DUST AND VAPOR SUPPRESSION TECHNOLOGIES FOR USE DURING THE EXCAVATION OF CONTAMINATED SOILS, SLUDGES OR SEDIMENTS

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ABSTRACT

Currently available dust and vapor suppression technologies for use during the excavation of contaminated soil, sludges, and sediments were surveyed. Several types of commercially available suppression technologies were identified for utilization 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 guidelines and selected case studies are also discussed.

INTRODUCTION

As the number of Superfund sites undergoing remediation increase, there is a growing need for dust and vapor suppression measures at the job site during remediation activities such as soil loading, unloading, and transport prior to treatment or disposal of hazardous material. Although personnel protective equipment has been used successfully to mitigate adverse on-site exposure to dust and vapor, this measure cannot typically be extended to mitigate potential adverse off-site exposures.

Site remediation activities historically have included the excavation, loading, transportation, and unloading of hazardous materials, and the need for dust and vapor control technologies beyond conventional construction dust control measures has been recognized recently to be of growing importance. As a result, research, commercial development and application of new control technologies are in an early and active phase. This study was commissioned to provide a current update on the state-of-the-art and to provide the individual assigned to design the remedial program with current information on availability and application. As a logical outgrowth of the study, areas where further research is necessary to develop technologies and/or to provide objective and accurate performance data were also identified.

APPROACH

One of the first steps in conducting the study was to identify the types of materials, pollutants, unit operations, and environments that would confront the typical remedial program designers in their efforts to develop dust and vapor control plans for Superfund sites. A review of existing EPA Record of Decision (ROD) files for Superfund sites provided representative information. This served as a basis for characterizing future dust/vapor control requirements and also provided information on which technologies are currently in use.

In parallel with this effort, information on conventional and newly available technologies was obtained using computer assisted literature searches and personal contacts with U.S. EPA personnel, remediation contractors, consultants, and others working in the remediation design/implementation area.

In this paper, each technology is briefly discussed and summary information is provided on how these technologies may be appropriately applied. Two tables were developed summarizing cost data as well as providing brief assessments of applicability and performance. The project report provides additional detail on selection and performance as well as case histories where various dust and vapor suppression technologies have been applied. These case histories provided additional insight in visualizing how the individual suppression techniques can be effectively applied to control the emissions during an active excavation.

TECHNOLOGIES

Thirteen categories of commercially available dust and vapor suppression technologies were identified. These are briefly described as follows:

1. Water - The addition of water to soils and excavations needing 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. Repeat applications are necessary due to evaporative losses. The effectiveness of many of the other control techniques for dust is frequently related to that for water alone as a standard for reference because it is the most well-established dust control technology.

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 reduce the frequency of application and the attendant labor costs relative to waste alone. Adhesive type polymers such as latexes, acrylics, and the waste-derived lignosulfonates are typical examples of this class of dust suppressant. Numerous commercial formulations are available.

3. Inorganics - 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.

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 than water, and thus remain effective longer than water.

5. Foams - Vapor and dust suppression has been demonstrated by foams which are produced by air entraping water additives. This relatively new technology was originally developed for fire fighting and 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. Specialized nozzles or conventional fire fighting foam producing nozzles are used depending on the commercial formulation.

6. Air-Supported Structures - Commercially available air supported membranes have been applied to enclose areas undergoing excavation. The membrane provides a barrier which prevents uncontrolled release to the atmosphere. In conjunction with air lock entrances and exhaust stream dust and vapor pollution control equipment, these structures have the capability for relatively high effectiveness where site conditions permit their use.

7. Acid Gas Neutralization Additives - Drilling technologies adapted from the nature 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. While it has not been commercially applied to soil excavation, such solutions may be applied topically during excavation.

8. In Situ Treatment - Several technologies are available for in situ treatment of volatile organic compounds which could be applied to remove vapors prior to, or in lieu of, 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. These can provide a barrier to release of contaminants from the work area. 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 fined successful application during excavations. One reported application included a moving self-supported structure that advanced on rails along side 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 fluid enough to flow to the pickup nozzle. In these cases it can provide a more controlled alternative to excavation and loading. Similarly, paved roads can be swept clean and vacuumed to control dusts.

11. Covers, Mats, Membranes - Various systems are available for covering soil with physical barriers. These include thin (4-6 mil) plastic sheets, thicker (30-40 mil) covers, mats, geotextiles, and bulk materials such as straw, wood chips, and sludges. Some barriers are applied from rolls which are held in place and later removed during excavation. These are only effective for controlling the release of dust and vapors between active soil handling unit operations (i.e., inactive excavation, stockpiling, transport in truck, etc.). 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 - Agricultural engineering practices include the use of windscreens to reduce windshear over soils to control the amount of soil erosion. Similar methods can find use in controlling emissions from excavations and temporary waste storage piles. Design guidelines and effectiveness measurements are currently available in the literature.

13. Seasonal Scheduling - Planning excavations according to the seasons can reduce the overall potential for emissions by taking advantage of lower temperatures and wind speeds, and avoiding excessively dry weather. In addition, monitoring the emissions downwind during remediation activities can also be used to adjust daily work schedules and, if necessary, stop work or apply additional dust or vapor controls as meteorological conditions and observed emission levels vary.

APPLICATIONS

A survey of current practices where dust and vapor emissions were considered a potential problem was performed polling on-scene coordinators or other responsible persons who could relate the experience obtained at the sites of interest. The majority of the roughly 100 sites we surveyed either practiced no overt dust and vapor control or employed some form of natural dispersion to the atmosphere. Water spraying, daily or seasonal scheduling, and covers of various types were the technologies that were the most commonly used. Relatively few sites reported use of chemical additives to enhance water spraying or the enclosure of the remediation in a temporary building or structure. Specifically, 15 sites utilized water spray to control dust and 11 sites utilized covers, mats and membranes for dust or vapor suppression. Four sites utilized chemical suppressants to aid in vapor control. Four sites specifically utilized to control dust.

Additional quantitative performance and cost data are required to justify the use of temporary enclosures or chemical additives. Similarly, additional quantitative estimation of potential emissions based on site conditions may be needed at the planning stage. The survey highlighted the less-established control methods. Foams, for example, do not appear to have been used much in the control of dust and vapor to date.

1. Planning--The remedial program designer must first consider the site conditions, soil/sediment/waste characteristics, and planned remedial activities in order to quantify the potential for dust and vapor emission control problems. The following parameters should be considered when making this estimate:

    1) Distance to nearest residence or other receptors

    2) Relative volatility of the potential vapors

    3) Threshold Limit Value (TLV) or other relevant standards for contaminants of concern

    4) Odor threshold of the potential vapors

    5) Temperature, wind direction and speed, humidity, time of year, and other meteorological parameters prevail during the time of the planned excavation

    6) Particle size distribution and moisture content of the soils and sediments

    7) Square footage of area to be excavated and the planned depth of excavation

Generally, given contaminants of moderate mobility and toxicity at moderate concentrations, the designer 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. If during remedial activities monitoring should detect elevated concentrations of dust and vapor, other, more aggressive, techniques (i.e., foams, windscreens, scheduling in response to meteorological conditions) can be specified as contingency measures.

If contaminants of concern are present at higher concentrations (i.e., waste materials) or have relatively high toxicity and mobility, a more rigorous projection of off-site impacts during remediation may be warranted, if not already completed, in the site assessment or RI/FS work. 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 assessment are available in the technical literature.

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 which can exert positive control of emissions.

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

NYANZA CHEMICAL, ASHLAND, MASSACHUSETTS, is noteworthy for its use of in inflatable building. An area approximately 80' wide by 105' long was enclosed. The building was leased to save money after a vendor was found who would accept the decontamination procedures. However, unplanned expenses were incurred when it was found to be necessary to bring in a drilling subcontractor to set the anchors for the building even though the vendor has indicated manual installation of the anchors would suffice. Even so, the leased building was less expensive to install and use than comparably sized self-supporting structures. The inflatable building was leased at a rate of $14,000 for four months; a comparable self-supporting structure was estimated at a cost of $120,000. 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 3/4" to 1 1/4" above atmospheric pressure. 15,000 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 design carbon adsorption unit with a relatively low pressure drop overcome by a separate, dedicated 5-hp fan. Work inside the building was carried out in level B protective gear because of the carbon monoxide levels resulting from operating 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 weather and moisture from the soils to be excavated.

The main lesson in this case history is 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 1930's 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. A substantial amount of this remedial work was completed when hydrogen sulfide and other related acidic gases were encountered during the remediation work. Analytical results from test borings showed hydrogen sulfide emissions approaching 1,000 ppm by volume in the air.

Modified drilling methods were used to contain and actively vent the trapped acidic vapors to a carbon adsorption train. Ironite drilling mud was utilized to adsorb hydrogen sulfide. A special well head was fabricated to facilitate sampling of the well for water and the air headspace. The cost of the special well requirements were not broken out. The drilling subcontract cost of installing 10 shallow wells, 10 deep wells and 6 soil borings was approximately $150,000.00. In summary, previously stabilized sludge was used to form a cover over the remaining lagoon surfaces, specialized drilling mud and special well head construction were used to penetrate this cover while installing monitor wells which act as vent pipes, and carbon adsorption was used to clean the vented acidic gases.

TEST SITE, CINCINNATI, OHIO. Test work performed at a small farm near Cincinnati, Ohio, was analyzed in detail because of its effort to quantify the effectiveness of conventional dust control measures while using a front-end loader and a dump truck, two earth-moving devices that are commonly used at excavation sites.

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

A spray treatment with water and with water and a water extender achieved dust suppression efficiencies of 60 to 70 percent on particles less than 2.5 microns from the excavation itself. Water curtains and foam treatments at the dump truck loading station were less effective and suffered operational problems.

3. Application Guidelines--The applicability of each technology to vapor and dust control problems was evaluated in the study. The advantages, disadvantages, and constraints in applying each technology are summarized in Table 1. Several technologies, (including water additives, inorganics, organics, and foams) 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 which impact costs. The products identified in this study are listed in Table 2 along with a summary of the available information on final material costs in dollars per acre.

The costs of implementing other vapor suppression technologies were estimated based on material costs and a generic conceptual application to arrive at an installed cost on the basis of dollars per square yard of contaminated surface. These estimated costs were developed solely for comparative purposes. These 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, whether point source air pollution control devices may be necessary, as well as the site-specific cost factors such as regional labor rate differences and the impact of working with Health and Safety equipment.

CONCLUSIONS AND RECOMMENDATIONS

This study provides a broad review of currently available dust and vapor control technologies. The performance of the older conventional control methods for dust appears more firmly understood. However, the performance of the newer vapor suppression technologies such as in situ treatment and foam is much more uncertain at this time.

This uncertainty suggests additional research is needed to support a model allowing the quantification of emissions of different pollutants from different soils during various excavation processing steps with changing weather conditions.

Moreover, while existing atmospheric models and health related ambient air standards may be used to define the downwind concentrations resulting from these estimated emissions, additional research into quantifying the effectiveness of the proposed and newly developed control measures is needed.

Given the cost and time required that will be required to gain this experience, it will be necessary to mobilize and monitor the performance of dust and vapor suppression technologies in the field during removal actions or site remediations while monitoring their performance during use without knowing beforehand what the overall efficiency will be. The costs of collecting and monitoring suitable operational variables during work in the field should be included in the planning stages of the remediation.

In addition, another area of concern and one requiring additional research is the treatment and disposal of any dust and vapor suppressant residuals on a site. The limited data to date indicates the potential for environmental contamination, technology feedstock problems and the formation of additional toxic materials on-site.

TABLE 1. APPLICATIONS GUIDELINES FOR DUST AND VAPOR TECHNOLOGY

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 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 BAS Neutralization Additives	Yes	Yes	Reaction with pollutants untested in this application	Demonstrated technology for same contaminants in drilling applications.

TABLE 1. APPLICATIONS GUIDELINES FOR DUST AND VAPOR TECHNOLOGY (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 pollutant 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 condi-tions - rigorous timing constraints	Seasonal scheduling - least costly method. Can be applied on contin-gency basis.

TABLE 2. REPRESENTATIVE SUMMARY OF DUST AND VAPOR SUPPRESSANT PRODUCTS

Product Type	Typical Material Cost ($/Acre)	Form
Calcium Lignosulfates	60	Organic Binder
Calcium Chloride	230	Inorganic Binder
Sodium Silicate	340	Inorganic Binder
Vinyl Acetate Resins	480	Water Additive
Acrylic Emulsions	500	Water Additive
Ammonium Lignin Sulfates	620	Organic Binder
Asphalt Emulsion	1,100	Organic Binder
Soil Enzyme	1,400	In Situ Injectable
Wood Fibers with Plastic Netting	1,700	Covers, Mats, Membranes
Cellulose Fabric	2,200	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

TABLE 3. APPLICATIONS AND COST GUIDELINES FOR DUST AND VAPOR TECHNOLOGY

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