, and personnel.

Another way to employ scheduling is to respond to real-time site perimeter monitoring data and adjust site activities when downwind air monitors indicate excessive levels of pollutant migration. Excavation may be halted until wind conditions change; night work may be employed to reduce the effects of heat and sun; or contingency dust and vapor suppression techniques (e.g., water, foam, etc.) may be used. This type of scheduling is reported to be commonly used when air pollution from excavation at Superfund sites is identified as a potential problem, and monitoring confirms that intermittent problems are, in fact, occurring.

Scheduling should be considered at any site where the potential for emissions necessitates the use of real-time perimeter air monitoring. Seasonal scheduling is an even more effective technique at excavation sites where emission problems are anticipated. Seasonal scheduling could be used in conjunction with perimeter air monitoring during the excavation, and these methods could be supplemented by other methods of dust and vapor suppression as well.

SECTION 6

SPECIFIC APPLICATIONS AND CASE STUDIES

This section reviews three case studies in which features of some of the established and recently developed control technologies discussed in Section 5 were utilized. The Nyanza Chemical site illustrates some of the practical design issues encountered while performing excavation and soil handling inside an enclosure. The Bruin Lagoon site illutrates the use of acid gas neutralization techniques in controlling gaseous emissions from contaminated soils and sludges. These techniques were adapted from natural gas exploratory drilling practices. Test work performed on control dust emissions during excavation with a front-end loader illustrates the effectiveness that can be obtained from the relatively low-cost option of using water sprays and water curtains.

NYANZA CHEMICAL, ASHLAND, MASSACHUSETTS

The Nyanza Chemical hazardous waste site is located west of Boston in an industrial park in Ashland, Massachusetts. It derives its name from a former textile dye manufacturing operation that was abandoned, leaving behind a variety of industrial waste sludges. Mercurous, chromic, nitro-aromatic, and chloro-aromatic compounds were found in these sludges and in site soils. Groundwater and surface water pollution was also observed.

The site is in a densely populated area and is adjacent to an ongoing manufacturing operation in the same industrial park. In planning the remedial action, it was concluded that uncontrolled excavation of the waste sludges would release harmful vapors into the neighborhood and adversely affect the public and the nearby industrial site workers.

Nitrobenzene, dichlorobenezene, and trichlorobenzene were some of the specific compounds found at the site. On-site incineration in a 20-TPD rotary kiln was the preferred treatment scheme for the waste sludges. Enclosure of the excavation and the material handling system feeding the incinerator was also judged to be necessary in light of the population density in the area and the hazardous nature of the vapor and particulate contaminants.

A portable rigid frame structure capable of enclosing the excavation site was estimated to cost $120,000 (not including set-up costs) in 1987, and it would require two weeks to erect. Leasing an air-supported structure was also evaluated (Lilley, 1987).

Initially, some vendors did not want to lease their equipment for use at a hazardous waste site for fear that inadequate decontamination procedures would preclude their leasing the equipment to subsequent customers. The sale price for an air-supported structure capable of enclosing an area 80 feet wide by 105 feet long was approximately $70,000. Eventually, a vendor was identified who would lease a suitably sized air-supported structure for approximately $14,000 for four months. This estimate did not include setup and breakdown

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costs. A standard air lock 15 feet wide by 30 feet long by 18 feet high was provided that allowed earth moving equipment to enter and exit the air-supported structure without significant loss of the air pressure inside the structure.

Installation requirements were initially underestimated. It was found that anchors required to hold down the perimeter could not be adequately installed by hand. It was necessary to utilize the services of a drilling subcontractor to properly set the anchors in the soil. This additional work cost approximately $6,000 in subcontractor fees and disrupted the planned installation schedule. Also, an additional $7,000 to 12,000 was required to assemble the building, partially due to inadequate equipment and no installation manual available from the vendor.

The air supported structure was made from 28-ounce fabric. Sandbags were used to supplement the anchors installed to hold down the perimeter. The structure was equipped with a pressure sensor that controlled two 7,500 ACFM blowers to maintain an inside air pressure that was approximately 3/4 to 1-1/4 inches W.C. above atmospheric pressure. This system provided approximately four to five air changes per hour. OVA and PID instruments provided real-time air monitoring for organics inside the structure.

Workmen wore level B personnel protective equipment when inside the structure, primarily because of the accumulation of carbon monoxide resulting from operating the earth-moving equipment within the enclosure.

Sludge and soil were excavated and staged for feed to the incinerator. Screening equipment inside the air-supported enclosure was used to remove debris greater than 3/4-inch from the material prior to its entering a screw conveyor. The screw conveyor conveyed the excavated sludge through a seal in a side wall of the enclosure and discharged into the incinerator.

Air pollution control equipment was used to treat exhaust/circulation air as it exited the air supported structure. A single carbon adsorption canister that featured a "low pressure drop" radial bed design was used. At this low pressure drop, four to five air changes per hour could be maintained at low-power consumption. A single 3,000 ACFM I.D. fan driven by a 5-hp motor was used to draw spent air through the air pollution control equipment. A more conventional design proposed by another vendor would have used three parallel carbon adsorption units at a high capital and operating cost.

The equipment at Nyanza is reportedly no longer in active use.

BRUIN LAGOON, BRUIN, PENNSYLVANIA

The Bruin Lagoon site occupies approximately three acres in Bruin Borough, Butler County, Pennsylvania (Zickler and Heston, 1984). Operations at the site began in the 1930s and, for over 40 years, it was used for the disposal of mineral oil production wastes, which included concentrated acids and oil sludges, motor oil reclamation wastes, coal fines, and fly ash. The acid sludges found in Bruin Lagoon were typically 30 to 35 percent hydrocarbons and 65 to 70 percent sulfurous compounds such as sulfonic and sulfuric acid, acid esters, and sodium sulfate. Due to the acidic components, the sludges had a low pH, typically in the range of 2.0 to 4.0. Heavy metals and alkyl benzene sulfonate (ABS), a detergent, were also present in the sludges. In September 1984, Bruin Lagoon ranked third among 538 sites listed on the National Priorities List (NPL) published by the U.S. EPA (Bruin Lagoon, Bruin, Pennsylvania 1986).

An initial RI/FS was conducted in 1981-1982 with a Record of Decision issued in June 1982. The selected remedial alternative consisted of on-site stabilization and containment. A substantial amount of remedial work was completed by May 1984, when hazardous subsurface gases sickened the equipment operators during the excavation. The remedial work was suspended. Air samples and borings from the sludge were collected to assess the potentially dangerous nature of the gas and mist releases. Analytical results showed hydrogen sulfide concentrations approaching 1,000 parts per million (ppm) in one bore hole.

Based on these samples, the estimates of potential community exposure, and the proximity of residential areas, Region III of the U.S. EPA declared an emergency situation at Bruin Lagoon in June 1984. Stabilization activities were suspended indefinitely. Emergency on-site work activities were begun in mid-July.

The details of this emergency action and the specific equipment that was used can be found in the OSC report and the RI/FS that was prepared (Bruin, 1984 and 1986). In general, the overall strategy of the emergency action was to contain the vapors below ground, while providing a means for this controlled release to a vent and air pollution control system. The first step of the emergency action was to backfill the open lagoon area using approximately 15,000 cubic yards of the stabilized sludge that had been stockpiled on-site during the initial remediation work. This provided a cover over the source of the emissions. Further, the lime in the lime-stabilized sludge was an effective neutralizing agent to treat acidic gases that might emanate from below.

Once contained, the plan called for sampling and releasing the acidic gases in a controlled manner by installing a system of wells and vents to direct the gases to air pollution control equipment. Installation of this system was complicated by the fact that the gases appeared to build up pressure beneath the cover.

The emergency response designer adapted a technology used in the natural gas exploration industry, where similar circumstances often prevail. An important feature of the drilling technique used was the use of drilling muds conditioned with ferrous compounds capable of reacting rapidly with the acidic gases down in the bore hole to form a nonvolatile salt. "Ironite" was the particular formulation used. By recirculating and pressurizing the drilling mud with its ferrous additive, it was possible to contain the released gases during the drilling. A casing was first installed and grouted into the stabilized soil cap. Subsequent drilling and well installation was conducted through a low-pressure seal (see Figures 2, 3, and 4).

Once the drilling was complete and a well was installed under the pressure seal, the well head was connected to a pipeline for conveyance of the gases to an air pollution control system. This system consisted of a knockout drum,

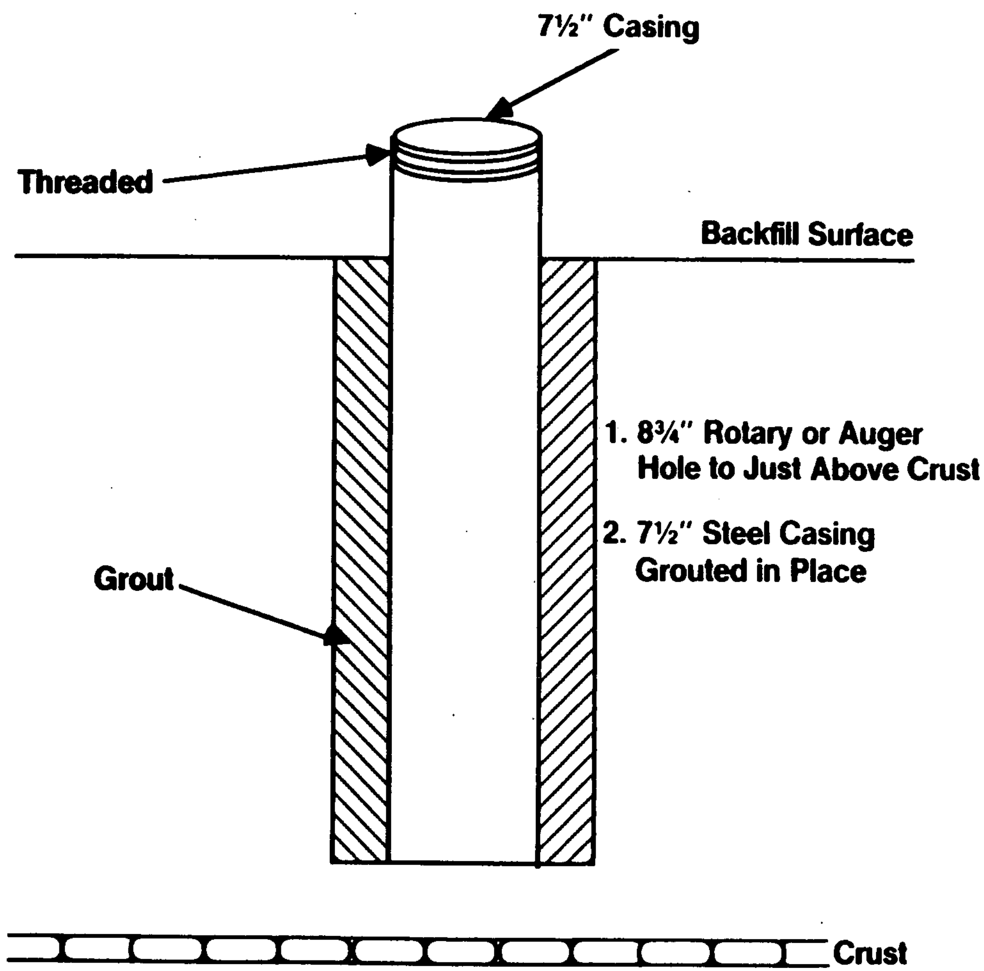

FIGURE 2 ACID NEUTRALIZATION INITIAL WELL CASE INSTALLATION

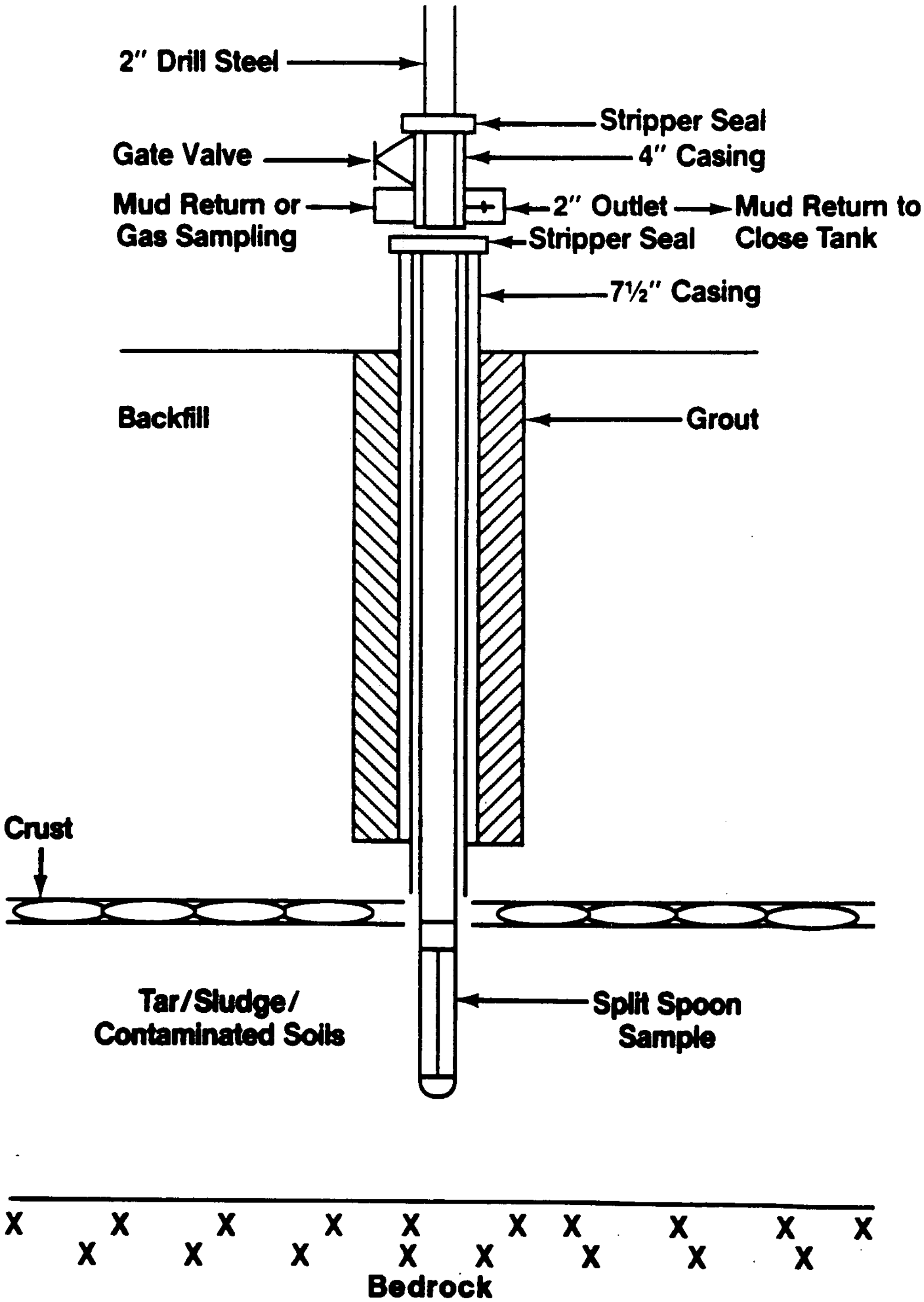

FIGURE 3 ACID NEUTRALIZING DRILLING MUD WELL CONSTRUCTION SPECIFICATIONS

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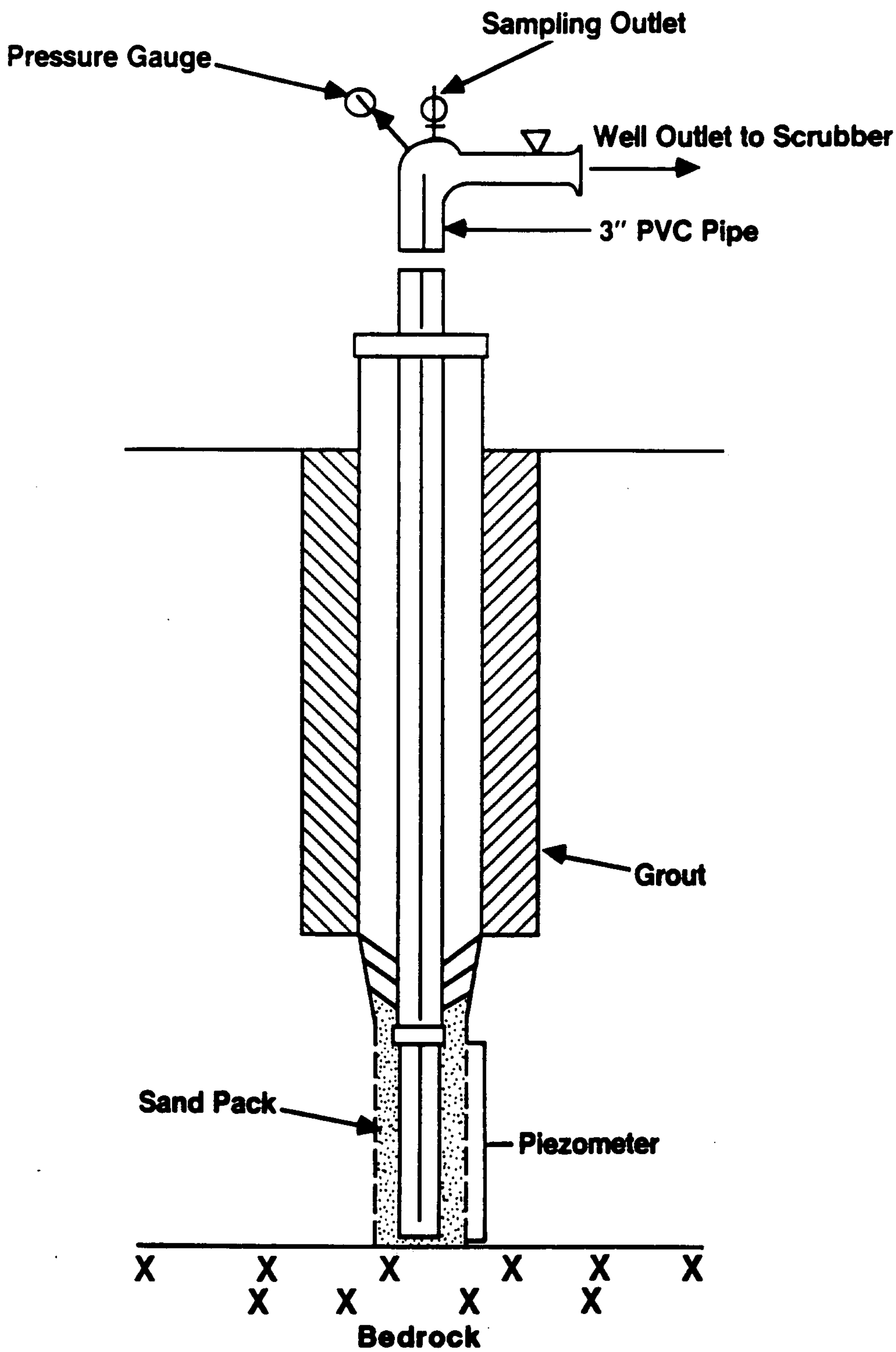

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FIGURE 4 COMPLETED PIEZOMETER AT BRUIN LAGOON demister, and a three-canister carbon adsorption process train that used caustic impregnated vapor phase activated carbon (see Figures 5 and 6).

The cost for backfilling the lagoon with stabilized sludge was approximately $120,000. This included labor and equipment for moving an estimated 15,400 cubic yards of material. With all the on-site work performed in level B health and safety protective gear, the sampling, measuring, and drilling of 13 wells cost upwards of $400,000. The cost of the air pollution control system with an additional standby process train of three carbon adsorption canisters was $7,500. When the emergency action was completed, the total project cost amounted to approximately $813,000 in 1984.

FRONT-END LOADER/DUST CONTROL TESTS, CINCINNATI, OHIO

Rosbury and James (June 1985) tested the effectiveness of four dust control measures during an excavation that simulated cleanup measures at a Superfund site. The soils that were undergoing excavation were not contaminated, but they were marked with a tracing compound. During the simulation, a front-end loader (FEL) was used to excavate soil and carry it to a dump truck at a truck loading station. Ambient air conditions were monitored with sampling towers that were located upwind and downwind of the excavation and the truck loading station.

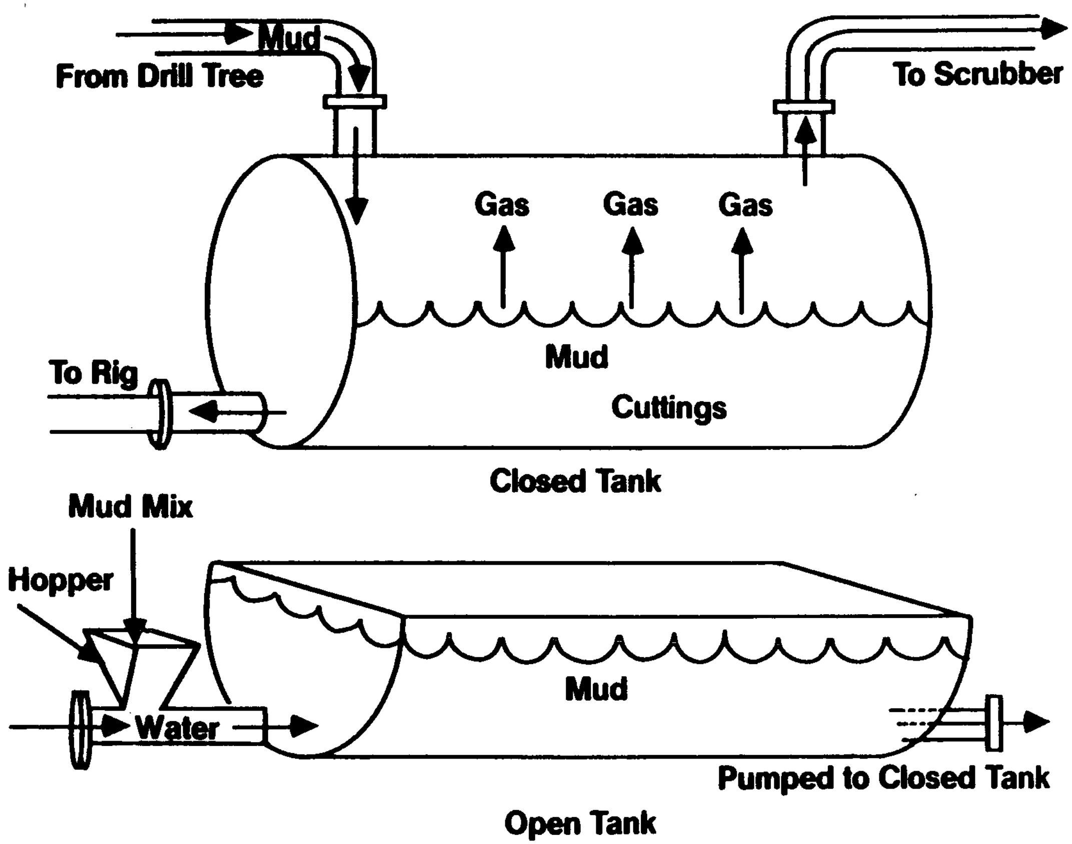

FIGURE 5 DRILLING MUD TANK-BRUIN LAGOON

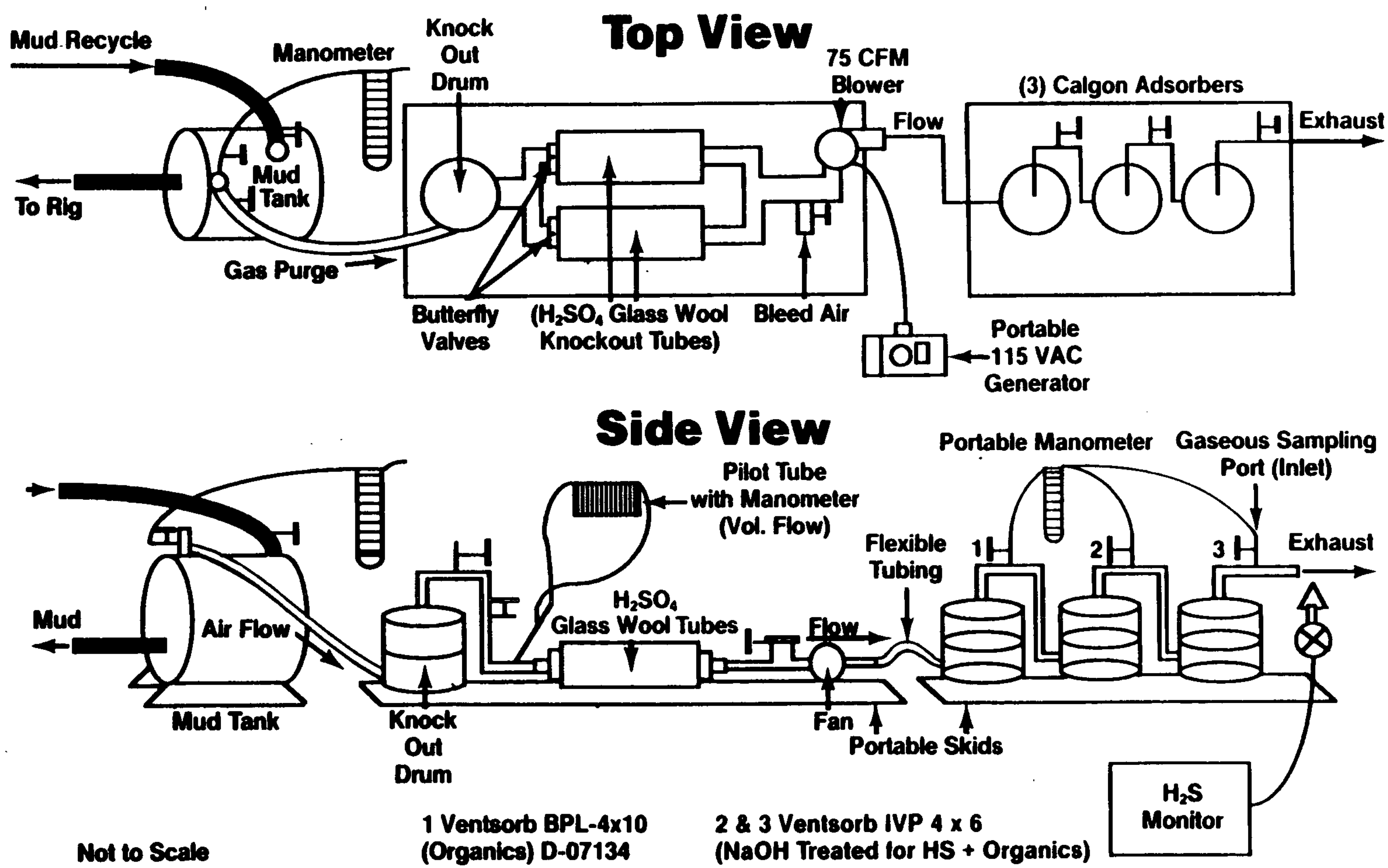

FIGURE 6 ACID GAS AIR EMISSION CONTROL SYSTEM, BRUIN LAGOON SITE

The first control measure consisted of spraying water on the active working face of the excavation area ahead of the FEL and on the travel path between the excavation and the truck loading station. Water was applied at roughly 0.9 gal/yd^2 by using a portable 200-gallon tank, pump, generator, hose, and spray nozzle.

The second control measure was the same as the first except that a surfactant (Johnson March Compound MR) was added to the water in the 200-gallon tank. The areal application rate with the additive was about 0.75 gal/yd^2.

The third control measure used a water spray bar with six nozzles to continuously envelop the dump truck box in a water spray. The application rate during this test was approximately 1.5 gallons of water per cubic yard of soil. Less water consumption without a loss in effectiveness was projected by Rosbury and James for designs that would turn on the water spray only when the load was being dumped into the truck. During this test, however, the spray was on continuously while the truck was in the loading station.

The fourth control measure utilized a foam spray to control dust at the truck loading station. Surfactant was added to the water to generate a stream of foam. Here, however, the foam was sprayed only during the dump. About 0.4 gallon of mixture per cubic yard of soil was used.

The weather during the tests was described as wet and the soil was described as a uniform clay from a small farm near Cincinnati, Ohio. The water spray bar design was thought to need improvement and several operational problems were reported for the foam spray.

The control efficiency test results reported for two different particle sizes are presented in Table 4. In comparison to no dust control measures during the excavation, spraying water during the loading station resulted in 64 percent fewer <2.5 micron particles and 42 percent fewer <30 micron particles. The surfactant-enhanced water spray resulted in even higher control efficiencies at lower application rates.

Spraying water at the excavation site resulted in roughly 60 to 70 percent fewer (2.5 micron and <30 micron) particles at the loading station than were present when no previous control measures were taken. However, the foam and water curtains at the loading station were both observed to be less effective than water spraying.

Unfortunately, the overall effectiveness of combining water spraying at the excavation site with applying a curtain at the loading station was not reported.

TABLE 4. EFFICIENCY TEST RESULTS FOR FRONT-END LOADER OPERATION AND TRUCK LOADING

Operation	Control Measure	Control Efficiency <2.5 um	Percent <30 um
FEL scraping and traveling	Method I - Areal spray-water (0.9 gal/yd^2)	64	42
	Method II - Areal spray-water surfactant (0.75 gal/yd^2)	70	63
Truck loading	Method I - Areal spray-water (0.9 gal/yd^2)	66	69
	Method II - Areal spray-water surfactant (0.9 gal/yd^2)	62	77
	Method III - Water curtain (1.5 gal/yd^3)	56	50
	Method IV - Foam curtain (0.4 gal/yd^3)	41	46

SECTION 7

APPLICATION AND UTILIZATION GUIDELINES

This section is intended to serve as additional guidance for the selection of those technologies discussed in Section 5. It relies strongly on the insight of the designer in interpreting the key site and waste-related factors that may impact on use of the technology at various stages of remediation. The conclusions reached from the analysis should take into consideration past use and success rates of the technologies.

Specific questions listed herein are for illustrative purposes and are not intended to be used as a checklist.

The remedial program designer should employ a "top-down" method of analysis by assessing the potential dust and vapor problems on the site, determining the extent of control that will be necessary, and then selecting the appropriate technology. The most likely source of pertinent information to aid in this analysis is the site Remedial Investigation/ Feasibility Study (RI/FS) Report. This report should contain a detailed summary of all contaminants and waste types found on the site, including concentrations and areal extent of contamination. Necessary information such as the type and location of the contaminant, e.g., the presence of volatile compounds beneath the surface, can usually be determined from the RI/FS. It is up to the designer to define as well as the data will permit what the physical states of the contaminants are. Additional information such as particle size distribution may not be reported, thus necessitating an educated estimate or consultation with an expert in soil science. For example, the designer may choose to obtain a representative sample of the on-site soils for optical or sedimentological particle size analysis. The degree of information required is usually driven by the level of sophistication of recognized computer models used to predict the on-site and off-site migration/dispersion of the contaminants. Results of the modeling should be considered along with secondary factors (e.g., moisture content). Secondary factors that cannot be determined from a particle size analysis will often act as a natural dust suppressant.

The designer must carefully consider what types of activity will be occurring on the site before, during, and after the remediation. He should obtain details about the equipment to be used; what types and amounts of dust could be generated by equipment use; and if the excavated soils will generate volatile emissions.

The applicability of each technology to excavation site operations that may cause vapor and dust control problems is evaluated and summarized in Table 5. Table 6 summarizes the relative effectiveness of the dust or control technologies and presents pertinent comments on the benefits of and constraints on usage of each technology. Table 7 provides the same information for vapor emissions. The applicability and effectiveness summary, in conjunction with the detailed review in Section 5, should allow the designer to qualitatively rank technologies according to effectiveness for each particular application. For example, enclosures are very effective for

TABLE 5. APPLICABILITY OF SUPPRESSION TECHNOLOGIES TO SITE ACTIVITIES

Suppression Technologies	Excavation of Soil Sludge and Sediment	Dredging of Sludge and Sediment	Loading of Soil Sludge and Sediment	Transport of Excavated Material On-Site	Staging and Stockpiling On-Site	Vehicular Traffic On-Site	Inactive Face of an Excavation	Long-Term Storage/ Stockpiling On-Site	Processing of Soil for On-Site Treatment	Intensive Site/ Remedial Investigation or Design Phase Sampling Activity
Water	D				D	D		D		
Water Additives	D				D	D	D	D		
Inorganics					D	D		D		
Organics					D	D	D	D		
Foam	D, V			D, V	D, V		D, V	D, V	D, V	
Air-Supported Enclosures	D, V	D, V			D, V			D, V		D, V
Acid Gas Neutralization	V[1]									V
In Situ Treatment	V				V		V	V	V	V
Self-Supported Enclosures	D, V	D, V			D, V			D, V		D, V
Vacuum Trucks	D, V	D, V	D,V						D	
Covers, Mats, and Membranes				D, V	D, V		D, V	D, V		D, V
Wind Screens	D	D	D		D	D	D	D		D
Scheduling	D, V	D, V	D	D		D			D	

[1]Potentially useful, reportedly not in use at this time.
D = applicable in dust control.
V = applicable in vapor control.

TABLE 6. APPLICATIONS GUIDELINES - FUGITIVE DUST CONTROL TECHNOLOGY

Technology	Effectiveness In Dust Control	Constraints In Use	Benefits of Use	Relative Capital Cost
Water	**Moderate**	Runoff Reaction with pollutants Costly repeat applications Time consuming	Cost-effective method Widely available	Low
Water Additives	**Moderate to good**	Runoff Reaction with pollutants Limited availability	Extend benefits of water by reducing costs of repeated application	Low
Inorganics	Moderate	Reaction with pollutants Effective only on relatively undisturbed soils	Cost-effective method that requires infrequent application	Low
Organics	Moderate	Specialized applications Reaction with pollutants Material handling constraints Application temperature dependent	Effective in dust suppression May add BTU value to soil May provide tough dimensionally stable continuous membrane May be used with geotextiles	Low to moderate
Foam	Moderate	Reaction with pollutants Specialized applications Material handling constraints Relatively short life Some toxic decomposition products upon heating	Existing marketing towards HW site use Overnight vapor suppression May produce stable blankets Slow drainage rate May resist product pickup	High
Air-Supported Enclosures	Good to excellent	Cost may restrict use to smaller sites Potential greenhouse effect	Available nationwide for lease/purchase No chemicals introduced into system	High
Acid Gas Neutralization Additives	Not applicable			

(continued)

TABLE 6. (continued)

Technology	Effectiveness In Dust Control	Constraints In Use	Benefits of Use	Relative Capital Cost
In Situ Treatment	Not applicable			Moderate to high
Self-Supporting Encldsures	Good to excellent	Cost may restrict use to small sites Construction may disturb site Potential greenhouse effect	Effective containment of dust	High
Vacuum Trailers	Good	Requires control of airborne pollutant Limited to applicable materi- als (e.g., sludges, loose granular material)	Additional chemicals used	Moderate
Covers, Mats, and Membranes	Good to excellent when in place	Must be removed during active material handling Mat/liner failure Potential greenhouse effect	Ease of application Effective control in many situations	Moderate
Windscreens	Poor to moderate	Subject to wind direction Marginally effective on stockpiles		Low to moderate
Scheduling	Moderate	Dependent on weather conditions Rigorous timing constraints	Seasonal scheduling Least costly method Can be applied on con- tingency basis	Very low

TABLE 7. APPLICATIONS GUIDELINES - FUGITIVE VAPOR CONTROL TECHNOLOGY

Technology	Effectiveness In Vapor Control	Constraints In Use	Benefits of Use	Relative Capital Cost
Water	Low	Runoff Reaction with pollutants Costly repeat applications Time consuming		Low
Water Additives	Low	Reaction with pollutants Limited availability		Low
Inorganics	Low	Reaction with pollutants Effective only on relatively undisturbed soils		Low
Organics	Moderate to good	Reaction with pollutants Material handling constraints Application temperature dependent		Low to moderate
Foam	Moderate	Reaction with pollutants Specialized applications Material handling constraints Relatively short life Some toxic decomposition products upon heating	Existing marketing towards HW site use Overnight vapor suppression May produce stable blankets Slow drainage rate May resist product pickup	High
Air-Supported Enclosures	Good to excellent	Cost may restrict use to smaller sites Potential photochemical reactions	Available nationwide for lease/purchase No chemicals introduced into system	Moderate
Acid Gas Neutralization Additives	Moderate	Reaction with pollutants untested in this application	Demonstrated technology for some contaminants in drilling applications	Low to moderate
In Situ Treatment	Good	Effective on highly permeable soil Use on limited group of compounds Effectiveness dependent on soil character	Removes vapors before excavation May obviate need for excavation	Moderate to high

(continued)

TABLE 7. (continued)

Technology	Effectiveness In Vapor Control	Constraints In Use	Benefits of Use	Relative Capital Cost
Self-Supporting Enclosures	Excellent	Cost may restrict use to small sites Construction may disturb site Potential for photochemical reactions		High
Vacuum Trailers	Moderate	Requires control of airborne pollutant Limited to applicable materi-als (e.g., sludges, loose granular material) Additional chemicals used		Moderate
Covers, Mats, and Membranes	Poor to moderate	Must be removed during active material handling Mat/liner failure Potential for photochemical reaction	Ease of application Effective control in same situations	Moderate
Windscreens	Not applicable			Low to moderate
Scheduling	Moderate	Dependent on weather conditions Rigorous timing constraints	Seasonal scheduling Least costly method Can be applied on con-tingency basis	Very low

suppressing fugitive dusts and vapors, while windscreens are probably the least effective. Combinations of technologies might result in an overall effectiveness greater than the sum of the parts. For example, the use of water to suppress fugitive dust from a yellow cake (uranium) tailings pile in rural Wyoming prior to or during an excavation with windscreen protection might result in a total suppression effectiveness approaching that obtained with an enclosure for a fraction of the cost.

Faced with mitigating exposure to contaminants of moderate mobility and toxicity at moderate concentrations, the designer should approach the problem by utilizing readily implementable, conventional technologies (i.e., water, water additives, organics, inorganics, covers, and seasonal scheduling) in conjunction with site perimeter monitoring for contaminants of concern or representative indicator parameters. Other, more aggressive technologies can be specified as contingency measures if monitoring detects elevated concentrations during remedial activities (i.e., foams, windscreens, scheduling of excavation response to meteorological conditions).

If contaminants of concern are present at higher concentrations or have relatively high toxicity and mobility, a more rigorous projection of off-site impacts during remediation may be warranted. This may consist of a focused risk assessment, including dust/vapor generation and dispersion modeling in conjunction with the identification of appropriate short-term exposure risk action levels. The methodologies available for such risk assessments are available in the technical literature.

If the assessment indicates that significant off-site exposures could potentially result, more positive emission control technologies should be applied such as programmed use of windscreens and foams or enclosures.

Figure 7 illustrates an example of a decision tree that the designer can use as guidance to conceptualize the choice of an emissions supression technology once full knowledge of the contaminants, pathways, and receptors has been obtained. The technologies, grouped according to whether the emission is dust or vapor, tend towards more specialized considerations as one progresses down the tree. The final choice of a technology will be constrained by cost considerations, as demonstrated in Section 8.

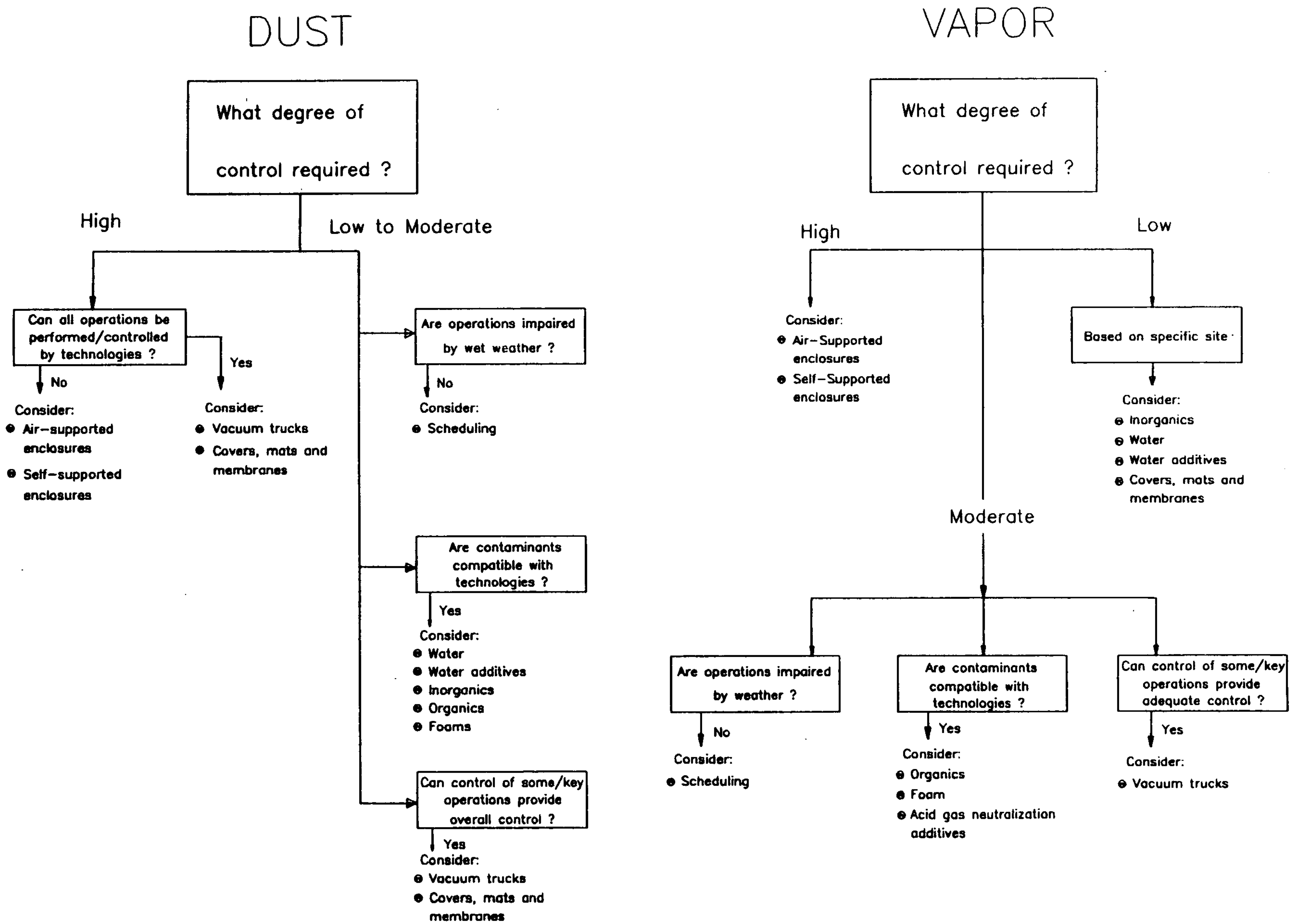

FIGURE 7 DUST/VAPOR DECISION TREE

SECTION 8

FINANCIAL CONSIDERATIONS

The designer should be aware that cost and technology effectiveness are not necessarily related because, independently, both are site specific. For example, water spray combined with mats may completely eliminate a dust problem for a fraction of the cost of a geodesic dome and filters, providing no volatiles are present.

The designer should evaluate the applicability and cost-effectiveness of different suppression technologies by ranking the applicable methods according to effectiveness until the most cost-effective subset can be found. Note that the costs given are vendor costs only. The designer must consider other logistical costs such as personnel protective equipment, decontamination costs, etc.

Some quantitative performance data are available in the literature. For example, Table 8, which is adapted from Rosbury (June 1985), summarizes the effectiveness of various topically applied formulations 15 and 30 days after application and supplies a comparison between cost of liner material and effectiveness.

Other attempts to quantify performance have not been so successful. For example, Shan (1984) reports no statistically significant difference at the 95 percent confidence level when comparing "no control" to "control" in cases that used water to control dusts from excavations performed by a backhoe, dump truck, and bulldozer combination that was similar to Rosbury's (June 1985).

TABLE 8. COST AND EFFECTIVENESS OF VARIOUS DUST SUPPRESSION FORMULATIONS ON A 50-foot x 50-foot EXPOSED TEST AREA[a]

Material Cost/Acre Dollars[b]	Type of Formulation	Application Concentration[c]	Application Rate	Effectiveness[d] @ 15 days	@ 30 days
1,642	Latex acrylic copolymer	3%	1.0 gal/yd^2	0	0
2,661	Carboxylated styrene-butadiene copolymer	20%	0.6 gal/yd^2	Not given	5%
5,481	Nonwoven geotextile	8 oz/yd^2	12-ft rolls	44%	0
70	Lignosulfonate	17%	0.5 gal/yd^2	8%	0
548	Vinyl acetate resin	10%	0.2 gal/yd^2	0	0
309	Synthetic resin	3%	0.3 gal/yd^2	0	0
1,009	Latex	7.2%	0.5 gal/yd^2	15%	0
959	Petroleum resin	25%	0.5 gal/yd^2	0	0
906	Straw mulch with emulsified asphalt	NA	NA	0	0
77	Vegetable gum	0.3%	1.4 gal/yd^2	36%	4%

[a] Adapted from Rosbury (June 1985).

[b] Material costs updated to August 1988 dollars by Chemical Week (CW) price service index of industrial chemical prices. Actual increases for specific chemicals may vary.

[c] Percent formulation in water.

[d] Percent effectiveness = $1 - \dfrac{\text{controlled ppm}}{\text{uncontrolled ppm}} \times 100$.

The relative costs of the 13 suppressant technologies identified here are presented in Tables 9 and 10, allowing semi-quantitative decisions to be made.

Some general introduction about estimating the costs of equipment and materials for dust and vapor suppression are found in Perry (1973), Means (1987), and Richardson (1988).

In the following discussion, it is assumed that the reader has knowledge at the levels presented in the above texts of cost estimating principles, cost adjustment principles for regional differences in labor and material rates, and some experience with Superfund site conditions. Experience is also required with techniques to correct labor estimates for the adverse effects of working with the personal protection equipment often required at Superfund sites.

The following tables can assist the knowledgeable cost estimator in preparing material and total cost estimates for the dust and vapor suppression technologies discussed here. Table 9 summarizes representative estimates for unit costs of products that were identified in the survey and are based on application guidelines and costs provided by vendors. Table 10 summarizes the results of the vendor cost survey. The material cost estimates are based on suggested dilution ratios and other vendor-supplied application guidelines.

Table 11 summarizes the cost information on most of the remaining technologies presented in Section 5 of this document. The costs of air-supported structures and self-supporting structures are for purchasing the structures. Leased structures may be available for lower cost, but will necessarily incur extensive decontamination procedures and costs. Purchased structures may be more amenable to available disposal

TABLE 9. REPRESENTATIVE SUMMARY OF DUST AND VAPOR SUPPRESSANT PRODUCTS

Product Type	Typical Material Cost ($/Acre)[A]	Form
Calcium Lignosulfonates	67	Organic Binder
Calcium Chloride	230	Inorganic Binder
Sodium Silicate	340	Inorganic Binder
Vinyl Acetate Resins	480	Water Additive
Acrylic Emulsions	840	Water Additive
Ammonium Lignosulfonates	620	Organic Binder
Asphalt Emulsion	1,180	Organic Binder
Soil Enzyme	1,400	In Situ Injectable
Wood Fibers with Plastic Netting	1,700	Covers, Mats, Membranes
Polyurethane-Polyurea Foam	8,400	Foam
Sodium Bentonite Clay	16,500	Covers, Mats, Membranes
Sodium Bentonite and Geotextile Fabric	26,100	Covers, Mats, Membranes

[A]Costs updated to August 1988 dollars by vendor information.

TABLE 10. DUST AND VAPOR SUPPRESSANT PRODUCT COST SUMMARY[a,b]

Manufacturer	Product (Type)	Material Cost ($/Acre) August 1988 Dollars	Dilution Ratio (Water/Material)	Gal/sq yd of Mixture	$/gal of Product
Flambeau Paper Co. P.O. Box 340 Park Falls, WI 54552	Flabinder (calcium lignosulfonate)	67	5.5	0.5	0.18
Woodchem, Inc. P.O. Box A Oconto Falls, WI 54154	Woodchem LS (ammonium ligno-sulfonates)	617	1	1.5	0.17
Georgia-Pacific Corp. P.O. Box 1236 Bellingham, WA 98227	Lignosite Road Binder (calcium ligno-sulfonate)	165	4	0.5	0.34
Soil Stabilization Products Co. P.O. Box 2779 Merced, CA 95344	Soil Seal (acrylic-latex copolymer emulsion)	838	30	0.6	8.95
	Western Sodium Bentonites (sodium bentonite clays)	16,350	N/A	N/A	N/A
	Claymax (sodium bentonite & geotextile fabrics)	26,136	N/A	N/A	N/A
	Excel Excelsior Erosion Control Blankets and Netting (aspen wood fibers and plastic netting)	1,742	N/A	N/A	N/A
	Bio CAT 300-1 (soil catalyst)	1,422	N/A	N/A	N/A

(continued)

TABLE 10. (Continued)

Manufacturer	Product (Type)	Material Cost ($/Acre) August 1988 Dollars	Dilution Ratio (Water/Material)	Gal/sq yd of Mixture	$/gal of Product
Johnson-March Corp. 555 City Line Ave. Bala Cynwyd, PA 19004	Compound SP-301 (acrylic emulsion)	2,783	1	0.25	4.60
Wen-Don Corp. P.O. Box 13905 Roanoke, VA 24034	Dustallay Plus DP-10 (organic surfactants & penetrants)	15	1500	0.5	9.05
DuBois Chemical Co. 3630 E. Kemper Rd. Sharronville, OH 45241	Retain (asphalt emulsion)	1,178	10	0.45	5.95
	D-Dust (surfactant)	2	1700	0.06	9.95
The Delta Co. 616 Gendview Drive Charleston, WV 25314	Genaqua Erosion Control Latex 743 (vinyl acetate resin)	484	10	0.2	5.50
	Lignosulfonate Binder 93 (vinyl acetate resin)	847	4	0.5	1.75
Midwest Industrial Supply, Inc. P.O. Box 8431 Canton, OH 44711	Soil-Sement (acrylic emulsion)	1,263	7	0.9	2.32
	Haul Road Dust Control (surfactant)	5	3000	0.75	4.25
Dow Chemical Larkin Laboratory Midland, MI 48640	LiquiDow Calcium Chloride (calcium chloride)	227[c]	1	0.47	0.20
	Dowflake PelaDow	—	—	—	—

(continued)

TABLE 10. (Continued)

Manufacturer	Product (Type)	Material Cost ($/Acre) August 1988 Dollars	Dilution Ratio (Water/Material)	Gal/sq yd of Mixture	$/gal of Product
Mona Industries, Inc. P.O. Box 425 76 E. 24th St. Patterson, NJ 07544	Monawet MO-70E (sodium dialkyl-sulfosuccinates)	—	—	—	6.37
The PQ Corporation P.O. Box 840 Valley Forge, PA 19482	Sodium Silicate (alkaline adhesive)	339	4	0.5	0.70
Environmental Security, Inc. 352 Abbeyville Rd. Lancaster, PA 17603	Phirex (surfactant foam)	—	33.3	—	24.95
National Foam 150 Gordon Dr. Leonville, PA 19353	Hazmat NF1 (special additive foams)	—	15.7	—	19.00
	Hazmat NF2 (special additive foams)	—	15.7	—	23.00
	Universal (synthetic foams)	—	15.7	—	14.75
3M Bldg. 223-6S-04 3M Center St. Paul, MN 55144	FX-9162 (temporary) (polyurethane-polyurea foam)	8,405[d]	15.7	1.50	19.30
	FX-9161 (stabilized) (polyurethane-polyurea foam)	12,630[d]	7.3	0.72	29.89

TABLE 10. (Continued)

Manufacturer	Product (Type)	Material Cost ($/Acre) August 1988 Dollars	Dilution Ratio (Water/Material)	Gal/sq yd of Mixture	$/gal of Product
Witco Corporation Golden Bear Division P.O. Box 456 Chandler, AZ 85244	Coherex (Petroleum Resin Emulsion)	535	9	0.5	2.20

N/A = Not Applicable
[a]Costs updated to August 1988 dollars by vendor information.
[b]Dilution ratio and application rate vary with site characteristics and degree of dust/vapor suppression required.
[c]Costs based on 1984 vendor information.
[d]Costs based on 1987 vendor information.

TABLE 11. ESTIMATED RELATIVE COSTS OF DUST AND VAPOR SUPPRESSANT TECHNOLOGIES

Suppression Technology	Unit Material Costs* $/sq yd	Total Cost** $/sq yd	Total Cost** $/cu yd
Liners and mats[a]			
Polyethylene sheeting, 6 mils	1.05-1.60	3.15-3.70	---
Tarpaulins	1.05-1.60	2.45-3.80	---
Plastic netting 2" x 1" mesh 20 mils	0.26-0.52	0.42-0.78	---
Mulch (wood chips) 2" deep	0.36-0.57	0.93-1.45	---
Polyvinylchloride sheets 20 mils	1.60-2.60	5.65-9.35	
Sealed air Bubble polyethylene Solar blanket	2.35-2.60	---	---
Liner hypalon (36 mil) Bracketed with heavyweight fabric	---	19.7-24.90	---
Air supported structures[a]			
Polyester/vinyl fabric 24 oz. 1,000-3,000 sq yd floor space	31.20-52	36.40-60.30	---
Self-supporting structures[a]			
Dual radius hemisphere wood framing, wood decking 100-150 yd diameter	140.10-207.50	166.10-249	

(continued)

TABLE 11. (continued)

Suppression Technology	Unit Material Costs* $/sq yd	Total Cost** $/sq yd	$/cu yd
Chemical suppressants[b]			
Dustproofing Silicate liquids/coat	0.18-0.36	0.83-1.61	---
Lime fixation into 5-inch cover soil	---	2.35-3.55	---
Asphalt membrane sprayed on	---	2.35-4.15	---
Soil cement stabilization	---	3.55-4.15	---
Polyurethane foam	---	---	11.74-14.10
In situ volatilization[c,d]			
500 cu yd soil to be treated	---	---	280-376
7,000 cu yd soil to be treated	---	---	64-72
80,700 cu yd soil to be treated	---	---	13-16

*Cost estimates based on Means (1987) and other published technical and vendor literature.

**Estimated total costs are for relative comparisons of suppression technologies; regional labor rates and other site-specific costs will affect total installed cost estimates.

[a]Cost estimates updated to August 1988 dollars by general Engineering News Record (ENR) materials and construction indexes. Actual specific increases may vary.

[b]Materials cost estimates updated to August 1988 dollars by general Chemical Week (CW) price service index of industrial chemical prices. Construction cost estimates updated to August 1988 dollars by general ENR construction indexes. Actual specific increases may vary.

[c]Cost estimates updated to August 1988 dollars by Chemical Engineering (CE) plant cost index and 5 percent inflation factor or development and operation costs. Actual specific increases may vary.

[d]Costs are dependent on depth as well as areal extent of contamination.

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procedures. The labor and equipment costs presented in this table reflect only initial installation costs and do not contain operation costs for moving structures as the excavation workface proceeds. The higher labor and equipment costs, incurred when work is being done in higher levels of personnel protective equipment, are not factored into the data presented in either table. Cost data should always be qualified according to the amount of relevant vendor or commercial experience in use of these technologies at comparable hazardous waste sites.

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APPENDIX A

VENDOR MAILING LIST

Computer-based literature databases, industrial telephone directories, and personal contacts were used to develop a mailing list of approximately 48 potential suppliers of dust and vapor suppressor chemicals.

Fourteen sources of commercially available formulations were identified in this manner. The names and addresses of these sources are provided in Table A-1, along with the type of formulation they can supply. This table should help the reader identify a commercial source of a given chemical type of dust and vapor suppression formulation.

The response to our mailing suggests a great deal of change is taking place in this market. Some companies appear to be in an early startup mode, while others are reluctant to offer their products for use at hazardous waste sites. We also observe the formulations that are derived from waste products will vary in price and availability, as the economic health of the process that produces the waste varies.

TABLE A-1. VAPOR/DUST SUPPRESSING FORMULATIONS

Manufacturer	Adhesives					Foams For:		
	Lignosulfonates	Acrylics	Bitumens	Inorganic Salts	Surfactants	Acids	Alkaline Materials	Neutral Materials
Flambeau Paper Company P.O. Box 340 Park Falls, WI 54552	X							
Woodchem, Inc. P.O. Box A Oconto Falls, WI 54145	X							
Georgia-Pacific Corporation P.O. Box 1236 Bellingham, WA 98227	X							
Johnson-March Corporation 555 City Line Avenue Bala Cynwyd, PA 19004		X						
Wen-Don Corporation P.O. Box 13905 Roanoke, VA 24034					X			
Dubois Chemical Company 3630 E. Kemper Road Sharonville, OH 45241			X		X			
Midwest Industrial Supply, Inc. P.O. Box 8431 Canton, OH 44711		X			X			
Dow Chemical Larkin Laboratory Midland, MI 48640				X				
Mona Industries, Inc. P.O. Box 425 76 E. 24th Street Paterson, NJ 07544					X			

(continued)

TABLE A-1
(continued)

Manufacturer	Adhesives: Lignosulfonates	Adhesives: Acrylics	Bitumens	Inorganic Salts	Surfactants	Foams For: Acids	Foams For: Alkaline Materials	Foams For: Neutral Materials
The PQ Corporation P.O. Box 840 Valley Forge, PA 19482				X				
Environmental Security, Inc. 352 Abbeyville Road Lancaster, PA 17603						X		X
National Foam 150 Gordon Drive Lionville, PA 19353						X	X	X
3M Industrial Chemical Products Division Building 223-68-04 3M Center St. Paul, MN 55144-1000						X		X

TECHNOLOGY VENDOR LIST

The following vendor equipment and product list of suppression technologies was prepared from vendor literature received during the course of the project. Additional equipment and material sources can be found by reviewing the telephone business yellow pages for the area in which a site exists. In addition the Thomas Register has listings for these vendors, and others may have identical or similar equipment and products which could achieve the same results. This list was prepared to enable the remedial designer to begin an initial vendor and product search.

In selecting equipment and products to be utilized, the purchaser should review each vendor items such as unit/costs, additional required equipment for application, transportation charges, delivery times, equipment maintenance requirements, product incompatibility, required operator experience and safety precautions and any other pertinent or special needs.

INORGANIC

Dow Chemical Larkin Laboratory Midland, MO 48640	LiquiDow Calcium Chloride Dowflake DelaDow
Mona Industries, Inc. P.O. Box 425 76 E. 24th Street Patterson, NJ 07544	Monawet MO-70E
The PQ Corporation P.O. Box 840 Valley Forge, PA 19482	Sodium Silicate

ORGANIC

Flambeau Paper Company P.O. Box 340 Park Falls, WI 54552	Flambinder
Woodchem, Inc. P.O. Box A Oconto Falls, WI 54154	Woodchem LS
Georgia-Pacific Corp. P.O. Box 1236 Bellingham, WA 98227	Lignosite Road Binder
DuBois Chemical 3630 E. Kember Road Sharronville, OH 45241	Retain
The Delta Company 616 Glendview Drive Charleston, WV 25314	Genaqua Erosion Control Latex 743 Lignin Soils Binder 93
Midwest Industrial Supply, Inc. P.O. Box 8431 Canton, OH 44711	Soil Sediment
Witco Corporation Golden Bear Division P.O. Box 456 Chandler, AZ 85244	Coherex

FOAM

National Foam 150 Gordon Drive Lionville, PA 19353	Hazmat NF1 Hazmat NF2 Universal
Environmental Security, Inc. 352 Abbeyville Road Lancaster, PA 17603	Phirex
3M Bldg. 223-65-04 3M Center St. Paul, MN 55144	FX-9162 FX-9161

Air Structures Air Tech International
30-32 Rockland Park Avenue
Tappan, NY 10983
1-800-AIR BLDG
(914)359-9007

Catenary Anchorage System
Field Junction Seam Joints

Aero Tec Laboratories, Inc. (ATL)
Department T
Spear Road Industrial Park
Ramsey, NJ 07446

SELF-SUPPORTING ENCLOSURES

Air Structures Air Tech International
30-32 Rockland Park Avenue
Tappan, New York 10983
1-800-AIR BLDG
(914)359-9007

Nomadic Structures, Inc.
7700 Southern Drive
Springfield, Virginia 22105
1-800-336-5019

TEMCOR
2827 Toldeo Street
Torrance, California 3039
1-800-421-2263

General Electric
3135 Easton Turnpike
Fairfield, Connecticut 06431
(203)373-2211

Spandome Corp.
180-T Morris Avenue
Mountain Lakes, New Jersey 07046
(201)335-5140

Spitz Space Systems, Inc.
P.O. Box 198, Department TR
Chadds Ford, Pennsylvania

VACUUM TRUCKS

Inventive Machine Corp. 104 Walter Street Bolivar, OH 44612 1-800-325-1074	Blast N'Vac
Guzzler Manufacturing, Inc. P.O. Box 66 Birmingham, AL 35201-0066 1-800-VAC-TRUK	The Guzzler MAC Aqua-Flow
Terravac Sales Company 1025-T E. Oak Street Stockton, CA 95205 (209)462-5394	Terravac
Peabody Myers Corp. 1621 S. Illinois Street Streator, IL 61364 1-800-672-3171	Vactor 2045 Vactor 1030
Central Engineering Co., Inc. 4427 W. State Street Milwaukee, WI 53208 (414)933-4567	VCR Series
Super Products P.O. Box 27225 Milwaukee, WI 53227 (414)784-7100	Octopus

COVERS, MATS, MEMBRANES

DuPont de Nemours
E.I., + Co., Inc.
1007-T Market Street
Wilmington, DE

Kimberly-Clark Corp.
Filter Fabrics Dept. CFM
1400 Holcomb Bridge Road
Roswell, GA 30776
(405)587-8088

Tex Tech Industries
Main Street
P.O. Box 8
North Monmouth, ME 04265
(207)933-4404

Crown Zellerbach
Nonwoven Fabrics Division
3720-T Grant Street
Washougal, WA

Soil Stabilization Products Co.
P.O. Box 2779
Merced, CA 95344

Western Sodium Bentonites
Enviromat
Bemnet
Biocat 300-1
Excel Excelsior Erosion
Control Blankets and
Netting

WINDSCREENS

Wind and Shade Screens, Inc.
1775-T-La Costa Meadows Drive
San Marcos, California

Armbruster Manufacturing Company
8601 Old Route 66 South
Springfield, Illinois 62707
(217)483-2463

Humphry's Textile Products Company
1243 Carpenter Street
Philadelphia, Pennsylvania 19147
(215)463-3000

Newark Wire and Cloth Company
365 Verona Avenue
Newark, New Jersey 07869
1-800-221-0392

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WATER

VENDOR	PRODUCT
Efficiency Production, Inc.	Porta-Tank Water Spray System
Peabody Myers Corp. 1617 S. Illinois Street Streator, IL 61364 815-672-3171	
Malsbary Cleaning Systems 9185 T LeSaint Drive Fairfield, OH 45014 1-800-437-7576	Model 400 HPC Model 2010 HPC Model 3510 HPC
Continental-Belton Inc. Box 600, Department 007 Belton, TX 76513 (817)939-3731 Ext. 007	CK-41-50E CK-31-50E

WATER ADDITIVES

Johnson-March Corp. 555 City Line Avenue Bala Cynwyd, PA 19004	Compound SP-301
Wen-Don Corp. P.O. Box 13905 Roanoke, VA 24034	Dustallay Plus DP-10
DuBois Chemical Company 3630 E. Kemper Road Sharronville, OH 45241	D-Dust
Soil Stabilization Products Company P.O. Box 2779 Merced, CA 95344	Soil Seal

APPENDIX B

ON-SCENE COORDINATOR AND SITE SURVEY CONTACTS

SITE NAME	OSC
American Cresote, Pensacola, FL	Ed Hatcher
Bog Creek Farm, NJ	Rich Schwartz
Bossard Site, Utica, NY	Jack Harmon
Bunker Hill Mine, Kellog, ID	Jeff Webb
Chem Waste Management, Vickery, OH	Jerry Lesser
City Chemical, Winter Park, FL	Diane Hazaga
Crystal Chemical Co, Houston, TX	Wally Coper
D'Imperio Property, NJ	Larry Lango
Dayton Walther, Porthsmouth, OH	Mary Logan
Del Noute Pesticide, Crescent City, CA	Brad Shipley
Denny Farms, McDowell, MO	Joyce Perdek
Diamond Alkali/Shamrock, Newark, NJ	John Joseph
Fairchild Republic Co., Hagerstown, MD	Bob Caron
GE Moreau	Mel Hauptman
Gallup Site, CT	
Gems Landfill, NJ	Sharma Certa
Goose Farm, Ocean Co. NJ	R. W. Chapin
Hollingsworth Solderless Terminal, FL	Ed Hatcher
Howe Chemical Inc., Minneapolis, MN	Chuck Slausstas
Iron Bound Area Sites, Newark, NJ	John Witkowski
Keete Envir Service, NH	Chet Janowski
Marty's GMC, Kingston, MA	
Newcome Bros Site, MS	McCardy
Ni-Chro Nicroplating, Louisville, KY	Jim Kopotich
Norco Battery, Riverside, CA	Bill Lewis
Nyanza Chemical Waste Dump, Ashland, MA	Frank Lilley
Old Bethpage Landfill, Bethpage, NY	Mel Hauptman
Plymouth Harbor/Cannon Eng, Plymouth, MA	Greg Roscoe
Rohm & Hass Landfill, Bristol, PA	Mary King
Salvesio, San Jose, CA	Mathew Monseis
Sol Lynn/Indust. Transformers, Houston TX	Ms. Ferust
Sprigelberg Landfill, Livingston Co, MI	Tom Thomas
Standard Steel, Anchorage, AK	John Sainbury
Sylvester, NH	Chet Japowski
Twin City Munitions Plant, MN	Auther Kleinrat
Unnamed, Cortland, NY	Jack Harman
Upjohn, Barceloneta, PR	Jose Font
Vertac, Jacksonville, AR	
Wide Beach Development, Lake Erie, NY	Robt. Cobiella

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