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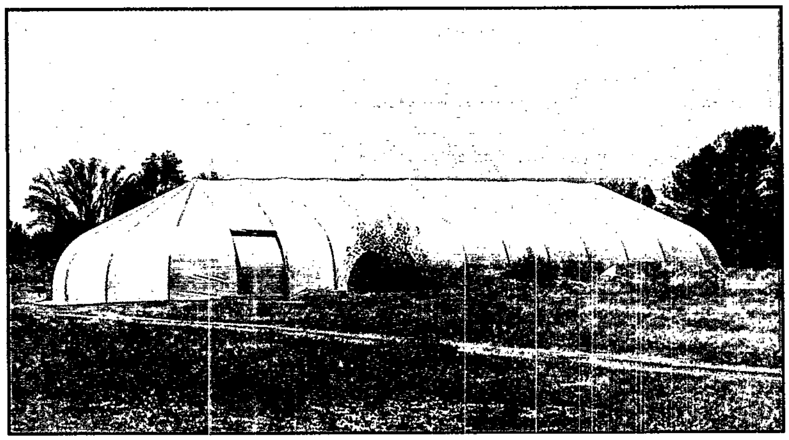
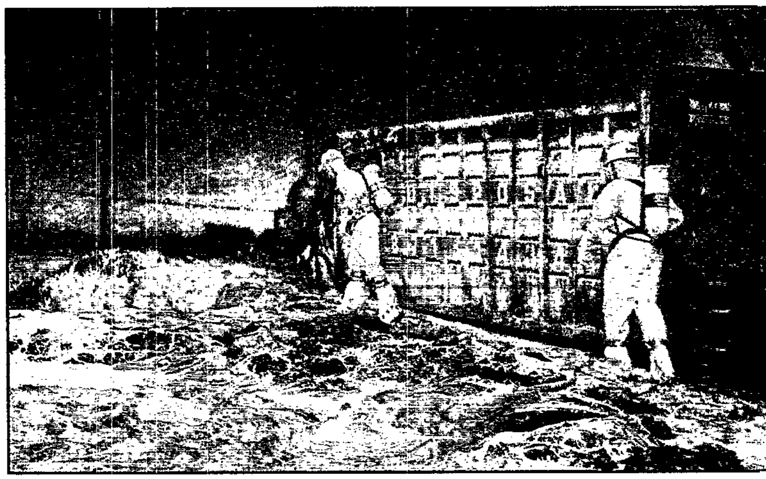
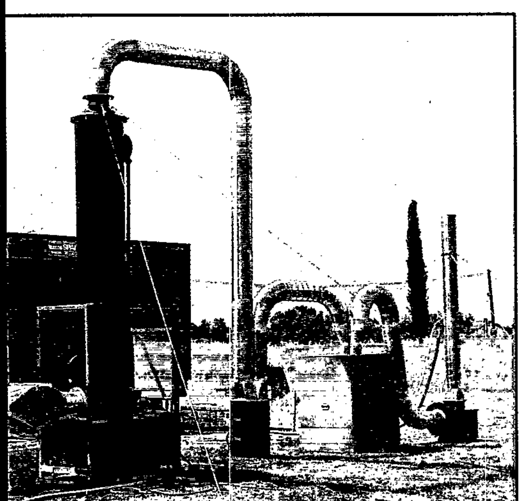
EPA

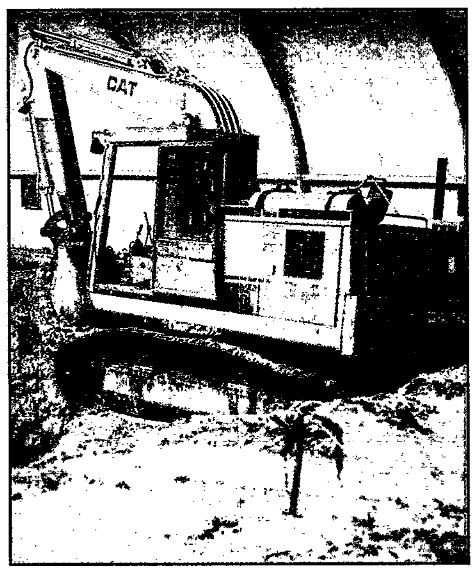
Demonstration of a Trial Excavation at the McColl Superfund Site

Applications Analysis Report









SITE

SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

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Demonstration of a Trial Excavation at the McColl Superfund Site

Applications Analysis Report

Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

Printed on Recycled Paper

Notice

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Foreword

The Superfund Innovative Technology Evaluation (SITE) program was authorized in the 1986 Superfund amendments. The program is a joint effort between EPA's Office of Research and Development and Office of Solid Waste and Emergency Response. The purpose of the program is to assist the development of hazardous waste treatment technologies necessary to implement new cleanup standards which require greater reliance on permanent remedies. This is accomplished through technology demonstrations which are designed to provide engineering and cost data on selected technologies.

This project describes the trial excavation performed at the McColl Hazardous Waste Site. Excavation at this site presents unique problems due to the high potential for release of sulfur dioxide and volatile odorous compounds contained in the waste. The excavation demonstration was used to obtain information on the utilization of an enclosure and associated air treatment systems around the excavation to minimize air emissions and the use of foam vapor suppressants to reduce emissions from the waste during excavation. In addition, information was obtained on processing the tar fraction of this waste by mixing it with cement and fly ash. The demonstration is documented in two reports: 1) a Technology Evaluation Report describing the field activities and laboratory results; and 2) this Applications Analysis Report, which interprets the data and discusses the potential applicability of the technology.

A limited number of copies of this report will be available at no charge from EPA's Center for Environmental Research Information, 26 Martin Luther King Drive, Cincinnati, Ohio 45268. Requests should include the EPA document number found on the report's cover. When the limited supply is exhausted, additional copies can be purchased from the National Technical Information Service, Springfield, VA 22161, (703) 487-4650. Reference copies will be available at EPA libraries in the Hazardous Waste Collection.

E. Timothy Oppelt, Director

Risk Reduction Engineering Laboratory

Abstract

In June 1990, the U.S. Environmental Protection Agency's Region IX Superfund Program, in cooperation with EPA's Air and Energy Engineering Research Laboratory (AEERL), and EPA's Superfund Innovative Technology Evaluation (SITE) Program performed a trial excavation of approximately 137 cubic yards of waste at the McColl Superfund Site in Fullerton, California. The purpose of this work was threefold: 1) to determine if the waste could be excavated by use of conventional equipment, 2) to decide if any treatment was necessary to improve the waste's handling characteristics, and 3) to determine the magnitude of air emissions that could result from excavation efforts. This information will be useful in the planning of a full-scale remediation of the highly acidic petroleum refinery waste buried at the site. The trial excavation was conducted within a temporary enclosure from which air was exhausted through a sodium-hydroxide-based wet scrubber and activated-carbon-bed adsorber to reduce air emissions of sulfur dioxide and volatile organic compounds. Vapor-suppressing foam was used in an attempt to suppress atmospheric releases from the raw waste during excavation, storage, and processing. The air exhaust was monitored for total hydrocarbons and sulfur dioxide before and after the air emission control system. In addition, total hydrocarbons and sulfur dioxide were monitored along the site perimeter to determine the potential impact of air emissions on the nearby community.

The McColl waste consists of mud, tar, and char. Excavation was conducted with a trackhoe, and the waste was separated into stockpiles of mud, tar, and char for subsequent study and experimentation. Upon completion of the work, the majority of the waste was placed back into the excavation pit and covered with topsoil. Excess waste materials was stockpiled on-site in a controlled manner.

This Application Analysis Report presents an evaluation of the equipment used to control emissions and to measure the resulting emissions before and after the air control system. An assessment of the foam vapor suppressants and information on the full-scale remediation costs of the technology are also provided. The information contained in this report will assist in planning the full-scale remediation of the McColl site and other similar waste sites throughout the country.

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Abbreviations and Symbols

AA	Atomic Absorption
acfm	Actual cubic feet per minute
AEERL	Air and Energy Engineering Research Laboratory
APCD	Air pollution control device
ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
BDAT	Best demonstrated available technology
BNA	Base neutral/acid (extractable)
CAM-WET	California Wet Extraction Test for Metals
CCR	California Code of Regulations
CEM	Continuous Emission Monitor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cm/s	Centimeters per second
cfm	Cubic feet per minute
ft^3	Cubic feet
yd^3	Cubic yards
DAS	Data acquisition system
DHS	California Department of Health Services
DSA	Drum storage area
EPA	U.S. Environmental Protection Agency
EP Tox	Extraction Procedure Toxicity Test–leach test
FID	Flame ionization detector
ft/s	Feet per second
g/ml	Grams per milliliter
GC/MS	Gas chromatograph/mass spectrometer
h	Hour
hp	Horsepower
HSWA	Hazardous and Solid Waste Amendments to RCRA--1984
ICP	Inductively coupled plasma
IDLH	Immediately Dangerous to Life and Health
kW	Kilowatt(s)
LDRs	Land disposal restrictions
lb/min	Pounds per minute
MACT	Maximum achievable control technology
m/s	Meters per second
MDL	Method detection limit
mg/kg	Milligrams per kilogram
mg/m^2 - min	Milligrams per square meter per minute
mg/l	Milligrams per liter
ml/g	Milliliters per gram
NAAQS	National Ambient Air Quality Standards
NCP	National Contingency Plan
NIOSH	National Institute for Occupational Safety and Health
NPL	National Priorities List
ORD	Office of Research and Development
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
PAHs	Polycyclic aromatic hydrocarbons
Pb	Lead
PCBs	Polychlorinated biphenyls
PEL	Permissible Exposure Limit
PID	Photoionization detector
ppb	Parts per billion
PPE	Personal protection equipment
ppm	Parts per million
psi	Pounds per square inch
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act of 1976
RFP	Request for proposal
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPD	Relative Percent Difference
RREL	Risk Reduction Engineering Laboratory
SARA	Superfund Amendments and Reauthorization Act of 1986
SITE	Superfund Innovative Technology Evaluation Program
SO_2	Sulfur dioxide
SROA	Supplemental Reevaluation of Alternatives
TCLP	Toxicity Characteristic Leaching Procedure
TECP	Totally encapsulating chemical suit
THC	Total hydrocarbons
TNMHC	Total nonmethane hydrocarbons
TOC	Total organic carbon
TSCA	Toxic Substances Control Act of 1985
TSP	Total suspended particles
µm	Micrometer
µg/l	Micrograms per liter
$\mu g/m^3$	Micrograms per cubic meter
VOC	Volatile organic compound

Acknowledgements

This report was prepared under joint direction and coordination of Jack Hubbard, Superfund Innovative Technology Evaluation (SITE) Project Manager, U.S. Environmental Protection Agency (EPA), Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, Ohio and Pam Wieman, McColl Project Manager, United States Environmental Protection Agency, Region IX, Hazardous Waste Management Division, Superfund Program. Contributors to and reviewers of this report included John Blevins, EPA-Region IX, Gordon Evans of EPA's SITE Program and Richard Gerstle of IT Corporation, Cincinnati, Ohio. Authors were Majid Dosani of IT Corporation in Cincinnati and Edward Aul of Edward Aul and Associates, Inc., Chapel Hill, North Carolina.

Section 1
Executive Summary

Introduction

Region IX of the U.S. Environmental Protection Agency (EPA), in cooperation with EPA's Air and Energy Engineering Research Laboratory (AEERL) and EPA's Superfund Innovative Technology Evaluation (SITE) Program, and with assistance from the California Department of Health Services (DHS), conducted a trial waste excavation project at the McColl Superfund site in Fullerton, California.

In the early to mid-1940s, the McColl site was used for disposal of acidic refinery sludge, and in 1982, it was placed on the National Priorities List (NPL). The McColl waste is known to release volatile organic compounds (VOCs) and sulfur dioxide (SO_2) whenever disturbed. Since 1984, the entire site has been covered with soil in an attempt to minimize atmospheric emissions of VOCs and SO_2.

In February 1989, EPA and DHS issued a proposed plan for the McColl project that named thermal destruction, either on or off site, as the preferred remedy. Important components of this remedy are the excavation and waste-handling activities that must occur as a precursor to thermal destruction or any other remedy that would involve ex-situ treatment of the waste. Region IX determined that the trial excavation was necessary to ascertain if the McColl waste could be excavated with conventional equipment without releasing significant amounts of VOCs and SO_2 into the surrounding community. The trial excavation was also necessary to define the treatment needed, if any, to improve the handling characteristics of the waste as a precursor to thermal destruction. A summary of the SITE demonstration at the McColl site is presented in Appendix B.

Objectives

The objectives of the trial excavation at the McColl Superfund site were as follows:

1. To excavate approximately 100 yards of waste to assess waste-handling characteristics and to determine if any treatment is required to improve handling characteristics as a precursor to thermal destruction.
2. To determine the atmospheric emissions resulting from the excavation activities.
3. To assess the degree of SO_2 and total hydrocarbons (THC) emissions control achieved through the use of an enclosure and an enclosure exhaust treatment system.
4. To determine the emission levels for SO_2 and VOCs at the fenceline of the McColl site as an indicator of impacts on the local community.
5. To assess the effectiveness of vapor-suppressing foam.
6. To assess potential problems that might occur during excavation.

Conclusions

Based on the goal and objectives of the project, EPA believes that the trial excavation was successful and that significant information was obtained that will be useful in the design phase of the full-scale remediation. The conclusions reached were as follows:

- Excavation under an enclosure is technically feasible.
- Excavation and waste-handling activities are not feasible without an enclosure equipped with an exhaust treatment system.
- Existing technologies can be used to treat SO_2 and THC emissions generated by excavation activities.
- Waste material was successfully treated to improve its handling characteristics so it could be easily processed into a thermal destruction unit if desired.
- Workers were able to perform excavation and treatment of the waste material at McColl while wearing Level B or Level A personal protective equipment (PPE) within the enclosure.

- The trial excavation had no significant adverse impacts on the surrounding community.
- The vapor-suppressing foam did not perform as well as expected in controlling SO_2 and THC emissions within the enclosure and therefore cannot be relied upon exclusively to control emissions during activity-related disturbances of waste.

Design of Air Emission Control Technologies

System designs prepared for full remediation of the 12 sumps at the McColl Superfund Site call for the use of the excavation and fugitive emission control systems evaluated during the McColl trial excavation. The general workflow for the scenario evaluated calls for waste to be excavated from one sump under an enclosure (with dimensions of 120 ft wide by 300 ft long by 60 ft high) and loaded into rolloff bins for transport by truck to the storage facility. Backfill operations take place simultaneously at a second sump under a second enclosure. At the same time, a third enclosure is erected on the next sump to be excavated. In this manner, excavation and backfill operations proceed continuously to provide feed material to the final treatment system. Storage operations take place under a fourth enclosure (with dimensions of 120 ft wide by 240 ft long by 57 ft high).

The use of an enclosure for excavation and backfill operations requires that the larger sumps be excavated in two or more steps, which results in re-excavation of a portion of these sumps. Overall, approximately 25% more material must be excavated when the enclosure is used than would be required without the enclosure. Assuming the final treatment operations process a nominal 100 tons/day of contaminated material plus additives, the time required to excavate the entire volume of material at the McColl site is estimated to be approximately 6.4 yrs, based on 300 operating days/yr. Evaluation of waste-specific excavation rates indicates that excavation operations are not the rate-limiting step under this treatment scenario. Under the requirement that workers inside the enclosures operate in Level B PPE, calculations indicate that excavation operations could produce an average of about 160 tons/day of contaminated material over an 8-hr operating period and about 235 tons/day over a 12-hr period.

For waste excavation at the McColl site, SO_2 will be the primary contaminant of concern and the basis for the air ventilation system design. A system has been designed to maintain SO_2 exposure for Level B-equipped workers at or below 50 ppm. This SO_2 level was selected as a reasonable compromise between the Immediately Dangerous to Life and Health (IDLH) level of 100 ppm and the Permissible Exposure Limit (PEL) level of 2 ppm. This level was selected by EPA for conceptual design purposes only. It is recognized that the actual acceptable level of emissions within the enclosure will be dictated by OSHA regulations and any applicable or relevant appropriate requirements (ARARs). The 50-ppm concentration limit, together with projections for "upper reasonable" SO_2 emission flux rates and extent of waste surface areas exposed, result in the specification of a 130,000 acfm ventilation airflow rate for the excavation enclosure; 27,000 acfm for the backfill enclosure; and 32,000 acfm for the storage enclosure.

Air pollution control devices (APCDs) have been designed to remove contaminants from the ventilation air before this air is released to the atmosphere. Each APCD train consists of a 35,000-acfm wet scrubber for SO_2 and particulate matter (PM) emissions control, three 12,000 acfm modular GAC units operating in parallel for THC/organics emissions control, and associated fan, blower, and ducting systems. For full-scale remediation, the air delivery system will be arranged to provide a continuous flow of fresh air past workers in high-emission areas. In addition, the exhaust system will be designed to capture emissions close to their sources to minimize the amount of contaminants that escape into the general enclosure volume. This approach will require that flexible, movable exhaust and air-supply ducting be extended from the enclosure walls to areas within the enclosures. In addition, the ducting should be fitted with hoods to maximize emissions capture. Based on the air ventilation requirements and the APCD size limitation, four APCD trains will be required for the excavation enclosure and one APCD train each will be required for the backfill and storage enclosures.

Economic Analysis

The cost for full excavation of all contaminated material at the McColl site with the systems described in the preceding paragraphs was estimated to be $69.2 million, which translates to a cost of $593/ton of in-place waste. This cost assumes that equipment is purchased at the start of remediation; the estimated cost to lease equipment over the 6.4-yr remediation period would be approximately 7% higher. The break-even time period between the purchase equipment option and the lease equipment option is about 3 yrs. These estimated costs include waste excavation, waste storage, and fugitive emissions controls; however, they do not include the final waste treatment and disposal systems or pretreatment systems.

The largest components of the estimated costs are labor (22%), supplies/consumables (21%), equipment (12%), and utilities (11%). Most of the cost items are directly influenced by the amount of time required for remediation. These cost estimates reflect a 6.4-yr remediation period, based on a final treatment processing rate of 100 tons/day. Excavation rate calculations indicate that excavation operations are not the rate-limiting step under this scenario and that remediation activities could be accomplished in less time, which would reduce overall costs.

Specification of the SO_2 limit within the enclosure dictates the size, and hence the cost, of the air ventilation system and APCD equipment. For the design examined, the marginal costs for fugitive emission control are slightly more than twice the costs for excavation without such control.

Section 2
Introduction

This section presents information about the Superfund Innovative Technology Evaluation (SITE) Program, discusses the purpose of this Application Analysis Report, and provides a list of key personnel who may be contacted for additional information.

Purpose, History, and Goals of the SITE Program

In response to the Superfund Amendments and Reauthorization Act of 1986 (SARA), the EPA's Office of Solid Waste and Emergency Response (OSWER) and Office of Research and Development (ORD) established a formal program called the SITE Program to promote the development and use of innovative technologies to clean up Superfund sites across the country. The primary purpose of the SITE Program is to enhance the development and demonstration of innovative technologies applicable to Superfund sites so as to establish their commercial availability.

The SITE Program comprises four major elements:

- Demonstration Program
- Emerging Technologies Program
- Measurement and Monitoring Technologies Program
- Technology Transfer Program

The objective of the SITE Demonstration Program is to develop reliable engineering performance and cost data on selected technologies so that potential users can evaluate each technology's applicability to a specific site compared with the applicability of other alternatives. Demonstration data are used to assess the performance and reliability of the technology, the potential operating problems, and approximate capital and operating costs.

Technologies are selected for the SITE Demonstration Program through annual requests for proposal (RFPs). Proposals are reviewed by EPA to determine the technologies with the most promise for use at Superfund sites. To qualify for the program, a new technology must have been developed to pilot or full scale and must offer some advantage over existing technologies. Mobile technologies are of particular interest.

Once EPA has accepted a proposal, the Agency and the developer work with the EPA Regional Offices and State agencies to identify a site containing wastes suitable for testing the capabilities of the technology. The developer is responsible for demonstrating the technology at the selected site, and is expected to pay the costs to transport, operate, and remove the equipment. The EPA is responsible for project planning, sampling and analysis, quality assurance and quality control, preparing reports, and disseminating information.

The Emerging Technology Program of the SITE Program fosters further investigation and development of treatment technologies that are still at the laboratory scale. The third component of the SITE Program, the Measurement and Monitoring Technologies Program, provides assistance in the development and demonstration of innovative measurement and monitoring technologies.

In the Technology Transfer Program, technical information on technologies is exchanged through various activities that support the SITE Program. Data from the Demonstration Program and existing hazardous waste remediation data are disseminated in an effort to increase awareness of alternative technologies available for use at Superfund Sites.

SITE Program Reports

The results of each SITE demonstration are incorporated in two documents: the Technology Evaluation Report and the Applications Analysis Report. The Technology Evaluation Report provides a comprehensive description of the demonstration and its results. This report is intended for engineers performing a detailed evaluation of the technology for a specific site and waste situation. The purpose of these technical evaluations is to obtain a detailed understanding of the performance of the technology during the demonstration and to ascertain the advantages, risks, and costs of the technology for the given application. This information is used to produce conceptual designs in sufficient detail to enable the preparation of preliminary costs estimates for the demonstrated technology.

The purpose of the Applications Analysis Report is to estimate the Superfund applications and costs of a technology based on all available data. The report compiles and summadesign and test data, and other laboratory and field applications of the technology. It discusses the advantages, disadvantages, and limitations of the technology. Estimated costs of the technology for different applications are based on available data on pilot- and full-scale applications. The report discusses the factors, such as site and waste characteristics, that have a major impact on costs and performance.

The amount of available data for the evaluation of an innovative technology varies widely. Data may be limited to laboratory tests on synthetic wastes or may include performance data on actual wastes treated at the pilot or full scale. The conclusions regarding Superfund applications that can be drawn from a single field demonstration are also limited. A successful field demonstration does not necessarily ensure that a technology will be widely applicable or fully developed to the commercial scale. The Applications Analysis attempts to synthesize whatever information is available and draw reasonable conclusions. This document will be very useful to those considering the technology for Superfund cleanups, and it represents a critical step in the development and commercialization of the treatment technology.

Key Contacts

Additional information on the demonstration of trial excavation at the McColl Site or the SITE Program can be obtained from the following sources:

McColl Site Demonstration

Richard Gerstle, P.E.
IT Project Manager
IT Corporation
11499 Chester Road
Cincinnati, OH 45246
(513) 782-4700

Edward F. Aul, Jr., P.E.
Vice President
Edward Aul & Associates, Inc.
115 Cedar Hills Drive
Chapel Hill, NC 27514
(919) 942-4411

The SITE Program

Jack Hubbard
SITE Project Manager, McColl Site Demonstration
U.S. Environmental Protection Agency
Office of Research and Development
Risk Reduction Engineering Laboratory
26 West Martin Luther King Drive
Cincinnati, OH 45268
(513) 569-7507

Region IX

Pam Weiman
McColl Project Manager
U.S. Environmental Protection Agency
Southern California Section
Superfund Remedial Branch
Hazardous Waste Management Division
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-2242

John Blevins
Section Chief
U.S. Environmental Protection Agency
Southern California Section
Superfund Remedial Branch
Hazardous Waste Management Division
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-2241

Section 3
Technology Applications Analysis

This section addresses the applicability of the waste excavation/processing and emission control technologies to remediate various sites contaminated with wastes similar to those of the McColl Superfund Site in Fullerton, California. The evaluation of the technology's effectiveness and its applicability to other potential cleanup operations is based primarily on the results of the SITE demonstration, which are presented in the Technology Evaluation Report (EPA 1990). The data generated during this SITE demonstration will be used to aid in the design of an effective air emission control system to potentially be used during the full-scale remediation of McColl and other similar Superfund sites.

Technology Description

Excavation at the McColl site presented unique problems because of the high potential for the release of sulfur dioxide and volatile odorous compounds contained in the waste. As a means of avoiding the potential impact of air emissions on the nearby community, the following measures were implemented during trial excavation:

- Use of an enclosure operated under negative pressure
- Use of vapor-suppressing foam
- Operation of an SO_2 scrubber
- Operation of an activated-carbon-bed adsorber

The trial excavation was conducted within a temporary enclosure from which air was exhausted through a sodium-hydroxide-based wet scrubber and an activated-carbon-bed adsorber to reduce air emissions of sulfur dioxide and organic compounds. Foam was used in an attempt to suppress atmospheric releases from the raw waste during excavation, storage, and processing. The air exhaust was monitored for total hydrocarbons (THC) and sulfur dioxide (SO_2) before and after the air emission control system. The air was also monitored for THC and SO_2 along the site perimeter to determine the potential impact of air emissions on the nearby community. A detailed description of the technology is presented in Appendix A.

Conclusions Reached During SITE Demonstration at the McColl Site

The overall goal of the trial excavation at the McColl site was to obtain information on excavation and waste-handling activities to support the selection of thermal destruction or any other remedy that would involve excavation activities as a portion of the preferred remedial action and to aid in the design of this remedy after its selection in a Record of Decision (ROD). Of particular interest was whether the McColl waste could be excavated with conventional equipment without having significant adverse impacts on the surrounding community.

Based on the goal and objectives of the project, EPA believes that the trial excavation was successful and that significant information was obtained that will be useful in the design phase of the McColl remediation process. The results of the trial excavation, which are discussed in the Technology Evaluation Report (EPA 1990), are summarized in Appendix B. Conclusions and observations pertaining to the trial excavation are presented below:

- More than 130 solid yd^3 of waste material from Sump L-4 was excavated with conventional excavation equipment without significant adverse impacts on the community.

- Excavation under an enclosure is technically feasible.

  The enclosure used during the trial excavation was successfully operated at or near negative pressure, which allowed for emissions generated during the excavation activities to be processed through an enclosure exhaust treatment system consisting of a sodium-hydroxide wet scrubber and an activated-carbon-bed adsorber.

  Although unexpected problems during the trial excavation impeded the ability to excavate under the enclosure, EPA believes that these problems can be resolved by engineering practices during the design of the final remediation. The most important impediment to the trial excavation was the higher-than-expected THC and SO_2 emissions within the enclosure. These higher-than-expected emissions necessitated upgrading the personal protective equipment for the workers within the enclosure from Level B to Level A protection (completely enclosed chemical-resistant suit with supplied air).

- The SO_2 emissions generated during the excavation activities can be effectively treated (up to 99% removal efficiency) with existing technologies. The high SO_2 emissions entering the sodium-hydroxide wet scrubber were efficiently treated to less than 1 ppm throughout the trial excavation. The removal efficiencies were greater than 95% during most of the trial excavation and actually reached as high as 99%.

- The THC emissions generated during the excavation activities can be effectively treated (up to 90.7% removal efficiency) with existing technologies. Although the THC emissions were not controlled as effectively as expected (greater than 90%) with activated carbon, the removal efficiency ranged from 40 to 90.7% throughout the trial excavation. The EPA believes that the less-than-expected removal efficiencies can be corrected during the design phase of the final remediation. Based on other experiences with activated carbon, this is considered an appropriate technology for removal of organics.

- The waste material was successfully treated to improve its handling characteristics so it could be easily processed into a thermal destruction unit if desired.

- Lower airflow rates through the activated carbon unit increased the THC removal efficiencies. This result supports the theory that residence time is a critical factor in the ability of activated carbon to remove organic compounds in an airstream.

- The vapor-suppressing foam did not perform as anticipated in controlling SO_2 and THC emissions within the enclosure, and its use cannot be relied upon exclusively to control emissions during activity-related waste disturbances.

  Visual observations and dynamic-condition calculations indicate that the vapor-suppressing foam was not as efficient as expected in controlling emissions from activities related to excavating and processing the waste.

  Visual observations indicated that the foam chemically reacted with the McColl waste, which inhibited its ability to form a vapor-suppressing seal on the waste. This reaction caused the foam to change color (from yellow to red and orange) and to disintegrate before forming a seal on the waste.

  Dynamic-condition calculations indicated that the effectiveness of the vapor-suppressing foam ranges from 50 to 80%, depending on the activity and the compound of concern.

  Excess water introduced into the enclosure through the foaming activities had a significant impact on operations within the enclosure. The excess water made the ground surface slippery for both workers and equipment.

- The trial excavation had no significant adverse impacts (i.e., exceedance of health-based levels established in the McColl Contingency Plan) on the surrounding community.

  Based on observations by personnel during the trial excavation, the noise level related to the excavation and treatment activities was minimal. At no time during the trial excavation were the health-based levels (established in the McColl contingency plan for SO_2 and THC) exceeded at the fence-line monitoring stations. Although a small number of odor complaints were received during the trial excavation period, they were not excessive. Most of the complaints were received after the trial excavation/treatment activities were completed for the day, and may not have been related to the excavation/treatment activities.

Applicability of Air Emission Control Technologies

Many Superfund sites in the United States have problems similar to those at the McColl site–i.e., the generation of toxic air emissions during waste excavation and transportation that may affect both site workers and residents of adjacent communities. Appendix C presents a list of current CERCLA sites where the emission control technologies used at McColl site may be applicable. This section discusses the general applicability and performance of air emission control technologies, which were used during the trial excavation at the McColl site.

Wet Scrubber

A wet scrubber system is based on the principle of mass transfer (called diffusion) in which the gaseous effluent stream containing the contaminant to be removed is brought into contact with a liquid in which the contaminant will dissolve. The concentration gradient between the two phases is established and diffusion occurs. The mass transfer rate at which absorption occurs depends on the amount of liquid surface exposed. It is a function of the liquid recirculation rate, the packing size and shape, and distribution of the liquid over the packing support plates.

Packed scrubbers are designed with either crossflow or countercurrent flow. In the crossflow packed scrubber, the airstream moves horizontally through the packed bed and is irrigated by scrubbing liquor flowing vertically downward through the packing. This scrubber is efficient in removing noxious gases, entrained liquid particles, and dusts. The gas stream in the countercurrent-flow packed scrubber moves upward in direct opposition to the scrubbing liquid stream, which moves downward through the packing.

Countercurrent flow is advantageous in that the gas stream with higher concentrations of contaminants contacts the spent liquor at the inlet of the packing, and the fresh liquor coming in at the outlet of the packing contacts with the least contaminated gas. This process drives the gaseous contaminant into the scrubbing liquid. When absorption is accompanied by chemical reaction, this advantage no longer exists because the gas phase equilibrium becomes zero.

A large interfacial area is required for the liquid to absorb gas contaminants effectively. Providing a packing medium over which the liquid is spread allows a greater area of contact to be achieved. Not only is a large area required, but continued liquid surface renewal is essential for efficient absorption. These characteristics are provided by commercially available packings.

An important feature of the scrubber unit is the design of the recirculation tank. Acting as a basin, this tank catches the effluent from the scrubber and provides additional time for the reactions to occur. The rate of recirculation is based on the chemical kinetics or treatment time required for each of the gas contaminants to react with the provided reagents in their respective stoichiometric quantities.

Reagent usage and concentrations are based on the contaminants in the effluent gas. The gas contaminant treatment time or residence time must be considered to determine adequate column capacity and the optimal liquid-to-gas flow ratio.

One of the advantages of an absorption system is a removal efficiency in excess of 99%. This not only results in low emission rates, but also allows recovery of the material for reuse in the process. Wet scrubbers have relatively small space requirements and are low in capital cost and energy consumption. The reagent-handling system, however, can substantially increase the maintenance cost of the system. There are also some disadvantages. For example, particulate matter in the gas stream may cause fouling and pluggage of the packing, and the blowdown stream must be treated and disposed of in an environmentally acceptable manner.

Wet Scrubber Performance During Trial Excavation at McColl Site

During the trial excavation, a countercurrent-flow, packed-bed, wet scrubber that used a mixture of sodium hydroxide (NaOH) in water was used to control SO_2 emissions. This scrubber was designed to achieve an outlet SO_2 concentration of 2 ppm on a continuous basis, assuming that the average inlet SO_2 concentration would be about 10 ppm and the maximum inlet SO_2 concentration would be 200 ppm. The data gathered during excavation show that the 2-ppm outlet SO_2 concentration limit was met with few exceptions. One exception was a 50-min period on June 13 when the scrubbing liquor pH was inadvertently allowed to drop to 2.9, well below the specified control range of 10 to 13. During this period, the outlet SO_2 concentration rose to a 5-min average maximum of 12 ppm. The achievement of the outlet SO_2 design criterion was especially impressive in light of the high inlet SO_2 concentrations experienced during a large portion of the operation.

As a result of these high inlet and low outlet concentrations, the SO_2 removal efficiency of the scrubber was higher than expected. For the operating days on which daily average SO_2 inlet concentrations were above 10 ppm, the daily average SO_2 removal efficiencies were always above 95%. On many of these days, SO_2 removal efficiencies exceeded 99%.

The normal operating range for the scrubber liquor pH was established at 10 to 13 by the scrubber manufacturer prior to the trial excavation. It was noted, however, that operation near the high end of this range often caused excessive foaming of the scrubber liquor near the bottom of the packed tower, which subsequently resulted in an overflow of liquor out through the inlet duct and into the filter box. In light of the high SO_2 removal levels demonstrated by the scrubber, the decision was made to reduce the pH operating range to 7 to 10. This change eliminated the liquor foaming and overflow problem, while consistently low outlet SO_2 concentrations were maintained.

The only other operational problem encountered with the SO_2 scrubber was occasional restrictions in the tower that caused low ventilation airflow. The first episode occurred on June 15 and was diagnosed as excessive solids passing through the filter (upstream of the scrubber) and building up in the scrubber packing. The low airflow conditions were relieved by blowing down the scrubber liquor, washing down the packing, and increasing the frequency of filter inspections and changes. The filter system used during the trial excavation was a low-efficiency, field-fabricated system that relied on residential furnace filters as the filter medium.

The second episode of low airflow occurred on July 11. The solids content of the scrubber liquor at this time was much lower than during the first episode. Inspection of the packing balls through the lower access port showed that many contained a buildup of black, soot-like material that appeared to be composed of very fine particulate matter. Experiments revealed that the airflow could be returned to normal levels by decreasing the liquor recirculation flow rate from its normal range of 15 to 20 gal/min to near 5 gal/min. The outlet SO_2 concentration remained low even at the lower liquor recirculation flow rate; therefore, this rate was maintained for the duration of the program.

At the conclusion of operations, the scrubber was shut down and opened at the top cone and the bottom access port for inspection. At the top of the scrubber, the mist eliminator pad was clean and free of any buildup. The packing balls at the top of the scrubber were in a similar condition. At the bottom of the scrubber, packing balls near the access port were found to be partially obstructed with the previously described black buildup plus a white crystalline material speculated to be crystallized sodium hydroxide. Together, the combined solids filled approximately 25% of the volume of these packing balls. After the first 6 in. of balls were removed from the lower access port, however, it was clear that the packing balls in the center of the tower were free of significant buildup. The air-distribution grid at the bottom of the packed tower was also free of solids buildup. Thus, the cause of the second incident of low ventilation airflow could not be identified. All other portions of the scrubber were in good working order at the completion of program operations.

With respect to a final remediation scrubber, one change recommended as a result of trial excavation operations would be the installation of a high-efficiency, industrial, particulate-collection device upstream of the scrubber. This device should be designed to capture both large and fine particles (e.g., diesel engine emissions) to a high degree and thereby prevent the buildup of solids in the scrubber liquor and packing material. In addition, an automatic pH control system should be added that will maintain the desired pH range by the addition of caustic soda, as opposed to the manual system used during the trial excavation.

Carbon Adsorption

Adsorption is a phenomenon that occurs when a gas or vapor is brought into contact with a solid substance, which results in the gas or vapor (called adsorbates) being collected on the surface of the solid. This is a result of surface forces acting on solids, gases, vapors, and dispersed material. The magnitude of these forces depends on the nature of the solid surface and the type of molecules in the fluid. The adsorbing solid (or adsorbent) is generally an extremely porous material with large internal surfaces. Adsorption may occur on the solid surface alone. It may also be accompanied by chemical reaction (so-called chemisorption). In the chemisorption process, gases or vapors form actual chemical bonds with the adsorbent surface groups.

In a typical full-scale adsorption system, before entering the adsorber, the gas stream from the emission source is passed through a filter to remove entrained moisture droplets. Multiple adsorber vessels are generally provided for on-line regeneration of the bed material. Gas will flow through one vessel, where VOCs are removed, while the other vessel is regenerated or on standby. Regeneration of the bed is achieved by passing a hot inert gas such as low-pressure steam through the unit in reverse direction. The bed is then dried and cooled by passing air through it. Dissolved VOCs are generally condensed in a shell and tube heat exchanger. The VOCs can be recovered by simple decantation (in the case of water-insoluble materials) or by distillation (in this case of water-soluble VOCs).

Activated carbon is one of the most versatile of the solid adsorbents. For a physical adsorption, activated carbon is limited to high-molecular-weight and nonpolar adsorbates. Activated carbon can be specially treated with compounds of transitional elements or chemicals to enhance the adsorption capability for polar and low- molecular-weight gases or vapors.

The performance of a carbon adsorption system depends on the following conditions:

- Type of activated carbon
- Concentration of the adsorbates
- Temperature
- Humidity
- Gas flow rate and velocity.

The various sources and manufacturing processes used in making activated carbon produce different grades of activated carbons. An activated carbon with many pores big enough for gas molecules to enter is very important for effective adsorption. A steeper slope in the adsorption isotherm creates a higher rate of adsorption. A higher rate of adsorption utilizes the adsorbent more efficiently.

Carbon has an affinity for nonpolar molecules because of the differences in their ionic structure. Compounds such as hydrocarbons and most organic sulfur compounds (except H_2S) are adsorbed by carbon. This attraction makes carbon beds excellent adsorbers of VOCs. Carbon's affinity for water vapor in high-relative-humidity gas streams and sulfur compounds, however, will reduce the life of the bed, which results in higher operating costs for regeneration of the carbon.

Although the relative humidity of an emission stream may be high, there are methods that can reduce these effects and extend the life of the carbon bed. One such method is to mix the gas streams with lower-relative-humidity ambient air. This process will lower the cost of carbon regeneration by extending the life of the beds, but it will result in an increased expenditure for capital equipment and higher power consumption due to the larger gas volume through the system. An alternative method of reducing the relative humidity in the emission stream involves cooling and condensing the water. This can be accomplished in a shell and tube heat exchanger. The gas stream would then be reheated to a temperature corresponding to the desired relative humidity.

Carbon adsorbers are available in packaged units containing all the necessary equipment. They are available in many different sizes and configurations up to 100,000 scfm and can be custom-designed for any application.

Fuel and power costs are minimal, and a high VOC removal efficiency (99%) can be attained with low inlet concentrations. Wastewater produced from regeneration of the carbon bed may contain organic compounds that will require treatment prior to disposal.

Carbon Adsorber Performance During Trial Excavation At McColl Site

During the trial excavation, a granular activated-carbon bed was installed after the wet scrubber. Two types of granular activated carbons were used in the carbon adsorber to remove hydrocarbon pollutants from the ventilation airstream. The first was a coal-based carbon that was used during the first 9 days of excavation operations between June 7 and 15. The coal-based carbon was replaced with a coconut-based carbon that was used during the remaining operation period until system shutdown on July 18, for a total of 32 operating days.

For an assessment of the performance of these carbons, the hydrocarbon removal efficiencies associated with the maximum 5-min average inlet THC concentrations were calculated and compared over time for the two carbon types. These data show that the average daily hydrocarbon removal efficiency for the coal-based carbon ranged from 61.8% (fresh carbon) to 49.4% over a 9-day period. For the coconut-based carbon, average hydrocarbon removal efficiency ranged from 90.7% (first full day of operation on new carbon) to 58.4% over the first nine days of operation. By comparison, the performance of the coconut-based carbon was slightly superior to that of the coal-based carbon with respect to both initial activity and activity over a 9-day period.

For the remainder operating period with the coconut-based carbon, average hydrocarbon removal efficiency declined from 78.1% on June 26 to 24.2% on July 18. The exception to this trend was an increase in average removal efficiency from 55.9% on July 10 to 71.6% on July 11. During other short-term periods on those days, hydrocarbon removal efficiencies reached 93% on July 10 and 92% on July 11. The high removal efficiencies on July 11 corresponded closely to the periods of low airflow rates measured on this day; after the airflow rate was returned to normal levels (by adjustment of the scrubber recirculation rate), the hydrocarbon removal efficiencies decreased. Although no airflow rate data are available for July 10, the hydrocarbon removal efficiency data suggest that the flow rate was also low on this day.

Post-operative inspection of the activated carbon unit showed no visible damage to or buildup on the spent carbon particles. Water corrosion was evident on the steel rollers at the bottom of the accumulator cabinet, however. It is unlikely that this water came in the form of carryover water droplets from the wet scrubber because the scrubber mist eliminator packing was in good condition at the end of operations and the knock-out pot (installed between the scrubber and the carbon unit) showed very little water accumulation when checked regularly. A more likely source of water was air moisture condensation on the inside of the accumulator cabinet during the cool nighttime and early morning hours. The air entering the cabinet was no doubt saturated after passing through the packed-bed scrubber. Contact of this saturated gas with cold cabinet walls would be sufficient to cause water condensation and accumulation. Such condensation and accumulation were noted on the top inside panel of the accumulator cabinet during periodic field inspections. The presence of water in the carbon unit was also supported by the hard black powdery deposits found on the fan vanes and housing after operations were completed. These deposits were likely formed by the combination of moisture and attrited fine pieces of carbon from the activated carbon unit.

The presence of moisture in the carbon unit helps to explain the lower-than-expected hydrocarbon removal performance of this system during the trial excavation. The design specifications for this system were 95% THC removal. The inlet THC concentration, however, was much higher than expected because of the low vapor-suppression effectiveness of the foam. Nevertheless, the manufacturer of the carbon unit still expected performance levels to be above 90% removal. Moisture condensation onto carbon particles with subsequent reduction in active surface area still appears to be the most likely explanation for less than design performance. This explanation is consistent with the gradual loss of carbon THC removal efficiency observed over time, as well as the increase in removal efficiency that occurred when the airflow rate was significantly reduced on July 10 and 11.

Several options would be available to eliminate moisture condensation problems for a final remediation activated-carbon unit. These include installation of an air dryer upstream of the carbon unit to lower scrubbed ventilation air moisture content, use of a dry scrubber in place of the wet scrubber used for the trial excavation, adding insulation/heaters to the accumulator cabinet, and operating a duct heater upstream of the carbon unit to maintain ventilation air temperature above the stream's dewpoint.

Vapor-Suppressing Foam

Aqueous, nondraining, air foams, i.e., stabilized foams (developed by 3M Company) are useful for control of undesirable vapors and particulates such as those found at some industrial sites (cement factories, mines, etc.), at waste sites accepting hazardous materials (e.g., California Class I or II sites), or National Priority List sites during remediation activities. The products work by forming a protective barrier over a source of vapor or particulate emissions. They are sprayed onto an area and form a tough, continuous, foam layer as they "cure" in place. For time periods of at least several days, these foams provide nearly total elimination of emissions of organic chemical vapors such as benzene, trichloroethylene, cyclohexane, etc., and complete control of particulates and dust.

Vapor-suppressing foams are made by combining a foaming agent (FX-9162) and a "stabilizer" (FX-9161) with water and air, using an eductor system, and spraying this solution through an air-aspirating nozzle. Each agent is proportioned into the water line at a concentration of 6%. The foam "sets up" (makes the transition from a fluid to a flexible solid foam) in about 2 minutes.

It is also possible to use the foaming agent without the stabilizer for temporary vapor suppression. For example, during the remediation of a volatiles-containing waste site, temporary foam could be used to cover the hazardous waste as it is being excavated. Stabilized foam could be used to cover trucks after they are loaded, excavation surfaces that are temporarily inactive, and the entire workface overnight or through weekends.

Depending on the nozzle type chosen and the products used, foams of various expansions can be made. (Expansion = Volume of foam ÷ Volume of unfoamed liquid). Foams of low expansion (4:1 to 8:1) provide the best control of many VOCs. In cases of extremely toxic emissions, low-expansion foams are recommended. A fog nozzle, such as those used by many fire departments, produces foam in this expansion range when FX-9161 and FX-9162 are used, each at 6% in water.

In some field situations, highly irregular surfaces make a somewhat higher foam expansion a more practical choice. The Boots and Coots medium-expansion nozzle or a foam tube such as that made by Elkhart can be used to produce foams in the 8:1 to 20:1 expansion range when FX-9161/FX-9162 are used.

A new 3M product, FX-9164 Penetrant, was developed specifically to control dust and particulate matter. When FX-9164 is combined in water with FX-9161 Stabilizer, the liquid sprayed from the nozzle thoroughly wets essentially any type of dust or particulate and then gels to form a solid, flexible mass not easily disturbed by wind. FX-9164 is proportioned at a 1% concentration and FX-9161 at a 6% concentration into the water line. These products work best with a fog nozzle and are applied as a liquid (not as a foam).

The effectiveness of stabilized foam as a vapor-suppressing medium is influenced by foam variables such as formulation, foam depth, expansion ratio, and age, as well as the nature of the particular hazard. Laboratory and field tests were conducted with aqueous stabilized foam to investigate the effects of foam variables and the nature of the hazard on vapor suppression performance (Alm et al., 1987). The following trends were noted:

- For a period of days, the percentage suppression of hydrocarbons did not change significantly. In a 12-day laboratory experiment with cyclohexane and a 7-day field trial with JP-5 fuel, the suppression was greater than 97%, even after the foam had dehydrated to form a membrane.

- With high-polarity VOCs such as acetone and MEK, suppression was in the 90 to 100% range for the first several hours, decreased to the 80 to 90% range after 10 hours for foam application weights of at least 0.62 g/cm^2. The higher polarity allows these VOCs to diffuse faster than other hydrocarbons through the aqueous matrix of the foam.

- In general, vapor-suppression properties of stabilized foams were not greatly affected by variation in concentration of the FX-9162 foamer and FX-9161 foam stabilizer components. Some improvement in suppressing acetone vapors was noted when FX-9161 stabilizer concentration was doubled from 6% to 12%, whereas a slight decrease in suppression of cyclohexane vapor was noted when the FX-9162 foamer concentration was increased.

- The application weight of stabilized foam used should be determined by the nature of the hazard. Lowering the application weight of 4:1 expanded foam from 0.62 to 0.31 g/cm^2 did not significantly hurt performance on cyclohexane; however, doubling the application weight of stabilized foam from 0.62 to 1.24 g/cm^2 on acetone cut emissions by more than 50%.

- Both laboratory and field tests showed that vapor suppression performance was affected by the foam expansion ratio, particularly with nonpolar VOCs such as cyclohexane. Thus, increasing the air content of foam to improve coverage should be practiced only after careful consideration.

Foam Efficiency Evaluation During Trial Excavation At McColl Site

During trial excavation, two types of water-based foam supplied by 3M Corporation were selected: a temporary foam that is effective for up to about an hour, and a stabilized foam that is effective for at least a day. The earlier reported foam effectiveness values were based on measurements of emissions from stationary samples of waste (i.e., static conditions) with and without foam application. No data were available on the ability of the foam to control emissions during actual excavation operations (i.e., under dynamic conditions).

Field Use of Foam During Excavation

During excavation, temporary foam was sprayed manually on freshly excavated waste material or initially on stored material. Stabilized foam was then sprayed on all waste surface areas at the end of each work day. The overall qualitative assessment of the foam vapor suppressants used during this trial was that they were not as effective as expected. This assessment was based on visual observation of the foam, which disintegrated and neither adhered well to the raw wastes nor formed a cohesive film. The foam appeared to react with the highly acidic waste and sometimes turned from greenish yellow to deep red. Moreover, total hydrocarbon and sulfur dioxide concentrations of the airstream in the enclosure exhaust control system were higher than expected, primarily because the foam failed to control them. When stabilized foam was placed on the waste at the end of a period of activity, air concentrations slowly decreased. This decrease, however, was partially due to no fresh waste being excavated and exposed and partially due to a constant flow of ambient ventilation air sweeping across the enclosure, which had the effect of reducing concentrations, to an equilibrium level. In an effort to increase the effectiveness of the stabilized foam, the concentration of stabilizer was increased. The intent was to double the stabilizer concentration. Analytical data from 3M indicated the concentration increased from 9.6 to 10.5%. Although the increase in the foaming strength increased the foam's effectiveness, it did not solve the existing problems.

Foam Use During Mud Excavation and Movement

No significant SO_2 emissions were observed for either mud excavation or movement; small increases in THC concentrations were recorded during these operations. The latter were likely due both to THC emissions from operating equipment with diesel engines and to emissions from mud waste. Because of the limited number of comparison periods and the low emission levels recorded for excavation with and without foam, no substantial conclusions can be drawn regarding foam-control effectiveness.

Foam Use During Tar Excavation and Movement

For tar excavation, the use of low-strength (9.6%) foam resulted in a 73% reduction in the average SO_2 change rate* and a 65% reduction in the average THC change rate. Other factors being equal, the concentration change rate is directly proportional to the waste emission rate. During the tar movement periods, both low- and high-strength (10.5%) foams were applied. Use of low-strength foam during tar movement operations resulted in a 50% reduction in the average SO_2 change rate and a 55% reduction in the average THC change rate. Increasing the foam concentration to higher strength (10.5%) resulted in a 79% reduction in the average SO_2 change rate and a 73% reduction in the average THC change rate. No data are available for tar excavation with high-strength foam.

Foam Use During Char Excavation and Movement

Because of the high emissions expected and observed during char excavation and movement, these operations were always conducted with foam being applied. As a result, no data are available for char operations without foam and, hence, no levels of foam-control effectiveness can be established. The data do show, however, that foam-controlled average SO_2 and THC concentration change rates were higher for char excavation than for tar excavation.

With respect to char movement, average SO_2 concentration change rates were 23% lower with high-strength foam (10.5%) than with low-strength foam (9.6%). Average THC change rates were 35% lower with high-strength foam than with low-strength foam.

Problems Related to Foam Application

The traction difficulties encountered by the wheel-mounted loader on the muddy floor of the enclosure were due to the chemical breakdown of temporary and stabilized foam caused by the char and tar wastes and the accumulation of purge water from stabilized foam applications. At the completion of stabilized-foam applications, foam and water had to be purged from the delivery lines to prevent the foam from setting up in the system; purging was not required after temporary foam applications. The foam breakdown and purge water accumulation resulted in a layer of mud and foam 6 to 12 in. deep on the floor. Besides making traction difficult for the loader, the mud also prevented the free movement of tar and waste bins about the enclosure (because of sinking) and made personnel footing quite uncertain.

For the trial excavation, the problem was addressed by substituting a track-mounted Bobcat for the wheel-mounted loader. Because of the Bobcat's smaller bucket size, this change reduced the waste-moving productivity of operating personnel. In addition, personnel took more care in directing the stabilized-foam purge water into 55-gal drums rather than onto the enclosure floor.

If foam application is retained for a full-scale remediation, it may be necessary to devise a drainage system around waste-handling areas to drain off accumulated water. In addition, portable blowdown tanks should be located near foaming operations to catch purge water and to remove it periodically from the enclosure. Depending on the success of these systems, track-mounted equipment may be required for material-handling operations.

A more effective vapor-control system would be desirable to address these concerns in the full-scale remediation. Alternative formulations for foam should be investigated, especially those that contain chemical bases and have the potential for chemically bonding with the surface of the acidic McColl waste. Alternatively, other vapor-suppression systems should be evaluated, including the use of lime or limestone slurry such as that applied to suppress dust in coal mines.

Even with improvements, however, the vapor-suppression system cannot be expected to provide complete control of waste emissions because of the dynamic conditions of waste excavation and movement. Maintaining pollutant concentrations inside the enclosure between the Immediately Dangerous to Life and Health (IDLH) and Permissible Exposure Limit (PEL) levels will require a larger air-ventilation system. This means a larger fan, air pollution control devices (APCDs), and associated ducting. By generating a higher airflow rate, the larger ventilation system would provide more frequent turnover of the air inside the enclosure and hence lower pollutant concentrations.

Enclosure Structure

For Superfund sites, where a fugitive air emission problem exists, an enclosure structure can be very effective during the excavation and transportation of waste. The enclosure ventila

* Change rate is the rate at which SO_2 concentration increases over time.

$$\text{Change rate} = \frac{\text{Conc. of } SO_2 \text{ at end of activity (ppm)} - \text{Conc. of } SO_2 \text{ at start of activity (ppm)}}{\text{Time elapsed (min).}}$$

tion air will be routed through an emission-control system to prevent the escape of significant air emissions into the area surrounding the excavation zone.

During the trial excavation at the McColl site, a rigid-frame, PVC-covered enclosure structure was erected over part of the L-4 Sump prior to the start of excavation. The enclosure proved to be effective in preventing the escape of air emissions during excavation.

Problems Related to Enclosure Structure

The enclosure created a confined work space in which temperatures were approximately 20°F above the outdoor temperature. During the trial excavation, diesel engines were operated on the trackhoe, backhoe/loader, Bobcat, and pug mill. The emissions inside the enclosure resulting from these engines directly contributed to work stoppages due to low visibility, and high THC levels. The exhaust gases from diesel engines add heat, particulate matter, and hydrocarbon species to the enclosure air (SO_2 contributions were no doubt small because of the low sulfur content in diesel fuel).

The high emission levels of SO_2 and THC measured for the tar and char waste materials during the trial excavation caused work stoppages. These were due to health and safety concerns, and interference with equipment steering and braking systems. Since the ventilation air flow rate was fixed, this system was not able to provide enough fresh air to keep pollutant concentrations below design levels.

Other Equipment

For the full-scale remediation, one approach would be to use electric engines instead of diesel engines. The pug mill could have been equipped with an electric engine for the trial excavation had the electrical demand requirements not exceeded the available supply on site. Further work should be conducted on the size of the pug mill required for full-scale remediation and the associated power requirements. It also may be possible to use an electrically powered gantry crane system inside the enclosure to move the material and to excavate some or all of the waste materials.

If diesel engines on some of the operating equipment cannot feasibly be eliminated for the full-scale remediation, a system for directly venting the engine exhaust to the APCDs should be investigated. It may be possible to suspend movable ducting from the enclosure ceiling and to connect it to engine exhausts. Such ducting would directly transport exhaust gases to the APCD system without their entering the enclosure air. This approach would be easiest to accomplish on equipment that does not move about much within the enclosure (e.g., a pug mill or trackhoe). For more mobile equipment, it might be more feasible to direct exhaust gases through a filter, a carbon canister, and a water cooler system mounted directly on the machine. This approach would probably require frequent changing of the filter media, carbon, and water to maintain its effectiveness.

Section 4

Design Analysis

The excavation and fugitive emission control systems evaluated during the McColl trial excavation have been used in system designs prepared for the excavation operations, air ventilation system, and air pollution control devices (APCDs) associated with a commercial-size site remediation effort . These designs illustrate how these systems could be applied to a site where the excavation or handling of wastes would result in the release of significant fugitive emissions that could pose a potential health risk to nearby communities. In the example scenario, system designs are developed for full remediation of the 12 sumps at the McColl Superfund site in Fullerton, California.

The scope of the remediation activities evaluated in this analysis includes excavation of waste and associated material under a rigid-frame enclosure, backfilling of the excavated sump under a second enclosure, erecting a third enclosure on the next sump to be excavated, and transport of the waste material to an onsite storage facility consisting of a fourth stationary enclosure erected over a concrete pad. The fugitive emission control systems include vapor-suppressing foam application units, air ventilation systems for each enclosure, the APCDs required to reduce emissions of SO_2 and THC in the ventilation air to acceptable levels, an APCD emissions monitoring network, and a perimeter ambient air monitoring network. The scope does not include the final waste treatment and disposal systems or pretreatment systems.

The general workflow calls for waste to be excavated from one sump under an enclosure and loaded into rolloff bins for transport by truck to a storage facility consisting of a stationary enclosure. Backfilling operations will take place simultaneously at a second sump under an enclosure. While excavation and backfilling operations are proceeding under the first two enclosures, a third enclosure will be erected on a third sump. After excavation operations are completed on the first sump, the excavation equipment and crew will be moved to the third sump to begin its excavation. Backfill equipment and crews will move to the second sump to complete its backfill. Following completion of backfill operations, the backfill enclosure will be disassembled and reassembled on the next sump (or sump section) to be excavated. This sequence will be repeated until all sumps on the site are completely excavated and backfilled.

This arrangement has the advantage of allowing continuous excavation operations to provide feed material to the final treatment system. It is, however, only one of several feasible scenarios for the excavation of waste at the McColl site.

Design of Excavation Operations

Overall Excavation Rate

The maximum digging depth required to remove all waste and potentially contaminated soil at the McColl site is 55 feet. The sump requiring this depth of digging, identified as R-2, is approximately 144 ft wide and 144 ft long. The widest enclosure routinely available from Sprung Instant Structures, Inc., is 130 feet. The use of such a structure on large sumps such as R-2 requires the performance of the excavation in two or more steps, which necessitates re-excavation of some of the sumps. The use of a larger, specially engineered enclosure that would allow excavation of the entire sump under one enclosure was also examined; however, the high cost of the larger enclosure and APCD system exceeded the excavation cost savings that would result.

The general excavation procedure for a standard-sized enclosure is illustrated in Figures 4-1 through 4-3. The north half of Sump R-2 will be excavated in the first step. As shown in Figure 4-1, equipment and personnel will descend to a depth of 24 feet in the first excavation pass; the remaining material will be removed in the second pass. Because of the potential for cave-ins, the sides of the sump above the 24-ft level must be sloped in accordance with OSHA requirements in 29 CFR, Chapter XVII, Subpart P. It is assumed that the soil and mud at the site will fall into the Type C category and require the maximum slope of 1.5 foot horizontal-to-1.0 foot vertical (1.5H/1.0V). Because the lower portion of the waste material will be hard char, which formed stable vertical walls during the trial excavation, it is assumed that this material can be excavated during full remediation and that the vertical sides will remain intact while exposed. A slope of 0.5H/1.0V is specified for the contaminated soil below the waste to provide a stable support base for the unexcavated waste above the waste. Figure 4-1 shows that a 120-ft wide enclosure is required to perform this excavation, which allows for at least 10 feet of clearance on both sides of the pit for personnel movement.

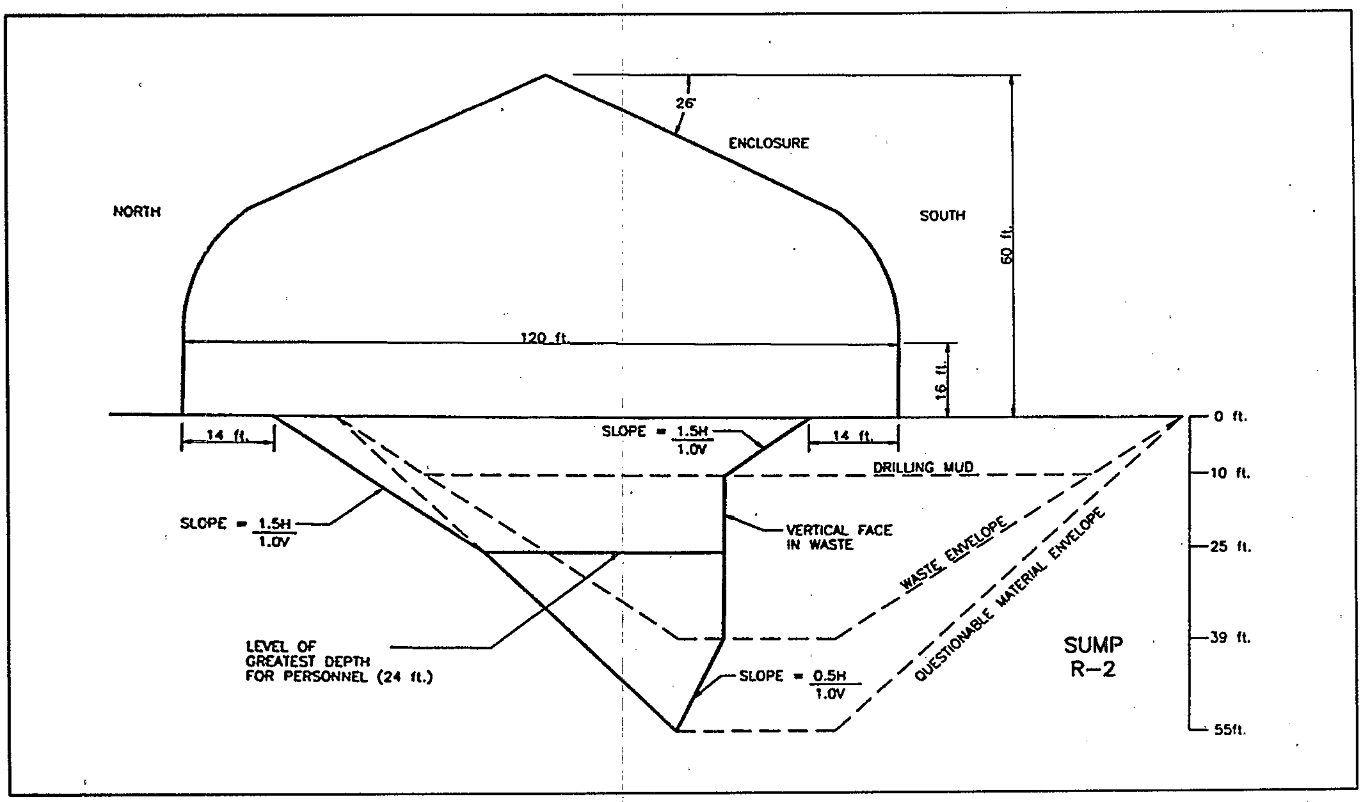

Figure 4-1. Excavation of North Half of Sump R-2.

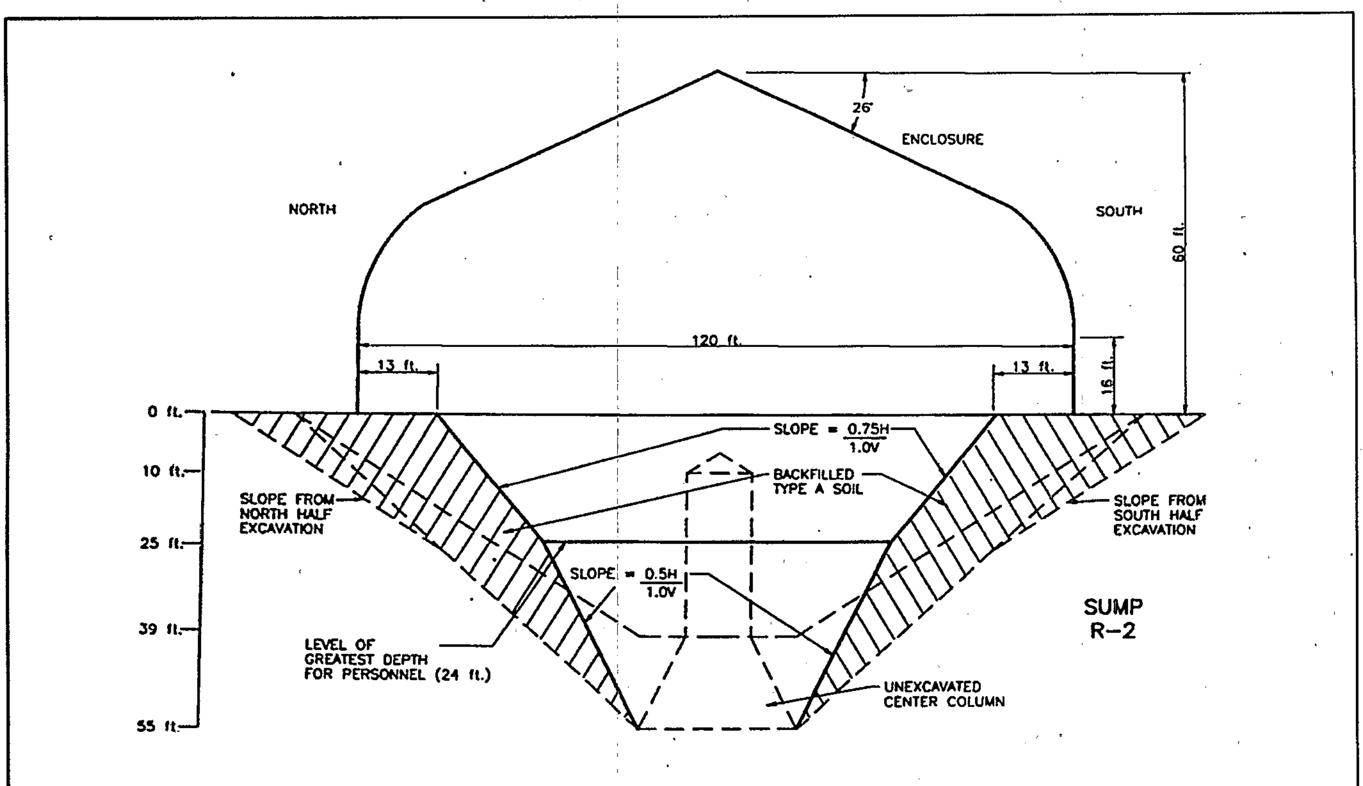

Figure 4-2. Excavation of Center Column in Sump R-2.

After the north half of the sump has been excavated, the pit will be backfilled and the enclosure moved to allow similar excavation of the south half during the second step. As shown in Figure 4-2, however, a column of unexcavated material will be left in the center of the sump after Step 2 is completed. For this center column to be excavated with the same size enclosure, it will be necessary to backfill the north and south halves of the sump with Type A soil (cohesive soils such as clay) as defined by OSHA. This will allow the center column to be excavated with sides sloping at 0.75H/1.0V (above the 24-ft level) instead of 1.5H/1.0V. After excavation of the center column material in the third step, the sump will be backfilled with clean soil for the final time. The three placements of the enclosure structure on Sump R-2 corresponding to the three excavation steps are diagrammed in Figure 4-3.

This excavation approach requires double- or triple-handling of a significant amount of material. Excavation of Sump R-2 will require the most rehandling of material of any of the sumps because of its depth. The number of enclosure placements and the amount of material that would have to be re-excavated for the remaining sumps at McColl being remediated by this technique have been evaluated; the results are summarized in Table 4-1. As shown, the smaller and shallower sumps require only one enclosure placement, whereas the larger and deeper sumps may require as many as seven placements for complete remediation. The estimated total amount of material to be handled with this approach is 151,700 yd^3, which is 25.3% greater than the in-place volume of waste, contaminated soil, and sump cover.

A major assumption in this analysis is that excavation operations will proceed at a pace consistent with feeding approximately 100 tons of material per day to a pretreatment or final treatment system. About 90% of this feed material would be contaminated, and the balance would consist of additives such as lime or cement. The final treatment device would operate 6 days/week. Excavation operations would also take place 6 days/wk, 50 wk/yr, which allows 2 wk/yr for overhaul/maintenance/downtime. A second assumption is that the onsite storage facility will accommodate up to 1 week's supply of contaminated materials.

The overall time required for complete excavation of all 12 waste sumps at McColl is based on the assumed final treatment feed rate of 90 tons of waste per day, the bulk density of excavated waste, and the total amount of contaminated material (both in-place material and material that becomes contaminated during re-excavation operations). As shown in Figure 4-1, the total excavation volume expected at McColl is 151,700 cubic yards bank measurement (cybm) versus an in-place volume of 121,200 cybm, which results in a re-excavation volume of 30,500 cybm. Based on materials handling experience at the trial excavation, it is estimated that as much as one-third of this

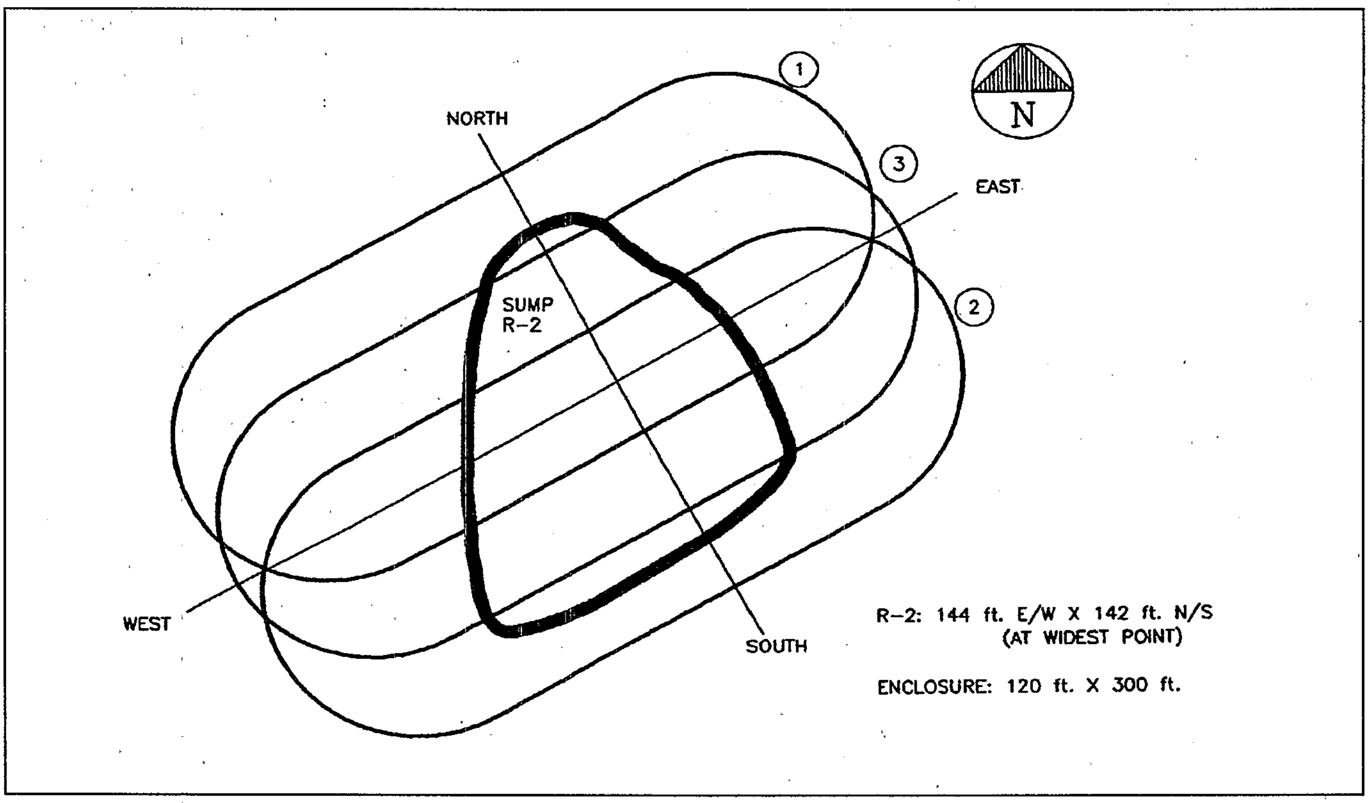

Figure 4-3. Positioning of Enclosure on Sump R-2.

Table 4-1. Planning Results for Excavation Under an Enclosure at McColl.

Sump	Number of Enclosure Positions	Depth[a], ft	Length x Width[b], ft	In-Place Volume[c], yd^3	Re-Excavation Volume[d], %	Total Excavation Volume, yd^3
Los Coyotes Area						
L-1	4	31	272 x 151	13,800	18.4	16,300
L-2	2	35	163 x 125	10,500	18.4	12,400
L-3	2	37	142 x 118	12,500	13.2	14,100
L-4	1	33	128 x 76	6,200	0.7	6,600
L-5	1	45	97 x 66	5,700	6.7	6,100
L-6	1	35	118 x 65	8,400	2.2	8,600
Ramparts Area						
R-1	4	28	144 x 132	8,800	7.2	9,400
R-2	3	55	144 x 142	9,800	144.9	21,100
R-3	2	31	161 x 142	6,800	5.9	7,200
R-4	2	30	146 x 116	7,300	10.0	8,000
R-5	2	35	170 x 87	11,800	23.3	14,500
R-6	7	45	234 x 148	19,600	39.8	27,400
TOTALS	31	—	—	121,200	—	151,700

[a] Depth of contaminated material.
[b] Length and width of sump at grade level.
[c] Based on CH2M-Hill (1989)
[d] Volume to be excavated in excess of in-place volume (including covers) as a results of material re-handling.

Table 4-2. Total Excavation Quantities and Material Types (cybm)

Material Type	In-Place Volume[a]	Reexcavation Volume	Total Volume
Waste	72,600	—	72,600
Designated	2,000	—	2,000
Questionable	22,500	10,200	32,700
Clean	24,100	20,300	44,400
TOTALS	121,200	30,500	151,700

[a] Based on CH2M-Hill (1989)

overexcavated material could become contaminated as a result of contact with other contaminated waste during backfilling and re-excavation. Table 4-2 summarizes the estimated quantities of the various materials to be excavated on the basis of this assumption and the SROA estimates of in-place materials.

The waste material in Table 4-2 was further segregated into mud, tar, and char based on the relative quantities of these materials encountered in the trial excavation. These quantities are shown in Table 4-3, in which bank measurement volumes (equivalent to in-place volumes) are converted to loose measurement volumes based on the material bulking factors measured during the trial excavation. The total estimated loose measurement excavation volume of 209,690 yd^3 consists of 143,690 yd^3 of contaminated material and 66,000 yd^3 of clean material.

As discussed, the overall objective of the waste excavation operations will be to supply 90 tons/day of contaminated material to final treatment operations. An overall bulk density of 89 lb/ft^3 was estimated for the composite stream of McColl contaminated material by using the methodology illustrated in Table 4-4. Thus, 90 tons/ day of contaminated material corresponds to 75 cubic yards loose measurement (cylm)/day of excavated material. Based on the ratio of clean-to-contaminated material shown in Table 4-3, 35 cylm of clean material must be excavated for every 75 cylm of contaminated material, on average. Thus the overall excavation rate required to supply 90 tons/day of contaminated material to final treatment will be (75 cylm + 35 cylm =) 110 cylm/day.

At an average excavation rate of 110 cylm/day, the time required to excavate the entire volume of material at the McColl site (i.e., 209,690 cylm) is estimated to be 1906 operating days. Total site excavation operations would be completed in approximately 6.4 years for the 300 days/year operating scenario discussed earlier.

Waste-Specific Excavation Rates

The feasibility of operating at an overall excavation rate of 110 cylm/day was evaluated by calculating waste-specific excavation rates and applying a factor to reflect the use of Level B personal protective equipment (PPE) for personnel working

Table 4-3. Conversion of Bank Measurement Volumes to Loose Measurement Volumes

Material Type	Total Volume, cybm	Bulking Factor	Total Volume, cylm	Percent of Total Material	Percent of Contaminated Material
Waste - Mud	13,070	1.5	19,610	9.4	13.7
Waste - Tar	10,160	1.2	12,190	5.8	8.5
Waste - Char	49,370	1.2	59,240	28.3	41.4
Designated	2,000	1.5	3,000	1.4	2.1
Questionable	32,700	1.5	49,050	23.4	34.3
Clean	44,400	1.5	66,600[a]	31.8	NA
TOTALS	151,700	—	209,690[a]	100	100

[a] Ratio of clean-to-contaminated material is 66,600/143,090 = 0.465.

Table 4-4. Bulk Density of Composite Contaminated Material Stream (Basis: 100 ft^3 of contaminated material, loose measurement)

Material Type	Volume[a], cflm	Bulk Density[b], lb/cflm	Weight, lb
Mud	13.7	84	1,151
Tar	8.5	33	281
Char	41.4	74	3,064
Designated	2.1	120	252
Questionable	34.3	120	4,116
TOTALS	100	—	8,863[c]

[a] cflm = cubic feet, loose measurement.
[b] Based on trial excavation measurements.
[c] 8863 lb/100 ft^3 = 89 lb/ft^3 composite stream bulk density.

within the enclosure. For a backhoe of the type expected to be required for this operation, the following average speeds apply (Church 1981):

- Drag speed for loading - 91 ft/min
- Hoist speed - 60 ft/min
- Swing-return speed - 3.0 revolutions/min
- Loading and dumping constant - 0.13 min.

Based on the depths of contaminated material reported in the SROA, the average total excavation depth of the McColl sumps is near 37 feet. The average effective excavation depth will be one-half this value, or 18 feet. An average dumping height of 15 feet was assumed for the excavation spoils pile and bucket length. An average swing-return angle of 120 degrees was assumed for the trackhoe during excavation operations. Based on these estimates, an excavation cycle time of 1.02 minutes was calculated by the methodology shown in Table 4-5. This cycle time would apply to the excavation of overburden, mud, and tar. A cycle time of 1.60 minutes was assumed for char excavation because more time will be required for milling out of this harder material by using the bucket (Church 1981).

Based on trial excavation results and recommendations in Church (1981), the dipper factors* (i.e., cubic yards bank measurement/cubic yards bucket capacity) assumed were 0.46 for overburden and mud and 0.66 for char and tar. The backhoe bucket capacity for full-scale remediation operations is expected to be near 3 yd^3.

For typical excavations of rock or soil, operations proceed for an average of approximately 50 min/hr (Church 1981). The anticipated use of Level B personal protective equipment (PPE) for the McColl excavation is expected to result in an overall production efficiency as low as 25% of typical efficiencies, or an average of 12.5 minutes of excavation per operating hour. This information, plus the factors cited in the preceding paragraph, were used to estimate excavation rates for individual waste types, as follows:

$$\frac{12.5 \text{ min/oper. h} \times 0.46 \text{ cylm/yd}^3 \text{ bucket capacity} \times 3.0 \text{ yd}^3 \text{ bucket/load}}{1.02 \text{ min/load}}$$

$$= 16.9 \text{ cybm/oper. h}$$

Applying the trial excavation bulking factor of 1.5 yields an excavation rate of 25.4 cylm per operating hour. This excavation rate applies to overburden and mud excavation. The same procedure, but with different values for the dipper factor, cycle time, and bulking factor, was used to calculate excavation rates of 29.1 cylm/h and 18.6 cylm/h for tar and char excavation, respectively.

A typical day will likely involve the excavation of only one type of waste. Based on the preceding waste-specific excavation rates (which incorporate Level B PPE effects), the follow ing operating times can be estimated directly for the five major types of contaminated materials to achieve the target average daily excavation volume of 110 cylm:

* Dipper factor is inversely proportional to bulking factor (bulking factor for overburden and mud is 1.5 and that for char and tar is 1.2).

Table 4-5. Excavation Cycle Time

Operation	Rate	Distance	Cycle Time, min
Loading and dumping	Constant	Constant	0.13
Hoisting within pit	60 ft/min	19 ft	0.32
Swinging	3.0 rpm	120°	0.11
Hoisting above grade	60 ft/min	15 ft	0.25
Returning and lowering to grade	3.0 rpm	120°	0.11
Lowering within pit	190 ft/min	19 ft	0.1
TOTALS			1.02

- Mud - 4.3 operating hours
- Tar - 3.8 operating hours
- Char - 5.9 operating hours
- Designated or questionable - 4.3 operating hours

For a composite daily waste stream, the calculations in Table 4-6 indicate an average of 4.8 hr of excavation operations would be required to meet the target volume of 110 cylm/day.

These system design considerations indicate that excavation of contaminated materials at the McColl site can be readily accomplished at rates sufficient to supply a final treatment system operating at 100 tons/day. Calculations indicate that excavation operations could produce an average of nearly 160 tons/day of contaminated material over an 8-hr operating period and nearly 235 tons/day over a 12-hr operating period (the maximum period for daylight operations).

Air Ventilation System Design

The design of the air ventilation system for the enclosure is predicated on the emission rate of contaminants within the enclosure and the specified limit for contaminant air concentrations. For the waste at the McColl Superfund Site, SO_2 will be the primary contaminant of concern in light of the high emission rates noted during the trial excavation and the concentration levels required to protect worker health. The ventilation air system has been designed to maintain worker SO_2 exposure (on an 8-hr time-weighted average) at or below 50 ppm. This level is chosen as a reasonable compromise between the IDLH level of 100 ppm and the PEL level of 2 ppm because workers inside the enclosure will be wearing Level B PPE. This level was selected by EPA for conceptual design purposes only. It is recognized that the actual acceptable level of emissions within the enclosure will be dictated by OSHA regulations and any applicable ARARs. This 50-ppm maximum SO_2 concentration, together with the SO_2 emission rate, defines the ventilation air requirements within the enclosure. For this discussion, design of the ventilation system for the excavation enclosure will be considered first, followed by the designs for the backfill and storage enclosures.

Excavation Enclosure Ventilation System

At the McColl site, waste is expected to be excavated via a backhoe operating within the pit at the working face. Excavated waste will be loaded onto a spoils pile near the working face to allow the backhoe to work at maximum efficiency. A front-end loader will pick up waste from the spoils pile and carry it to the truck-staging area near one end of the enclosure. The loader will load the waste directly into a truck's waste container (most likely a 40-yd^3 rolloff bin). After the rolloff bin is full, a layer of stabilized foam will be applied to the top surface and a tarp will be placed over the container to control emissions during transport and storage. The truck will then leave the excavation enclosure via a vehicle air lock and transport its load to the storage area.

Emissions of SO_2 within the excavation enclosure will come from two major source types: dynamic waste surface areas and static waste surface areas. Dynamic surface areas are those where the waste is being actively moved or disturbed. Static areas are those where the waste is exposed but is not being moved or subjected to regular disturbances. The dynamic waste areas will include the moving/disturbed areas associated with the working face, spoils pile, rolloff bin, backhoe, and loader buckets. Based on the trial excavation experience, no foam will be applied to these areas for vapor suppression because the effectiveness of foam is limited under dynamic conditions and

Table 4-6. Operating Time Requirements for Excavation of Composite Waste Stream (Basis: 110 cylm of excavated material, average daily volume)

Material Type	Volume, %	Volume, cylm	Excavation Rate, cylm/opr. hr	Required Operating Hours
Mud	9.4	10.3	25.4	0.41
Tar	5.8	6.4	29.1	0.22
Char	28.3	31.1	18.6	1.67
Designated	1.4	1.5	25.4	0.06
Questionable	23.4	25.7	25.4	1.01
Clean	31.7	34.9	25.4	1.37
TOTALS	100.0	110.0	—	4.75

because of other problems (such as slippery surfaces) related to its use. Static areas within the enclosure will consist of all other areas of exposed contaminated materials that are not actively involved in the excavation operations. Stabilized foam will be applied to these areas to suppress emissions. Based on the trial excavation experience, an average suppression efficiency of 70% is assumed to be achievable for these static areas by reapplying stabilized foam every 3 days.

Previous investigations at the McColl site indicated that SO_2 (and THC) emissions from contaminated materials occur in two forms: 1) as higher-level "puff" emissions generated immediately following waste disturbances, and 2) as lower-level steady-state emissions generated after puff emissions have subsided (Radian 1982). The duration of the puff emissions is on the order of 30 seconds to 1 minute, whereas measurements indicate that steady-state emissions may continue indefinitely. Based on data from the previously cited field investigations, "upper reasonable" SO_2 emission flux rates at McColl were estimated to be 47,000 mg/m²-min for puff emissions and 1000 mg/m²-min for steady-state emissions. These rates are characteristic of the upper range of the rates measured, but they do not include rates that were significant "outliers."

There will be four sources of puff emissions within the excavation enclosure, all associated with waste disturbance or movement operations. The first source will be at the excavation working face. The greatest source of puff emissions will be the char waste at the site because it accounts for the greatest volume of vapor-releasing material and has been associated with very high SO_2 emission levels (as measured during the trial excavation and previous field-study flux chamber measurements). Based on the preceding excavation operations discussions, the cycle time for char excavation is expected to be near 1.6 minutes. This implies an average of nearly 38 buckets per operating hour, assuming that operations continue uninterrupted for an hour. Based on bucket dimensions, the exposed surface area of the working face is estimated to be near 2 m².

The second source of puff emissions will be the deposit of excavated material by the backhoe onto the spoils pile near the working face. The frequency and the exposed area for puff emissions will be the same for this operation as for excavation because the same equipment will be involved.

The third puff emission area will be the pickup of waste material off the spoils pile by the loader. The frequency of disturbances by the loader is expected to be about 23 buckets/hour for a 5-yd³ loader working in conjunction with a 3-yd³ backhoe. The surface area of disturbed waste will be approximately 3.5 m², based on typical loader bucket dimensions.

The fourth area of puff emissions will be the deposit of waste by the loader into a rolloff bin. Because the same equipment will be used for this operation as for waste pickup from the spoils pile, the disturbance frequencies and areas will also be the same.

For design purposes, the maximum SO_2 emissions likely to be emitted at any time during planned operations must be considered. Therefore, puff emissions are assumed to persist for a full minute and to occur simultaneously within the enclosure. Overall SO_2 puff emissions from dynamic waste areas were estimated by summing the disturbance areas and frequencies just discussed and applying the upper reasonable emission flux rate:

$$E_{d,p} = 47{,}000 \text{ mg } SO_2\text{/min-m}^2 \text{ (38 buckets/h x 1 min/bucket x 2 m}^2 \text{ x 2}$$

$$+ \text{ 23 buckets/h x 1 min/bucket x 3.5 m}^2 \text{ x 2) x 1 g/1000 mg x 1 h/60 min}$$

$$= 246 \text{ g } SO_2\text{/min}$$

Steady-state SO_2 emissions will be generated from both foam-controlled surfaces and uncontrolled surfaces. The uncontrolled surfaces correspond to the dynamic operations for which foam will not be used; after puff emissions have subsided, these areas will continue to emit SO_2 at the lower steady-state rate. These dynamic waste areas will include the following:

- Bin Area - The surface area of a 40-yd³ rolloff bin (with dimensions of 21.8 ft by 7.4 ft) will be approximately 22 m² after allowing for a 1.5 bulking factor.
- Excavation Spoils Pile - The spoils pile is assumed to have a working volume of 40 yd³ arranged in a cone with a diameter of 20 ft and a height of 10 ft, corresponding to an exposed area of 62 m² after bulking.
- Loader and Backhoe Buckets - The loader and backhoe buckets are estimated to contribute 4 m² and 2 m², respectively, to the uncontrolled steady-state emission area (in addition to their roles in generating puff emissions).

The total uncontrolled steady-state emission area is estimated to be 90 m². Steady-state SO_2 emissions from these areas will be generated at the following rate:

$$E_{d,ss} = 1{,}000 \text{ mg } SO_2\text{/min-m}^2 \text{ x 90 m}^2 \text{ x 1 g/1000mg}$$

$$= 90 \text{ g } SO_2\text{/min}$$

Controlled steady-state SO_2 emissions will be generated from static waste surfaces to which vapor-suppressing foam has been applied. The maximum estimated static area corresponds to the contaminated area that will be exposed at the completion of the first excavation pass in Sump R-2. For this sump, material will be excavated to the 24-ft level during the first excavation pass. The contaminated area exposed at this point will consist of a 14-ft vertical wall and the floor of the pit, which will be in the shape of a semicircle with a 40-ft radius. The vertical wall will have a width of approximately 122 ft at the top and 91 ft at the bottom. The combined area of these two surfaces will be near 372 m². The steady-state SO_2 emissions from these surfaces will be reduced by approximately 70% by the application of stabilized foam, which yields net static area steady state emissions of:

$E_{s,ss}$ = 1,000 mg SO_2/min-m^2 x 372 m^2 x (1.0 - 0.7) x 1 g/1000 mg

= 112 g SO_2/min

The overall maximum SO_2 emission rate within the enclosure, E_t, will be the sum of the individual rates estimated in the preceding three equations. Thus the overall emission rate is estimated as 246 + 90 + 112 = 448 g SO2/min, or 7.4 g SO2/sec. This will be a maximum emission rate because it assumes that all component emissions occur at the same time and at maximum levels, which is not likely to occur in actual practice. The air ventilation system design should be based on this maximum potential SO_2 emission rate, however.

The air ventilation flow rate will be a function of the overall SO_2 emission rate, defined earlier, and the maximum allowable SO_2 concentration within the enclosure. For the purposes of this design, a maximum allowable SO_2 concentration of 50 ppm within the enclosure has been selected as a reasonable compromise between the IDLH level of 100 ppm and the PEL of 2 ppm. This level was selected by EPA for conceptual design purposes only. It is recognized that the actual acceptable level of emissions within the enclosure will be dictated by OSHA regulations and any applicable ARARs.

Under steady-state conditions, the mass of SO_2 leaving the enclosure with the ventilation air will be equal to the mass of SO_2 being emitted within the enclosure:

$$E_t = 50 \text{ ppm} \times F$$

or

$$F = E_t / 50 \text{ ppm}$$

where F is the ventilation air flow rate. Where the total SO_2 generation rate is 448 g/min, the required ventilation air flow rate to maintain enclosure air concentration at 50 ppm or below is given by:

$$F = \frac{448 \text{ g } SO_2\text{/min} \times 1 \text{ lb } SO_2\text{/454 g } SO_2}{50 \text{ lb-mole } SO_2\text{/}10^6 \text{ lb-mole air} \times 64 \text{ lb } SO_2\text{/lb-mole } SO_2 \times \text{lb-mole air/359 scf}}$$

= 110,700 scfm

or

= 110,700 scfm x (460° + 115°F)/(460° + 32°F)

= 129,400 acfm at 115°F

The calculated air ventilation flow rate was rounded up to 130,000 acfm, which will be sufficient to maintain SO_2 concentrations within the excavation enclosure below 50 ppm, even during periods of maximum SO_2 generation rates. During periods of lower SO_2 generation rates, the concentrations within the enclosure will be below 50 ppm if the ventilation system is maintained at the specified air flow rate.

Backfill Enclosure Ventilation System

During backfill operations, clean soil will be trucked into the backfill enclosure and moved into position by a front-end loader. A vibrating roller will be used to pack the backfilled soil. Backfill operations are expected to cause negligible disturbance of waste surfaces; therefore, puff emissions are also expected to be negligible. A wall of contaminated material, however, will be fully exposed at the start of backfill operations, which will emit SO_2 at the steady-state rate reduced by the application of foam.

For design purposes, the largest wall of contaminated material will be exposed at the start of backfilling of Sump R-2. This wall will be approximately 124 ft at the top, 26 ft at the bottom, and 45 ft high, with a total surface area of 314 m². The estimated static area steady-state SO_2 emission rate was calculated in the same manner as used for the excavation enclosure:

$E_{s,ss}$ = 1000 mg SO_2/min-m^2 x 314 m^2 x (1.0 - 0.7) x 1 g/1000 mg

= 94 g/min

Since there will be no puff emissions or uncontrolled steady-state emissions in the backfill enclosure, total SO_2 emissions will be equal to the calculated static area steady-state emissions.

The maximum allowable SO_2 concentration within the backfill enclosure will also be set equal to 50 ppm. The air ventilation requirement for this enclosure was calculated in the same manner as for the excavation enclosure:

$$F = \frac{94 \text{ g } SO_2\text{/min} \times 1 \text{ lb } SO_2\text{/454 g } SO_2}{50 \text{ lb-mole } SO_2\text{/}10^6 \text{ lb-mole air} \times 64 \text{ lb } SO_2\text{/lb-mole } SO_2 \times \text{lb-mole air/359 scf}}$$

= 23,300 scfm

or

= 23,300 scfm x (460° + 115°F)/(460° + 32°F)

= 27,200 acfm at 115°F

As with the excavation enclosure, if the air ventilation system operates at the same rate, SO_2 concentrations inside the backfill enclosure will decline as the sump is backfilled and the exposed waste area is reduced. The SO_2 concentrations will also be lower in smaller sumps, where the exposed waste surface area will be less than that estimated for Sump R-2.

Waste Storage Enclosure Ventilation System

Like backfill operations, waste storage operations will be characterized by steady-state emissions from controlled static waste areas (with negligible puff or uncontrolled steady-state emissions). The requirement to maintain 1 week's supply of contaminated material for feed to final treatment can be accommodated by 17 rolloff bins with approximate 40-yd^3 capacities. The surface area of the contaminated material in these bins will be covered with foam and a tarp.

The total waste-emitting surface area of the bins in the storage area at full capacity will be near 374 m^2, based on the bin dimensions and bulking factor cited earlier. Based on the same estimating procedures shown earlier, the total SO_2 emission generation rate within the storage enclosure was estimated to be 112 g SO_2/min. This emission rate translates to air ventilation requirements of 32,400 acfm to maintain SO_2 concentrations within the enclosure below 50 ppm.

Design of Air Pollution Control Devices

This section considers the design of major components of the ventilation air pollution control trains. Each train will consist of a wet scrubber for control of SO_2 and particulate matter (PM) emissions, a granular activated carbon (GAC) unit for control of hydrocarbon/organics emissions, and an associated fan, blower, and ducting system. The equipment designs for each train will be identical. For illustration purposes, the discussions that follow focus on the APCD trains for the excavation enclosure.

Wet Scrubber System

The wet scrubber system design will be comparable to the NaOH-based scrubber system used during the trial excavation. An NaOH-based scrubber system is advantageous in this application because its considerable buffering capacity allows it to accommodate wide swings in SO_2 inlet concentrations while maintaining high SO_2 removal rates and low outlet concentrations. The largest NaOH-based wet scrubber manufactured by Interel Corporation, the supplier of the trial excavation scrubber, is rated at 35,000 acfm.* This unit, Interel Model GW 300, includes 10 feet of packing, a 950-gal sump, an automatic pH control, an automatic sump level control, an automatic blowdown system, a mist eliminator, and 300 gal/min recirculation pump. The unit is constructed of high-density polyethelene, as was the trial excavation scrubber. The Model GW 300 is designed to achieve greater than 95% SO_2 removal and greater than 90% PM removal when operated according to specifications.

The scrubber tower will be filled with 2-in.-diameter plastic packing balls, which provide a high mass transfer coefficient and yet operate at a pressure drop in the range of 2 to 5 inches of water across the bed. The high-void-space design of the packing material allows the scrubber to accomplish PM removal at air loadings of up to 2000 mg/m^3 without plugging. The highest PM loading expected among the excavation, backfill, and storage enclosures will be less than approximately 120 mg/m^3.

For accommodation of the specified total air ventilation flow rate of 130,000 acfm, four Interel Model GW-300 scrubbers will be required for the excavation enclosure, each operating at an average of 32,500 acfm. One scrubber unit will be required for each of the backfill and storage enclosures operating at the average air ventilation flow rates specified. Each APCD train will have one wet scrubber unit.

Granular Activated Carbon System

The THC adsorption performance of the GAC unit used during the trial excavation was less than the level expected based on other similar applications. This lower-than-expected performance was believed to be due primarily to moisture condensation within the carbon bed, which reduced the effective activated carbon surface area. For avoidance of such problems during full-scale remediation, it is recommended that a small gas burner be installed in the ducting between the wet scrubber and the GAC units that is capable to raising the temperature of the air stream by 20° F. This is a common saturation approach temperature difference used in industrial applications to avoid condensation while allowing for the natural variability of industrial operations.

For operation in the South Coast Air Quality Management District, the burner should be designed to fire natural gas. Heat balance calculations indicate that a burner firing approximately 700 ft^3/h (or 700,000 Btu/h) of natural gas will be sufficient to raise the temperature of the scrubber effluent air by 20°F. Downstream of the natural gas burner, the total gas flow rate will be increased from 32,500 acfm at the inlet to the scrubber to about 35,200 acfm as a result of natural gas combustion and saturation of the air stream with water in the scrubber. Assuming that the wet scrubber operates near 100°F during the summer months, the temperature of the gas entering the GAC unit will be 120°F.

The largest GAC modules available from TIGG Corporation, the supplier of the trial excavation GAC unit, are rated at 12,000 acfm.** Three such units (TIGG Model N-12000) will be required to operate in parallel for each scrubber to match the

* Personal communication from P. Briscoe, Interel Corporation, to E. Aul, Edward Aul and Associates, Inc., April 10, 1991.

** Personal communication from J. Sherbondy, TIGG Corporation, to E. Aul, Edward Aul and Associates, Inc., March 22, 1991.

scrubber flow rates. A fourth module will be added to allow change-out of spent carbon without shutting down the entire train. Each unit will be a radial-flow module similar in design to the unit used during the trial excavation. Inlet gases flow downward through a vertical cylindrical distributor in the center of the unit and then flow outward through an annular carbon bed to an accumulator cabinet that collects the gases and directs them to a downstream fan. The pressure drop across the three parallel GAC modules is expected to be in the range of 5 to 8 inches of water. Each cannister will hold approximately 5100 lb of activated carbon, for a total of 15,300 lb of carbon on-stream per train. At 12,000 acfm, the gas residence time in the carbon beds will be near 0.8 second. This design, in connection with the previously discussed gas burner, should consistently provide at least 90% removal of THC in the inlet gas stream.

One of the key parameters affecting the operation of carbon adsorbers is the amount of adsorbate (THC emissions in this case) captured on the carbon beds. This factor determines the makeup rate for fresh carbon and the spent carbon generation rate, both important economic parameters. For a given set of operating conditions, the maximum (or equilibrium) amount of adsorbate captured on the bed is a function of the inlet concentration and can be calculated from an adsorption isotherm of the form (Vatavuk 1990):

$$m_e = ap^b$$

where m_e = lb adsorbate/lb adsorbent at equilibrium

p = partial pressure of adsorbate in gas stream (psia)

a, b = isotherm parameters.

The isotherm parameters are particular to the adsorbate, type of carbon, and adsorption temperature and are best determined in the laboratory under representative conditions. For design purposes, however, the adsorption isotherm parameters for the mixture of hydrocarbons expected from excavation operations can be estimated by using a representative organic species such as toluene. Toluene was selected because it has nearly the same molecular weight as the average molecular weight of the THC mixture. For toluene adsorption on 4x10 mesh carbon at 77 °F, the values of a and b are 0.551 and 0.110, respectively. The inlet concentration of THC during excavation operations is estimated to be 14.2 ppm, which corresponds to 2.08×10^{-4} psia. Substituting this value into the preceding equation with the appropriate isotherm parameters yields:

$$m_e = 0.551(2.08 \times 10^{-4})^{0.110}$$

$$= 0.217 \text{ lb adsorbate/lb carbon}$$

In actual practice, the amount of adsorbed carbon is not allowed to reach the equilibrium level because the bed's adsorption capacity would be exhausted at this point and the outlet concentration would quickly rise to the inlet level. For avoidance of this type of adsorbate breakthrough, carbon beds are typically allowed to operate until they reach 50 to 75% of equilibrium loading. Using the 75% level for design purposes implies that the maximum loading of carbon for the excavation ventilation air system will be 0.217 x 0.75= 0.163 lb adsorbate/lb carbon.

During nonoperating hours, the THC concentration of the ventilation air is projected to fall quickly to less than 1 ppm. At this low level, only minimal THC adsorption would be expected in the carbon-beds even if the enclosure is ventilated continuously. Thus, the useful life of carbon-bed modules will depend primarily on the duration of excavation operations.

Based on the calculated maximum loading rate, the useful life of the carbon-bed adsorbers for the four excavation enclosure APCD trains (each with 15,300 lb of carbon in three parallel N-12000 adsorbers) is about 435 operating hours. The previously discussed operating scenario for excavation calls for approximately 5 hours of excavation per day, or 30 hours per week. On this basis, a fresh charge of 15,300 lb of carbon would provide design-level THC adsorption for approximately 100 days, which implies that one spent GAC module should be changed out for a fresh carbon module every 33 days. Annual requirements for fresh carbon and for the disposal of spent carbon will be slightly more than 53,000 lb/year.

Ducting System, Blower, and Fan

A ducting system will be provided to exhaust ventilation air from the enclosure and to supply fresh makeup air. An induced-draft (ID) fan will be located at the end of the exhaust ducting to draw air from the enclosure and through the wet scrubber and GAC modules. A forced-draft (FD) blower at the end of the inlet ducting will push fresh air from outside the enclosure to points inside. Exhaust ducting must carry ventilation air containing dust from excavation operations. For medium- to high-density dust, a gas velocity of about 4,000 ft/min is recommended (Vatavuk 1990). At this velocity, a duct diameter of approximately 3 ft is required to accommodate 32,500 acfm of airflow. The diameter of the inlet ducting will also be specified as 3 ft to provide portability within the enclosure.

To increase the effectiveness of the air ventilation system, the air delivery system will be arranged to provide a continuous flow of fresh air past workers in high emission areas (e.g., the working face). The exhaust system will also be designed to capture emissions close to their source to minimize the amount of contaminants that escape into the general enclosure volume. This requires that exhaust and air supply ducting be extended from the enclosure wall to areas within the enclosure, as illustrated in Figure 4-4. On the supply side, air will be drawn from the atmosphere by a blower operating outside the enclosure and directed into the enclosure through fixed ducting (outside the enclosure) and movable ducting (inside the enclosure). The movable ducting inside the enclosure will be positioned near the high-emission working areas so that fresh air will flow past workers, preferably in the workers' breathing zone. The ducting inside the enclosure will be made of lightweight plastic or similar material that will allow the ducting to be flexible and easily moved for optimum positioning.

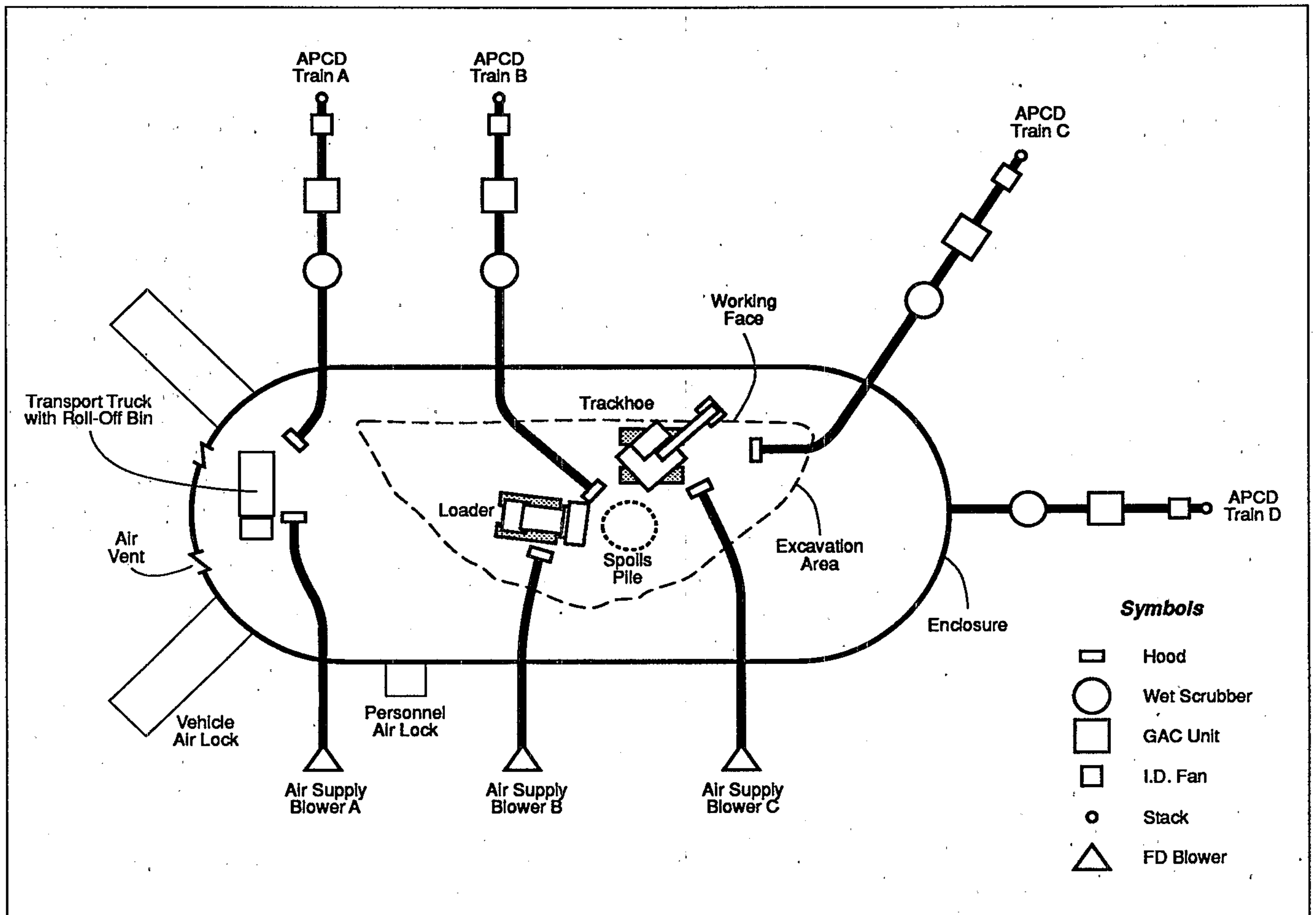

Figure 4-4. Air Ventilation System Schematic for Excavation Enclosure.

In a similar manner, exhaust ducting will extend within the enclosure to allow placement near major emission sources. This ducting will also be made of flexible and light-weight material to facilitate movement and placement near sources. A hood will be required at the end of each duct to maximize emissions capture. Based on ACGIH recommendations, a capture velocity of 500 ft/min at the face of the hood is specified for this operation (McDermott 1985). This corresponds to a square hood with dimensions of 8 ft by 8 ft for the ventilation flow rate of 32,500 acfm per train. A similar hood, equipped with baffles, is recommended for the air-supply ducting so that air velocities near workers are not high enough to cause significant dusting or unstable working conditions. The total length of exhaust ducting is estimated to be 300 ft for each train, which includes 150 ft of fixed, stainless steel ducting outside the enclosure (to connect the scrubber, GAC unit, and fan) and up to 150 ft of flexible ducting inside the enclosure. Air-supply ducting would also require up to 150 ft of flexible ducting inside the enclosure but only about 50 ft of fixed, carbon-steel ducting outside the enclosure to reach blowers.

The air ventilation system for the excavation enclosure calls for four trains of 32,500 acfm airflow each. It is recommended that three of these trains be positioned in the manner described in the preceding paragraph so that fresh air is supplied and contaminated air is exhausted locally near the excavation working face, the spoils pile, and the truck-staging area. The fourth system would exhaust air from the general enclosure volume and maintain a slight negative pressure within the enclosure to minimize/eliminate air leakage from inside the enclosure to the outside. This general arrangement is illustrated in Figure 4-4.

In the design of the FD blower, consideration must be given to the volume of air to be delivered and the pressure drop in the ducting to be overcome. The maximum volumetric flow rate for fresh air is specified as 35,000 acfm for each train. For a 3-ft-diameter duct, this flow rate corresponds to an air velocity of about 4950 ft/min. The pressure drop through the ducting can be estimated as follows (Vatavuk 1990):

$$\Delta P = 1.38 \times 10^{-7}(Q^{-0.5})(V^{2.5})$$

where ΔP = static pressure loss (inches water/100-ft duct)

Q = Volumetric flow rate of gas (acfm)

V = Gas velocity (ft/min)

For the air supply system,

$$\Delta P = 1.38 \times 10^{-7}(35{,}000^{-0.5})(4{,}950^{2.5})$$

$$= 1.3 \text{ in. water/100-ft duct}$$

The pressure drop across 200 ft of air supply ducting would be about 2.6 in. water. An additional pressure drop of 1 in. water is allowed for ducting fittings, elbows, baffles, and related obstructions, which brings the total estimated pressure drop in the air supply ducting to 3.6 in. water.

A motor specified for the blower must have sufficient horsepower to turn the blower at required speeds. Horsepower requirements for motors of this type are determined by the following equation:

$$BHP = 0.0001575 \times Q \times \Delta P/n$$

where BHP = motor brake horsepower (HP)

n = motor efficiency

A blower developing a static head of 3.6 in. of water and supplying 35,000 acfm of air will require approximately 40 HP when operating at a typical efficiency of 50%:

$$BHP = 0.0001575 \times 35{,}000 \times 3.6/0.5$$

$$= 40 \text{ HP}$$

For the exhaust ducting of each APCD train, a fan must be able to draw a maximum of 35,000 acfm from inside the enclosure and through the scrubber, GAC unit, and associated ducting. The maximum pressure drop in this train is estimated to be 20 in. of water, based on specifications for individual equipment pieces and the trial excavation experience. Available fan curves for an ID radial-blade centrifugal fan indicate that a fan with a wheel diameter of about 60 in. will be required (Vatavuk, 1990).

The horsepower requirement for a motor of this type is calculated in the same manner as discussed for the blower. For a fan drawing 35,000 acfm of air and overcoming 20 in. of water pressure drop, a motor of approximately 220 HP will be required.

Section 5
Economic Analysis

Introduction

The objective of this economic analysis is to estimate the cost of a commercial-size site remediation effort using the excavation and fugitive emission control systems evaluated during the McColl trial excavation. This evaluation illustrates how these systems could be applied to a site where excavation or handling of wastes would result in the release of significant fugitive emissions that could pose a potential health risk to nearby communities. In the example scenario, costs are estimated for full remediation of the 12 sumps at the McColl Superfund site in Fullerton, California.

Costs have been estimated for the full excavation of all contaminated material at the McColl site, which consists of an estimated 72,600 yd^3 of waste (consisting of mud, tar, and char, as discussed in Section 3), 2000 yd^3 of designated material, and 22,500 yd^3 of questionable material (CH2M-HILL 1989). Designated materials are soils directly adjacent to the wastes that fail one or more of the Federal or State hazardous waste criteria, based on an analysis of soil borings. Questionable materials are soils exceeding the background chemical concentration levels, but not qualifying as designated. An additional 22,500 yd^3 of clean soil forming sump covers also must be excavated. This makes a total of 121,200 yd^3 of in-place material to be excavated during full remediation.

The scope of the remediation activities examined in this analysis includes excavation of waste and associated material under a rigid-frame enclosure, backfilling of the excavated sump under a second enclosure, erecting a third enclosure on the next sump to be excavated, and transport of the waste material to an onsite storage facility consisting of a stationary enclosure erected over a concrete pad. The fugitive emission control systems include vapor-suppressing foam application units, air ventilation systems for each enclosure, the APCD used to reduce emissions of SO_2 and THC in the ventilation air to acceptable levels, an APCD emissions monitoring network, and a perimeter ambient air monitoring network.

This scope does not include the final waste treatment and disposal systems or pretreatment systems. Such systems as offsite disposal in a RCRA landfill, onsite thermal treatment (e.g., incineration), or offsite thermal treatment, among others, have been considered for this site; however, are not included in the scope of this economic analysis. The costs of such systems, as well as the costs of integrating such systems with the excavation and storage approaches considered, would have to be added to the costs developed in this analysis to arrive at an estimate for full remediation and disposal.

Depending on the final waste treatment option selected, the specification of one week of storage capacity may or may not be appropriate. For onsite treatment options such as incineration, the one-week storage capacity would be desirable to allow treatment operations to continue if excavation operations were temporarily slowed or halted. For offsite treatment options, this capacity probably would not be needed.

Conceptual designs have been developed for the excavation/backfill/storage operations, air ventilation systems, and air pollution control systems, as discussed in Section 4. Based on these designs, costs for major equipment items such as the enclosures, foam delivery trailers, SO_2 scrubbers, and GAC units were provided by their respective manufacturers/suppliers. Two costing options were evaluated for acquisition of equipment for excavation, backfilling, storage, and enclosure movement: 1) leasing of the equipment (costs based on literature data) and 2) purchase of equipment (costs provided by equipment suppliers). Cost estimates for minor equipment were based on literature cost data. All costs have been adjusted to a July 1990 basis and to an Orange County, California, location by using historical cost indices. This design and costing methodology is consistent with an order-of-magnitude estimate as defined by the American Association of Cost Engineers, which has an accuracy of plus 50 to minus 30%.

Results of the economic analysis and apparent trends are as follows:

- The estimated costs of waste excavation and storage at the McColl site range from $69.2 million (for the purchase option) to $74.3 million (for the lease option), or from $593/ton to $637/ton. The marginal costs for fugitive emission control are nearly twice the costs of excavation without such control.
- These costs reflect a remediation duration of 6.4 years, based on a specified final treatment processing rate of 90 tons/day of contaminated material. Excavation rate calculations indicate that excavation operations are not the rate-limiting step under this

scenario but that remediation activities could be accomplished in less time, which would reduce overall costs.

- Specification of the SO_2 concentration limit within the enclosure dictates the size and cost of the air ventilation system and APCD equipment.

Basis for Process Design, Sizing, and Costing

The basis for system process designs, equipment sizing, and cost estimates are provided in the following subsections, arranged according to the 12 cost categories specified by the SITE program. As discussed earlier, these costs encompass the waste excavation, backfilling, storage, and fugitive emission control systems, but they do not include systems for final treatment of excavated wastes. Detailed discussions of design analysis for excavation/backfill/storage operations, air ventilation systems, and air pollution control systems are presented in Section 4. Relevant design information that impacts cost estimates is summarized in the following subsections.

Site Preparation Costs

Based on the trial excavation experience, the enclosures will be placed on approximately level surfaces to ensure a good seal at the bottom; this minimizes outleakage of contaminated air during excavation/backfill operations. Although the supplier, Sprung Instant Structures, Inc., has indicated that legs can be added to accommodate slopes, level surfaces are preferred from the standpoint of worker safety and equipment performance. Because the McColl site terrain is characterized as gently rolling, a limited amount of clearing and grading will be required to provide level surfaces above and around the 12 sumps. In addition, connections must be installed for electric power, water, and natural gas from a point near the entrance of the site to the three major sump areas (i.e., Upper Ramparts, Lower Ramparts, and Los Coyotes) as required for operation of the APCD systems. Costs of these site preparation activities have been extrapolated to full scale from the costs incurred during the trial excavation (EPA 1990). Costs have also been added for providing a new equipment decontamination station, a personnel decontamination trailer, an office trailer, and a security check station. These costs are based on estimates from equipment suppliers.

Permitting and Regulatory Costs

Because McColl is a Superfund site, it is assumed that no Federal or State permits will be required. Nevertheless, it is recommended that project officials coordinate their activities closely with Federal OSHA, State OSHA, and other State and local regulatory groups.

Equipment Costs

Equipment required for this project can be divided into five general areas: excavation, backfill, storage, air ventilation system, and foam application. For excavation operations, a Caterpillar 245, or equivalent, track-mounted hydraulic backhoe with a 14.5-ft stick and a 3-yd3 bucket is expected to be used. This backhoe would have a 31-ft maximum depth of cut for an 8-ft level bottom and a maximum reach of 46 ft at ground level (Caterpillar Tractor 1985).

In addition to the track-mounted backhoe, other major equipment pieces required for excavation operations are a 6-yd^3 track-mounted, front-end loader and two off-highway trucks capable of hauling 40-yd^3 rolloff bins. Backfilling of clean soil is accomplished with a 5-yd^3 wheel-mounted loader operating at the borrow area and a 5-yd^3 track-mounted loader, a 10-ton tandem roller, and two off-highway 50-ton capacity dump trucks operating inside the enclosure. A total of 24 rolloff bins are included in the storage equipment costs (EPA 1990). Other supporting equipment required for excavation and backfill operations include a fuel and lube truck, a mechanics and welding truck, a water wagon, a crew truck, a pickup truck, a forklift, and compressors to provide air for the Level B supplied-air respirators. Costs for this supporting equipment are included in the excavation equipment category. Information regarding estimated lease and purchase costs for these equipment items is summarized in Table 5-1.

The air ventilation system consists of several equipment components. A blower provides fresh air to selected areas inside the enclosure to minimize worker exposure to air contaminants and to promote air mixing within the enclosure. A packed-bed scrubber operating on exhaust ventilation air from the enclosure is designed to remove 95% of the incoming SO_2 by reaction with sodium hydroxide. A small gas burner is specified in the ducting between the scrubber and GAC unit to raise the temperature of the air stream by 20°F to avoid potential moisture condensation on the GAC. After the gas burner, three modular GAC units operating in parallel are used to reduce total hydrocarbon emissions by 90% before the air is vented to the atmosphere. Ventilation air is drawn from the enclosure and through the scrubber and GAC units by an induced-draft fan capable of overcoming an estimated 20 in. of water pressure drop. A summary of specifications and costs for the APCD equipment is provided in Table 5-2.

The largest sodium-hydroxide-based scrubber module available from Interel is rated at 35,000 acfm capacity.* Thus, four such modules will be required for the excavation enclosure, whereas only one module would be required for the backfill and storage enclosures. Although the use of four APCD trains for the excavation enclosure complicates operations from the standpoint of the operation and movement of the systems, the smaller size is desirable to maintain portability around the

*Personal communication from P. Briscoe, Interel Corporation, to E. Aul, Edward Aul and Associates, Inc., July 17, 1990.

Table 5-1. Lease and Purchase Costs for Excavation, Backfill, and Storage Equipment and Enclosure Movement[a]

Quantity	Equipment	Lease Cost[b], $/month	Purchase Cost[c], $
	Excavation operations		
1	Track-mounted backhoe, 3-yd^3	23,600	571,300
1	Track-mounted loader, 3-yd^3	10,500	301,400
2	Off-highway trucks, 40-yd^3	26,100	818,600
1	Fuel and lube truck	3,900	170,400
1	Mechanics and welding truck	3,900	170,400
1	Water wagon	3,900	170,400
1	Crew truck	1,700	19,100
1	Pickup truck	560	16,900
1	Forklift, 10-ton	3,600	85,200
1	Air compressor	1,010	32,300
	Backfill operations		
1	Track-mounted loader, 5-yd^3	10,500	301,400
1	Wheel-mounted loader, 5-yd^3	10,500	230,200
1	Tandem roller, 10-ton	2,100	86,500
2	Off-highway trucks, 40-yd^3	26,100	818,600
	Storage operations		
24	Rolloff bins, 40-yd^3	280	210,200
	Enclosure movement		
1	Articulated boom lift, 500-lb	11,400	82,200
1	Truck-mounted crane, 10-ton	7,500	192,600
2	Rolling tower scaffolding, 20-ft	600	2,600

[a] All costs are adjusted to July 1990 and Orange County, California, site.
[b] Source: Means (1990).
[c] Sources: Personal communications from E. Hooks, Caterpillar - Gregory Poll Equipment Co., August 23, 1991; W. Wilkerson, D&J Trucks, Inc. August 23, 1991; B. Bergstrom, Hyster Co., June 19, 1991; and M. Nelson, Prime Equipment Co., June 12, 1991, to E. Aul, Edward Aul & Associates, Inc.

site as the enclosures are moved. In addition to the six operating APCD trains, a seventh train will be purchased as an onsite backup unit.

The largest GAC modules available from TIGG are rated at 12,000 acfm.* Three such units will be required to operate in parallel for each scrubber to match the scrubber flow rates. A fourth module will be added to allow change-out of spent carbon without shutting down the entire train.

A trailer-mounted foam application system supplied by Boots & Coots will be used to apply vapor-suppressing foam to exposed static waste surfaces in the three enclosures. This system includes a water tank, a stabilizer tank, a foam tank, a proportioning system, and a diesel-powered booster pump sized to provide up to 500 ft^2 of double-strength stabilized foam per minute. A nitrogen cap system is also incorporated to prevent deterioration of the stabilizer by air or moisture during operation and recharging. A separate foam trailer will be required for each of the enclosures, plus a spare trailer as onsite backup. As in the trial excavation, the trailers will be operated outside the enclosure to supply foam via hoses for application to waste surfaces inside the enclosure. The cost of purchasing each trailer is approximately $35,000.** Another $5,000 per unit has been added for hosing and nozzles.

A final category of equipment is the equipment required to erect and then teardown the rigid-frame enclosures to be positioned over sumps during excavation and backfilling operations. Based on the trial excavation experience and discussions with representatives of Sprung Instant Structures, this equipment will include two 20-ft rolling scaffolding towers, a gas-powered lift with an articulated boon capable of reaching to 60 ft, and a 10-ton truck-mounted crane.

Startup and Fixed Costs

The major cost items included in this category are the three excavation and backfill enclosures, the APCD monitoring network, and the perimeter monitoring network. The excavation and backfill enclosures are each 120 ft wide by 300 ft long by 60 ft high. These width and length requirements are based on detailed excavation planning for the 12 sumps at McColl. As in the trial excavation, the enclosure structures consist of aluminum support members covered by a PVC skin. Each enclosure includes two 60-ft-long air lock tunnels that will allow vehicle entry and exit with a minimum of outleakage of air from inside the enclosure. Two additional smaller air locks are provided for personnel entry and exit.

*Personal communication from J. Sherbondy, TIGG Corporation, to E. Aul, Edward Aul and Associates, Inc., March 22, 1991.

**Personal communication from B. Smith, Boots & Coots, to E. Aul, Edward Aul and Associates, Inc., April 2, 1991.

Table 5-2. Air Ventilation System Specifications and Costs

Component/Specifications	Estimated Cost[a]
Air supply blower 35,000-cfm throughput 4 inches water pressure drop 40-hp motor	$18,000
Air supply ducting 3-ft diameter 50 ft of carbon steel (exterior) 150 ft of FRP with hood (interior)	$24,700
SO_2 scrubber 35,000-cfm throughput 2 to 5 inches water pressure drop 10-ft packed bed 300-gpm recirculation pump Automatic controls for pH and sump level Blowdown pump Reagent metering pump Mist eliminator HDPE construction	$120,000
Induced-draft fan 35,000-cfm throughput 20 inches water suction pressure 220-hp motor	$20,900
Reagent storage tank 550-gallon capacity FRP construction	$1,800
Blowdown wastewater storage tank pump 2000-gallon capacity FRP construction 220-gpm transfer pump	$6,700
Duct burner 20°F temperature rise 1 million Btu/h heat input	$5,000
GAC adsorber modules 3 operating modules, 1 spare 12,000-cfm throughput each 5 to 8 inches water pressure drop 5100-lb carbon each 0.8-second gas residence time	$80,000
Air exhaust ducting 3-ft diameter 150 ft of 316 SS (exterior) 150 ft of FRP with hood (interior)	$136,600
TOTAL EQUIPMENT COSTS	$413,700

[a] Costs are for equipment only and do not include freight and installation costs.

The fourth enclosure for storage is smaller; it measures 120 ft wide by 240 ft long by 57 ft high. Because of the heavy vehicular traffic and potential requirement to move rolloff bins inside, the enclosure is erected over a 6-in. pad of 3500-psi reinforced concrete. Installed costs for the pad are estimated to be $6.24/ft² (Means 1990). The estimated costs for the three excavation and backfill enclosures are $1,242,500 each, as supplied by Sprung Instant Structures; costs for the storage enclosure are estimated to be $510,250.* Delivery costs to the site would be negligible because McColl is only 40 miles from Sprung's Fontana, California, operations office. Startup costs also include costs for four closed-circuit television systems to monitor operations within the enclosures, as was done during the trial excavation.

A perimeter monitoring network is called for in the McColl Community Safety/Contingency Response Plan for continuous monitoring of SO_2 and THC in the ambient air around the site during remediation. The network consists of seven stations on the perimeter of the site and three stations at interior locations, each equipped with an SO_2 analyzer, a THC analyzer, calibration equipment, and strip chart recorders. Each of

*Personal communication from C. Spitzka, Sprung Instant Structures, Inc., to E. Aul, Edward Aul and Associates, Inc., July 17, 1990.

these stations will be housed in a climate-controlled 8 ft by 24 ft office trailer. A meteorological station is also specified to measure and record data for windspeed, wind direction, and temperature. Four data acquisition systems are required for data storage and manipulation. Total costs for the system, including installation, are estimated to be $864,500 (Radian 1983).

A similar network will be operated to monitor and record the emissions reduction performance and outlet emissions for the six APCD trains operating on the site. For each train, an SO_2 analyzer will determine SO_2 concentrations in the ventilation air entering the scrubber and exiting the stack; a THC analyzer will determine THC concentrations entering the GAC units and exiting the stack. System support hardware and housing analogous to that for the perimeter network will be required for the APCD network. Both networks will be connected to a central control station via buried communication cables. Total installed costs for the APCD network are estimated to be $471,400 (Radian 1983).

Labor Costs

As discussed in Section 4, remediation activities would be conducted on a schedule of 6 days/wk and 50 wk/yr. Operating labor would include equipment operators for the backhoe, track-mounted loader, two wheel-mounted loaders, tandem roller, four trucks, and a fuel/lube truck. Five other laborers and a mechanic would be required for excavation, backfill, and storage operations. Tear-down, movement, and re-erection of the excavation and backfill enclosures will require a team of 12 laborers, a crane operator, and a Sprung technical consultant for approximately 30 days per move. In addition, project management personnel would include a site manager, two operations supervisors, and a safety officer.

One team of two laborers would be required to operate the excavation foam application trailer; a second team of two laborers would operate the backfill and storage trailers because of their more intermittent operation. A part-time supervisor would also be required to oversee the foam trailer operations and maintenance.

Combined labor requirements for the perimeter and APCD monitoring networks consist of three technicians, a data analyst, a quality assurance technician, a part-time meteorologist, and a part-time supervisor.

Supplies and Consumables

A major consumable for excavation, backfill, and storage operations would be Level B safety gear. Costs for Level B gear for 15 persons are estimated to be $180/person per day, based on the trial excavation experience (EPA 1990). Backfill clay (i.e., Type A soil) for Sump R-2 is expected to have a delivered cost of around $4/ton (Means 1990).

A second major consumable for these operations will be vapor-suppressing foam. Based on experience from the trial excavation and discussions with the foam trailer supplier, 5 gal of foamer and 10 gal of stabilizer are expected to be required to cover 1200 ft^2 of static waste surface with a foam layer of 3/4- to 1-in. thickness.* It is assumed that the foam will have to be reapplied every 3 days to undisturbed surfaces so as to maintain an overall average vapor-suppression effectiveness of 70%. The costs for 3M-brand foamer and stabilizer solutions are approximately $21/gal and $42/gal, respectively (3M Company 1990).

The air ventilation system will require makeup sodium hydroxide, which is available as a 50 weight percent solution in water at a cost of around $0.20/lb,** and replacement activated carbon at a cost of around $1.00/lb.*** As discussed in Section 4, it was assumed that the carbon is allowed to reach 75% of equilibrium loading before being replaced with new virgin carbon.

If excavation and backfill equipment pieces are purchased, it will be necessary to provide fuel and lubricants on a regular basis for this machinery. Total costs for these items are based on a diesel fuel price of $1.30/gal and typical hourly consumption rates for equipment operated under expected conditions (Caterpillar 1985). Fuel and lubricant costs are not included under the lease option because these costs are typically included in the monthly lease rate.

Utilities Costs

The only significant utilities required for waste excavation and storage are associated with the air ventilation system. These are electricity for the blower, an induced-draft fan, a scrubber circulation pump, and natural gas to be burned in the induct burner located between the scrubber and GAC unit. Unit costs of $0.10 per kilowatt-hour for electricity and $4.00 per million Btu for natural gas are used in the analysis.

Effluent Treatment and Disposal Costs

A wastewater effluent stream will be generated by the SO_2 scrubbers because of the need for periodic purging of collected sulfur and dust. This wastewater will be disposed of as a hazardous waste, as the ventilation air may contain hazardous constituents. Calculations indicate that SO_2 generation rates and the desire to maintain outlet SO_2 gas concentrations at or below 2 ppm will be controlling factors in determining the wastewater purge frequency and amount. These factors dictate that the blowdown rate for each excavation APCD train will be near 280 gal/operating day; blowdown rates for the backfill and storage APCD trains will be lower because of lower SO_2 generation rates. At these blowdown rates, the solids content of the wastewater will be near or below 3 weight percent, which is acceptable from the standpoints of pumpability and disposal.

*Personal communication from B. Smith, Boots & Coots, to E. Aul, Edward Aul and Associates, Inc., April 8, 1991.

**Price quotation from Holchem Inc., Orange, CA, June 8, 1990.

***Personal communication from J. Sherbondy, TIGG Corporation, to E. Aul, Edward Aul & Associates, Inc., March 22, 1991.

It is assumed that wastewater will be collected from individual APCD trains and held in a central storage tank on site. Wastewater will be picked up at the site on a weekly basis and transported to a RCRA-certified disposal facility. In 1990, costs per shipment for this service were $0.55/gal plus $350 for transportation and $200 for analytical services, which are included in the Analytical Costs category.*

Residual and Waste Shipping, Handling, and Treatment Costs

Disposal costs will also be incurred for spent activated carbon. Like scrubber wastewater, spent carbon must be disposed of at a RCRA-permitted facility. Because of land-ban restrictions, it is expected that the spent carbon will be disposed of by incineration at a cost of about $1.20/lb (Ensco 1991). Analytical costs are estimated at $500/sample and are included in the Analytical Costs category.

Analytical Costs

Analytical costs for wastewater and spent carbon were discussed previously. In addition, wastewater analysis costs of $200/sample have been allowed for two water- runoff events per year. Finally, general analytical costs of $500/day are allowed for waste, soil, and groundwater samples in the absence of a site sampling and analysis plan.

Facility Modification, Repair, and Replacement Costs

Equipment maintenance costs have been estimated for the air ventilation systems and foam-application trailers. In both cases, annual costs for maintenance labor and materials were estimated to be 4% of the purchase cost of operating equipment (spare units excluded). No maintenance costs are included for excavation, backfill, storage, and enclosure movement equipment under the lease option, as these costs are reflected in their lease rates. Under the purchase option, annual maintenance costs are estimated as 4% of purchase costs.

Decontamination/Demobilization Costs

Based on the trial excavation experience, decontamination costs are estimated to be approximately $1700 per major equipment piece (EPA 1990). It is assumed that equipment will be decontaminated an average of 12 times during the remediation effort for maintenance or change-out. In addition, costs to recontour the site (after excavation/backfill) to prevent water accumulation and erosion are included at a rate of $4.50/yd^3 yard (Radian 1983). It is assumed that a soil volume equivalent to 20% of the total contaminated site volume will require recontouring. Demobilization costs are included in equipment mobilization costs.

Results of Economic Analysis

Itemized costs estimated for waste excavation, waste storage, and fugitive emission controls for the McColl Superfund site are summarized in Table 5-3. The quantity of contaminated material to be removed at this site totals 97,100 yd^3 or 116,700 tons. As shown in the table, total estimated costs for the purchase equipment option, including project contingency and management, are $69.2 million, which translates to a cost of $593/ton removed. The purchase equipment option has lower overall estimated costs than the lease equipment option – $74.3 million, or $637/ton. The higher costs of fuels/lubricants and maintenance under the purchase option are more than offset by the lower costs for equipment over the projected 76-mo remediation period. Based on these factors alone, the break-even time period for the lease option and purchase option is slightly over 3 years. The largest components of the estimated purchase option costs are labor (22%), supplies/ consumables (21%), equipment (12%), and utilities (11%). All other categories account for less than 10% of overall costs.

The impact of fugitive emission controls on overall costs can be estimated by adding the costs for site preparation (without utility hookups), costs for site decontamination/demobilization, and those costs (i.e., equipment, labor, supplies/consumables, analytical, and maintenance) specifically associated with waste excavation, backfill, and storage. For the purchase option, costs for these items total approximately $23 million, based on the information in Table 5-3. Thus, the addition of fugitive emission control systems raises overall costs by nearly $46 million, or a factor of 2.0.

Most of the cost items in the Table 5-3 are directly influenced by the amount of time allowed for remediation. Setting the overall excavation rate at 90 tons/day of contaminated material for feed to final processing results in a projection of 6.4 years for complete remediation of the site. Calculations of excavation rates based on equipment cycle times and the assumption of 25% overall work efficiency due to Level B protective equipment indicate that excavation and backfill operations are not limiting in this case (see Section 4 for details). The overall time required for remediation, and hence costs, would be reduced if the final treatment processing rate were increased.

The specification of the SO_2 limit within the enclosures dictates the size and cost of air ventilation systems. At the 50-ppm SO_2 limit, equipment costs for the ventilation systems are estimated to be $3.9 million, or 5.6% of total costs. Costs for equipment of this type often follow the "0.6 power rule" as throughput or capacity is increased (i.e., costs increase in proportion to the ratio of capacities raised to the 0.6 power). Using this relationship, ventilation system costs are projected to increase to approximately $10 million for an SO_2 limit of 10 ppm and to $27 million for an SO_2 limit at the 2 ppm PEL level. At the latter limit, nearly all the costs for Level B safety equipment ($5.1 million) could be deleted. The increase in size and/or number of APCD trains, however, would significantly

*Personal communication from S. Browning, Asbury Environmental Services, to E. Aul, Edward Aul and Associates, Inc., July 25, 1990.

Table 5-3. Estimated Costs for Waste Excavation, Waste Storage, and Fugitive Emission Control.[a]

Item		Lease Option, $	Purchase Option, $
1. Site Preparation	Clearing/grading	58,600	58,600
	Electric/water/gas hookups[b]	293,900	293,900
	Equipment decon. station	22,800	22,800
	Personnel decon. trailer	70,000	70,000
	Office/security trailers	21,100	21,100
	Subtotal	466,400	466,400
2. Permitting and Regulatory		0	0
3. Equipment	Excavation equipment	5,984,000	2,356,000
	Backfill equipment	3,735,200	1,436,600
	Storage equipment	510,700	210,200
	Foam trailers[b]	160,000	160,000
	Air ventilation system[b]	3,851,500	3,851,500
	Enclosure erection/tear-down[b]	747,500	277,400
	Subtotal	14,988,900	8,291,700
4. Start-up/Fixed Costs	Three Excavation/backfill enclosures[b]	1,878,100	1,878,100
	One Storage enclosure/pad[b]	686,800	686,800
	APCD monitoring network[b]	508,600	508,600
	Perimeter monitoring network[b]	864,500	864,500
	Subtotal	3,938,000	3,938,000
5. Labor Costs	Excavation	3,852,400	3,852,400
	Backfill	1,968,600	1,968,600
	Storage	1,051,600	1,051,600
	Enclosures[b]	412,500	412,500
	Foam application[b]	2,278,000	2,278,000
	Air ventilation system[b]	1,461,100	1,461,100
	APCD monitoring network[b]	2,540,800	2,540,800
	Perimeter monitoring network[b]	1,579,800	1,579,800
	Subtotal	15,144,800	15,144,800
6. Supplies and Consumables	Safety equipment	5,154,300	5,154,300
	Fuel/lubricants	0	1,249,300
	Backfill clay	38,000	38,000
	Foam chemicals[b]	2,925,200	2,925,200
	Sodium hydroxide[b]	751,400	751,400
	Activated carbon[b]	2,699,900	2,699,900
	APCD monitoring network[b]	348,000	348,000
	Perimeter monitoring network[b]	1,112,400	1,112,400
	Subtotal	13,029,200	14,278,500
7. Utilities	Air ventilation system[b]	7,480,800	7,480,800
	APCD monitoring network[b]	122,300	122,300
	Perimeter monitoring network[b]	147,800	147,800
	Subtotal	7,750,900	7,750,900
8. Effluent Treatment/Disposal	Scrubber wastewater[b]	3,801,000	3,801,000
9. Residual/Waste Disposal	Spent activated carbon[b]	2,626,900	2,626,900
10. Analytical Costs	Wastewater[b]	63,700	63,700
	Spent carbon[b]	88,200	88,200
	Runoff water analyses	5,200	5,200
	General site samples	954,500	954,500
	Subtotal	1,111,600	1,111,600
11. Equipment Maintenance	Foam application system[b]	26,800	26,800
	Air ventilation system[b]	841,100	841,100
	Excavation equipment	0	600,300
	Backfill equipment	0	307,400
	Storage equipment	0	53,500
	Enclosures[b]	653,500	724,200
	Subtotal	1,521,400	2,553,300
12. Site Decontam./Demob.	Decontaminate field equipment	160,000	160,000
	Re-contour site	85,800	85,800
	Subtotal	245,800	245,800
13. Contingency (10%)		6,462,500	6,020,900
14. Project Management (5%)		3,231,200	3,010,400
TOTAL ESTIMATED COSTS		**74,318,600**	**69,240,200**

[a] Quantity of waste excavated = 116,700 tons; Volume of waste excavated = 97,100 cubic yards.
[b] A marginal cost item associated with fugitve emission control.

complicate the logistics of moving the enclosures and associated ventilation equipment around the site.

The operating costs associated with the use of activated carbon for THC control are estimated as $2.7 million for replacement virgin carbon and $2.6 million for spent carbon disposal. Given these significant costs, it may prove less expensive overall to regenerate the spent carbon thermally on site. Such a system would have higher initial equipment costs but lower operating costs. Other emissions associated with the regeneration process, such as nitrogen oxides and particulates, should also be evaluated, however. As an alternative to activated carbon systems for THC control, some sites may also consider thermal or catalytic incineration.

Foam chemicals also represent a significant fraction of the costs of supplies/consumables. In the full remediation plan, foam usage has been reduced over the trial excavation experience by specifying that only stabilized foam be used on static waste areas and that temporary foam not be used on dynamic areas. Officials of 3M Company have indicated that improved foam performance might be achieved by further experimentation with application techniques and foam formulations. For the final remediation plan, other vapor-suppressing systems may also merit consideration, such as a lime slurry that dries on contact or the "shotcrete" system used in mining operations for wall stability and dust control. Any increase in the degree of vapor suppression will directly reduce the size and cost of required ventilation systems.

In the full remediation plan, it has been assumed that the excavation and backfill enclosures will have to be torn down and reerected each time the enclosures are moved. For smaller enclosures, Sprung Instant Structure officials have indicated that structures can be moved via wheels or a crane without tearing them down. The feasibility of moving larger structures in this manner will be determined during the fall of 1991 at a site in the Southwest, where a similar large structure will be used for remediation of a hazardous waste site.*

Several site-specific factors that have influenced the estimation of costs for excavation and fugitive emission controls for the McColl site should be considered when extrapolating designs and costs to other sites. First, the depth, width, and length of contaminated sumps largely determine 1) the size of the enclosure required for excavation, 2) the number of enclosure movements, and 3) the amount of material that must be reexcavated. For other sites, a detailed excavation plan should be developed that takes these factors into consideration.

Second, SO_2 emissions from the McColl waste are higher than those for hydrocarbon or other species and, combined with the toxicity characteristics of SO_2, determine the ventilation rate required for the enclosure to protect worker health. If SO_2 emissions are not significant, emissions of specific hydrocarbon species (e.g., benzene) would dictate the size of the ventilation equipment and the associated capital and operating costs.

Finally, because this site is located in Southern California, no provisions have been added for freeze protection of equipment such as the scrubber and foam application systems. In colder climates, such provisions will add to the cost of equipment and to operational complexity.

Conclusions and Recommendations

Conclusions

The design and economic analyses performed for the McColl Superfund site indicate that excavation of waste under an enclosure for control of fugitive emissions is technically feasible and is expected to cost around $69 million (1990), or $593/ton. The addition of the enclosures and other fugitive emission control systems increases the cost of excavation, backfill, and storage by an estimated factor of 2.0.

Total remediation costs are most sensitive to the overall processing rate of the final treatment system. This rate effectively determines the time required in the field for remediation and, hence, the costs of remediation. Excavation and backfill costs are also sensitive to the geology of the contamination, especially the depth, length, and width of areas to be remediated. Ventilation/APCD system costs are sensitive to the emission limits set for hazardous species within the enclosure.

Recommendations

It is recommended that EPA use the excavation rate as the limiting factor for remediation time instead of the final processing rate when investigating the costs for waste excavation and storage. Also, the feasibility and costs of using thermal regeneration of activated carbon instead of replacement/disposal should be investigated as a means of reducing operating costs for THC control. In the same vein, the use of thermal or catalytic incineration should be evaluated for THC control as an alternative to activated carbon adsorption. Finally, research should be conducted on alternative foam formulations and on the use of lime slurry and shotcrete systems for the suppression of vapors from acidic refinery sludge wastes such as those present at the McColl site.

*Personal communication from J. Fisher, Sprung Instant Structures, Inc., to E. Aul, Edward Aul and Associates, Inc., April 25, 1991.

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Appendix A
Description of Technologies

Several measures were implemented during excavation operations to ensure that these operations did not create a public health impact. These measures were aimed at controlling air emission releases from the operations, which represented the only potential source of impact expected. The measures implemented for this purpose were as follows:

- Use of enclosure structure
- SO_2 scrubber
- Activated carbon unit
- Use of vapor-suppressing foam

Waste processing technologies planned during this program consisted of size reduction by crushing the char and mud wastes and tar solidification by using cement and fly ash mixtures.

Enclosure and Exhaust Air Control System

Excavation Enclosure

A rigid-frame, PVC-covered enclosure structure was erected over part of the L-4 sump and adjoining land prior to the start of excavation. Before its erection, the site was graded to provide a smooth, level area. The enclosure, supplied by Sprung Instant Structures and shown in Figures A-1 and A-2, was nominally 60 ft wide by 157 ft long and 26 ft high at the center. The white opaque PVC cover was 26 mils thick and impervious to gaseous emissions. The lower edge was covered by 12 to 18 in. of soil along the ground level to prevent air leakage. Translucent panels located along the roof peak allowed light to enter. Personnel entry was through an airlock door, which minimized fugitive emissions during entry. Equipment was moved inside the enclosure through a sliding door that was 14 ft high and 9 ft 5 in. wide.

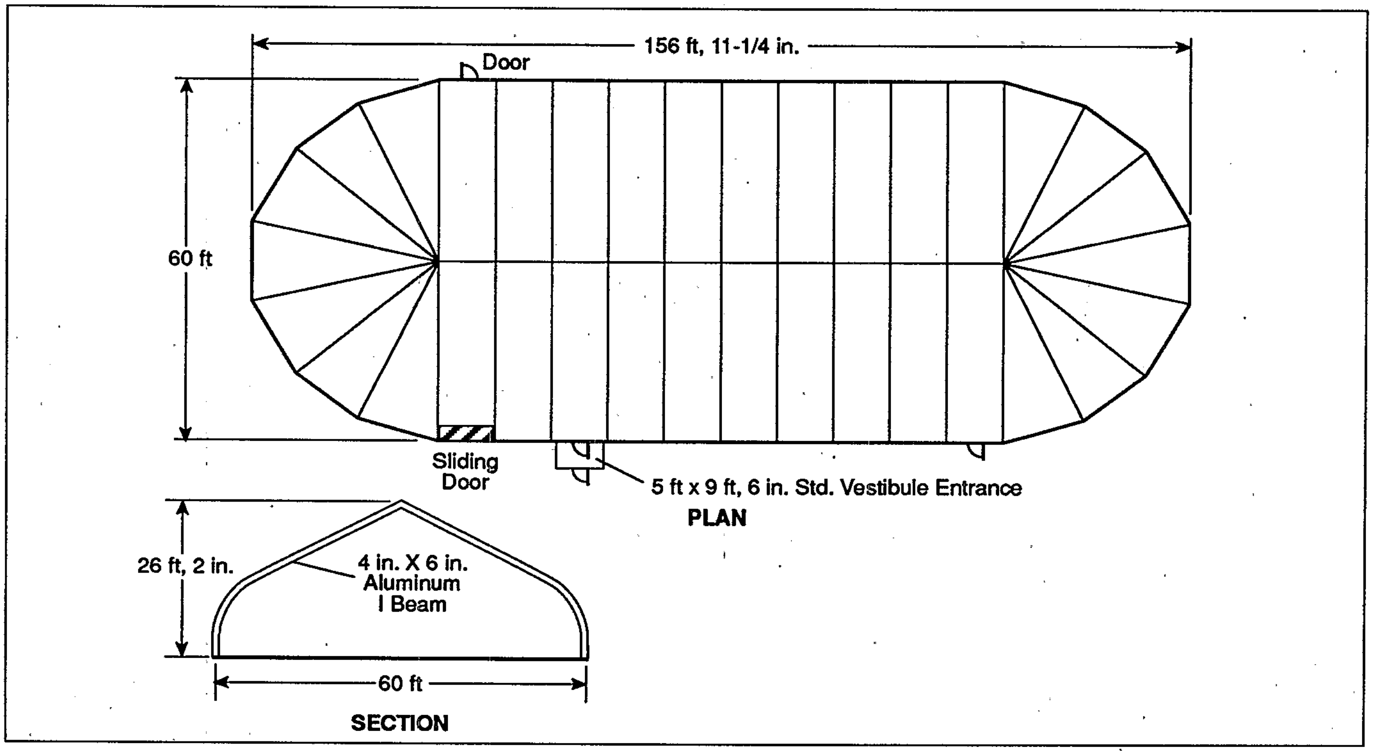
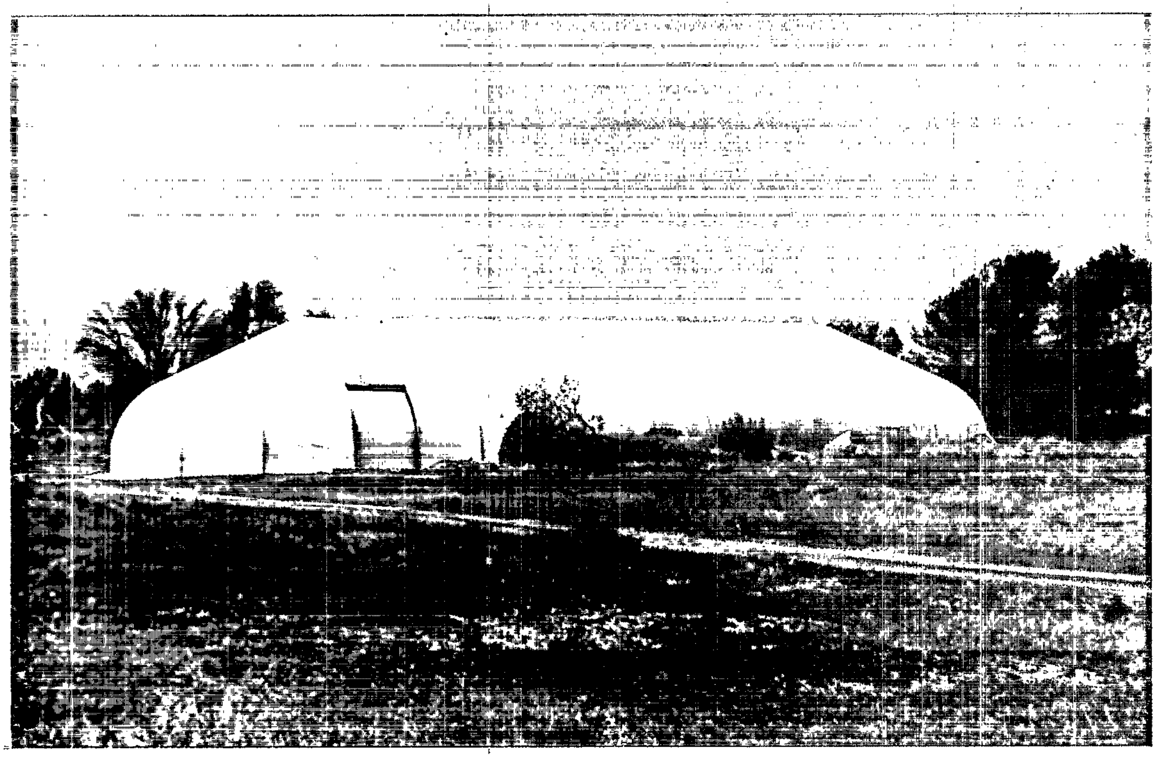
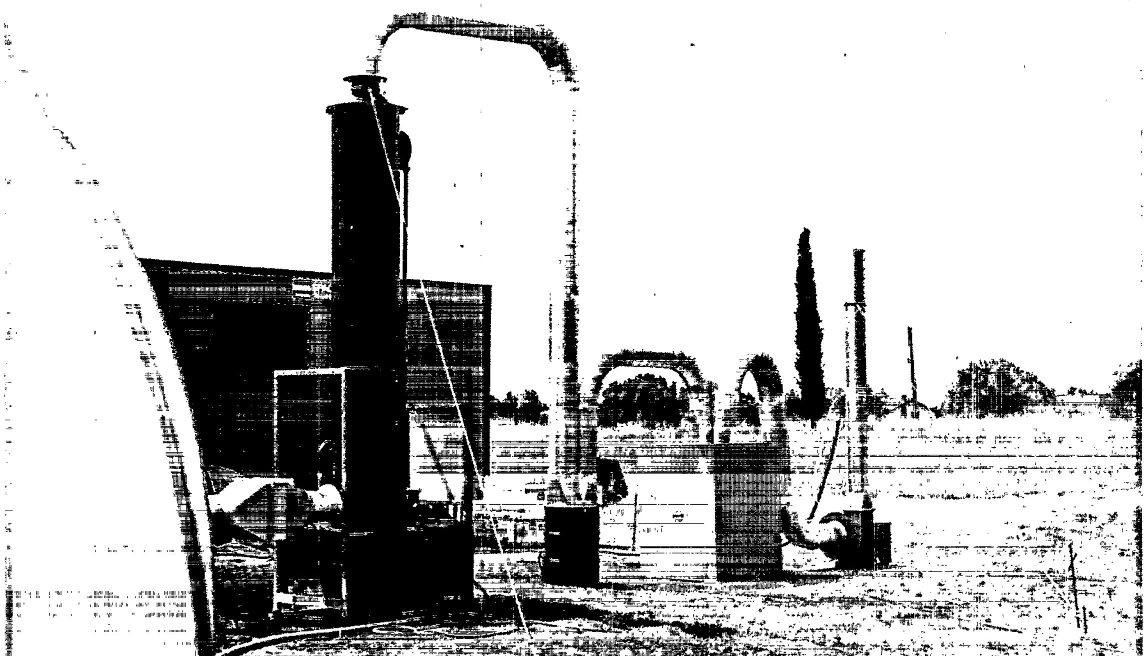


Figure A-1. Enclosure Plan and Section.



View from east side.



View from west side showing air emission control system and monitoring trailer.

Figure A-2. ***Excavation Site Enclosure.***

The volume of the enclosure was approximately 192,000 ft^3, and air was drawn through the building at a rate of approximately 1000 ft^3/min. This air entered the building through five small, adjustable, slot-type air vents and was exhausted through three dampered openings along the west side of the building. This exhaust system provided an air turnover rate of about 7 air changes per day and maintained a slight negative pressure of about 0.005 inch of water inside the enclosure. This ventilation air rate was based on maintaining the SO_2 level in the enclosure below 100 ppm. This was in turn based on an estimated SO_2 release from the exposed waste and a 95% reduction in these releases by use of foam suppressants.

The enclosure proved to be very effective in preventing the escape of any air emissions and was quite satisfactory even though it created a confined work space in which temperatures were approximately 20°F above the outdoor temperature.

Air Emission Control System

The enclosure ventilation air was routed through an emission control system consisting of a wet scrubber and an activated carbon bed in series, followed by a fan and vent stack, as shown in Figures A-3 and A-4. The basis for the design of the air control system is discussed in detail in the Technology Evaluation Report.

Wet Scrubber

A counterflow, packed-bed, wet scrubber that used a mixture of sodium hydroxide (NaOH) in water was used to control sulfur dioxide emissions. The system was designed for a nominal gas flow rate of 1000 ft^3/min at 100°F and a maximum outlet SO_2 concentration of 2 ppm. The maximum inlet SO_2 concentration was estimated to be 200 ppm; therefore, the required control efficiency was 99%. A maximum pressure drop of 10 inches of water was specified. The scrubber selected, based on Figure A-3 these specifications, was supplied by Interel Corp. in Englewood, Colorado. The specifications for the actual scrubber and fan are shown in Table A-1, and the scrubber cross-section is shown in Figure A-5.

In operation, scrubber liquid was initially maintained at a pH of 10 to 13. When considerable scrubber liquor foaming was encountered at this pH level, the pH was reduced to the 7 to 10 range after operation showed that the high SO_2 removal could be maintained in this range without foaming. The nominal liquor recirculation rate of 20 gpm provided a liquor-to-gas ratio (L/G) of 20 gal/1000 ft^3/min.

Activated-Carbon Bed

For the reduction of VOC emissions, a granular activated carbon bed was installed after the wet scrubber. A knockout chamber was inserted between the scrubber and carbon bed to trap any liquid carryover from the scrubber. Specifications for this adsorber called for a 95% minimum removal of total organics at a flow rate of 1000 ft^3/min at 100°F and a pressure drop not to exceed 5 in. of water.

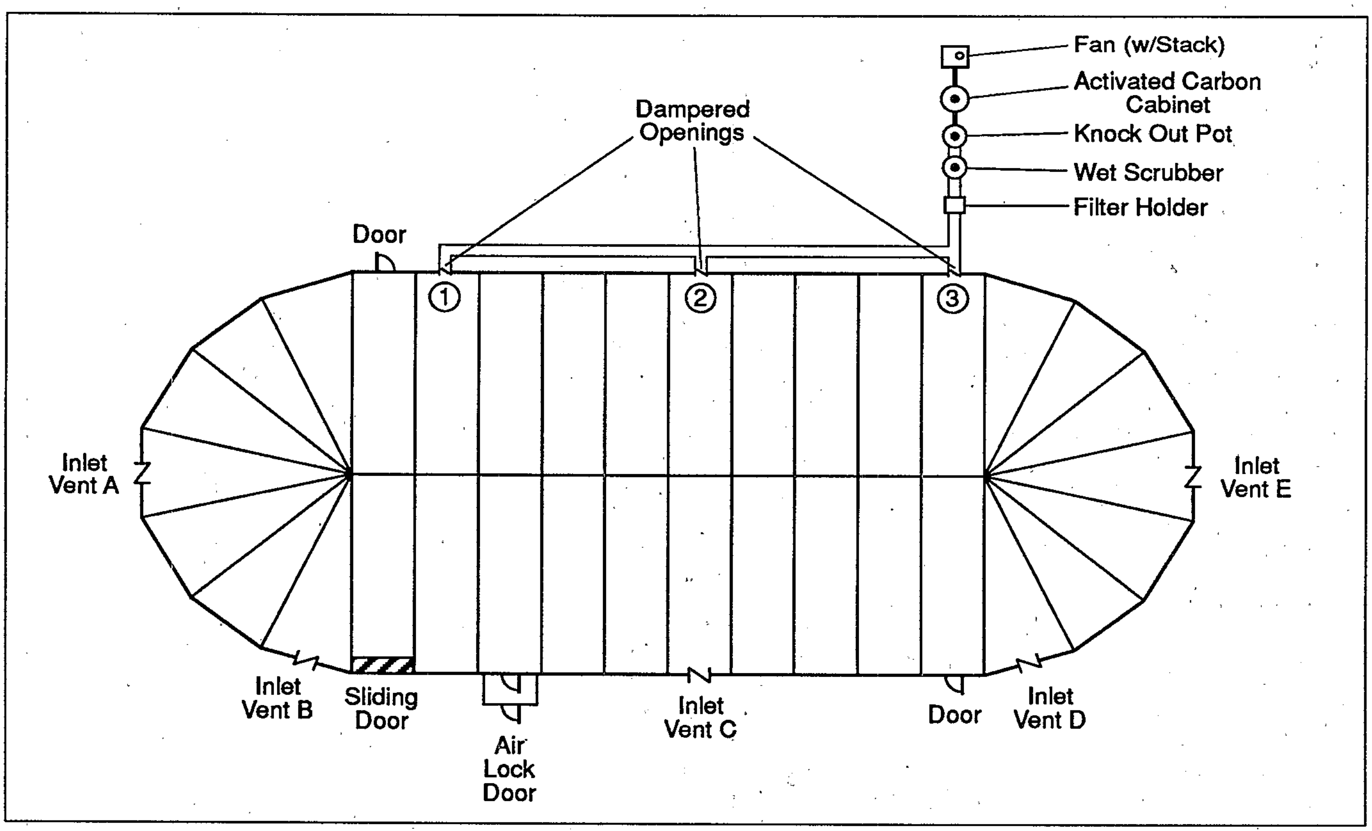


Figure A-3. General Arrangement of Ventilation Air Cleaning Equipment.

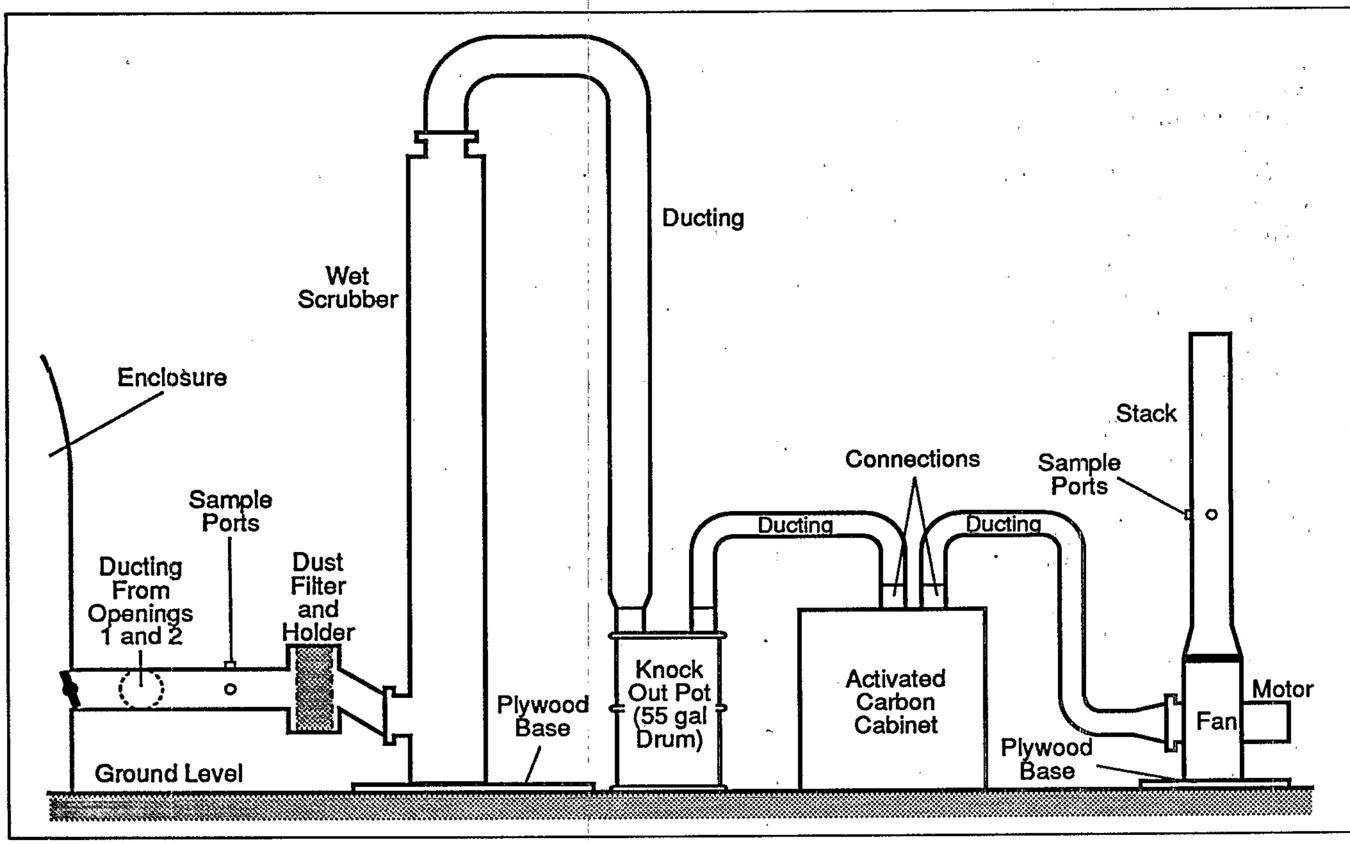


Figure A-4. Ventilation Air Cleaning Equipment and Ducting Layout.

The radial-flow, packed-bed, carbon adsorber selected was NIXTOX Model 1500 from TIGG Corp. in Pittsburgh, PA. Specifications for this unit are shown in Table A-2.

Foam Vapor Suppressants

Two types of water-based, commercially available foam supplied by 3-M Corporation were selected for this study: a temporary foam that is effective for up to about 1 hr, and a stabilized, more permanent foam that is effective for at least 1 day. These foam reagents are mixed with water and sprayed onto the waste through a hand-held nozzle. The temporary foam is a mixture of 6% concentrate and 94% water, and the more permanent foam is produced by adding a 6% concentration of stabilizer to the temporary foam mixture. The foam was generated in a self-contained, trailer-mounted system (Boots & Coots Model 100) outside of the enclosure and pumped through a hose that passed under the enclosure's edge to an air-aspirating nozzle. The temporary foam was sprayed on freshly excavated waste surfaces in the excavation pit and on waste in storage areas. Stabilized foam was sprayed on all exposed waste after each day's work was completed. According to 3M, 200 gal of foam concentrate (FX 9162) and 200 gal of foam stabilizer (FX 9161) are required to form a 1-in.-thick layer over 1 acre of surface, or about 0.9 gal/100 ft^2. The properties of the two types of foam used in this work are shown in Table A-3.

Waste Treatment Techniques

Tar Treatment

Because of its viscous nature and size (as excavated), the tar was expected to require some type of solidification and size reduction before it could be fed to a thermal destruction system. The two solidification agents most widely used with hazardous waste are portland cement and lime-based pozzolana (Arniella 1990). In addition to providing stabilization, these agents were expected to reduce the acidity of the low-pH tar to mitigate SO_2 emissions during processing. Both of these agents were evaluated during the McColl tar treatment operations.

Pozzolana is a material that contains aluminum and silica and that hardens at ambient temperatures in the presence of lime and water (by itself, however, it displays no cementing reactions). The two most common pozzolanic materials are fly ash and cement kiln dust. Fly ash from a nearby powerplant was used for the McColl tests because it was readily available (cement kiln dust is itself considered a hazardous material in California and therefore more difficult to transport and use). The chemical and physical properties of the fly ash and portland cement delivered to the McColl Site are summarized in Table A-4.

Excavated tar was combined with portland cement, fly ash, and water in a pug mill, both to mix these materials and to reduce

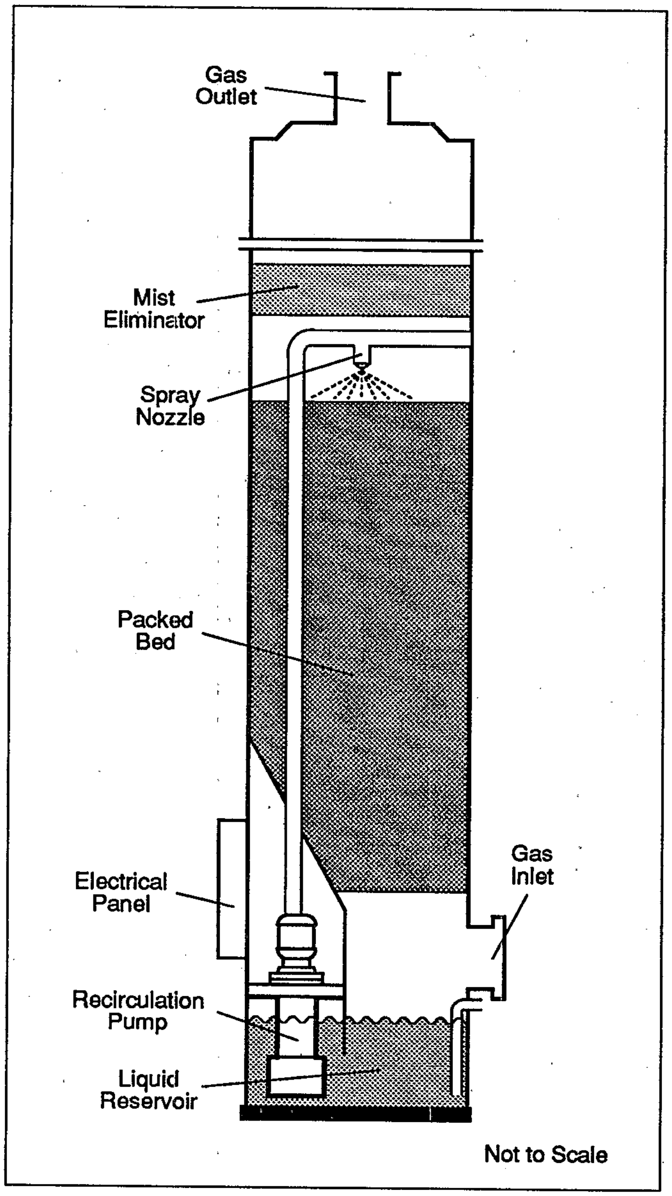


Figure A-5. Scrubber Cross Section.

Table A-1. Scrubber and Fan Specifications[a]

Scrubber	
Scrubber size	GWX 1200
Design flow rate	1200 ft ^{3}/min
Diameter	24 inches
Sump capacity	190 gallons
Circulation rate	25 gal/min
Pump motor	1.5 hp
Type of packing	2-inch hollow spheres
Packing height	11 feet
Scrubber overall height	17 feet
Type of mist eliminator	Chevron
Empty weight	650 lb
Operating weight	2350 lb
Purchase price	$22,600
Fan	
Material of construction	Steel
Corrosion-resistant coating	Polyurethane
Gas flow rate (standard air density)	1200 ft/min
Static pressure (Neg./Pos.)	20 inches WG
Motor rating	7.5 hp
Purchase price	$2,200

[a]Supplied by Interel Corp. 5/14/90.

Table A-2. Specifications for Carbon Bed Adsorber[a]

Flow rate, max.	1500 ft^3/min
Temperature, max.	350°F
Connections	7-in. duct
Diameter/height	32-in./44-in.
Adsorbent fill	300-lb virgin TIGG 5C 0410 (coal-based)
Minimum contact	0.4 second
Shipping weight	475 lb
Materials of construction	Coated mild steel with 316 stainless steel screen
Purchase price	$2450 FOB plant (including initial carbon fill)
Lease payment per month	$700
Virgin TIGG 5C 0410, per fill	$600

[a]From TIGG Corporation, 3/3/90.

the size of the tar lumps. The pug mill used for this project (Figure A-6) was a Barber Green Mixer (Model 848) that reportedly was built during the 1950s. At one end of the mill, tar, cement, and fly ash were charged into a small feed hopper with a capacity of approximately 1.2 yd^3. The material moved down through the hopper and flowed onto a moving belt. The clearance between the bottom of the hopper and the belt was almost 8 in. The belt transported the material to the head of the pug mill, where water was added manually. The mill consisted of two shafts fitted with short heavy paddles that rotated in the opposite inward direction (from the bottom to the top) in an open half cylinder. The mixing/conveying action of the paddles pushed the material from the head of the mill to its tail, where the mixed material fell into a small product hopper (approximately 2-yd^3 capacity). The hopper, in turn, emptied directly onto the ground. The feed belt and paddle shafts were powered by a 175-horsepower diesel engine.

The pug mill cylinder was approximately 10 ft long, 45 in. wide, and 27 in. deep, which corresponds to an overall volume of 5.1 yd^3. The paddles were 7 in. long and 4 in. wide at the tip. Two paddles (set at 180 degrees from each other) were set every 6 in. along the two tapered shafts; this resulted in a clearance of 2 in. between paddle sets. As shown in Figure A-7, each set was offset 90 degrees from adjoining sets. The throughput capacity of the mill was reported to be almost 100 tons/hr.

Char and Mud Treatment

The objective of the char and mud processing operations planned for this project was to reduce the size of these materials to less than 2 in. so they would be suitable for feed to a thermal destruction system. The crusher brought on site for this purpose was a Masterskreen Explorer, manufactured by M&KK Quarry

Table A-3. Properties of Foam Reagents[a]

Properties	FX-9161 foam stabilizer	FX-9162 foam concentrate
Appearance	Yellow, clear liquid solution	Amber liquid solution
Density, lb/gal	8.99	8.51
Viscosity at 77°F (25° C), cp	1500	2300
Specific gravity at 77°F (25°C)	1.08	1.02
pH at 77°F (25°C)	–	7.8
Flash point, °F	200	–
Freeze point, °F	–	28
Minimum-use temperature, °F	–	32
Storage temperature, °F	40 to 100	35 to 120
Noncorrosive	Yes	Yes
Moisture-sensitive	Yes	No
Price, $/lb	4.65	2.55

[a]From 3M Corp., St. Paul, MN.

Table A-4. Fly Ash and Portland Cement Properties[a]

	Fly ash	Portland cement
Silicon dioxide, %	61.04	22.61
Aluminum oxide, %	18.59	3.78
Iron oxide, %	5.16	3.25
Sulfur trioxide, %	1.07	1.84
Calcium oxide, %	5.97	65.15
Loss on ignition, %	0.29	0.88
Bulk density[b], lb/ft^3	86	78
Classification	Class F	Type V

[a]From Amcal Minerals Corporation, 1990.
[b]From field measurements

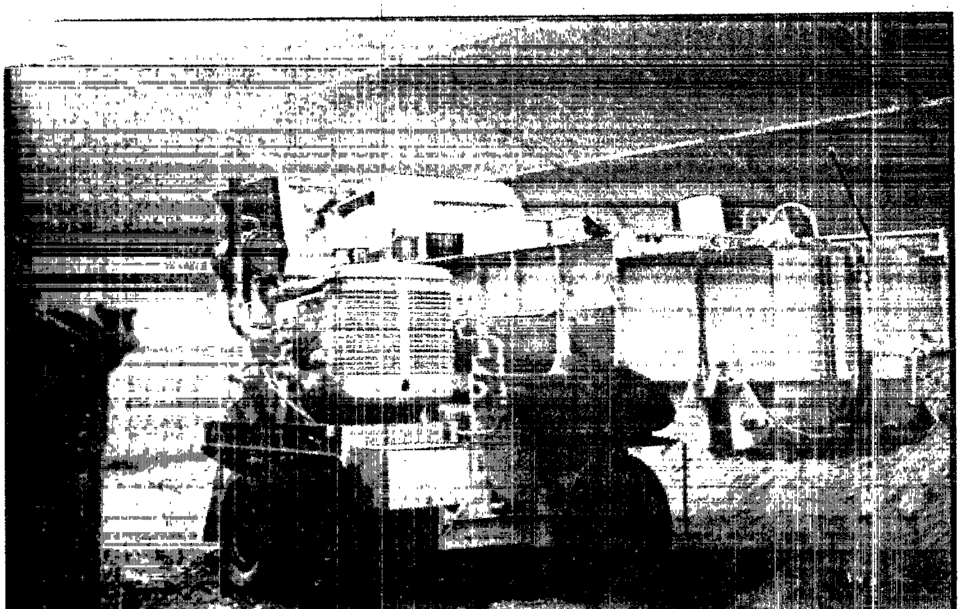


Figure A-6. Pug Mill (with Product Hopper in Foreground).

Plant Ltd. in 1989. With this system, material is dumped into a 4-yd^3 tray feed hopper fitted with 6-in. stationary bars. From the hopper, material is transported by a feed belt into the jaws of the crusher. After passing through the crusher, material is picked up by a product conveyor and transported to a vibrating screen with 2-in.-square openings. Undersize material passes through the screen to the ground, whereas oversize material rolls off the screen to another pile on the ground. The conveyor belts, crusher, and hydraulic control system were powered by a diesel engine.

The crusher was expected to operate on both char alone and on a mixture of char and mud. A schematic of the crusher is shown in Figure A-8. The overall dimensions of the unit were 51 ft long, 7 ft wide, and 17 ft deep.

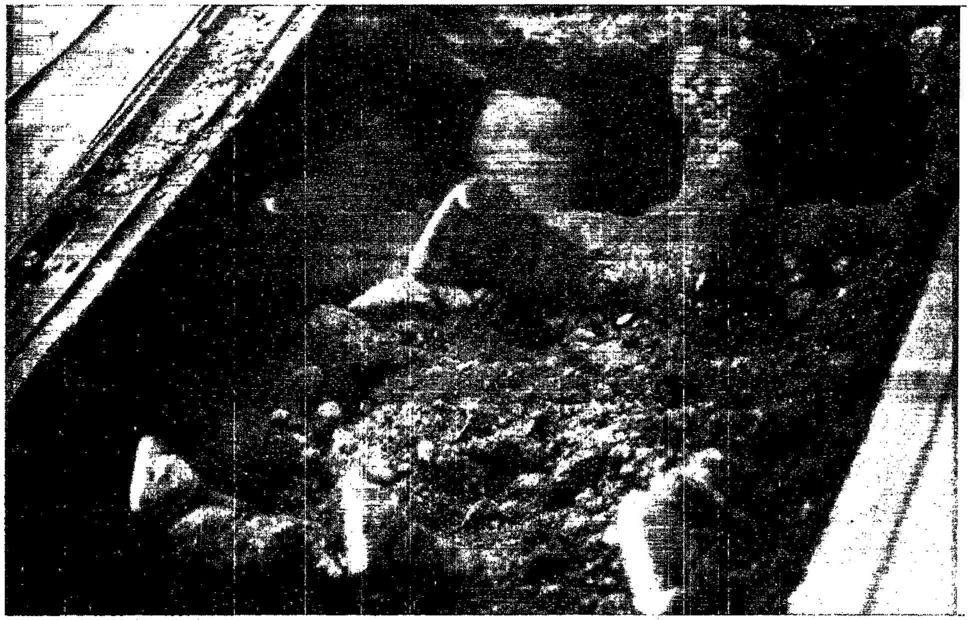


Figure A-7. Pug Mill Paddles During Tar Processing.

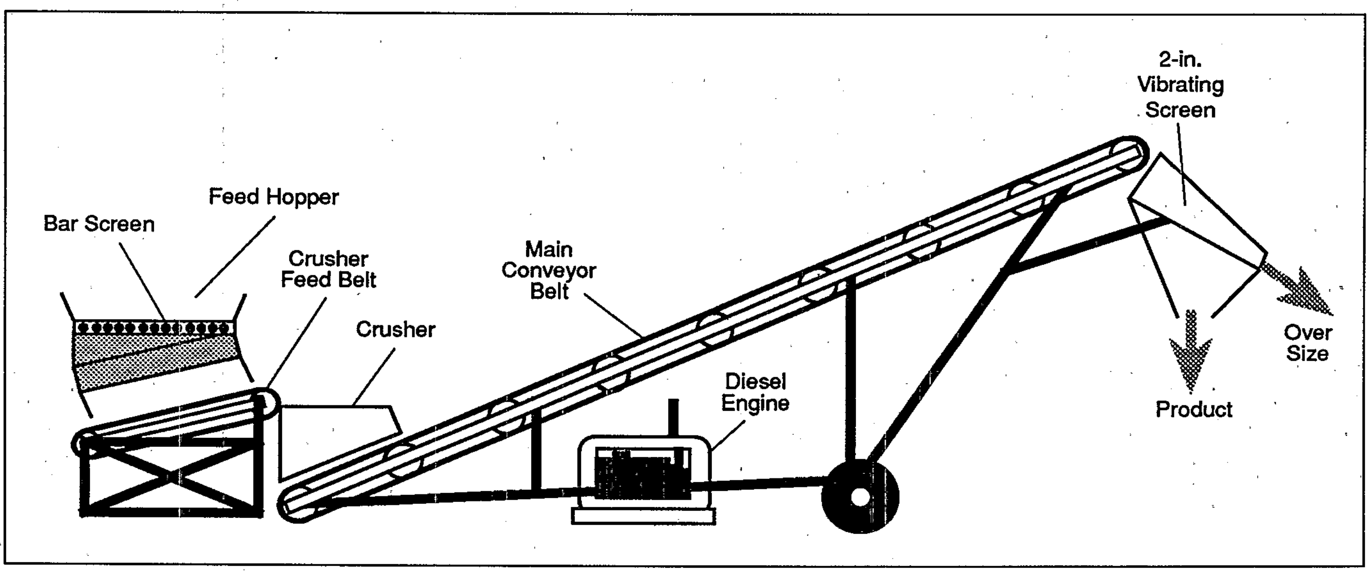


Figure A-8. Char/Mud Crusher Schematic.

Appendix B
Summary of SITE Demonstration at McColl Superfund Site

Introduction

The McColl hazardous waste site is an inactive waste disposal facility located at 2650 Rosecrans Avenue in the city of Fullerton, Orange County, CA. The site was used in the early and mid-1940s for the disposal of acidic refinery sludge, a by-product of the production of aviation fuel. A series of pits or sumps were excavated on the site to receive the refinery sludge at that time. Onsite disposal of refinery sludge ceased in 1946. From 1951 through 1962, fill material (soil) and drilling mud from oil exploration activities near the Coyote Hills were deposited in some of the pits in an attempt to make the site suitable for future development.

By 1962, the Upper Ramparts area had been covered with soil and has existed since that time as unoccupied open space. In the early 1980s, a clay cap was placed on the Lower Ramparts area to reduce odors. The Los Coyotes area was covered with 4 to 5 ft of soil and developed as part of the Los Coyotes Country Club golf course.

Areas east of the McColl site were subdivided and developed for residential housing in the late 1970s and the early 1980s. Recreational facilities were constructed west of the site at the Ralph B. Clark (formerly Los Coyotes) Regional Park. As the population increased and development continued, residents began complaining of odors emanating from the site. Odor complaints were first received by the Orange County Health Department in 1978. Subsequent environmental investigations at the site identified extensive contamination. In 1982, the McColl site was placed on the National Priorities List (NPL).

In February 1989, EPA and DHS issued a proposed plan for the McColl project that named thermal destruction, either on or off site, as the preferred remedy. Important components of this remedy are the excavation and waste-handling activities that must occur as a precursor to thermal destruction. The overall goal of the trial excavation was to obtain information pertaining to these activities to support the selection of thermal destruction as the preferred remedy and to aid in the design of a thermal destruction remedy or any other remedy involving excavation of the waste material after its selection in a Record of Decision (ROD).

Region IX of the EPA determined that the trial excavation was necessary to ascertain if McColl waste could be excavated with conventional equipment without releasing significant amounts of VOCs and SO_2 into the surrounding community. The trial excavation was also necessary to define the treatment needed, if any, to improve the handling characteristics of the waste as a precursor to thermal destruction, or any other remedy which would involve treatment of the waste.

Site Characteristics

The McColl site covers approximately 20 acres, and approximately 8 acres of the site contain waste in pits or sumps. As shown in Figure B-1, the site is divided into two distinct areas, the Ramparts area and the Los Coyotes area. The Ramparts area comprises the eastern portion of the site and contains six buried waste pits or sumps (R-1 through R-6). The Los Coyotes area, located immediately southwest of the Ramparts area, also contains six pits (L-1 through L-6). The six pits in this area were covered with soil during the construction of the golf course. The site is bordered by the West Coyote Hills Oil Field to the north, housing developments to the east and south of the Ramparts area, Los Coyotes Country Club golf course to the south, and the Ralph B. Clark Regional Park to the west. All pits are covered with soil, and the site is secured with a chain-link fence and 12-hr guard.

Objectives

The trial excavation was conducted on a portion of Los Coyotes Sump L-4 (see Figure B-1). The objectives of the trial excavation are as follows.

1. To excavate approximately 100 yd of waste to assess waste-handling characteristics and to determine if any treatment is required to improve handling characteristics as a precursor to thermal destruction.

   More than 130 solid yd^3 of waste material (mud, tar, and char) was excavated under the enclosure by conventional excavation methods.

   During the trial excavation, it was determined that the mud and char material did not need further treatment. For the mud, it was apparent that the waste could be easily sized to the nominal 2-in.-diameter thermal destruction requirement. For the char, it was determined that more than 50% of the excavated char was under 2 in. in diameter and that the remaining material could easily be sized by conventional methods (i.e., pug mill, shredder).

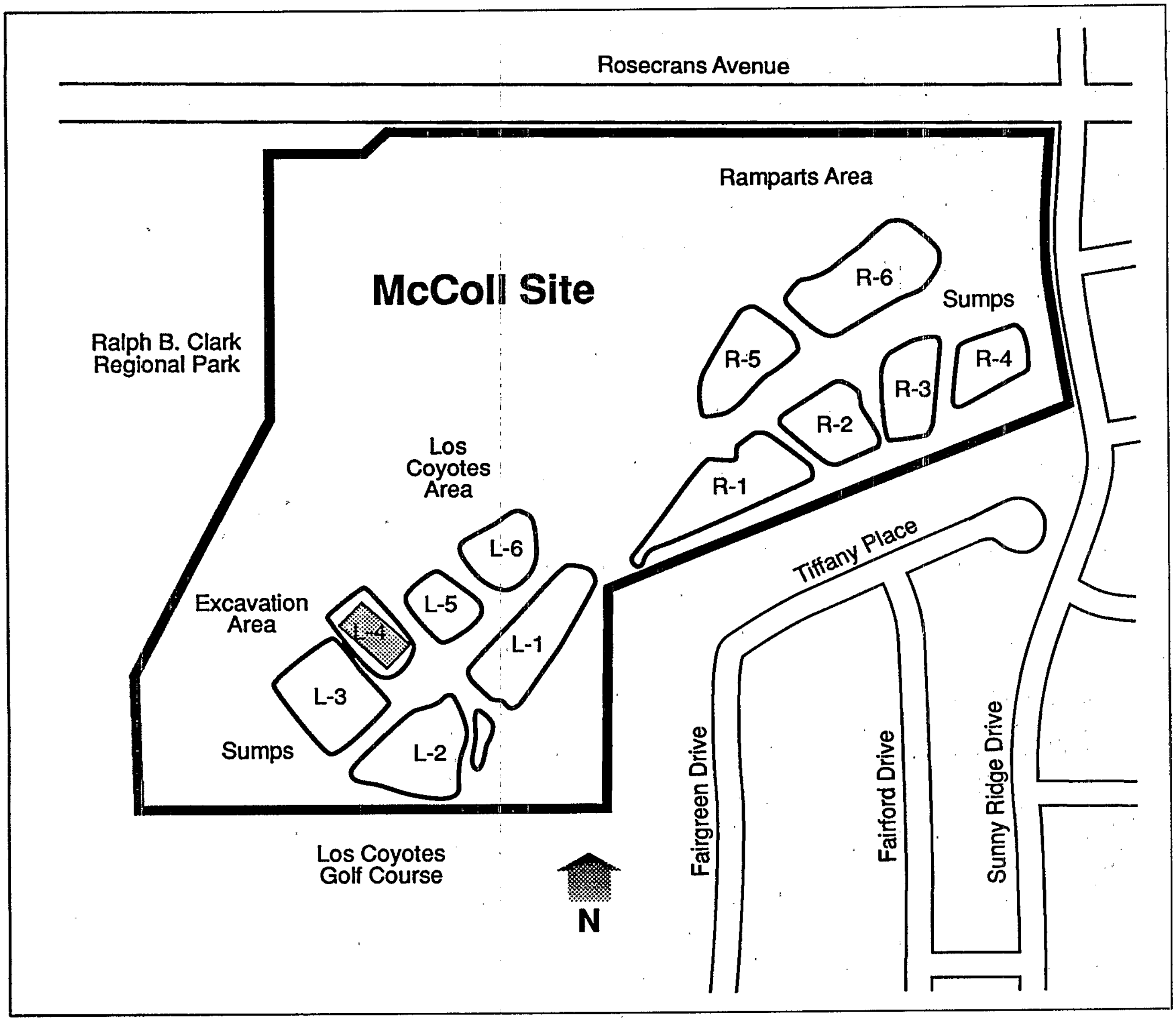


Figure B-1. McColl Site.

The tar material was determined to require additional treatment to allow for future processing into a thermal destruction unit. This was accomplished by mixing the tar with cement or fly ash and water in a pug mill. The result of this treatment process was pellets that were less than 2 in. in diameter.

2. To determine the atmospheric emissions resulting from the excavation activities.

This objective was only partially achieved during the trial excavation. Data for SO_2 and total hydrocarbons (THC) are reported; however, no data for organic species or reduced sulfur species are reported.

High-quality data were obtained for SO_2 and THC emissions exiting the enclosure exhaust treatment system. Five-minute averages for SO_2 emissions were maintained at less than 1 ppm throughout the project. The highest 5-min average for THC emissions was 98.1 ppm. Samples for organic and reduced sulfur compounds were collected from the stack and analyzed, but the data were determined to be invalid by an EPA audit.

Benzene (a known carcinogen), toluene, ethyl benzene, and xylenes are known to be the major constituents of the THC concentrations reported, but no quantifiable concentrations of these compounds can be reported for the reason given in the preceding paragraph.

3. To assess the degree of SO_2 and THC emission control achieved through the use of an enclosure and an enclosure exhaust treatment system.

This objective was achieved by erecting an enclosure around the excavation area and exhausting the ventilation air through an enclosure exhaust treatment system consisting of a sodium-hydroxide scrubber and an activated carbon unit.

The daily average removal efficiency for SO_2 ranged from 71.8 to 99.9%, with greater than 90% removal being achieved on most days.

The daily average removal efficiency for THC ranged from 15.8 to 90.7%, with greater than 50% removal being achieved on most days.

4. To determine the emission levels for SO_2 and VOCs at the fenceline of the McColl site as an indicator of impacts on the local community.

   This objective was partially achieved for the reasons outlined in Objective 2. Reliable data for SO_2 and THC emissions were collected at four perimeter monitoring stations, with no levels being detected that would adversely affect the surrounding community.

5. To assess the effectiveness of vapor-suppressing foam.

   This objective was partially achieved. Reduction efficiency rates have been calculated for dynamic conditions. Reduction efficiency rates could not be calculated for static conditions because analytical data were determined to be invalid by an EPA audit.

   Under dynamic conditions, it has been estimated that the vapor-suppression foam can be up to 80% effective for SO_2 control and 60% effective for THC control.

6. To assess potential problems that might occur during excavation.

   Assessments were made regarding problems that occurred because of the following: higher-than-expected emissions of SO_2 and THC from the tar and char; high particulate diesel emissions; heat gain; working in Level B and Level A personal protection equipment; excess water in a confined space; and seepage of tar material.

Excavation and Waste Processing

Removal of overburden and excavation of the underlying waste were readily performed with a trackhoe equipped with an extended boom and a 1-yd³ bucket. The waste, which was found to be fairly well segregated into layers, was placed in rolloff bins or piles for subsequent use. Removal of the overburden proceeded routinely and was followed by excavation of a 3-ft-thick mud layer. A 4-ft-thick tar layer was excavated next. After the tar was removed, a trench shield was placed in the excavated area to reduce seepage of additional tar into the opening. After the tar layer was excavated, a hard, coal-like, char layer was encountered. This material was broken up and excavated.

During the tar excavation, SO_2 and total hydrocarbons (THC) levels within the enclosure increased dramatically and reached 5-min average values of 1000 and 492 ppm, respectively. The enclosure exhaust treatment system removed up to 99.9% of the SO_2 and 60% of the THC during this excavation period. The use of the enclosure and enclosure exhaust treatment system prevented any significant amounts of these pollutants from reaching the site perimeter, as evidenced by the low concentrations measured there. The higher-than-expected concentrations within the enclosure required an upgrading of personal protection equipment from Level B (coated tyvek overalls with supplied air) to Level A (completely encapsulating suit with supplied air).

Char excavation was also accompanied by high concentrations of SO_2 and THC, which reached 5-min average values of 755 and 350 ppm, respectively. The enclosure exhaust treatment system operated efficiently during the entire study with up to 99% removal of the SO_2 and up to 90.7% removal of the THC.

Higher-than-expected levels of SO_2 and THC within the enclosure were caused by the failure of vapor-suppressing foams to form an impermeable membrane over the exposed wastes. The foams reacted with the extremely acidic waste, which severely impacted the foam's ability to suppress emissions.

This ability was improved somewhat, however, when the concentration of foam reagents in water was increased. Though difficult to estimate, the overall reduction achieved by applying foam was estimated at up to 80% for SO_2 and 60% for THC, based on concentrations measured at the enclosure exhaust treatment system inlet during excavation activities with and without foam.

In all, 137 yd³ of waste and 101 yd³ of overburden were excavated. Maximum and average trial excavation rates are summarized in Table B-1.

The average excavation rates achieved during this trial excavation will be increased considerably during full-scale excavation, as fewer observations and measurements would be needed. Average excavation rates that could be expected to be achieved during full-scale excavation are estimated at 49, 32, and 25 yd³/h for overburden and mud, tar, and char, respectively.

The tar waste was further processed to reduce its size and to form a solid and easier-to-handle pellet. This was accomplished by mixing the tar with cement, fly ash, and water in a pug mill. Ten test runs were made within the enclosure at various ratios of tar, cement, fly ash, and water. A ratio of 1 part tar to between 2.3 and 7 parts cement and fly ash and from 0.26 to 1 part water formed a solid, easy-to-handle pellet. Tar processing rates of approximately 3 tons/h were achieved during the trial excavation, and it is estimated that this rate could

Table B-1. Maximum and Average Trial Excavation Rates (yd³/h)

Component	Maximum	Average
Overburden	51	7.6
Mud	66	4.1
Tar	58	4.3
Char	9	2.6

be increased by up to a factor of 2 with a more continuous operation. Indications were that tar processing with alkaline materials such as cement and fly ash reduced the amount of SO_2 released by the tar. The mud and char waste fractions did not require further processing, but could have been fed through the pug mill if necessary.

Previous investigations at the McColl site indicated that the waste has the potential to emit significant amounts of VOCs, organic sulfur compounds, and SO_2. For the trial excavation, this potential air emission impact was mitigated by the erection of a temporary enclosure 60 ft wide, 160 ft long, and 26 ft high in the center of the excavation area. Air from the enclosure was vented through an enclosure exhaust treatment system consisting of a sodium-hydroxide-based wet scrubber and an activated-carbon adsorber in series before being released to the ambient air.

For the trial excavation, this potential air emission impact resulted in having workers wear Level B or Level A protection at all times while inside the enclosure. Concentrations of SO_2 and THC were continuously monitored before and after the enclosure exhaust treatment system.

Waste Characteristics

Three major waste types are present at the McColl site: 1) hard, black, char-like asphaltic wastes; 2) viscous, black, tar-like wastes; and 3) mud. The predominant waste type found at the site is a black asphaltic waste that is apparently the result of chemical and physical changes in acidic refinery sludge that have occurred over the last 40 years. This asphaltic waste has a low pH (acidic) and contains elevated levels of organic compounds. When disturbed, the waste emits sulfur dioxide (SO_2) and hydrocarbon vapors. Because of its acidic nature, the McColl waste is characterized as RCRA corrosive waste according to CFR 261.22.

Borings previously made in the L-4 Sump showed that both tar and char were present in fairly segregated layers under a layer of moist soil or mud, which was in turn under approximately 8 ft of overburden soil. During previous studies at this site, two types of air emissions were observed when the waste was disturbed. The initial disturbance generally caused a high level or "puff" release of contaminants, followed by a rapid decline to lower levels (Radian 1983). These steady-state emission levels were then observed for longer periods of time and gradually decreased over several hours. The emission potential in the Ramparts area ranged from 130 to 130,000 mg/m² per min for SO_2 and 10 to 3600 mg/m² per min for THC for all disturbed waste types. Average steady-state emissions from asphaltic waste were 5200 mg/m² per min for SO_2 and 190 mg/m² per min for THC. Hydrocarbon analysis of air samples showed an average composition of 60% aliphatic and oxygenated species, 30% aromatic species, and 10% organic sulfur species. The waste composition did vary from sump to sump, however, and even with depth within a sump (Schmidt 1989).

Samples of excavated waste were analyzed to determine heat value and the concentrations of selected constituents. The information obtained by these analyses is summarized in Table B-2.

The mud fraction of this waste consisted largely of inorganic, noncombustible material with an ash content of 82.9% and a heating value of less than 500 Btu/lb. The raw tar sample contained a high percentage of combustible material and had a heating value of more than 9000 Btu/lb, an ash content of less than 2%, and a high sulfur content (10.6%). The treated tar sample contained cement dust and fly ash (low-sulfur, high-ash components), and the addition of this material decreased all of the combustible parameters and increased the ash value. Raw char has a fairly high ash level (about 55%), a sulfur content of 4.5%, and a heating value of 5200 Btu/lb.

Common indicators for petroleum waste are the concentrations of benzene, toluene, ethylbenzene, and xylene (BTEX). The McColl samples data show that the tar fraction of this waste contains the highest levels of these compounds and that the mud layer contains only a relatively small portion of these compounds.

Toxicity characteristics of the raw tar and char were determined by the Toxicity Characteristics Leaching Procedure (TCLP) and California Wet Test. No metal constituents exceeded the regulatory limit in either case. Benzene in the tar and char waste extract exceeded the EPA TCLP limit of 500 µg/liter by greater than a factor of 2.

Community Impact

Perimeter air monitoring for SO_2 and THC was conducted continually during this study. Windspeed and wind direction were also recorded continually at the site. This information was obtained to comply with the Community Contingency Plan, which mandates that all site work be stopped if SO_2 levels at the perimeter exceed 0.5 ppm for 5 min or if THC levels exceed 70 ppm for 30 sec. These levels were never reached during this study. The maximum 1-hr readings obtained at any perimeter station in June, which was the period of highest emissions from the waste, were 0.08 ppm for SO_2 and 21.9 ppm for THC. Specific compounds in the air at the perimeter of the site and in the neighborhood were sampled and analyzed.

Health and Safety Issues

Both health and safety and commun ity exposure issues were assessed prior to the trial excavation demonstration. These issues are discussed in the following subsections:

Table B-2. Waste Characteristics, As-Received Basis

	Mud	Tar	Treated tar	Char
Moisture, %	13.2	11.6	8.1	21.2
Sulfur, %	0.8	10.6	3.6	4.5
Fixed carbon, %	0.2	16.9	2.0	4.0
Ash, %	82.9	1.6	75.9	54.7
Benzene, ppm	<0.7	240	NA[a]	97
Toluene, ppm	1.5	580	NA	150
Xylene, ppm	8.6	910	NA	220
Ethylbenzene, ppm	0.9	140	NA	35
Heat value, Btu/lb	<500	9160	2200	5200

[a]NA = Not analyzed. Use of cement additive would reduce concentrations found in raw tar sample.

Worker Safety

Excavation work inside the enclosure was conducted either in Level B or Level A personal protective equipment. Level B equipment consisted of supplied-air respirators, coated Tyvek overalls, steel-toed boots, inner and outer gloves, and a hard hat. Air bottles were mounted on the trackhoe, loader/backhoe, and Bobcat for operator air supply; other members of the crew used air lines supplied from air cylinders located outside the enclosure. Level A requirements included the addition of a totally encapsulating chemical protective (TECP) suit to the preceding equipment list. Air supplies to these suits were either from air lines (as previously discussed) or from a self-contained breathing apparatus inside the suits.

The observation camera used was an invaluable tool for observing/recording activities that occurred within the enclosure. The camera also allowed all workers to be observed from a health and safety standpoint. The camera also assisted in a reduction of the number of employees necessary within the enclosure, which allowed for more efficient operations and reduced the risk of employee accidents.

Community Exposure

Because of the nature of the contamination at the McColl site, community exposure was determined to be a significant concern. Perimeter air monitoring for SO_2 and THC was conducted continually during this study. Windspeed and wind direction were also recorded continually. This information was obtained to comply with the Community Contingency Plan, which mandates that all site work be stopped if SO_2 levels at the perimeter exceed 0.5 ppm for 5 min or if THC levels exceed 70 ppm for 30 sec. These levels were never reached during this study.

Based on observations by personnel during the trial excavation, the noise level related to the excavation and treatment activities was minimal. At no time during the trial excavation were the health-based levels established in the McColl Contingency Plan for SO_2 and THC exceeded at the fenceline monitoring stations. Although odor complaints were received during the trial excavation period, they were not excessive. Most of the complaints were received after the trial excavation/treatment activities were completed for the day, and may not have been related to the excavation/treatment activities.

Costs of Excavation and Tar Processing

The costs for the field aspects of this trial excavation work consisted of those involved with the enclosure and the enclosure exhaust treatment system, actual excavation labor and equipment, foam application, tar processing, and air monitoring. Much of the equipment for this project (e.g., enclosure framework, scrubber, and excavation machinery) was rented on a monthly basis; therefore, total costs consisted of the monthly machinery charges, labor, and fixed costs required to mobilize and demobilize. These costs are summarized in Table B-3 for the 2-month duration of the field work.

Table B-3. Summary of Onsite Costs

Item	Total cost, $
Enclosure	70,976
Air exhaust control system	40,415
Foam vapor suppressants	89,591
Excavation [a]	82,512
Tar processing	17,367
Air monitoring	100,160
Total	401,021

[a]Based on 18 days of excavation.

Appendix C

Applicability of the McColl Enclosure and Excavation Technologies to Current CERCLA Sites

Many CERCLA sites share the problem of soil contaminated with volatile organics, volatile metals, and metal-laden dust that can result in toxic air emissions during waste excavation, processing, and treatment. Table C-1 presents a list of current CERCLA sites where the McColl enclosure and excavation techniques may be applicable. These sites were selected based on the existence of airborne contaminants and the site's proximity to areas threatened by the release of these contaminants. Other site-specific conditions may preclude the use of some or all of the McColl techniques at certain sites.

Table C-1. Current CERCLA Sites Where the McColl Enclosure and Excavation Technologies May Be Applicable

Site name/location	Air contaminants	Threatened areas
Region I		
Silresim Chemical Corp. Lowell, MA	Pesticides, VOCs	Business district Residential
Region II		
Combe Fill North Landfill, Mount Olive Township, NJ	Bis (2-ethylhexyl) phthalate, chlorobenzenes, phenol, VOCs	Residential
Fried Industries, East Brunswick Township, NJ	VOCs	Residential
Glen Ridge Radium Site, Glen Ridge, NJ	Radon	Residential
Montclair/West Orange Radium, Montclair/West Orange, NJ	Radon	Residential
Woodland Township, Route 532 and Route 72 Sites, Woodland Township, NJ	Organic solvents	Residential Agricultural
Richardson Hill Road Landfill, Sidney Center, NY	VOCs	Residential
Port Washington Landfill, Port Washington, NY	Methane Benzene Toluene Xylene Vinyl chloride	Residential Golf Course School
Region III		
Abex Corp., Portsmouth, VA	Heavy metals	Residential
Greenwood Chemical Co., Newton, VA	VOCs	Residential Agricultural
Rhinehart Tire Fire Dump, Frederick County, VA	VOCs	Agricultural
Kane & Lonbard Street Drums, Baltimore, MD	Acrolein Benzene Ethyl benzene Xylene Chromium	Residential
Ambler Asbestos Piles, Ambler, PA	Asbestos	Residential Playground
Brown's Battery Breaking, Shoemakersville, PA	Lead	Residential
McAdoo Associates, McAdoo, PA	Heavy metals PAHs Phthalate esters VOCs	Residential
Taylor Borough Dump, Taylor, PA	Heavy metals, VOCs	Residential Community Park
Region IV		
Interstate Lead Co., Leeds, AL	Lead	Residential
Brantley Landfill, Island, KY	Ammonia Dust Heavy metals	Residential
Fort Hartford Coal Co., Inc., Olaton, KY	Ammonia	Residential Recreational
Maxey Flats Nuclear Disposal, Hillboro, KY	Tritium	Residential
Carolawn, Fort Lawn, SC	Heavy metals Phenols VOCs	Residential

(continued)

Table C-1. (continued)

Site name/location	Air contaminants	Threatened areas
Region V		
Taracorp Lead Smelter, Granite City, IL	Lead	Residential
Berlin & Farro, Swartz Creek, MI	Pesticide byproducts	Residential
Feed Materials Production Center, Fernald, OH	Radon	Residential Agricultural
Region VI		
Bayou Sorrel Site, Bayou Sorrel, LA	Volatile organic and inorganic pollutants	Industrial
Combustion Inc., Denham Springs, LA	VOCs	Residential Agricultural
Dutchtown nontreatment Plant, Ascension Parish, LA	VOCs	Residential
Lee Acre Landfill, Farmington, NM	VOCs	Residential Recreational
Cal West Metals, Lemitar, NM	Lead	Residential Recreational
Region VII		
A.Y. McDonald Industries, Inc., Dubuque, IA	Lead	Residential
Peoples Natural Gas Co., Dubuque, IA	Cyanide PAHs Phenols	Business district, Residential
White Farm Equipment Co., Charles City, IA	Heavy metals, dust	Residential, Wetlands
Missouri Electrical Works, Cape Girardeau, MO	Aroclor 1260, Aroclor 1260, dust	Residential, Wetlands
Weldon Spring Quarry, St. Charles County, MO	Radioactive dust	Industrial
Region VIII		
Uravan Uranium Project, Uravan, CO	Uranium	Wildlife habitat
Richardson Flat Tailings, Summit County, UT	Heavy metals	Residential, Recreational
Silver Creek Tailings, Park City, UT	Heavy metals	Residential
Region IX		
Montrose Chemical Corp. Torrance, CA	DDT	Industrial, Residential
South Bay Asbestos Area, Alviso, CA	Asbestos-laden dust	Residential, Wildlife Refuge
United Heckathorn Co., Richmond, CA	DDT	Residential
Region X		
Teledyne Wah Chang Albany, Albany, OR	Metals, VOCs, radioactive dust	Residential
Seattle Municipal Landfill, Kent, WA	1,2-Dichloroethane, tetrachloroethylene	Residential

TECHNICAL REPORT DATA

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15. SUPPLEMENTARY NOTES

Project Manager: S. Jackson Hubbard (513) 569-7507

16. ABSTRACT

A trial excavation of approximately 137 cubic yards of waste was performed at the McColl Superfund Site in Fullerton, CA, to better determine the nature of this waste, any treatment needed to improve its handling characteristics, and the extent of air emissions that might occur during excavation. This type of information is necessary to plan full-scale remediation of this highly acidic petroleum refinery waste buried at this site. The trial excavation was conducted within a temporary enclosure with air exhausted from the enclosure through a sodium hydroxide-based wet scrubber and activated-carbon bed adsorber to reduce air emissions of sulfur dioxide and organic compounds. Foam was used in an attempt to suppress atmospheric releases from the raw waste during excavation, storage, and processing. The air exhaust was monitored for total hydrocarbons and sulfur dioxide before and after the air emission control system. In addition, total hydrocarbons and sulfur dioxide were monitored along the site perimeter to determine potential impact of air emissions on the nearby community.

This report presents an evaluation of the equipment used to control emissions and to measure the resulting emissions before and after the air control system. An assessment of the foam vapor suppressants and information on the full-scale remediation costs of the technology are also provided.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Excavation Petroleum	Hydrocarbons Sulfur Dioxide Petroleum Wastes	

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