
FIRE FIGHTING TRAINING UNIT

**REVISED WORKPLAN
FOR EXCAVATION OF DRAINAGE PIPING
AND FIELD PILOT STUDY FOR
BIOREMEDIATION OF PETROLEUM
CONTAMINATED SOIL**

**NAVAL TRAINING CENTER
GREAT LAKES, ILLINOIS**

July 1997

Prepared by:

**BELING CONSULTANTS
UNDER CONTRACT #N68950-95-D-9021**

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1.0 INTRODUCTION AND OBJECTIVES

This Work Plan has been prepared in accordance with Contract #N68950-95-D-9021 between Beling Consultants (Beling) and the Department of Navy, Great Lakes Naval Training Center, Great Lakes, Illinois. This Plan describes activities scheduled as part of the demolition of the Fire Fighting Training Unit (FFTU) at Naval Training Center, Great Lakes, Illinois. This Plan is intended to provide information regarding the Scope of Work, sequence of activities, responsibilities, performance expectations and time schedules. It is not intended to serve as a bidding specification, and as such, does not specify quantities, ways and means for engineering or contractor requirements, nor detailed material requirements.

Refer to Figure 1, Site Map and Piping Layout, which provides the layout of surface features associated with the former fire fighting activities, and the layout of underground piping for pressurized fuel delivery systems, pressurized water delivery systems, and drainageway piping. Seaman recruits were formerly trained at this facility to fight fires fueled by the fuel oil pipes, and controlled with water from the water pipes. The drainageway piping accommodated runoff from the activities. Surface structures with the exception of Building 3304 and three (3) aboveground storage tanks (ASTs) have been removed. Removal of the underground piping is scheduled for July and August 1997.

This Plan includes removal of subsurface piping as depicted in Figure 1. Approximately 21,600 linear feet of underground piping is to be removed.

Beling will provide technical oversight for product containment if encountered, implementation of the Stormwater Management Plan, soil sampling, and

documentation of field activities during removal of subsurface piping and substructures.

The Environmental Contractor (the Contractor) selected by the Navy will provide demolition equipment such as a backhoe and a hammer, to trench along pipelines and remove piping in a safe and systematic manner.

This Work Plan includes a description of specific demolition activities and the Contractor's requirements for containment, decontamination and disposal of materials including wastes. The Contractor is required to have a site-specific Health & Safety Plan, be familiar with Beling's site-specific Health & Safety Plan, and follow the Stormwater Pollution Prevention Plan (SWP3) specific for this remediation project. Documents related to this Work Plan are referenced in the Table of Contents, and have been made available to the Contractor, IEPA, and USEPA.

2.0 SITE DESCRIPTION

The FFTU site comprises approximately 8.5 acres. The condition of the site is flat with broken concrete, gravel, and asphalt surfaces, and grassy vegetated areas around the perimeter ditch. A perimeter ditch on the east and north sides of the site discharges to a 15" culvert noted as culvert "X" on Figure 1. The perimeter ditch is a wetland area. Contractor is not to disturb the wetland area. All buildings and surface structures, except Building 3304, have been razed.

Based on a review of existing information, there are approximately 21,600 linear feet of underground piping:

3.0 EMERGENCY TELEPHONE NUMBERS

Following are the names and telephone numbers of key personnel to be contacted in case of an emergency:

J.P. Messier	Navy Engineer in Charge	(847)688-4295
Terry Aide	Program Manager/Alternate for J.P. Messier	(847)688-5997
Lt. Joe McConnell	Navy EFA-MW Environmental Deputy	(847)688-4197
Michael A. Hanson	Navy EFA-MW/Environ Engineer	(847)688-5997
Kelly Devereaux	Navy Sr. Environmental Coordinator Waste Disposal	(847)688-2628
Molly Arp	Beling Consultants/Project Manager	(309)757-9800
Phil Ramos	Beling Consultants/Field Coordinator	(312)986-0390
Karl E. Meier	Beling Consultants/Biopile Coordinator	(312)986-0390
Medical Emergency	Fire/Police	(847)688-3333
Kevin Reinhard	Heritage Environmental	(630)378-1600
Geoffrey Langley	Heritage Environmental Lamont Office	(630)378-1600 (630) 739-1151

and decontamination of pipes with petroleum contamination. The 40 x 40 area has been designed to accommodate one or two day's accumulation of LUST pipes and valves removed from the trenches. The Contractor will utilize a pressure washer to decontaminate steel piping so it may be recycled as scrap. The Contractor is responsible to recycle or otherwise dispose of demolition materials in accordance with local, State and Federal laws. Decon wash waters will be collected and stored on site. The Contractor is responsible for waste analysis and proper disposal.

4.2.1 Punch List for Decon Area

To accommodate decontamination of pipes, demolition debris, trucks, heavy equipment and storage containers, a shallow excavation 8 inches deep 40 feet long and 40 feet wide will be constructed, double lined with 10-mm plastic and filled with pea or washed gravel to grade. The Contractor will be responsible to pump water from the decon pit to a storage tank as necessary. Other items required to decontaminate heavy equipment include:

- Pressure washer with spray nozzle.
- Triphosphate soap powder or equivalent.
- Buckets and brushes.

The Decon Area will serve as a Contaminant Reduction Zone (CRZ) for workers. Items necessary, in addition to these above, for contaminant reduction of Contractor employees, Navy personnel, engineering support and sampling personnel include:

- Drums or bags for collection of discarded personnel protective equipment (PPE) such as Tyvek booties, Tyvek coveralls disposable outer gloves, and disposable inner gloves and overnight storage.

- Laydown Area for respirators and communication equipment if used.
- Bucket of soapy water to wash and scrub boots.
- Bucket of soapy water to wash hands.
- Rinse water for hands.
- Storage area for clean PPE such as Tyvek coveralls and booties, inner and outer gloves, tape, goggles, rolls of plastic sheeting, rubber work boots, hard hats and respirator cartridges.

The Decon Area will also serve as a first aid station with a first aid kit, two chairs, fresh drinking water, eyewash station, stretcher, and clean towels.

4.3 MAINTAIN DRAINAGEWAY PIPE LAYDOWN AREA

The second Laydown Area will accommodate clay tile pipes and cast iron pipes which formerly accumulated and directed drainage from the FFTU activities toward the oil/water separator system. This laydown area will be approximately 60 feet by 40 feet located near the west end of Building 3304 as shown on Figure 1. All surface run-on and run-off will be collected by the Contractor. Stockpiled materials will be covered with polyethylene sheeting pending decontamination, analytical evaluation, and disposal. The Contractor will be responsible for chemical analyses to profile all wastes stored in this area prior to disposal. This area will be lined with 2-ply, 10-mm, polyethylene sheeting or equivalent. Materials to be stockpiled in this area include drainageway piping, and demolition debris from excavation of the subsurface structures.

Materials stockpiled in this laydown area must be analytically profiled within 30 days. If the materials are determined to be hazardous, a hazardous waste generator identification number must be obtained, manifests must be appropriately

completed, and a licensed hazardous waste hauler must transport and dispose of the waste in accordance with Federal and State regulations.

4.4 SITE SAFETY MEETINGS

The Contractor will hold daily site safety meeting with its employees on site, to discuss work objectives, waste containment and control responsibilities, equipment hazards, and communications. The Contractor will work with Navy project personnel, Beling personnel and other Contractors, as appropriate, to maintain site security and to enforce safe work procedures around subsurface trenching operations and the decontamination areas.

The Contractor and subcontractors are required to hold current certification for OSHA Hazwoper training. Due to the history of the site, the Contractor Safety Plan will include decontamination procedures for personnel and equipment for petroleum constituents and hazardous contaminants known to be present at the site. The Contractor should be aware that residual flammable materials may be present on-site and precautions shall be taken to prevent potential fire or explosion.

Utilities have been disconnected from the site, except for the golf course cart storage area which has water and electricity. Electrical power will be provided by the Navy to serve a work trailer at the FFTU Site. The location of the trailer, to be provided by the Contractor, will be close to the entrance gate at the southeast side of the site.

The Contractor is responsible for lock-out tag-out operations for equipment on site.

5.0 SEQUENCE OF TRENCHING ACTIVITIES

Trenching operations are scheduled to begin July 28, 1997 in the northeast corner of the site, close to the former location of the carrier compartment building "D." Removal of all subsurface pipes will be attempted by trenching north to south and east to west across the site.

5.1 FREE PHASE FUEL PRODUCT

The fuel supply piping, water supply piping and drainageway piping will have been drained, but may contain residual pockets of fuel or groundwater. Groundwater will be allowed to drain back into the ground, when encountered in ruptured or broken pipes. Pockets of fuel or other waste materials, if encountered, will be vacuumed or pumped into a drum, or other container. Liquids, solids, and other waste materials will be handled and disposed by the contractor in accordance with Federal and State regulations.

5.2 SLUDGE

In the event deposits of sludge are encountered in the drainage pipes or in the trenches, the Contractor will containerize the material in a drum for subsequent disposal in accordance with Federal and State regulations.

5.3 PIPE REMOVAL

The Contractor will utilize a backhoe to trench along pipe lines. Soil from the trenches will be temporarily maintained along the edge of the trench while piping is removed. Beling will utilize a photoionization detector (PID) to scan soils from

the trenches, document observations, and correlate field activities to a sampling grid.

A determination will be made in the field regarding petroleum contaminated soil. Excavated soil believed to be contaminated with fuel oil will be utilized in the construction of a biopile, which is designed to remediate up to 4,000 c.y. of petroleum-contaminated soil. Please refer to Attachment 1, Field Pilot Study Remediation of Petroleum Contaminated Soils.

Groundwater, if encountered in the trenches, will not be pumped to a storage unit except if necessary to irrigate the biopile. The resulting trenches may be concave. Site topography will be leveled during the final stages of SWP3 implementation.

5.4 SOIL SAMPLING

A Quality Assurance Project Plan (QAPP) has been developed for sampling and analysis protocols. The QAPP follows the Region V Model QAPP. Upon review and approval by IEPA and USEPA, the plan will be implemented.

Soil sampling locations have been proposed in the QAPP to attempt to determine if soil remediation in addition to the Pilot Biopile will be required.

5.5 TRENCH BACKFILLING ACTIVITIES

Following determination of soil contamination condition, the soils not designated for the biopile will be returned to the trench. At completion of each trench line, the Contractor will provide suitable fill matter to grade, if necessary.

5.6 BIOPILE CONSTRUCTION AND REMEDIATION

A biopile will be constructed concurrently with trenching operations to handle soil known to be impacted by petroleum releases. Refer to Attachment 1 for a discussion of Biopile Construction, Operation and Closure.

6.0 WASTE PROFILES

The Contractor will be responsible to perform waste profiles by collecting samples of drummed materials, derived wastes, oily water in storage tanks, decon water, materials on or in pipes, concrete rubble and other materials prior to disposal.

Toxic Characteristic Leaching Procedure (TCLP) analysis will be required to determine if a waste is hazardous. The Contractor is responsible to handle and dispose hazardous wastes, if encountered, in accordance with Federal and State regulations.

The Contractor is responsible to handle and dispose of materials classified as special wastes in accordance with Federal and State regulations. The Contractor will provide options and price estimates to the Navy for disposal of wastes. The Navy will direct the Contractor to proceed with an appropriate disposal procedure for demolition wastes.

7.0 ORGANIZATION AND SCHEDULE

The Navy's Engineer in Charge throughout demolition tasks at FFTU will be J.P. Messier with an alternate, Terry Aide. Their offices are located at the Great Lakes

Naval Base, within five miles of the FFTU sites. They can be reached at (847) 688-4198 or 5997.

Beling's Coordinator of Field Operations for this project is Phil Ramos, who will be present on site to provide technical oversight and to document demolition activities. He will coordinate daily demolition tasks, with the Contractor and the Engineer in Charge. He will report to Beling's Project Manager, Molly Arp, who reports to the Navy's Engineer in Charge and Contracting Officer. Phil Ramos may be reached on site or at (312) 986-0390. Molly Arp may be reached on site or at (309) 757-9800. Coordination of biopile construction and remediation operations will be managed by Karl E. Meier. He will work with Phil Ramos, the Contractor, and report to Molly E. Arp. He can be reached on site or at (312) 986-0390.

The Contractor will be Heritage Environmental Services, Inc. based in Romeoville, Illinois. Heritage, a qualified environmental remediation service company, will be authorized directly by the Navy to perform demolition tasks described in this Work Plan.

Removal of the piping is scheduled to begin July 28, 1997. Preparation of decon areas and installation of silt fences is planned for July 21. Preparation tasks are expected to require 3 or 5 days.

Demolition of piping is expected to take six weeks. Biopile construction will be concurrent with trenching activities.

**REVISED WORKPLAN EXCAVATION OF
DRAINAGE PIPING**

ATTACHMENT 1

**FIELD PILOT STUDY
REMEDICATION OF PETROLEUM
CONTAMINATED SOILS**

FIRE FIGHTING TRAINING UNIT

July 1997

Prepared by

**BELING CONSULTANTS
CONTRACT # N68950-95-D-9021**

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APPENDIX D - SUCCESSFUL PROTOTYPES REFERENCES

1.0 INTRODUCTION

As a result of past fire fighting training exercises, soil and shallow groundwater contamination was identified at the Great Lakes Naval Training Center Fire Fighting Training Unit (FFTU). Fuel oil was burned, therefore, the chemical compounds of concern are Benzene, Toluene, Ethylbenzene, Xylene (BTEX) and Polynuclear Aromatic Hydrocarbons (PNAs). Bio-pile technology will be the remedial method utilized in this pilot study. The bio-pile technology involves placing petroleum-contaminated soils into piles or cells above ground and stimulating aerobic microbial activity within the contaminated soils.

1.1 IEPA Purview

Illinois EPA is the implementing agency regarding cleanup and closure of petroleum contaminated soils resulting from underground storage tank (UST) systems in Illinois. Reports regarding progress and closure will be provided to the IEPA upon completion of the pilot study. If additional LUST soil remediation is required to close this site, additional bioremediation may be recommended. TACO Tier 2 or Tier 3 cleanup objectives may be determined applicable to this site under 35 IL Adm. Code, Part 742.

1.2 Clean-up Objectives

The general objective of the pilot study is to mitigate and minimize threats to public health and the environment in accordance with Federal and State laws. The clean up objectives for petroleum contaminated soil and associated groundwater remediation are found in Title 35 Illinois Administrative Code Part 742 - Tired Approach to Clean-up Objectives.

1.3 Biodegradation Process Description

The Soil Remediation Field Pilot Study will use an ex-situ biological soil composting process. The purpose of the site remediation pilot study is to address the identified petroleum contamination in the most efficient and economical manner. In addition, the remedial activities are designed to prevent further contamination and remove contaminants from the soil and groundwater in a low-tech and low-maintenance manner.

The bio-pile process to be utilized is based on ex-situ aerobic biological degradation of the petroleum based compounds. The bio-pile purpose is to supply air, nutrients and micro-organisms to the contaminated soil. The Bio-pile process encourages bioremediation by maximizing the portion of remediation which occurs by oxygen replenishment and bio-metabolism. Use of slotted piping placed in the bio-pile eliminates the need for mechanical stripping of volatiles from the extracted soil. Biodegradation occurs as oxygen is replenished in the impacted soil.

A limited amount of groundwater can be effectively remediated using biopile technology, because water is used to irrigate the pile. The moisture encourages biological breakdown.

When oxygen is added via the slotted piping to the areas of contamination within the bio-pile, the metabolism of the petroleum compounds occurs. Aerobic bacteria use hydrocarbon-containing compounds as an electron source and oxygen as an electron acceptor. Hydrocarbon compounds are converted to carbon dioxide and water by a reaction generally described by the following equation:



This destruction process is economically attractive. Within the bio-pile, hydrocarbons are destroyed and CO₂ and water are produced. In summary, the bio-pile process involves adding air, micro-organisms, nutrients, and moisture to the contaminated soil and allowing the process to proceed.

1.4 Bio-Pile Technology Review

The Soil Remediation Field Pilot Design has been successfully used as an effective and economic means for treatment of petroleum contaminated soils. The design is founded upon the Minnesota Department of Transportation composting process for bioremediation of petroleum contaminated soils. Appendix D provides several references of successful prototypes for review.

In addition, the Bio-pile Design and Construction Manual, provided by Naval Facilities Engineering Service Center, Port Hueneme (TM-2189-ENV), was utilized in development of this pilot study.

2.0 PILOT TEST RESEARCH AND INVESTIGATION

2.1 Port Hueneme Study

A report titled "Bioremediation of Hydrocarbon Contaminated Soil at Great Lakes Naval Training Center" was completed by the Naval Facilities Engineering Service Center, Port Hueneme, California (see Appendix B). The report indicated that representative soil samples were analyzed for hydrocarbon degrading bacteria. Results of the analysis indicated that the soil contained petroleum degrading bacteria. This conclusion was based on comparison of before and after chromatograms of the contaminated soil. To confirm this conclusion, a detailed respiration test was conducted. Results of this test are presented in Section 2.2.

2.2 Bench Top Respirometry Study

Bench Top Respirometry Studies were completed by Ever Clear Environmental Technologies Corporation (see Appendix C). The respirometry tests consisted of the following:

1. Control - No additives or bulking agents add to the soil.
2. Kill Control - Same as #1 with mercuric chloride added
3. Treatment A - Bulking Agent #1 (Wood Chips)
4. Treatment B - Bulking Agent #2 (Horse Manure)
5. Treatment C - Bulking Agents #1 and #2 and Nutrients
6. Treatment D - Same as Treatment C plus microbid consortium

Results of the Bench Top Respirometry Study indicated that indigenous microbes were present within the native soil; however, there were not substantial populations of microbes to efficiently degrade petroleum contamination in a timely manner. Even with stimulation

from nutrients including oxygen, chelated iron, potassium, phosphate and ammonia nitrogen, the Respirometer Study indicated that the microbial colony count was deficient and incapable of efficiently remediating the contaminants of concern. The study concluded that the microbial population should be augmented in combination with the addition of nutrients. The construction of a bio-reactor for incubation and augmentation of microbe populations has been proposed in the Workplan (see Section 4.5).

2.3 Bio-Mass

Bio-mass is the organic material which supplies a carbon source and long term nutrients to the microbial colonies. The pilot study will utilize horse manure as the bio-mass material. The following local sources have been identified and may be utilized:

1. Name: Windermere farms
Location: 1/2 mile east of Route 41 on Route 173 in Wadsworth
Contact: John or Connie
Phone: 847-244-3662
Mileage: 15 miles, one-way
Amount: 1,000-1,500 cubic yards (and 50 yards per week)

2. Name: Kelly Stables
Location: Route 41 and Russel Road, wadsworth
Contact: Mike or Linda
Phone: 847-336-0670
Mileage: 17 miles, one-way
Amount: 500-700 cubic yards (and 30 yards per week)

3. Name: Field & Fences Stables
Location: Hunt Club Road and Stearns School Road, Gurnee
Contact: Anita
Phone: 847-244-4121
Mileage: 15 miles
Amount: 100 cubic yards (and additional 15 yards per week).

4. Name: John Ramirez, Contractor
Location: Various
Contact: John Ramirez
Office Phone #1: 847-541-8443
Office Phone #2: 847-541-8440
Mobile Phone: 847-878-0245
Pager #: 708-817-2058
Mileage: Materials delivered free of charge
Amount: 2,000 cubic yards

2.4 Bulking Agents

Bulking agents are fill materials which supply porosity to the soil mixture. Bulking agents are utilized in clayey soils to prevent clodding and enhance air movement within the bio-pile. The pilot study will utilize wood chips as the bulking agent as well as the bedding material (straw) found associated with the horse manure; The following local sources for bulking agent will be utilized:

1. Name: Willow Glen Golf Course Maintenance
Location: Great Lakes Naval Base
Contact: Maintenance

Phone:
 Mileage: <1 mile
 Amount: 100 cubic yards.

2. Name: John Ramirez, Contractor
 Location: Various
 Contact: John Ramirez
 Phone: 847-541-8443
 Mileage: Materials delivered free of charge
 Amount: 100 cubic yards at a time.

2.5 Microbial Augmentation

Based on the respirometry study, it was determined that microbial augmentation would be required to effectively remediate the soils in a reasonable period of time. A commercially available microbial consortium known as Microcat XR from Bioscience, Inc. will be used. This microbial augmentation was selected for its ability to degrade aliphatic and aromatic hydrocarbons. The microbial augmentation will be obtained by Beling and incubated in the bio-reactor and applied to the contaminated soils in the biopile.

3.0 BIO-PILE PLACEMENT AND DIMENSIONS

The pilot bio-pile will be constructed concurrent with pipe removal activities, which are scheduled to begin July 28 on the eastern side of the site. The biopile will be constructed in the area of the demolished carrier compartments, and extend the length of the site. Beling's Field Coordinator will make appropriate decisions for the extension of the biopile based upon logistics in the field. A second biopile may be constructed parallel to the first pile. Refer to Figure 1, for site layout, and Appendix A, Figures 1-3 for pile configuration.

A biopile unit is estimated to accommodate contaminated soil from a pipeline length of approximately 500 linear feet.

Dimensions for construction of each pilot bio-pile unit are estimated to be 16 foot wide by 50 foot long by 6 foot high. An equal volume of contaminated soil/chips/manure mixture will be required for each biopile. All mixing and placement of contaminated soil will be completed in the designated mixing areas on a double layer of 5 ml plastic. The mixing area will require a working area of approximately 100' x 100'.

4.0 BIO-PILE CONSTRUCTION

Based on an estimated 200 cubic yards of soil contamination for each 500 foot line of piping to be excavated, the following list of materials and methods will be used:

4.1 Materials

The following list of materials will be used to construct the "typical" bio-pile:

- 100 yards of dry manure (sheep, cattle, horse) with bedding.
- 100 yards of wood chips.
- 75 yards of medium grain sand.
- 55 gallons of 28-12-6 liquid fertilizer.
- 1,800 feet of 4-inch diameter PVC slotted drain tile.
- 12,000 square feet of black 5 mil polyethylene sheeting.
- 400 feet of flexible drip hose.
- One (1) rubber tired front end loader (3 yard).
- One (1) rubber tired backhoe.

4.2 Soil Preparation

The following soil preparation tasks will be completed:

- The contaminated soil from each trench will be excavated and placed in the designated mixing area.
- The wood chips and manure will be placed adjacent to the compost mixing area.
- Using a backhoe, all of the wood chips and manure will be mixed in a 1 to 1 ratio first to reduce odor and insects.

- The contaminated soil will be excavated starting at the farthest point away from the mixing area and progress towards the pile.
- Groundwater will be collected and treated in the bio-reactor and reapplied to the compost pile on an as need bases.
- Using a backhoe, the wood chips/manure and contaminated soil will be mixed in a 1 to 2 ratio on the impervious surface. This will be completed by placing two (2) buckets of contaminated soil on the impervious surface in a layer approximately 6 inch thick. One (1) bucket of chips/manure is then spread on the contaminated soil. The mixture will be lifted and dropped 3-5 times to achieve an optimum mixture.
- A second front end loader will supply the chip/manure and place in windrows.

4.3 Bio- Pile Construction

The bio-pile contains of three (3) lifts consisting of sand, contaminated soil/chips/manure mixture and chips/manure placed on a layer of polyethylene plastic (See Appendix A, Figures 1 and 2). The lifts are to be constructed simultaneously, starting at the furthest end of the pile and continuing until the desired length is reached. This is done to prevent the loader from driving over the bottom layer and compacting the compost. The following bio-pile construction tasks will be completed:

1. Place the two (2) layers of 5-mil poly sheeting down on graded surface. A 4-inch PVC drain pipe will then be placed to run length of the bio-pile in the center of the poly sheeting. The drainage pipe will then be covered with a six (6) inch layer of sand. The drainage piping will then be connected to plastic lined sump and used as a leachate collection system if required. Leachate is not expected to be produced due to the bio-pile cap.

2. Place a 30-36 inch deep lift of contaminated soil/chips/manure mixture on the sand drainage material.
3. Place a 12 inch deep lift of chips/manure mixture on the contaminated soil/chips/manure mixture.
4. Place an additional 30-36 inch deep lift of contaminated soil/chips/manure mixture on the chips/manure.
5. Place an additional 12 inch deep lift of chips/manure mixture on the contaminated soil/chips/manure mixture.
6. Within each lift of contaminated soil/chips/manure mixture, PVC drain tile will be placed across the width of the pile every five (5) feet (stagger with respect to lower piping) and extend one (1) foot beyond the pile edge (See Figure 2). This piping will allow for air to migrate into the pile.
7. Place three (3) 3/4 inch soaker hoses along the center top of the pile running the length of the windrow. The hosing will then be connected to the bio reactor and used as a moisture and nutrient distribution system.
8. The final step will be to cover with 5-mil black poly sheeting to prevent excess moisture (rain). The cover will be held down with rope placed over the drain pipe ends and sandbags placed along the pile base.

4.4 Groundwater Utilization

Groundwater encountered in the excavation phase will be collected through use of a sump pump and transferred into a bio-reactor (see Section 4.5) where microbes, nutrients and air will be added to remediate the groundwater. The remediated groundwater will then be used within the bio-pile to maintain the soil moisture content. Application of the collected water to the bio-pile will be on an as need bases (see Section 5.2 - Operations & Maintenance) and will not exceed the saturation limit of the soil. Any leachate which

may be generated (not anticipated) will be collected by the leachate collection system and remediated in the bio-reactor tank.

4.5 Bio-reactor Construction

The Bio-reactor consists of a minimum of two (2) 1,000 gallon holding tanks equipped with a liquid circulation pump and an air injection pump (See Figure 3 - Bio-reactor Detail). The bio-reactor will be filled with collected excavation water and/or well water. Micro-organisms, nutrients and air will be introduced to the collected water and blended for approximately 24 hours. The resulting mixture will be applied on an as needed bases to the bio-pile through use of the circulation pump and drip hose placed along the peak of the bio-pile.

5.0 BIO-PILE OPERATION AND MAINTENANCE

5.1 Monitoring Sampling

A minimum total of eight (8) monitoring samples will be randomly collected from the bio-pile. Soil samples will be collected from the contaminated soil layers on a monthly bases. A minimum of two (2) soil samples per event will be analyzed. The soil samples will be collected using stainless steel hand auger and packed with zero head space in 500 ml. jars with Teflon lined lids.

The collected samples will be screened using a PID meter. The sample with the highest PID reading will be analyzed. One (1) soil samples will be analyzed for BTEX (Method 8020) and one (1) for PNAs (Method 8310) per sample event. Results will determine when final closure sampling will occur.

5.2 Operation and Maintenance

The project engineer will examine the bio-pile weekly through construction. The following items will be addressed:

- Soil moisture content shall be maintained between 20 and 40 percent dry weight.
- Soil pH shall be maintained between 6.5 and 7.5.
- Periodic addition of water and nutrients may have to be completed based on soil moisture and analytical results.
- Additional chemical analysis will be addressed under the Site Sampling Plan.

The remediation period is expected to be six to eight months, based upon respirometry and past experience. The project engineer will examine the biopile every other week or as needed through the winter months to closure.

6.0 BIO-PILE CLOSURE

6.1 Closure Sampling

Closure sampling of the bio-pile will be conducted following two (2) consecutive bio-pile monitoring events for which all the sample results were below the site specific cleanup objectives. The closure sampling will consist of a minimum of six (6) soil grab samples from six (6) borings collected from the bio-pile. Samples will be collected at every one (1) foot of depth and proceed until the asphalt base is encountered. The soil samples will be collected using stainless steel hand auger and packed with zero head space in 500 ml. jars with Teflon lined lids.

The collected samples will be screen using a PID meter. The soil sample with the highest PID reading per boring will be analyzed for BTEX (Method 8020) and PNAs (Method 8310).

6.2 Decontamination Procedures

Decontamination of sampling equipment and bio-pile equipment will be conducted. Decontamination procedures will be as follows:

B. Bailers and Sample Equipment:

1. The bailers and sample equipment will be decontaminated by disassembling and placing the parts in an Alconox and water mixture.
2. The parts will be brush scrubbed, double tap water rinsed and final rinsed with distilled water.
3. Any decontamination liquids which may be generated will be collected and added to the bio-reactor tank.

B. Bio-Pile Materials:

1. Upon confirmation of clean-up levels the bio-pile will be disassembled.
2. The PVC piping will be pressure steam cleaned of all soil buildup and reused.
3. Any decontamination liquids which may be generated will be collected and remediated in the bio-reactor tank.

7.0 SCHEDULE OF EVENTS

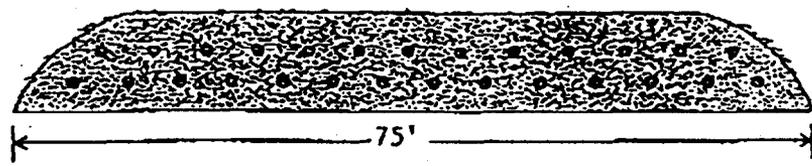
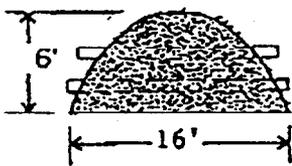
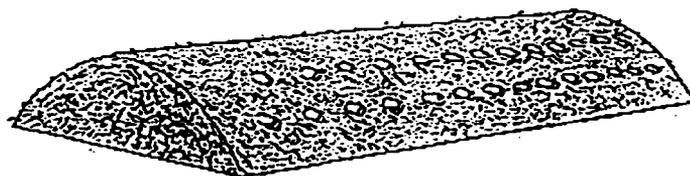
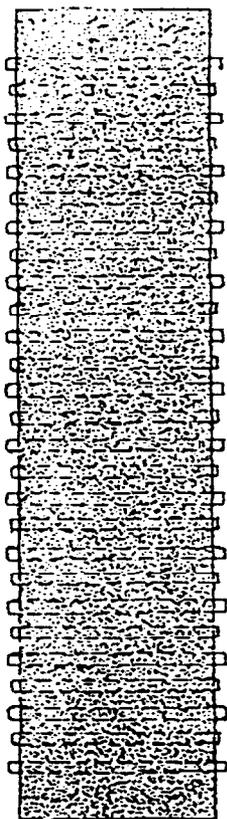
The following schedule of events table is given in weeks.

TABLE 1 - REMEDIATION SCHEDULE

	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	
Construct Pile	-----																					
Construct Bio-reactor	---																					
Remediation	-----																					
File Monitoring			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
File Sampling	X					X				X				X				X				
Closure Sampling																						X
Closure Report																						-----

**ATTACHMENT #1
APPENDIX A**

DETAIL DRAWINGS



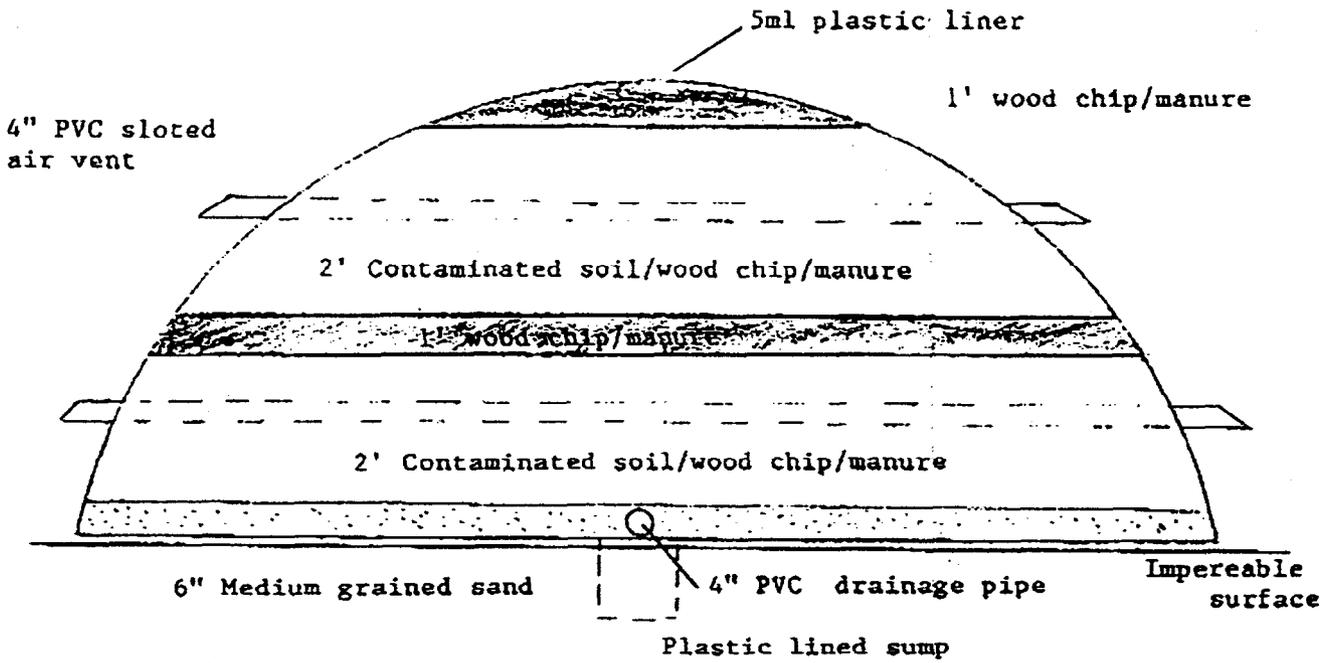
COMPOST PILE DESIGN

BELING CONSULTANTS, INC.

Professional Engineering and Environmental Services
 175 W. Jackson Blvd., Ste. A361 Chicago, Illinois 60604
 (312) 986-0330
 FAX (312) 986-0067

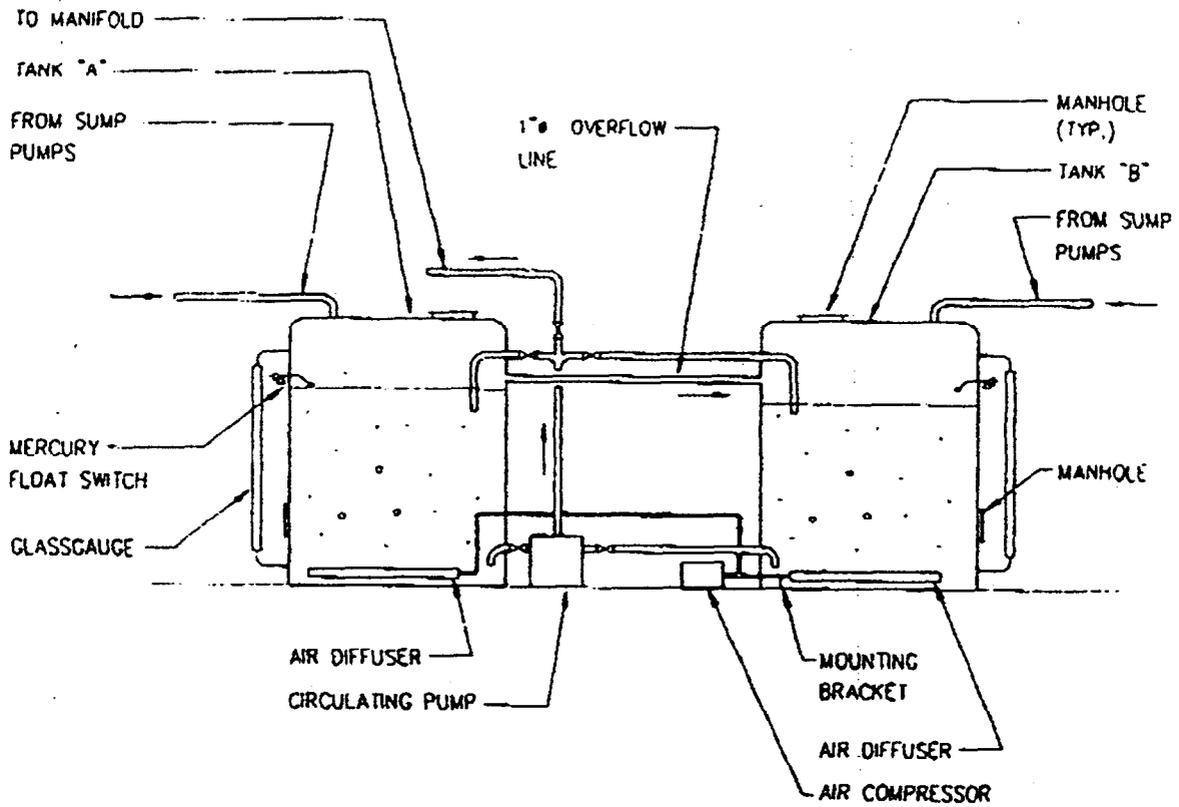
COMPOST PILE DESIGN

DRAWN:	CHECKED:	APPROVED:	DATE:	JOB NO.:	DWG. NO.:
					1



Note: 4 ml black polyethylene plastic to be used to enclose top and bottom of pile.

BELING CONSULTANTS, INC. <i>Professional Engineering and Environmental Services</i> 175 W. Jackson Blvd., Ste. A061 Chicago, Illinois 60604 (312) 899-0399 FAX (312) 899-0397				COMPOST PILE DETAIL	
DRAWN:	CHECKED:	APPROVED:	DATE:	JOB NO.:	DWG. NO.: 2



BELING CONSULTANTS, INC.

Professional Engineering and Environmental Services
 113 W. Jackson Blvd., Ste. A301 Chicago, Illinois 60604 (312) 986-0390 FAX (312) 986-0067

BIO -- REACTOR DETAIL

DRAWN:	CHECKED:	APPROVED:	DATE:	JOB NO.:	DWG. NO.:
					3

ATTACHMENT #1
APPENDIX B

PORT HUENEME STUDY

BIOREMEDIATION OF HYDROCARBON CONTAMINATED SOIL AT GREAT LAKES NAVAL TRAINING CENTER

INTRODUCTION

Representative soil samples were analyzed for hydrocarbons and hydrocarbon degrading bacteria. In these samples the hydrocarbon concentration varies from 2500 to 7500 ppm. and resembles degraded diesel fuel. The soil harbors substantial populations of heterotrophic and hydrocarbon degrading bacteria that the chromatograms suggest are degrading hydrocarbon contaminants in the soil. To promote bioremediation at this site, the addition of straw and manure has been suggested. However, it has been our experience that when these amendments are added in large enough proportions, they promote the growth of thermophilic bacteria. As a result, the temperature may increase from ambient to 55°C-60°C. These temperatures select for a more homogeneous population of hydrocarbon degrading bacteria with limited hydrocarbon degrading capabilities. Thus, the addition of excess amendments that would promote the growth of thermophiles should be avoided. Maintaining the temperature in the range 20°C - 40°C will promote the growth of a more diverse community of hydrocarbon degrading bacteria and more extensive degradation of the various classes of hydrocarbons.

MATERIALS AND METHODS

Hydrocarbons were extracted from the soil samples by mixing ~5 g with twice their weight of anhydrous sodium sulfate, adding 10 ml of methylene chloride, mixing vigorously for six hours and filtering through a 0.2 µm nylon filter. Extracts, usually 5 µL, were injected, split injection, injector temperature 250°C, 0.5 min purge delay, onto a 30 m DB-5 column using helium 60 ml/min as the carrier. The column was held at 30°C for 5 min, heated to 200°C at a rate of 5°C/min, held for 5 min, heated to 300°C at a rate of 6°C/min and held for 10 min. The detector was an FID at 250°C. Chemware software from Hewlett Packard was used to analyze the chromatograms. A standard curve was constructed by dissolving a known amount of marine diesel #2 in methylene chloride, preparing dilutions in methylene chloride, chromatographing and integrating the area under the chromatogram between 20 and 60 min, Figure 1. The best straight line through these data points was used to calculate hydrocarbon concentrations in the samples.

To measure nitrogen and phosphorus, soil samples were suspended in MilliQ water, shaken for 2 h, and centrifuged. Concentrations of nitrogen and phosphorus in the supernatants were measured using Hach kits and procedures.

Bacteria were enumerated using the fifteen tube most probable number (MPN) method by suspending ~20 g of sample in 20 ml of Bushnell-Hass (BH) basal salts or minimal medium A (MMA), vigorously shaking for 2 hours, and preparing 10-fold serial dilutions in BH or MMA. Heterotrophs were enumerated in nutrient broth and BH amended with

JUN 16 '97 12:18PM NFESC CLEAN AIR

P.4/10

Since the soil contains a healthy population of mesophilic, i.e., active at ambient temperatures, hydrocarbon degraders, bioremediation should promote the growth of these organisms. The addition of excess straw and manure has the potential to encourage the growth of thermophiles which in our experience are not as metabolically diverse as the mesophiles. As a result bioremediation may take longer and some classes of hydrocarbons may not be degraded. During the preparation of the soil, it would be beneficial to blend in nitrogen and phosphorus to an initial concentration of 200 ppm and 100 ppm respectively. These concentrations will decrease as remediation proceeds, however, the bacteria capture and recycle these nutrients. The moisture content should be monitored using tensiometers, e.g., from Soil Moisture, Santa Barbara, CA. phone (805)964-3525 and maintained at 70 - 80 % of field capacity. The advantage of using tensiometers is that the moisture content as a per-cent of field capacity can be read directly. It is also necessary to monitor the oxygen concentration in the soil gas. When the oxygen concentration falls below 5%, the soil should be aerated. The addition of nutrients and moisture and periodic aeration should stimulate the indigenous bacterial population and promote the degradation of hydrocarbon contaminants at the fire fighter training site.

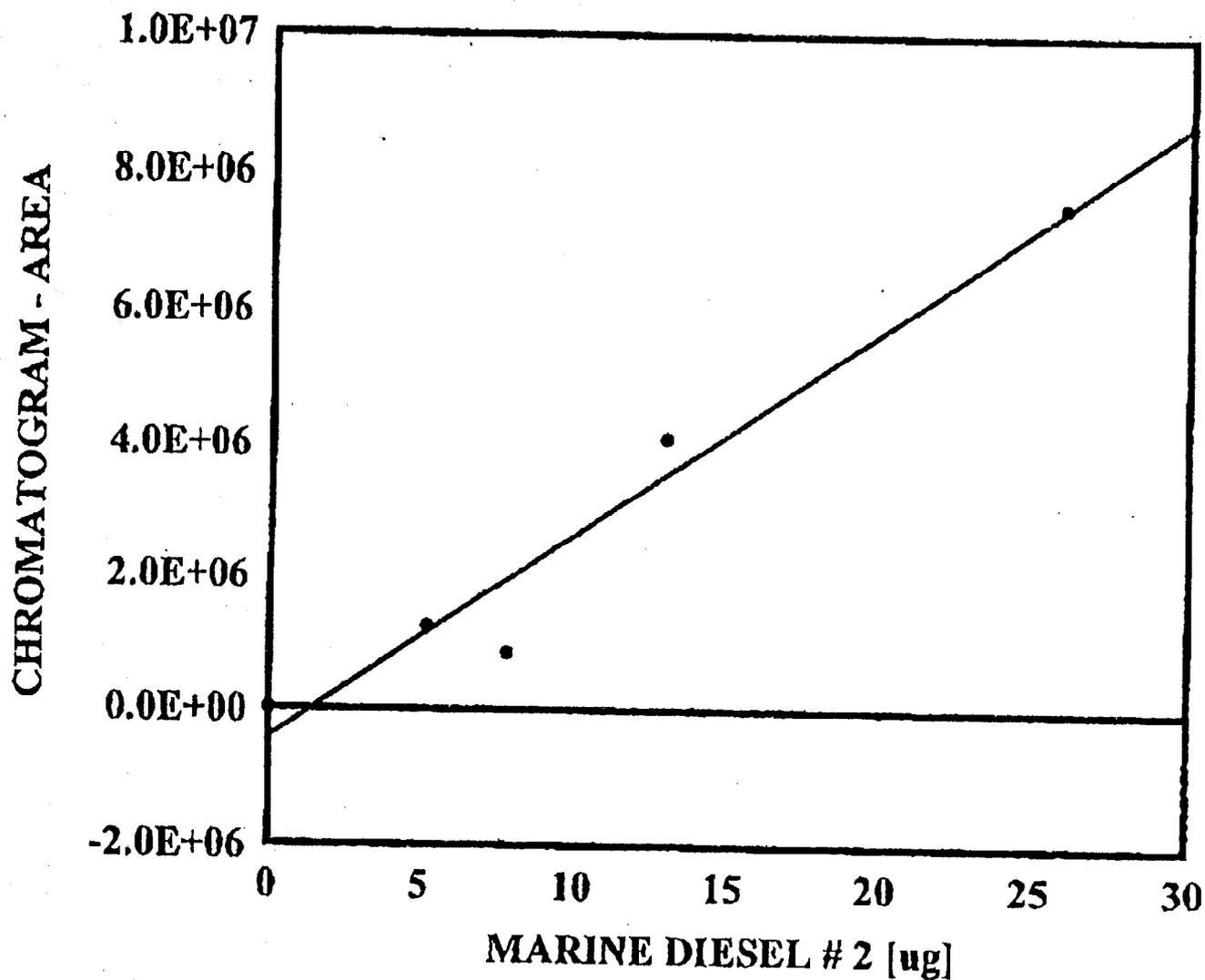


Figure 1. Standard curve used to calculate the concentration of fuel hydrocarbons in soil samples from the fire fighter training area at Great Lakes Naval Training Center.

Sig. 1 in C:\HP\CHEM\1\DATA\DIESEL2\DSL-1.D

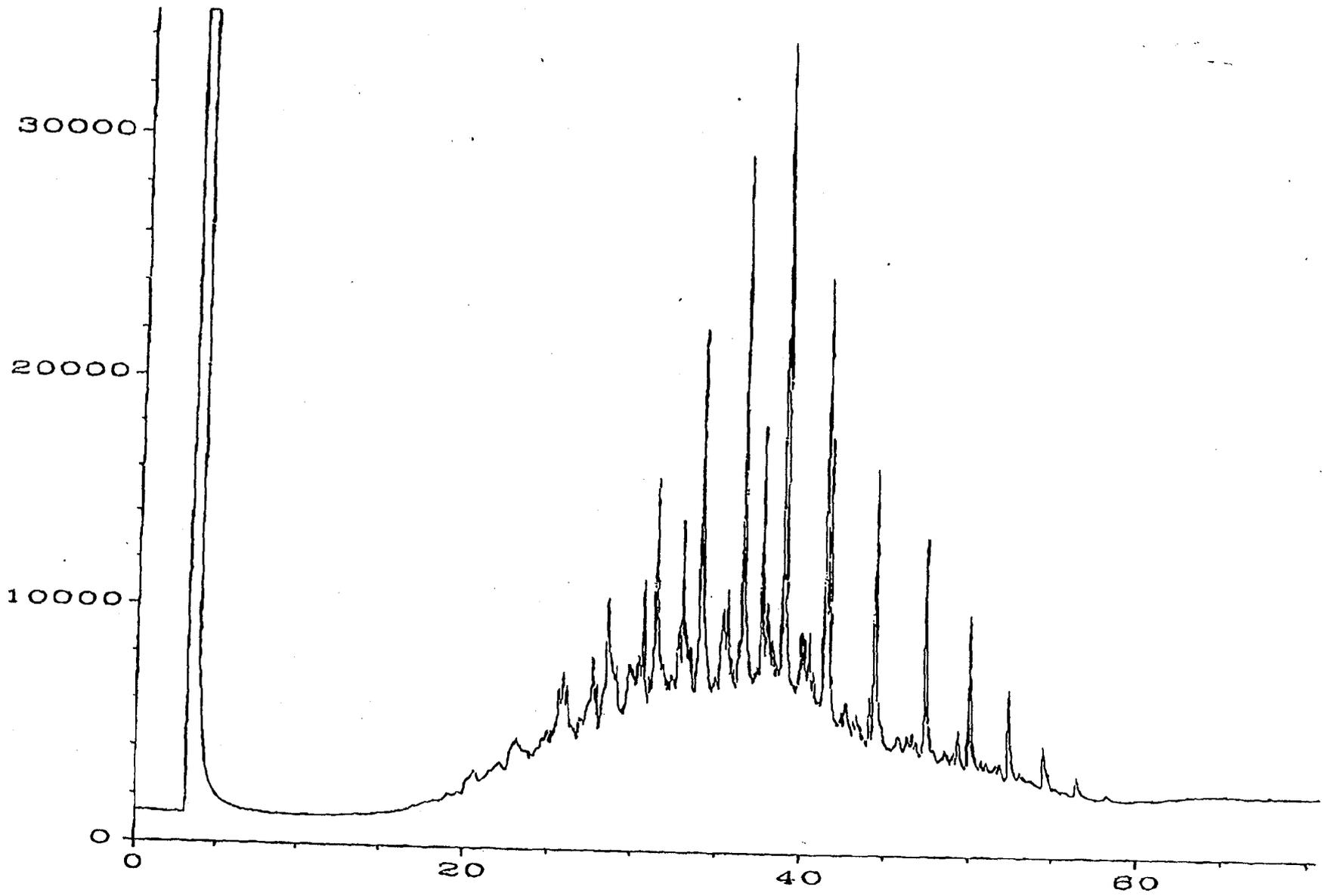


Figure 2. Chromatogram of marine diesel #2 dissolved in methylene chloride.

SIG. 1 IN C:\HP\CHEM\1\DATA\GR1KSN\SS-1.D

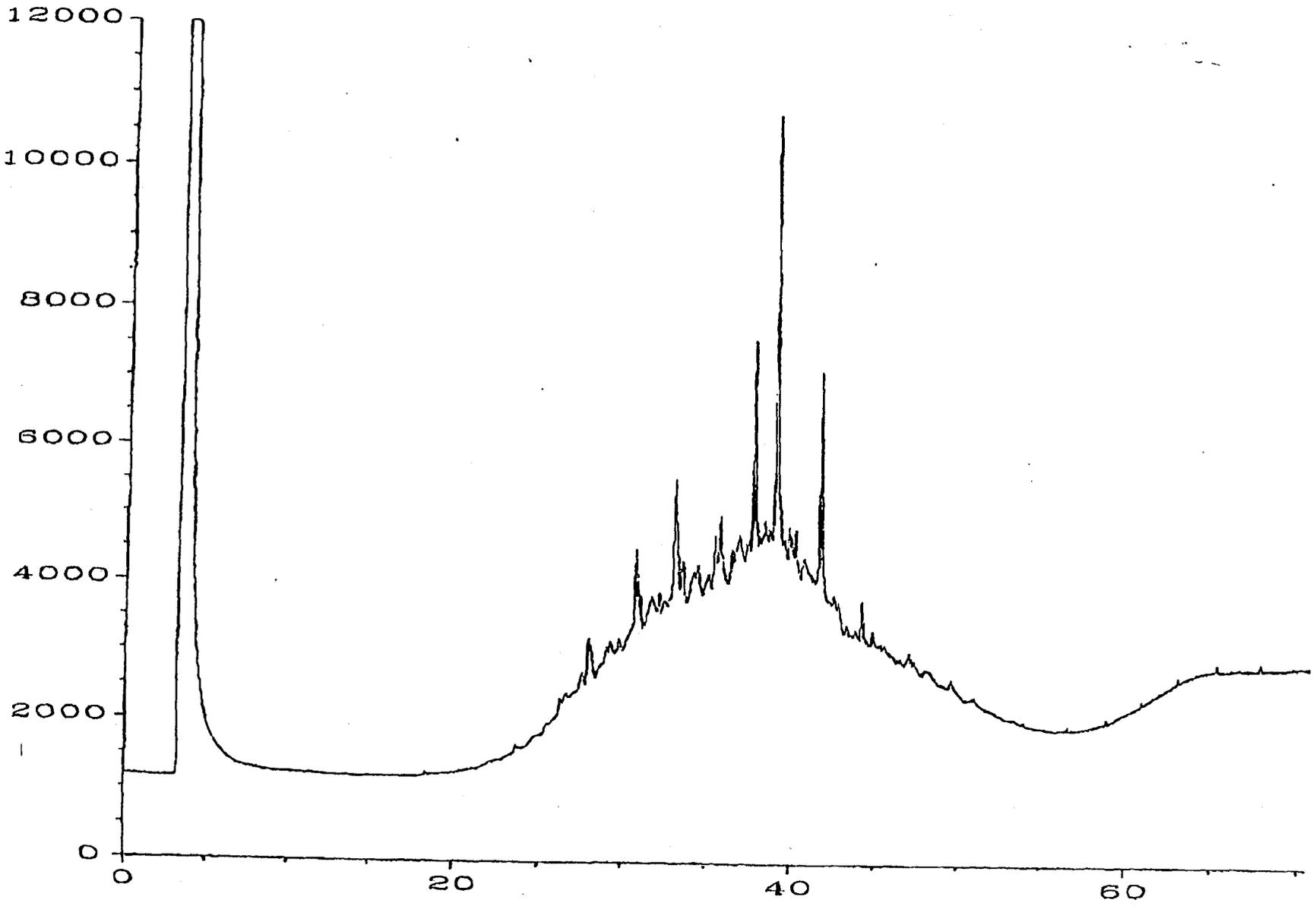


Figure 3. Chromatogram of a methylene chloride extract of hydrocarbons extracted from soil sample one.

Fig. 1 in C:\HP\CHEM\1\DATA\CRTLKS\SS-4.D

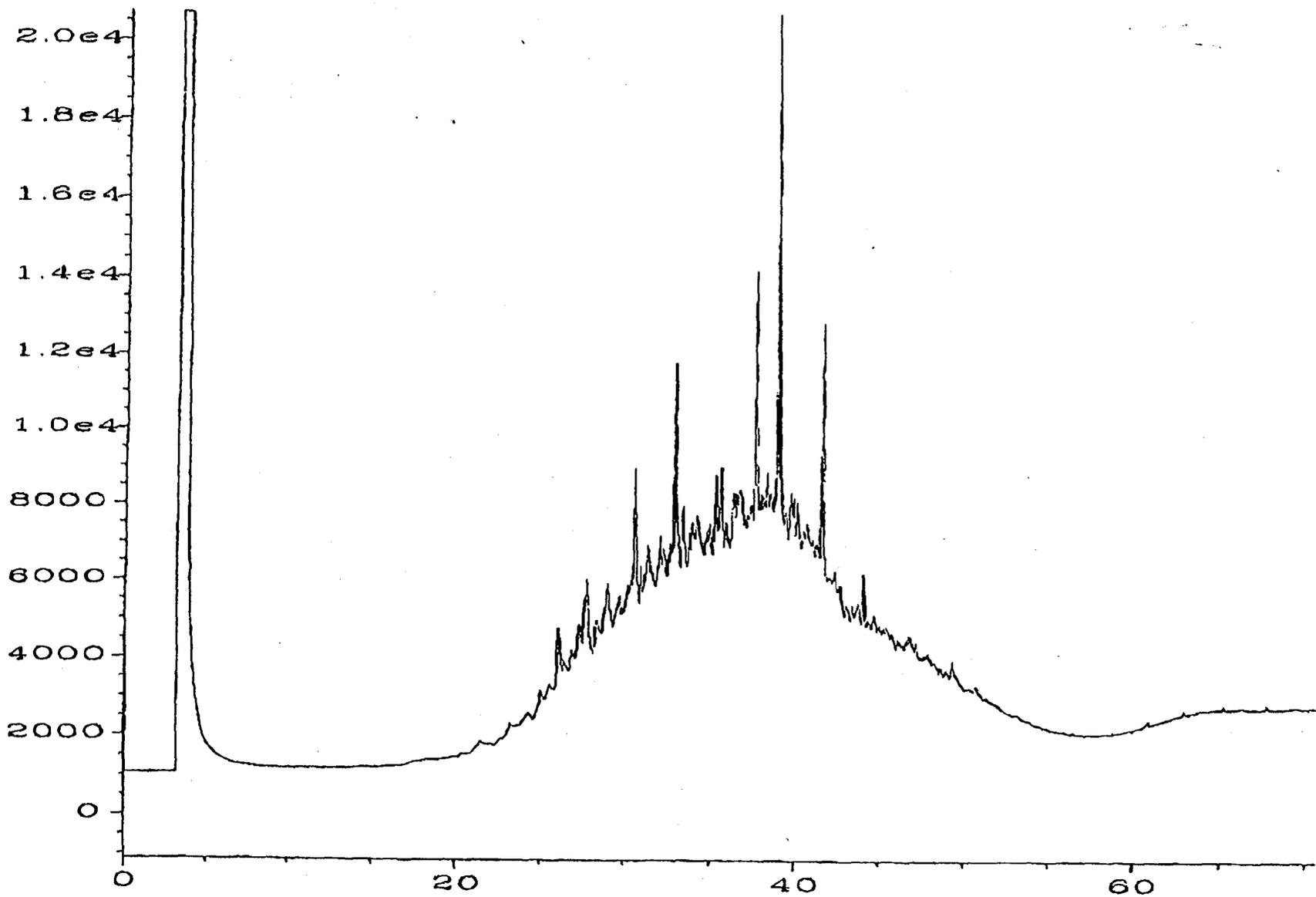


Figure 4. Chromatogram of a methylene chloride extract of hydrocarbons extracted from soil sample four.

C:\NHP\CHEM\1\DATA\GRTLK\S\S-4.D (merged)

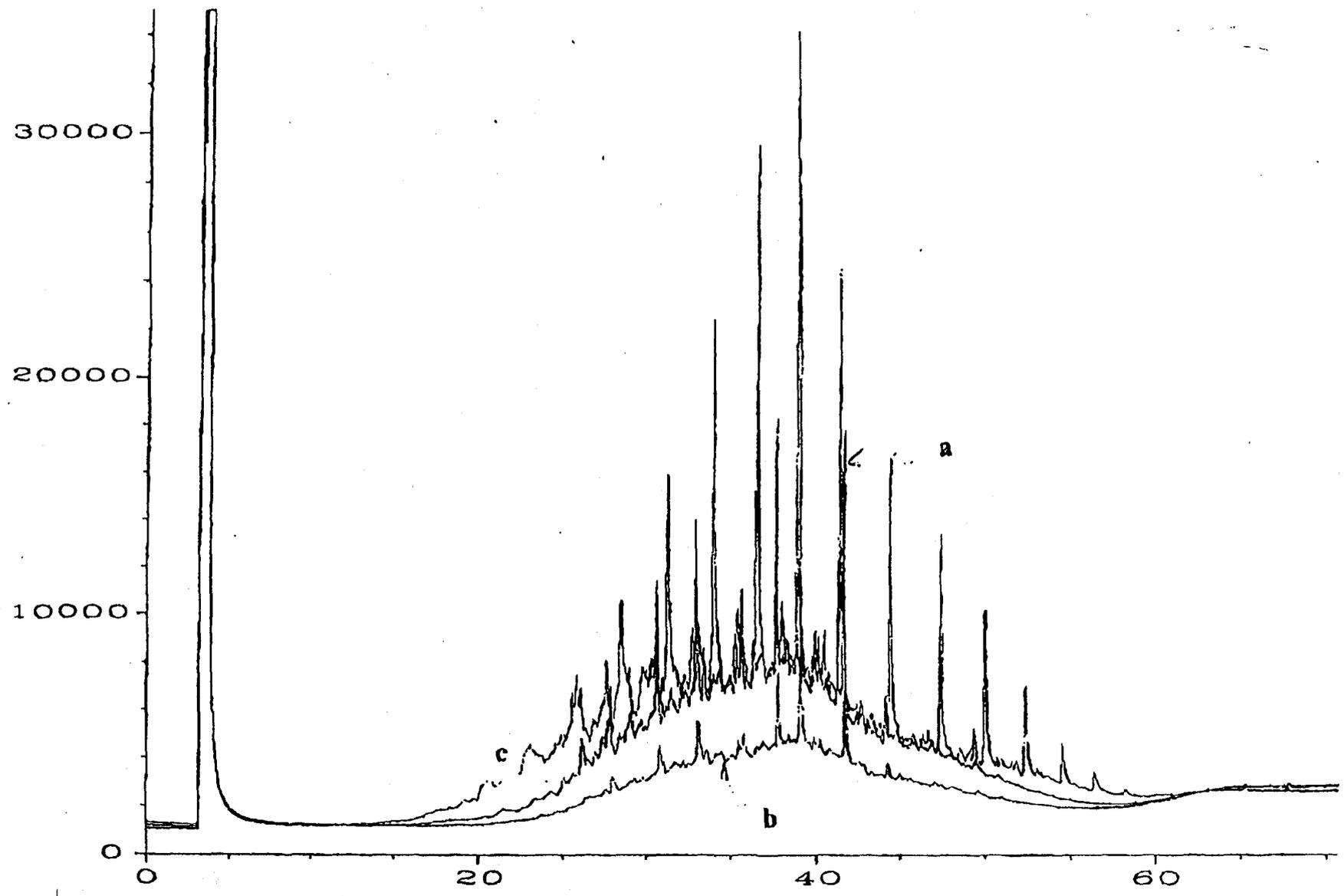


Figure 5. Chromatograms of (a) marine diesel #2 and methylene chloride extracts of soil samples (b) one and (c) four.

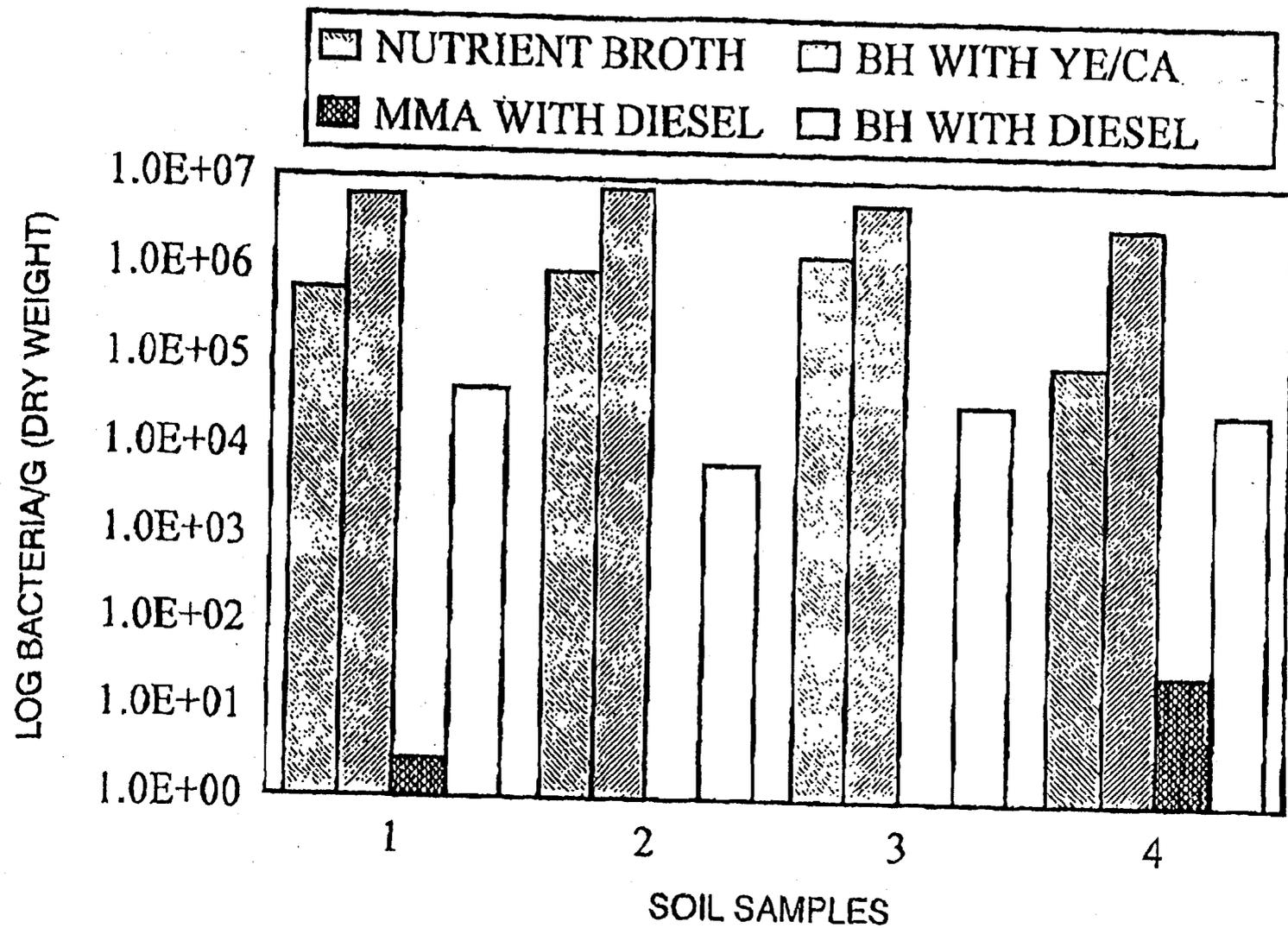


Figure 6. Enumeration of total heterotrophs and hydrocarbon degrading bacteria in soil samples from the fire fighter training site at Great Lakes Naval Training Center. MMA and BH are minimal medium A and Bushnell-Hass respectively. No hydrocarbon degraders were detected in soil samples 2 and 3 in MMA medium. YE and CA are yeast extract and casamino acids respectively.

**ATTACHMENT #1
APPENDIX C**

**BENCHTOP RESPIROMETRY
STUDY**

TREATABILITY STUDY REPORT



E v e r C l e a r
E n v i r o n m e n t a l
T e c h n o l o g i e s C o r p o r a t i o n

Custom Services & Solutions for Environmental & Wastewater Markets

Site:

Great Lakes

Client:

**Naval Training Center
Beling Consultants, Inc.**

Date Prepared:

July 11, 1997

Biotreatability Study Report
Great Lakes Naval Training Center
July 11, 1997

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1. Overview
2. Respiration Test #1 & #2
3. Respiration Test #3 & #4
4. Respiration Test #5 & #6
5. Conclusions
6. Principle of Operation

**Biotreatability Study Report
Great Lakes Naval Training Center
July 11, 1997**

**Prepared for: Beling Consultants, Inc.
Chicago, IL 60604**

**Site: Great Lakes Naval Training Center
Fire Fighting Training Unit
Great Lakes, Illinois**

Request: A representative sample of contaminated soil was collected from the Great Lakes Fire Fighting Training Unit on June 16, 1997 by Karl E. Meier P.E., of Beling Consultants, Inc. (Beling). A request for an aerobic respirometric treatability study was submitted.

Purpose: Communications with Karl E. Meier of Beling's Chicago office helped develop a purpose and a plan for the protocol to be used during the testing period for the Great Lakes Naval Training Center site. It was determined that six (6) aerobic respiration test cycles would be performed with various amendments (bulking agents) and with a commercially available microbial consortium. This data would be used to determine which bulking agent, nutrient/mineral supplement, or if a bacterial consortium would best stimulate mineralization of the organics found at the Great Lakes Naval Training Center site.

Initial Tests: The first test conducted on the contaminated soil was the SW 846-8260A GC/MS analysis to determine the quantitation of volatile organics present in the sample (see figure 1, this section). A number of volatile organic compounds (VOC's) were found to be present in the soil. The GC/MS chromatograph indicated that a diesel range and higher boiling point volatiles are present. However, no benzene, toluene, ethylbenzene or xylene (BTEX) were quantitated in the sample received.

**Biotreatability Study Report
Great Lakes Naval Training Center
July 11, 1997**

The next analysis method SW846-8310, determined that a number of PNA's are present in the soil (see figure 2, this section). This analysis, (PNA's) along with the volatiles analysis for BTEX were performed during the various respiration runs.

Also, a chemical profile (see figure 3, this section) analyses for various soluble anions and cations in the soil was completed. This provided information as to what available micro nutrients and minerals may be readily used by the indigenous bacteria at the Great Lakes site.

Additionally, a physical profile provided information as to measurement of pH, redox potential, colony counts and a solids/moisture ratio. This information is used to determine existing physical conditions at the Great Lakes site. (See figure 3, this section).

Finally, total carbon analysis along with organic and inorganic carbon was measured. These results reflect the total organic load that needs to be mineralized during the remediation process. A ratio of 100-20-5 or 100 parts carbon, 20 parts nitrogen and 5 parts phosphorous is a commonly used ratio for bioremediation.

Respiration Tests: Six (6) tests were conducted on a soil/slurry from the Great Lakes site. 200 grams of homogenized soil was used for each respiration test. These tests numbered one (1) through (6) are:

- | | |
|-----------------|--|
| 1. Kill Control | Mercuric Chloride added |
| 2. Control | No Additives or Bulking Agents |
| 3. Treatment A | Bulking Agent #1 - Wood chips |
| 4. Treatment B | Bulking Agent #2 - Horse Manure |
| 5. Treatment C | Bulking Agent #1 and #2 - Nutrients |
| 6. Treatment D | Bulking Agent #1 and #2 - Nutrients and Microbial Consortium |

All respiration test runs were performed in the presence of dissolved oxygen levels greater than 2.0 mg/l and the soil was amended with water to a consistency of 50% solids and 50% water. This is to promote good mixing and microbial contact with the organics to be degraded. This type of contact was able to theoretically prove if the organics of concern could be mineralized in a given period of time.

EverClear Environmental Technologies Laboratory

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Tel: (503) 652-6900

Fax: (503) 652-7900

Client: Beling Consultants Inc., 175 W. Jackson Blvd., Chicago, Il. 60604

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

BTEX

Method 8260A GC/MS

All values reported in parts per million (ppm) mg/kg unless noted.

BDL= Below Detection Limit

N/A= Test not performed

Sample ID: Representative Soil from Fire Fighting Training Area

Collected: 06/18/97

Analyzed: 06/19/97

Lab No.190697-4

Description	Results	MDL
Benzene	BDL	0.005
Toluene	BDL	0.005
Ethylbenzene	BDL	0.005
mp-Xylene	BDL	0.005
o-Xylene	BDL	0.005

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

Sample ID: Representative Soil from Fire Fighting Training Area Initial

Collected 6/18/97

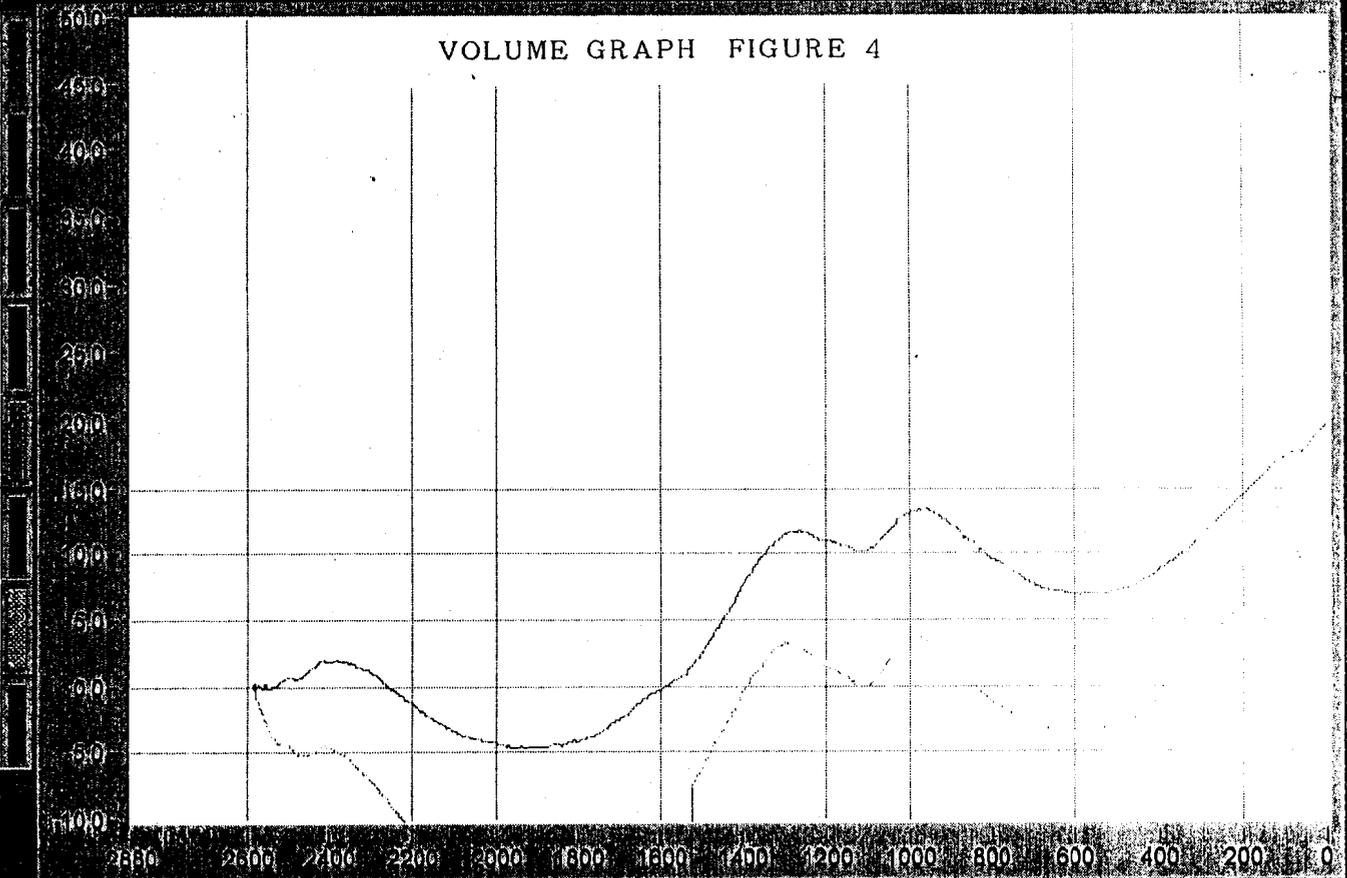
Analyzed 6/19/97

Lab No. 190697-8

Description	Results	Methods
Bacteria Count 24 hr.	5.8x10 ²	ASTM 9215
Bacteria Count 48 hr.	7.7x10 ²	ASTM 9215
Redox Potential	+10	ASTM 2580
Ph	7.07	SW846-9040A
Total Carbon	2.9%	415.1
Total Organic Carbon	2.0%	415.1
Total Inorganic Carbon	0.9%	415.1
Total Nitrogen	N/A	Chemoluminesance

When anion and or cations are tested, soil preparation consists of extracting 10 grams of sample with 100 ml of deionized water and filtering the extract through a 0.45 micron membrane filter. The results are expressed on a volume basis and represent the soluble anion or cation in the sample.

Kill Contr:
12.2 ml. CC



red
green

Volume

Graph Scale (ml) Time Scale (hr)

50

48

Preference Calibration Logging

TEST #1 (green pen) KILL CONTROL

TEST #2 (red pen) CONTROL

Biotreatability Study Report
Great Lakes Naval Training Center
July 11, 1997

Respiration Test #3: This respiration test was labeled **Treatment A**, bulking agent #1 (wood chips). A mixture of contaminated soil to bulking agent #1 was mixed in a 50/50 ratio with water and was homogenized. This test was performed to determine that in the presence of the electron acceptor oxygen and a bulking agent, if any oxygen uptake would occur. If oxygen uptake did occur, this would suggest that properties of the bulking agent (wood chips) contain micro-organisms and/or nutritive elements sufficient to stimulate mineralization of organic carbon.

See Figure 6 (Volume graph - green pen) and
See Figure 7 (Rate graph - green pen)

As the Volume graph and the Rate graph (green pen) indicate some oxygen uptake or biological activity was taking place in the **Treatment A** respiration test. As the Volume graph displays 60.6 mls of oxygen was utilized in a forty (40) hour period. the Rate graph, however, indicates only a maximum of 2.5 mls per hour of oxygen was used at a given time.

This respiration test demonstrated that under ideal dissolved oxygen conditions that the bulking agent #1 (wood chips) provided a slight increase in biological activity. This is an indication that increased amounts of micro-nutrients and/or bacterial populations are being leached from the bulking agent to encourage organic carbon mineralization.

To confirm this finding before and after analytical tests were performed on respiration test #3.

See Figure 8 (BTEX) and Figure 9 (PNA's)

As stated earlier in this report, no BTEX was found in the sample received. However, PNA's were detected and as indicated by Figure 9, labeled before and after, a slight decrease in the overall constituents is noted.

It can be stated that the bulking agent #1 (wood chips) had a slightly positive influence on the mineralization of the organic carbon. Since no toxic respiration effects were seen on the Volume or Rate graphs using this type of wood chips, it can be considered beneficial to the overall biological remediation program.

Biotreatability Study Report
Great Lakes Naval Training Center
July 11, 1997

Respiration Test #4: This respiration test was labeled **Treatment B**, bulking agent #2 (horse manure). A mixture of contaminated soil to bulking agent #2 was mixed in a 50/50 ratio with water and was homogenized. This test was performed to determine that in the presence of the electron acceptor oxygen and a bulking agent, if any oxygen uptake would occur. If oxygen uptake did occur, this would suggest that properties of the bulking agent (horse manure) contains micro-organisms and/or nutritive elements sufficient to stimulate mineralization of organic carbon.

See Figure 6 (Volume graph - red pen) and
See Figure 7 (Rate graph - red pen)

The Volume graph and the Rate graph (red pen) indicate an increase in oxygen uptake or biological activity was taking place in the **Treatment B** respiration test. As the Volume graph displays 166.6 mls of oxygen was utilized in a forty (40) hour period. Also, the Rate graph indicated a maximum of 9.0 mls per hour of oxygen was used at a given period of time.

This respiration test demonstrated under ideal dissolved oxygen conditions that the bulking agent #2 (horse manure) provided a fair increase in biological activity. This is an indication that increased amounts of micro-nutrients and/or bacterial populations are being leached from the bulking agent to encourage organic carbon mineralization.

To confirm this finding before and after analytical tests were performed on respiration test #4.

See Figure 10 (BTEX) and Figure 11 (PNA's)

As stated earlier in this report, no BTEX was found in the sample received. However, PNA's were detected and as indicated by Figure #11, labeled before and after, a fair decrease in the overall constituents is noted.

It can be stated that the bulking agent #2 (horse manure) had a positive influence on the mineralization of the organic carbon. Since no toxic respiration effects were seen on the Volume or Rate graphs using this type of horse manure, it can be considered beneficial to the overall biological remediation program.

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Client: Beling Consultants Inc., 175 W. Jackson Blvd., Chicago, Il. 60604

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

BTEX

Method 8260A GC/MS

All values reported in parts per million (ppm) mg/kg unless noted.

BDL= Below Detection Limit

N/A= Test not performed

Sample ID: Representative Soil from Fire Fighting Training Area	Respiration Test #3	Before
Collected: 06/20/97	Analyzed: 06/20/97	Lab No.200697-2

Description	Results	MDL
Benzene	BDL	0.005
Toluene	BDL	0.005
Ethylbenzene	BDL	0.005
mp-Xylene	BDL	0.005
o-Xylene	BDL	0.005

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Client: Beling Consultants Inc., 175 W. Jackson Blvd., Chicago, Il. 60604

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

Polynuclear Aromatics

Method: SW-846 8310

All values reported in parts per million (ppm) mg/kg, unless noted.

BDL= Below Detection Limit MDL= Method Detection Limit

Sample ID: Representative Soil from Fire Fighting Training Area Respiration Test #3 After

Collected: 06/22/97

Analyzed: 06/22/97

Lab No.220697-11

Analyte	Results	MDL
Naphthalene	0.438	0.010
Acenaphthylene	BDL	0.010
Acenaphthene	0.370	0.010
Fluorene	0.163	0.010
Phenanthrene	2.010	0.010
Anthracene	0.085	0.010
Fluoranthene	BDL	0.010
Pyrene	BDL	0.010
Benz(a)anthracene	BDL	0.010
Chrysene	BDL	0.010
Benzo(b)fluoranthene	BDL	0.010
Benzo(k)fluoranthene	BDL	0.010
Benzo(a)pyrene	BDL	0.010
Dibenz(a,h)anthracene	BDL	0.010
Benzo(g,h,i)perylene	BDL	0.010
Indeno(1,2,3-cd)pyrene	BDL	0.010
2-Methylnaphthalene	2.185	0.010

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Client: Beling Consultants Inc., 175 W. Jackson Blvd., Chicago, Il. 60604

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

BTEX

Method 8260A GC/MS

All values reported in parts per million (ppm) mg/kg unless noted.

BDL= Below Detection Limit

N/A= Test not performed

Sample ID: Representative Soil from Fire Fighting Training Area	Respiration Test #4	After
Collected: 06/22/97	Analyzed: 06/22/97	Lab No.220697-8

Description	Results	MDL
Benzene	BDL	0.005
Toluene	BDL	0.005
Ethylbenzene	BDL	0.005
m,p-Xylene	BDL	0.005
o-Xylene	BDL	0.005

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Location: Great Lakes Naval Training Center, Great Lakes, Illinois

BTEX

Method 8260A GC/MS

All values reported in parts per million (ppm) mg/kg unless noted.

BDL= Below Detection Limit

N/A= Test not performed

Sample ID: Representative Soil from Fire Fighting Training Area Respiration Test #5 Before

Collected: 06/24/97

Analyzed: 06/24/97

Lab No.240697-1

Description	Results	MDL
Benzene	BDL	0.005
Toluene	BDL	0.005
Ethylbenzene	BDL	0.005
mp-Xylene	BDL	0.005
o-Xylene	BDL	0.005

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Client: Beling Consultants Inc., 175 W. Jackson Blvd., Chicago, Il. 60604

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

Polynuclear Aromatics

Method: SW-846 8310

All values reported in parts per million (ppm) mg/kg, unless noted.

BDL= Below Detection Limit MDL= Method Detection Limit

Sample ID: Representative Soil from Fire Fighting Training Area Respiration Test #5 Before

Collected: 06/24/97

Analyzed: 06/24/97

Lab No.240697-13

Analyte	Results	MDL
Naphthalene	0.501	0.010
Acenaphthylene	BDL	0.010
Acenaphthene	0.277	0.010
Fluorene	0.308	0.010
Phenanthrene	1.360	0.010
Anthracene	0.172	0.010
Fluoranthene	BDL	0.010
Pyrene	0.115	0.010
Benz(a)anthracene	BDL	0.010
Chrysene	BDL	0.010
Benzo(b)fluoranthene	BDL	0.010
Benzo(k)fluoranthene	BDL	0.010
Benzo(a)pyrene	BDL	0.010
Dibenz(a,h)anthracene	BDL	0.010
Benzo(g,h,i)perylene	BDL	0.010
Indeno(1,2,3-cd)pyrene	BDL	0.010
2-Methylnaphthalene	2.450	0.010

EverClear Environmental Technologies Laboratory

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Fax: (503) 652-7900

Client: Beling Consultants Inc., 175 W. Jackson Blvd., Chicago, Il. 60604

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

Polynuclear Aromatics

Method: SW-846 8310

All values reported in parts per million (ppm) mg/kg, unless noted.

BDL= Below Detection Limit

MDL= Method Detection Limit

Sample ID: Representative Soil from Fire Fighting Training Area Respiration Test #5 After

Collected: 06/26/97

Analyzed: 06/26/97

Lab No.260697-8

Analyte	Results	MDL
Naphthalene	0.200	0.010
Acenaphthylene	BDL	0.010
Acenaphthene	0.045	0.010
Fluorene	0.196	0.010
Phenanthrene	1.071	0.010
Anthracene	0.144	0.010
Fluoranthene	BDL	0.010
Pyrene	0.080	0.010
Benz(a)anthracene	BDL	0.010
Chrysene	BDL	0.010
Benzo(b)fluoranthene	BDL	0.010
Benzo(k)fluoranthene	BDL	0.010
Benzo(a)pyrene	BDL	0.010
Dibenz(a,h)anthracene	BDL	0.010
Benzo(g,h,i)perylene	BDL	0.010
Indeno(1,2,3-cd)pyrene	BDL	0.010
2-Methylnaphthalene	2.128	0.010

EverClear Environmental Technologies Laboratory

3990 S.E. Roethe Road

Milwaukie, Or. 97267

Tel: (503) 652-6900

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Client: Beling Consultants Inc., 175 W. Jackson Blvd., Chicago, Il. 60604

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

Chemical/Physical Profile

ASTM 18th Edition

All values reported in parts per million (ppm) mg/L, unless noted.

BDL= Below Detection Limit

N/A= Test not performed

Sample ID: Representative Soil from Fire Fighting Training Area Respiration Test #6 Before

Collected: 06/24/97

Analyzed: 06/24/97

Lab No.240697-11

Description	Results	Methods
Nitrate Nitrogen	9.8	Adapted Std. Methods 8039
Nitrite Nitrogen	<0.2	Adapted Std. Methods 8153
Ammonia Nitrogen	89.2	Adapted Std. Methods 8038
Orthophosphate	75.0	Adapted Std. Methods 8114
Hexavalent chromium	<1	Adapted Std. Methods 8023
Sulfate	12.5	Adapted Std. Methods 8051
Sulfide	0.9	Adapted Std. Methods 8051
Copper	3.0	Adapted Std. Methods 8026
Cyanide	<1	Adapted Std. Methods 8027
Manganese	25.7	Adapted Std. Methods 8034
Aluminum	<1	Adapted Std. Methods 8326
Ferrous Iron	35.9	Adapted Std. Methods 8146
Total Iron	63.2	Adapted Std. Methods 8008
Cobalt	<1	Adapted Std. Methods 8078
COD	>30K	Adapted Std. Methods 8000
Percent Solids	47.7%	ASTM D2974
Percent Moisture	52.3%	ASTM D2974

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

Sample ID: Representative Soil from Fire Fighting Training Area Respiration Test #6 Before

Collected 6/24/97

Analyzed 6/24/97

Lab No. 240697-11

Description	Results	Methods
Bacteria Count 24 hr.	4.0x10 ⁷	ASTM 9215
Bacteria Count 48 hr.	2.7x10 ⁸	ASTM 9215
Redox Potential	+164	ASTM 2580
Ph	7.12	SW846-9040A
Total Carbon	3.4%	415.1
Total Organic Carbon	2.1%	415.1
Total Inorganic Carbon	1.3%	415.1
Total Nitrogen	N/A	Chemoluminesance

When anion and or cations are tested, soil preparation consists of extracting 10 grams of sample with 100 ml of deionized water and filtering the extract through a 0.45 micron membrane filter. The results are expressed on a volume basis and represent the soluble anion or cation in the sample.

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BTEX

Method 8260A GC/MS

All values reported in parts per million (ppm) mg/kg unless noted

BDL= Below Detection Limit

N/A= Test not performed

Sample ID: Representative Soil from Fire Fighting Training Area	Respiration Test #6	Before
Collected: 06/24/97	Analyzed: 06/24/97	Lab No.240697-5

Description	Results	MDL
Benzene	BDL	0.005
Toluene	BDL	0.005
Ethylbenzene	BDL	0.005
mp-Xylene	BDL	0.005
o-Xylene	BDL	0.005

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Client: Beling Consultants Inc., 175 W. Jackson Blvd., Chicago, Il. 60604

Location: Great Lakes Naval Training Center, Great Lakes, Illinois

Polynuclear Aromatics

Method: SW-846 8310

All values reported in parts per million (ppm) mg/kg, unless noted.

BDL= Below Detection Limit MDL= Method Detection Limit

Sample ID: Representative Soil from Fire Fighting Training Area Respiration Test #6 Before

Collected: 06/24/97

Analyzed: 06/24/97

Lab No.240697-13

Analyte	Results	MDL
Naphthalene	0.479	0.010
Acenaphthylene	BDL	0.010
Acenaphthene	0.325	0.010
Fluorene	0.286	0.010
Phenanthrene	1.370	0.010
Anthracene	0.138	0.010
Fluoranthene	BDL	0.010
Pyrene	0.132	0.010
Benz(a)anthracene	BDL	0.010
Chrysene	BDL	0.010
Benzo(b)fluoranthene	BDL	0.010
Benzo(k)fluoranthene	BDL	0.010
Benzo(a)pyrene	BDL	0.010
Dibenz(a,h)anthracene	BDL	0.010
Benzo(g,h,i)perylene	BDL	0.010
Indeno(1,2,3-cd)pyrene	BDL	0.010
2-Methylnaphthalene	2.280	0.010

Biotreatability Study Report
Great Lakes Naval Training Center
July 11, 1997

Conclusion: Each individual aerobic respiration test performed provided essential information on this particular soil matrix. For example, Test #1 and #2 were performed to find out if any indigenous bacterial consortiums might be available to cause mineralization to occur. Under ideal aerobic conditions little respiration was observed. It may be speculated that since the contaminated soil came from a fire training area, that the constant, repeated heat from the fire would destroy most of the bacteria and keep it from taking root in this soil matrix. This is evident from the colony count found in Figure #3.

However, when the soil was amended as in Test #3 and #4 with the bulking agents, aerobic respiration, although slight, began to be seen during the testing period. The bulking agents selected would contain leachable amounts of micro-nutrients, minerals and naturally occurring bacteria. These bulking agents in the presence of an oxygen source and moisture will in themselves cause bioremediation to occur.

The last battery of aerobic respiration runs, Test #5 and #6, had demonstrated the best reductions in organic carbon. In Test #5, the bulking agents provided (wood chips and horse manure) along with a nutrient package, aerobic respiration increased to over 200 mls of oxygen uptake in forty-eight (48) hours. Although this is not a great amount of oxygen being used it does demonstrate compatibility with the matrix. These bulking agents when used together in the presence of an oxygen and moisture will reduce the organic load.

Biotreatability Study Report
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July 11, 1997

The final respiration run, Test #6, had removed the most organic carbon and had the largest consumption of oxygen in the forty-eight (48) hour test period. A commercially available microbial consortium known as Microcat -XR from Bioscience, Inc. was selected for its ability to degrade aliphatic and aromatic hydrocarbons. Also, the same nutrient package found in Test #5 was used in the same proportions. This nutrient package consisted of :

Natures Gift - a mineral supplement of 72 elements
Iron - chelated form
Nutrients - 25-10-2 (N-as ammonia nitrogen)

Also, a substrate was used in Test #6. This substrate, methyl laurate, was used for its ability to stimulate production of bacterial enzymes. As seen from the oxygen uptake graphs (Figure #12 and #13) and the reduction in organic carbon, the stimulated bacteria did indeed achieve the goal of accelerated mineralization. Additionally, two (2) other essential elements must be kept in mind. Adequate moisture must be maintained. It is normally recommended that twenty-five (25) to thirty (30) percent moisture be maintained for the duration of the biological process. This may mean covering the remediation area or constant watering and monitoring.

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Also, a source of oxygen must be provided for the aerobic biological process. If composting is the remediation method of choice, a static pile maybe constructed with adequate ventilation. To reach areas where ventilated oxygen (air) cannot make contact with the soil and bacteria, a chemical source of oxygen in the form of ammonia nitrate can be considered. Concerning a build up of heat in the ex-situ bioremediation process, we feel this will not be a problem. Since the materials, bulking agents #1 and #2, are not the typical products found in composting i.e.(leaves, grass, and bark) elevated temperatures greater than 100 degrees Fahrenheit in the ex-situ assemblage should not occur.

The battery of tests that were performed have demonstrated that aerobic bioremediation of this soil matrix is possible. The actual remediation should be applied with the suggested amendments from respiration Test #6. The soil to moisture ratio for field application will be approximately 70 to 30%. When the respiration tests were performed, it was closer to a ratio of 50/50. This was to promote good biological contact with the contaminant. It also was to ascertain if the products that were used can indeed adequately degrade the contaminants of concern. Since this was found to be true and the products do indeed accelerate bioremediation, we feel confident that the cleanup objective can be met. However, since the ratio of soil to water will change to approximately 70 to 30% for field application, the process, even though it will take more time to remediate, most likely in less than a year's time, will indeed mineralize the chemicals of concern. Any questions regarding this study or the products used in this study will be openly discussed.

Regards,



John J. Orolin, M.S.
Environmental Scientist

I. PRINCIPLE OF OPERATION

The Arthur Automatic Respirometer is available with single or multiple measuring devices within a single water bath tank. Each measuring device utilizes a 2 liter size sample chamber, carbon dioxide scrubber, sensitive gas volume transducer, air pump, and automatic vent. The latter three are located in separate sealed compartments that can be easily disconnected and removed if necessary. The air pump provides continuous air circulation through the sample chamber and the scrubber. The entire air system is closed to the atmosphere. As the specimen in the chamber utilizes oxygen and generates carbon dioxide, the carbon dioxide is immediately removed by the caustic solution in the scrubber. The volume of carbon dioxide produced is, therefore, not present to balance the volume of oxygen utilized and there is a net loss of gas volume equal to the volume of oxygen utilized. The change of gas volume is sensed by the gas volume transducer. The transducer converts the volume of oxygen used to an electrical signal which is fed to a strip chart recorder or a computer via the optional serial port interface and software. The instrument produces a continuous graphical record of respiration. See Schematic of System in Fig. 1 below.

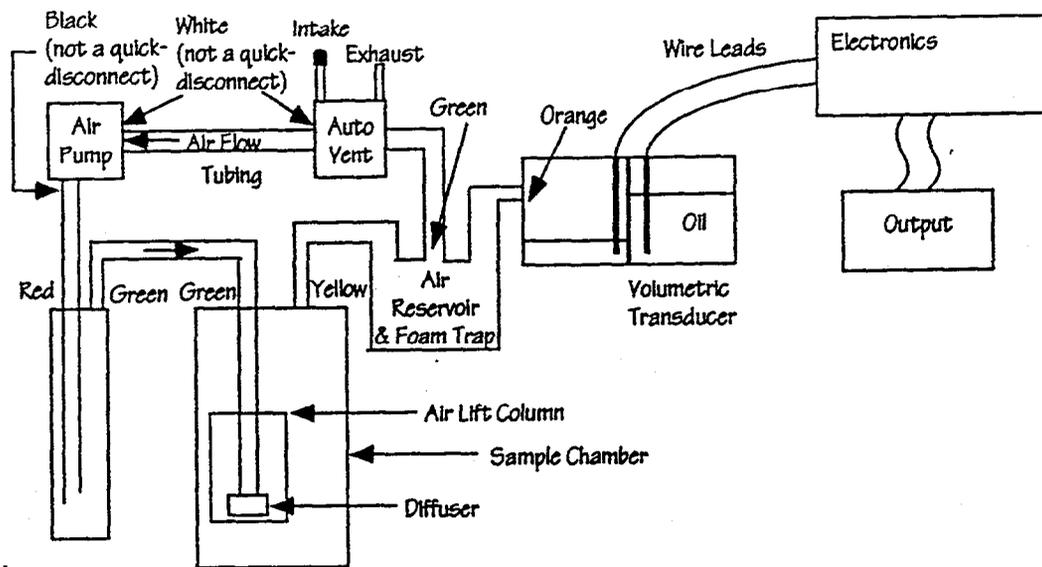


Figure 1
Air Circulation System

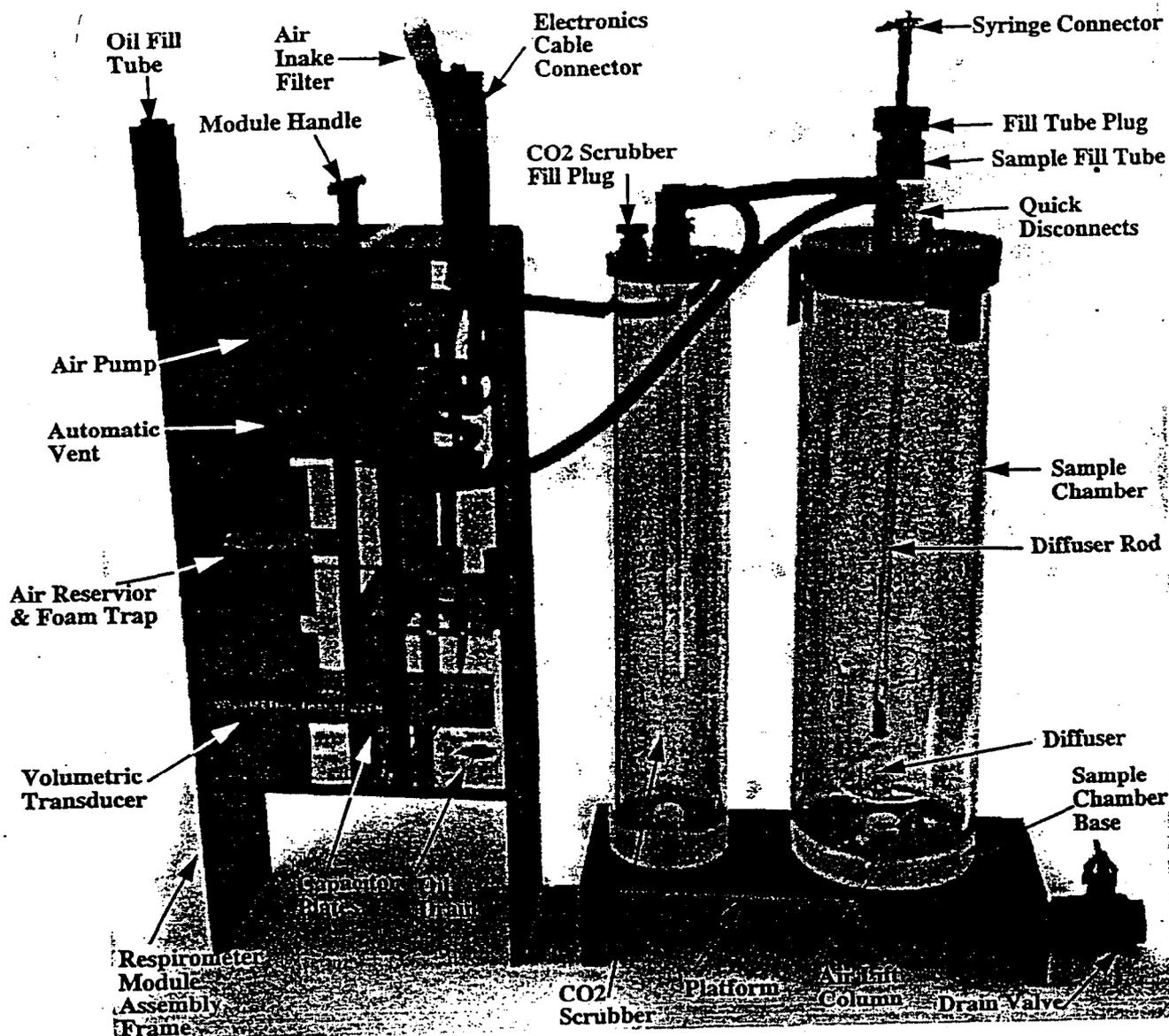


Figure 2
Parts Identification

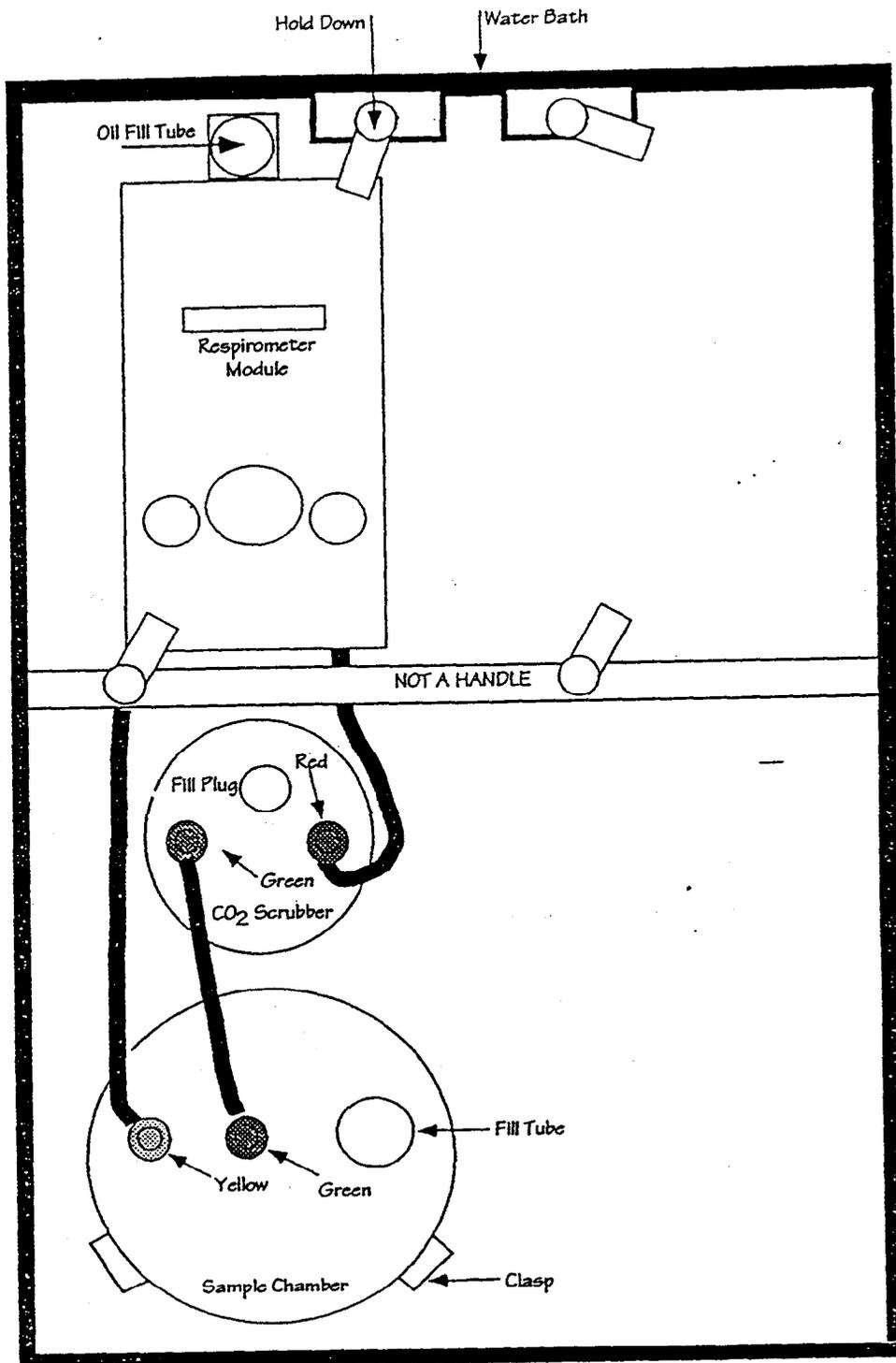


Figure 3
Instrument Assembly

7. Locate the blue sample fill tube plug and grease the O-ring with a clean laboratory grease. (**Important:** This is the **only** O-ring that is greased). Then screw the blue plug into the sample chamber fill tube (**finger tighten only**).
8. Place electronic module near water bath. To reposition electronic module handles, grasp handle near round knobs connected to module and pull outward. This unlocks the electronic module handles so that they may be re-positioned, making the connections at the back of the electronic module more accessible. Ensure that all switches on the electronic module front panel (Figure 4) are in off or downward position.
9. Plug power supply two pin female connector into power supply connector at back of electronic module (see Figure 4).

NOTE:The respirometer module and the electronics are a matched set. When setting up a double unit you will notice that the electronic modules are labeled with "Unit 1" and "Unit 2" labels. These correspond to the "Unit 1" and "Unit 2" labels atop the handles on the respirometer modules.

10. Attach large black electronic cable between large center jack on back of electronic module (Figure 4) and top of respirometer module. Both ends of the electronic cable are identical.

NOTE:Make sure connection cable pins are aligned properly. (Rotate gently until cable engages into jack. To secure, turn outside ring until it stops).

11. Connect recorder lead to recorder: black to negative, red to positive. Plug opposite end of leads into recorder jack at back of electronic module. (Figure 4).

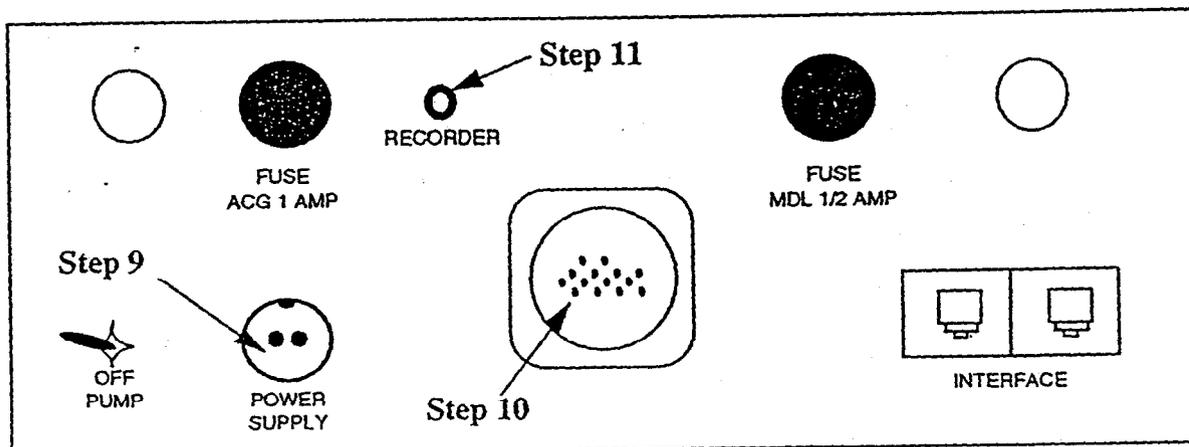


Figure 4
Back Panel

12. If the optional serial port interface has been purchased connect the cables as shown in Figure 5.

NOTE: The serial cable that connects the 25 pin connector on the RS-232 converter to the serial port on your computer is not included. Since all computer serial ports are not the same you will need to purchase the proper serial cable from your local computer vendor.

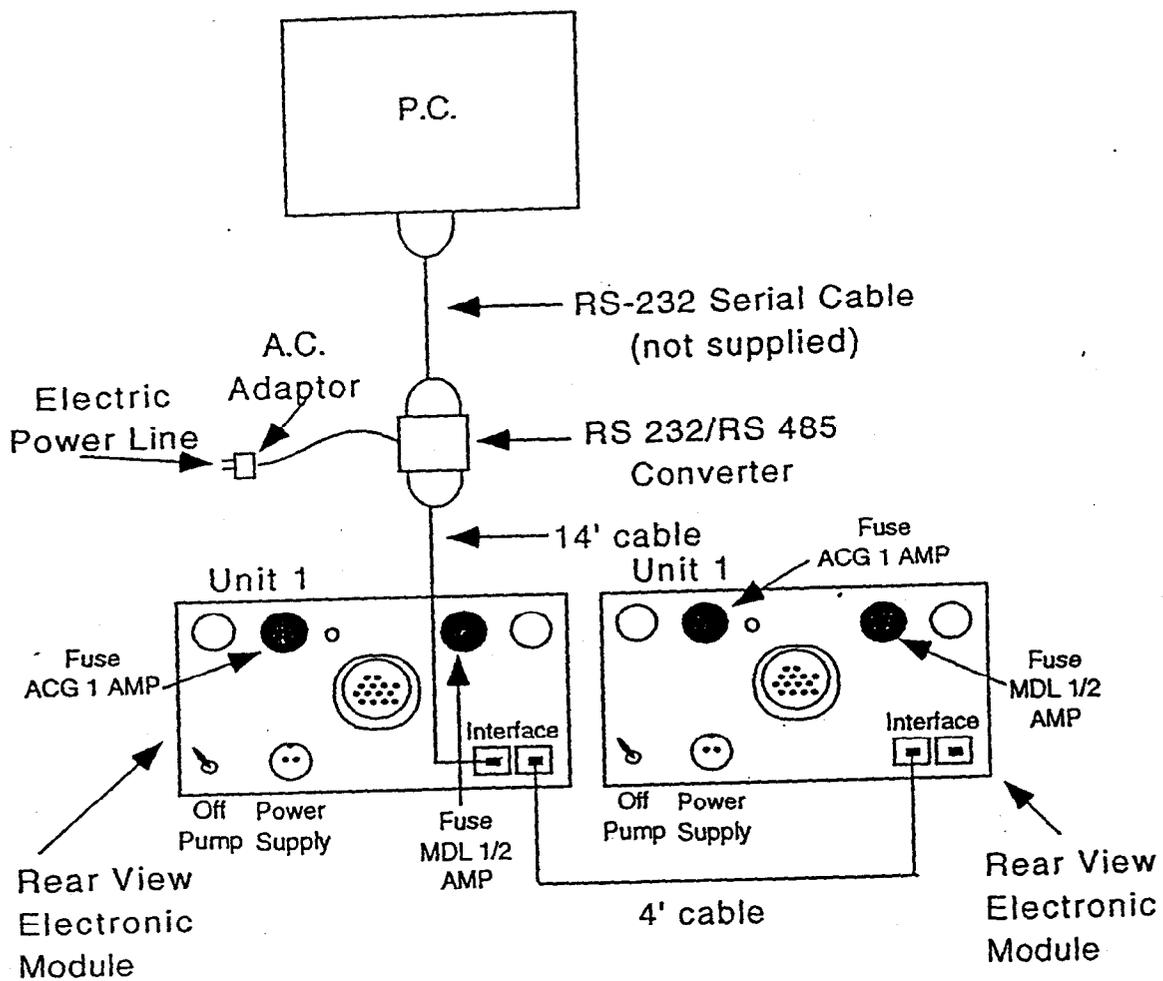


Figure 5
Serial Port Interface Connection

B. PREPARATION OF KOH SOLUTION

CAUTION

Potassium Hydroxide (KOH) is very corrosive. Extreme care must be used when using this chemical. Follow standard laboratory safety procedures, such as protective gloves and safety eyeglasses. If contact with eyes occurs, immediately flush eyes with copious amounts of water. Contact physician.

Preparation of KOH Solution

Using reagent grade KOH crystals, add 235 grams KOH to 1000 ml of distilled water. This results in an approximate 20% KOH solution. Add the contents of one pH indicator capsule to this solution. Allow to cool. Two pH indicator capsules are supplied and additional capsules are available from Arthur Technology Inc. KOH should be replaced when color changes from dark red to orange at pH 10.1. (A change from dark red to orange indicates weakened solution).

Addition of KOH Solution

Remove threaded red plug on top of the CO₂ scrubber. Using small funnel supplied, pour 400 ml of the 20% KOH solution with indicator into the scrubber chamber. Replace the plug. The remainder of the KOH solution can be stored for future use.

Replacement of Exhausted KOH

1. Shut off power to electronics. Drain water bath below level of quick disconnects.
2. Remove two quick disconnects atop CO₂ scrubber.
3. Unscrew scrubber from base.
4. Unscrew red threaded plug and empty KOH.
5. Replace with fresh KOH.
6. Reverse steps for re-assembly.

C. ADDITION OF MINERAL OIL

The respirometer must be completely assembled in the water bath tank. **Remove sample chamber fill tube plug to release air when adding oil.** With the small funnel provided, add approximately 500 ml of mineral oil to the tube inside the square oil fill tube connected to the volumetric transducer compartment (Figure 6).

Replacement of Mineral Oil

1. Shut off power to electronics. Drain water bath below level of quick disconnects. Remove electronics cable from the top of the module.
2. Disconnect red and yellow quick-connects atop CO₂ scrubber and sample chamber.
3. Loosen two module hold down tabs and rotate to clear module.
5. Unscrew bottom volumetric transducer plug and drain oil. Replace drain plug. **Do not overtighten.** (Check the entire diameter of the oil drain plug. The "O" ring must be compressed but not to the point that it has squeezed out).
6. Place the module back into the water bath.
8. Connect the red and yellow quick-connects to the CO₂ scrubber and sample chamber.
9. **Remove the sample chamber blue fill tube plug.**
10. Add approximately 500 ml of mineral oil to the "oil fill" tube. (Use only the same Squibb brand of mineral oil that was supplied with the instrument. Never mix different brands of mineral oils).

NOTE: Whenever the respirometer module assembly is removed, care must be exercised to keep the module upright as tipping may cause overflow of oil into other chambers.

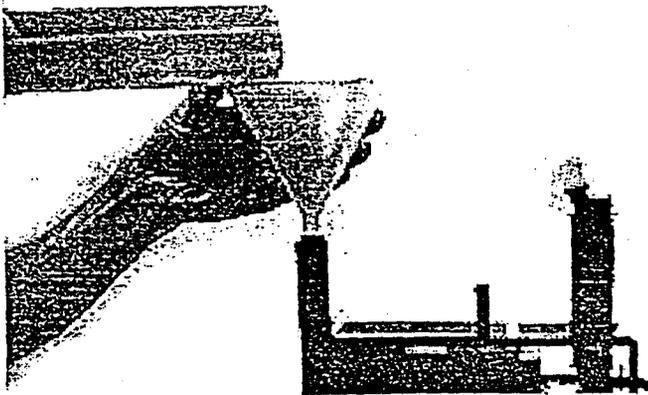


Figure 6
Addition of Mineral Oil

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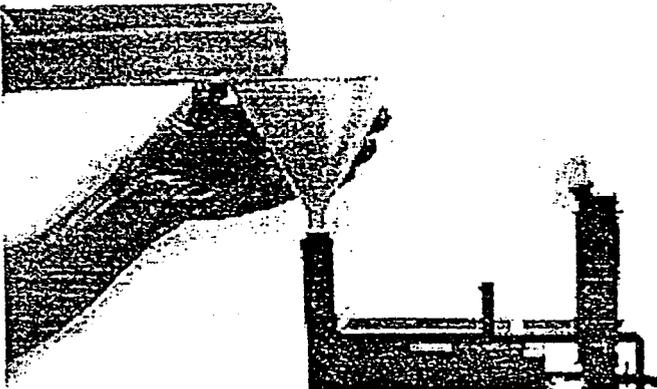


Figure 6
Addition of Mineral Oil

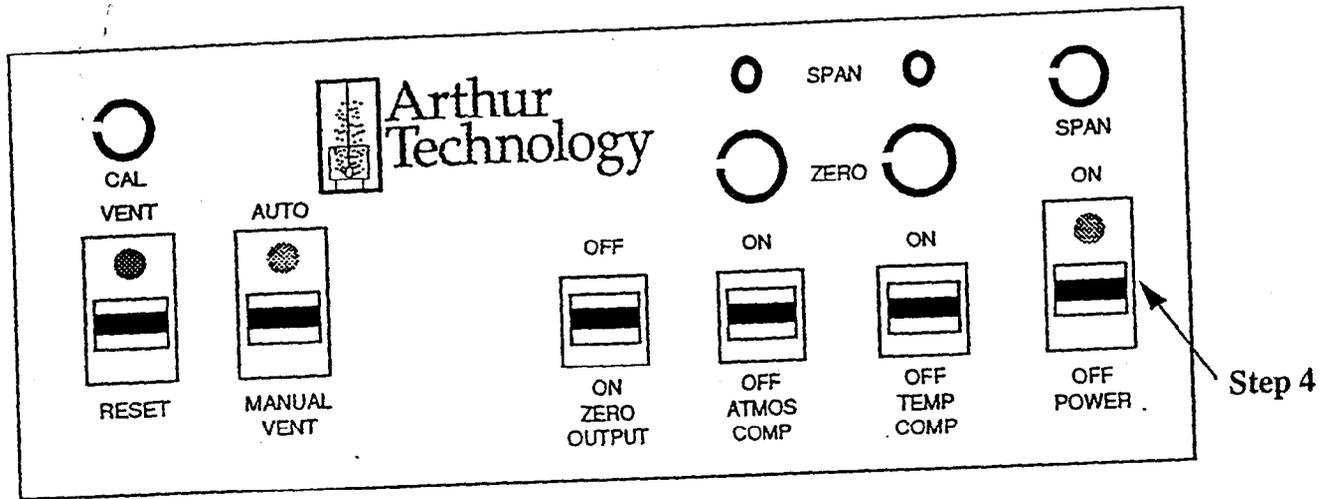


Figure 7
Electronics Front Panel

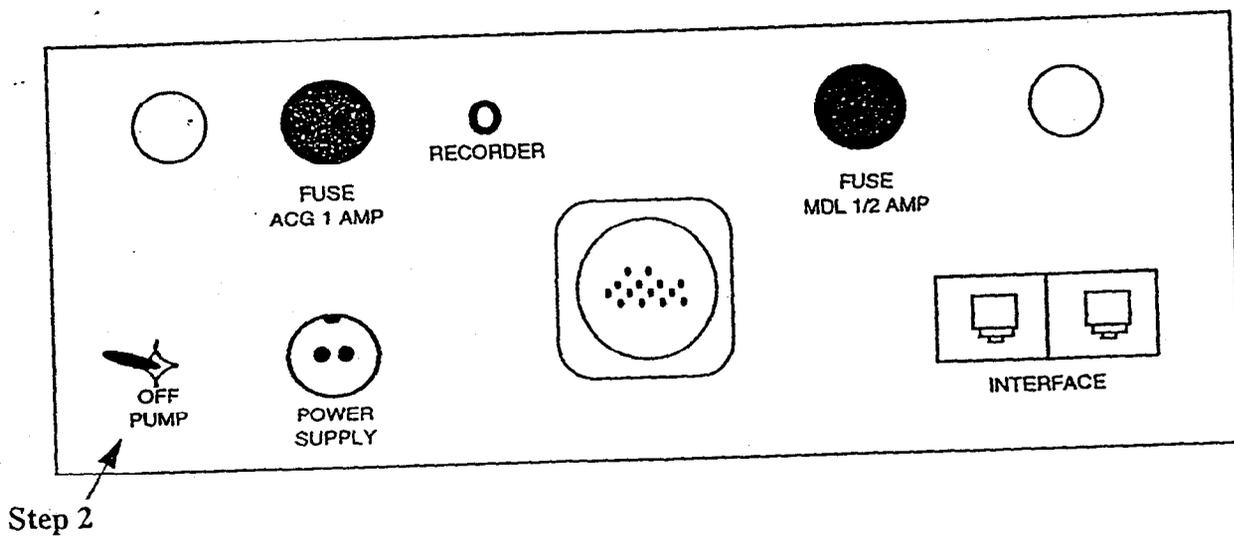


Figure 8
Back Panel

IV INSTRUMENT START UP

Now that the instrument is completely assembled it is ready to be activated.

1. Ensure that all switches on the electronics front panel (Figure 7) are in the off or downward position.
2. Place the pump switch on the electronic back panel in the "on" position.
3. Plug the power supplies power cord into a surge protected outlet.
4. Place the power switch "on". The green LED should light up and the air pump should be diffusing air through the CO₂ scrubber. (If the instrument does not activate check your power supply connections and verify your power source. Call Arthur Technology for further assistance).
5. Fill the water bath to the tank fill line on the front of the tank with room temperature water. (Ensure the tank drain valve is closed).
6. Inspect the sample chamber and respirometer module for any air or water leaks. (Note: If water leaks into the volumetric transducer it is heavier than the mineral oil. The water will have the appearance of shiny bubbles on the bottom of the transducer).
7. If you purchased a flow through heater or a heater and chiller you may now install these items in the water bath tank. Two clear acrylic tubes have been provided at the rear corners of the tank to hold in place the tubing from the temperature controllers. Be sure to follow the manufacturers instructions when installing, operating and priming these units. (If you have any question contact the manufacturer or Arthur Technology)

CAUTION: Do not plug temperature control devices into the same outlet as the respirometer.

8. Allow the instrument to run for an hour or so. Again, inspect the sample chamber and respirometer for any possible leaks.

V. CALIBRATION

The instrument is calibrated at the factory so that 10 mv full scale on a ten inch strip chart recorder is equivalent to 100 ml of oxygen demand. It will probably need to be re-calibrated for use with your recorder and also if you want to change the full scale range or change sample volume.

The principle of calibration is to simulate the removal of oxygen from the closed system. In an actual test, oxygen is removed from the system in the metabolic process. In the process carbon dioxide is created but this is absorbed by the potassium hydroxide (KOH) solution in the scrubber. The net effect is a loss in volume created by the removal of oxygen. A similar loss in volume can be created by simply removing a quantity of air from the system. This is accomplished by a calibrated syringe. The instrument is calibrated when the removal of a given quantity of air from the system produces the correct reading on the recorder.

CAUTION:

Do not adjust calibration so that full scale on the recorder is above 100 ml of oxygen, i.e., 10 millivolts must not be equivalent to more than 100 ml. Calibrating to above 100 ml may seriously limit the partial pressure of oxygen, and therefore, the concentration of dissolved oxygen may become limiting.

The following details the calibration procedure.

A. Instrument Calibration Procedure

NOTE: This procedure does not need to be performed daily. Calibrate the instrument before a leak test, any time your sample volume changes by more than 500 ml, and when initially starting up the instrument.

1. Before beginning the calibration procedure it is important that you start with a full water bath (filled to the tank fill line), a clean sample column, and a new diffuser. If you have not yet done this, turn to Page 27 and follow the "Diffuser Replacement Procedure".
2. Turn on the recorder. Adjust the recorder chart drive speed to about 5 cm/hr.
3. Following the recorder manufacturers instruction, adjust the recorder pen zero to 5 ml on the chart paper. This point is termed the reference point. (The position of the recorder zero (reference point) should not be changed during calibration or during a test).
4. Place the switches on the front panel in the positions shown below:

Power	On
Temp. Comp.	Off
Atmos. Comp	Off
Vent	Manual

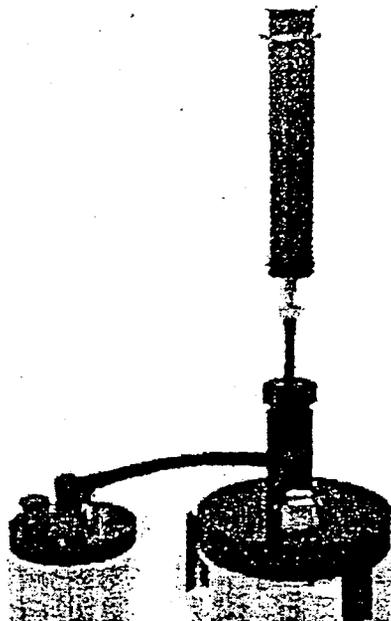


Figure 10
Syringe Connection

11. Turn the syringe connector handle to the vertical position and pull the plunger out to the 55 ml mark. **Close syringe connector.** (The bottom ring of the plunger should be on the 55 ml mark).
12. Adjust the span knob, if necessary, so that the difference in the final and initial recorder readings is equal to the amount of air removed by the syringe. (Tolerance is ± 1 ml)

Example: Initial Reading	=	5
(reference point)		
Final Reading	=	60
Total Air Removed	=	55

(60 minus 5), if final minus initial readings equal 55 then instrument is properly calibrated.

13. Open syringe connector. Push syringe plunger in to 0 ml (re-inject 55 ml of air). Close syringe connector. Allow 30 seconds for oil to stabilize. If recorder pen does not go back to initial reading, push "zero" output switch.
14. Repeat steps 11, 12 and 13 three times to check calibration.
15. Close syringe connector and remove syringe.

NOTE: Calibration is satisfactory when pen records within .5 to 1 ml of amount of removed air. See calibration graph supplied with instrument for an example of satisfactory calibration.

B. ATMOSPHERIC AND TEMPERATURE COMPENSATION CALIBRATION

The "temp comp" and "atmos comp" should be calibrated at the beginning of each test day.

NOTE: Turning the "atmos comp" and "temp comp" zero knobs counter-clockwise (ccw) will decrease the signal. Clockwise (cw) will increase the signal.

1. Place the auto-manual vent switch into the manual position (Figure 11). The green light should be off
2. Turn off the "atmos comp" and "temp comp" switches.
3. Press up on the vent-reset switch to activate the auto vent. The red vent light should turn on. Wait 30 seconds then press down to "reset" auto vent and turn off the red light. Wait 30 seconds.

NOTE: When the red vent light is on it is an indication that the auto vent reset circuits have been engaged. The output from the respirometer will be held at zero (5 ml reference mark) until 30 seconds after the vent light turns off. You must always wait a minimum of 30 seconds after resetting the vent before continuing.

4. The output should be at the reference point (i.e. 5 ml mark). Turn on "atmos comp" switch. If the output increases adjust the zero knob ccw to decrease the signal to within ± 2 ml of the reference mark. If the output decreases adjust the zero knob cw to increase the signal to within ± 2 ml of the reference mark.
5. Depress the "zero output" switch.

NOTE: Do not continue if a temperature control device is used to maintain the water bath at a constant temperature. The "temp comp" should not be used in conjunction with a temperature control device.

6. Turn on "temp comp" switch. If the output increases adjust the zero knob ccw to decrease the signal to within ± 2 ml of the reference mark. If the output decreases adjust the zero knob cw to increase the signal to within ± 2 ml of the reference mark.

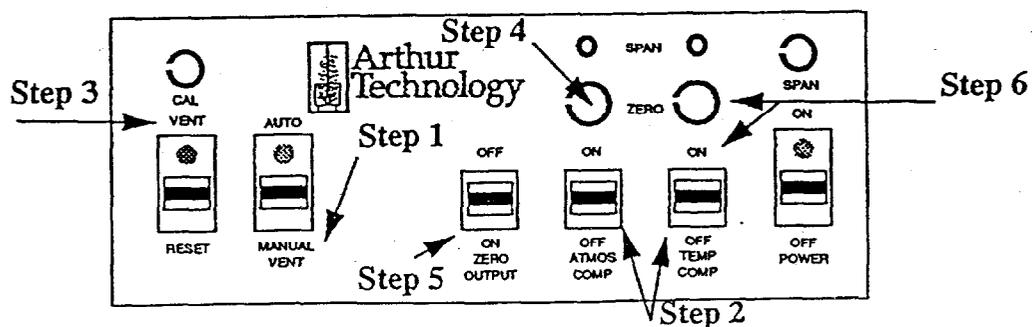


Figure 11 Electronics Front Panel

C. AUTO VENT OPERATION

The automatic vent relieves the operator from the task of venting the Arthur Respirometer each time the output reaches the upper limit of oxygen consumption. The electronics of the automatic vent senses the output voltage level of the respirometer, automatically opening the vent at a preset level. The adjustment setting of the auto vent allows the operator to pre-select a maximum value at which the vent is activated. The activation of the automatic vent opens a valve system which forces the air within the instrument out of the exhaust line and brings fresh air into the inlet line. The introduction of air restores the original air volume within the instrument (output moves back to the reference point). A timing device keeps the vent open three minutes to ensure that oxygen is restored to the system. After the preset time period has expired, the vent valve closes and 30 seconds later recording continues.

SETPOINT ADJUSTMENT OF AUTO VENT

Use the following procedure to change the setpoint of the automatic vent.

1. Place the auto vent switch into "auto" position (Figure 12). The green light will turn on.
2. Press up on the vent reset switch. The red light will turn on. Wait 30 seconds. Depress the switch to "reset" the vent and turn off the red light. Wait 30 seconds.
3. If the setpoint is to be increased, turn the "cal" knob (above the vent-reset switch) ccw 5 turns. If the setpoint is to be decreased make no adjustment.

NOTE: The "cal" knob is turned clockwise (cw) to decrease the setpoint, and is turned counter clockwise (ccw) to increase the set point.

4. Connect the calibration syringe to the syringe connector. Remove the amount of air required to bring the output to the desired setpoint level (i.e., if the system is to vent at 90 ml, remove air until your output is at 90 ml). If the auto vent activates before reaching the new setpoint, start over at Step 2.
5. Slowly turn the "cal" knob cw (it is a 20 turn potentiometer) until the auto vent activates. After 30 seconds depress the "reset" switch. Wait 30 seconds. The setpoint is checked by withdrawing the proper amount of air with the syringe.

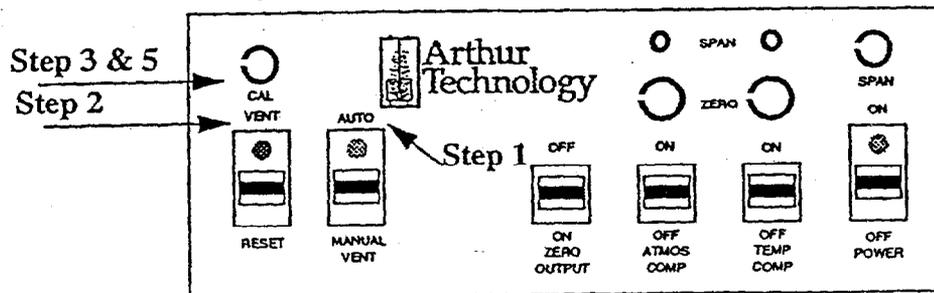


Figure 12
Electronics Front Panel

VI. INSTRUMENT OPERATION

A. ADDING A SAMPLE

1. Check to insure you have accomplished the following.
 - Water bath and instrument are equilibrated at the desired operation temperature.
 - The compensations are calibrated (Section V. B.) and in the on position. ("Temp comp" is off when using a temperature control device).
 - Recording device is connected and set up properly.
 - Auto vent is in auto mode (green light is on) and calibrated to the desired setpoint (Section V. C).
2. Prepare sample to be added to the chamber. The liquid sample must be adjusted to within .2°C of the operating temperature before adding to sample chamber. This temperature adjustment is critical.
3. "Vent" instrument (press up to "vent") and remove blue sample fill tube plug. Using the large funnel supplied, add proper volume of sample to sample chamber (2 liters is maximum volume). If the auto vent shuts off while adding sample, re-activate.

NOTE: If the sample begins to foam, immediately add Arthur Technology non-biodegradable antifoam. Add enough antifoam to stop foaming. If antifoam is not available, switch off the instrument and drain the sample. Call Arthur Technology to order antifoam. Do not use other brands of antifoam. (See additional caution under Air Reservoir and Foam Trap VI. D.)

4. Install blue sample fill tube plug and allow auto vent to time out. The output should be at the reference point. The instrument will now begin recording respiration.

B. CALCULATION OF RESPIRATION RATE

Step 1

Find the chart speed, vertical scale of the paper, and the calibrated full scale.

Chart speed is very critical and can vary widely between test runs. Always write the chart speed on the graph paper when a test is started, especially if an instrument is used by multiple technicians.

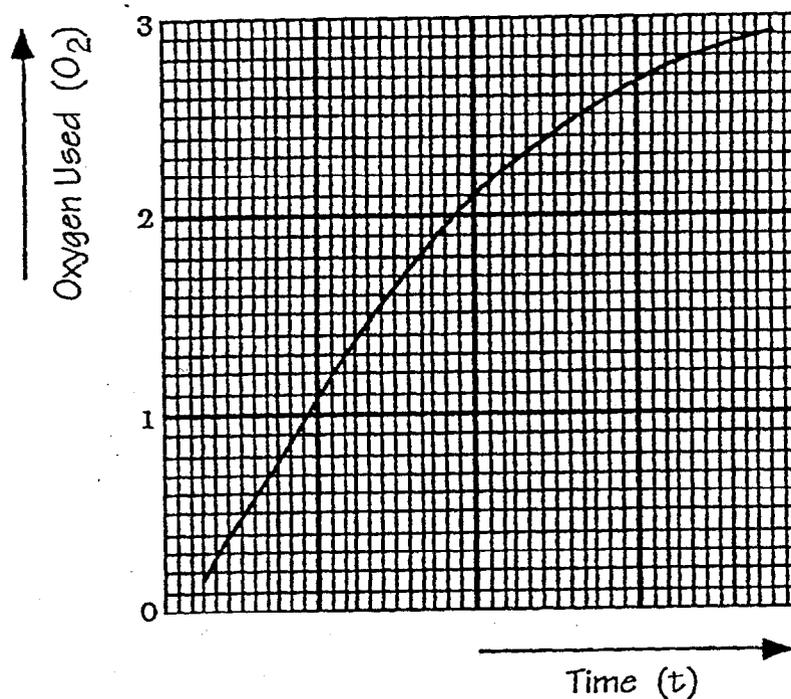
The vertical scale will depend on the chart paper, and is usually 4 mL/cm. Measure it occasionally to make sure it remains consistent.

The full scale will usually be 100mL, although ranges of 0-50mL and 0-200mL can be used in special circumstances

Chart Speed = 5 cm/hr

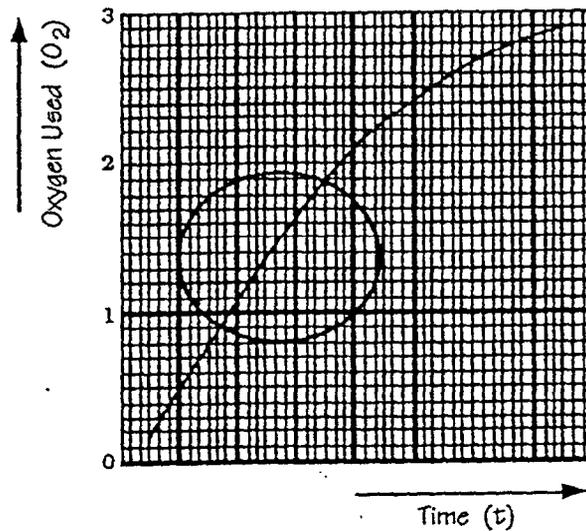
Vertical Scale = 4 mL/cm

Full Scale = 100 mL



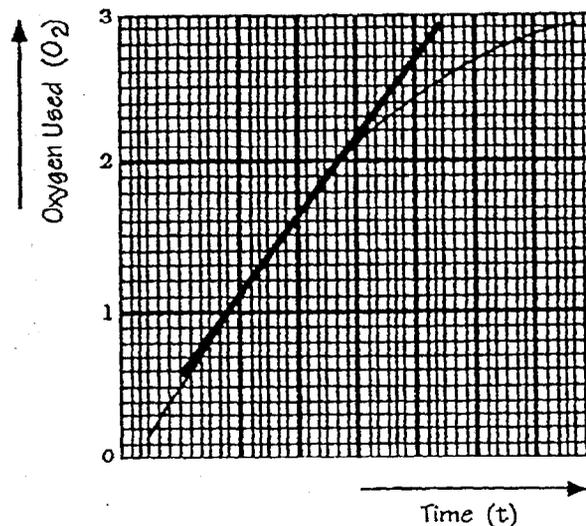
Step 2:
Identify the area to be measured.

This is a very simple procedure, but also very important. Try to measure in as small an area as possible to minimize measurement error. Do not try to measure on a curve



Step 3:
Draw a straight line tangent to the recorder trace, and make all subsequent measurements to that line.

This is the most critical step, and the major source of measurement error. Often, judgements must be made on the position of the line. Experience is the key to this step.



C. TIPS ON OPERATION

1. For some tests (e.g. toxicity), samples may be injected with syringe (without venting). After injecting, withdraw equal volume of air to provide visual continuity of graph trace.
2. The use of hollow insulating polypropylene balls (available from any lab supplier) floating atop the water bath surface greatly reduces heat loss if you use a heater. This also prevents evaporation.
3. Calibrate instrument with water taken directly from water bath (remember to replace equal amount to bath). Again, this will ensure that your instrument is calibrated to the exact operating temperature as well as helping to maintain clean bath water.
4. We suggest the use of centimeter recorder paper, as it seems easier to measure fractional tests lengths (e.g. 2.34 hrs) simply by placing a metric ruler onto the graph paper. Remember to clearly mark the following information on each graph: start and end points of each; test temperature; sample size, time, date and technician's initials. Arthur Technology supplies stick-on graph labels for this purpose (respirometer chart labels).
5. Maintain water bath at proper level. Add water periodically as evaporation occurs.
6. When partially draining the water bath, be sure to turn off your temperature controller (heater).

D. AIR RESERVOIR AND FOAM TRAP

The air reservoir and foam trap serves two functions. As an air reservoir, it increases the total "head air space" within the instrument providing an air flow "buffer" thus increasing instrument stability. As a foam trap it helps prevent the passage of foam to other components. However, anytime a sample has the potential to foam you should add Arthur Technology non-biodegradable antifoam to the sample chamber.

NOTE: When a sample foams into the air reservoir and foam trap your test is lost.

To add antifoam, "vent" instrument, remove blue sample fill tube plug, and add a few drops of antifoam through fill tube. Watch to ensure that the sample stops foaming.

CAUTION: Antifoam will weaken after a period of time. Antifoam added to a sample during the day may weaken during the night causing foaming to re-occur. Add additional antifoam prior to leaving the test run overnight. When testing samples with a severe foaming problem, a 1 liter sample size is recommended.

To empty water or foam from the air reservoir and foam trap, see page 31.

E. SHUTTING DOWN INSTRUMENT

For A Few Days:

The Arthur Respirometer is designed for continuous operation. It is advisable to keep the instrument running if more tests will be run within the next 2 weeks.

1. Press up on the vent-reset switch to activate the auto vent. The red light will turn on.
2. Remove the blue sample fill tube plug. Drain and rinse the sample chamber.
3. Add 2 liters of distilled or soft water to the sample chamber.
4. Replace the blue fill tube plug and leave the instrument operating until you are ready to run more tests.

For A Longer Period of Time:

1. Press up on the vent-reset switch to activate the auto vent. The red light will turn on.
2. Remove the blue fill tube plug and drain the sample chamber.
3. Press down vent-reset switch to "reset" the auto vent. The red light will turn off.
4. Switch the power off.
5. Drain the water bath, CO₂ scrubber, and volumetric transducer.
6. Clean all components.
7. Store in a dry temperature controlled environment.

ATTACHMENT #1
APPENDIX D

SUCCESSFUL PROTOTYPE
REFERENCES

Heap pile bioremediation is an effective and economical method to remediate hydrocarbon impacted soil

By Jeff O'Connor
John Wollenberg

Heap pile bioremediation is a viable, cost-effective and easy method to remediate hydrocarbon impacted soil. Microorganisms indigenous to a heap pile bioremediation facility consume the hydrocarbons as their primary food and energy source, producing nontoxic by-products (carbon dioxide and water). Indigenous microorganisms are more likely to survive in their natural environment and require less nurturing than exogenous microorganisms.

A bioremediation facility was recently constructed at the Marine Corps Air Station (MCAS) in Yuma, Ariz. The MCAS facility can remediate approximately 1,200 tons of soil per cycle. Cycle completion requires three to four months, depending upon hydrocarbon type and concentration. The facility is constructed on a 100 foot by 100 foot 10-inch thick concrete pad underlain with a 60 mm polyethylene liner. The pad contains four cells separated by 4 foot high concrete walls. This allows for soil with differing hydrocarbon concentrations and clean up level requirements to be treated continuously and simultaneously on an independent basis.

The concrete pad is sloped to a sump and oil water separator where liquids can be treated before discharge into the sanitary sewer. Water runoff and atmospheric emissions from soil piles are minimized by an imperme-

able cover. Soil piles are approximately 4 feet high and constructed on top of perforated pipes, which are connected to a vapor extraction/air injection unit.

This unit has two functions. First, it extracts (negative pressure) volatile hydrocarbon components from soil and destroys emissions through a catalytic oxidizer. Second, once volatile hydrocarbons are removed, the unit injects air into soil piles, raising soil oxygen content necessary for microbial stimulation. If the soil monitoring indicates the need for additional nutrients, a nutrient injection system that works in tandem with the drip irrigation system is activated.

Essential bioremediation components

These are the major components necessary for this type of bioremediation.

Oxygen. Like all living organisms, microbes need oxygen to thrive. If soil oxygen content drops below the natural atmospheric oxygen level, microbial consumption of hydrocarbons becomes less efficient. At the MCAS Yuma facility, oxygen is supplied by injecting air through a piping network in the soil piles. Soil oxygen content level is closely monitored to maintain the optimum soil oxygen content level of approximately 21 percent.

Water. Water is essential for microbial activity. The soil moisture content level is carefully regulated, because insufficient soil moisture inhibits microbial activity. Excessive moisture may "drown" microbes. Varying soil types require different amounts of moisture. However, optimal soil moisture content is typically between 10 percent and 25 percent.

Jeff O'Connor is an environmental engineer at the Southwest Division, Naval Facilities Engineering Command in San Diego, Calif. He did the concept design for the bioremediation system at MCAS Yuma, Ariz. John Wollenberg is an environmental protection specialist at the Naval Facilities Engineering Service Center in Port Hueneme, Calif.

Nutrients. Nutrients generally required for microbial proliferation are nitrogen, phosphorous, potassium, sulfur, magnesium, calcium, manganese, iron, zinc and copper. Insufficient nutrients reduce microbial activity. Nitrogen and phosphorous are most likely to be deficient in hydrocarbon impacted soil. These nutrients are introduced through a liquid injection system or applied in solid form during soil pile construction. The liquid injection system at Yuma is ideal for supplying nutrients.

pH. pH affects the solubility of certain components in soil. By elevating pH, metals which adversely affect microbes become less soluble.

Temperature. Temperature also affects biodegradation rate. Microbial activity slows with significant temperature decrease. Conversely, very high temperatures can essentially sterilize soil, creating an adverse environment for certain microbial activity. While microbes digest hydrocarbons, heat is given off within soil piles, often raising soil pile temperature 10 to 30 degrees Fahrenheit. Optimum atmospheric temperatures typically range from 50 to 100 degrees Fahrenheit.

Treatability or feasibility studies. Profiling soil before remediation maximizes the efficiency of the bioremediation. Profiling identifies the indigenous popu-

lation of microbes, nutrient levels and soil characteristics such as pH, porosity and moisture content.

Treatability study and degradation

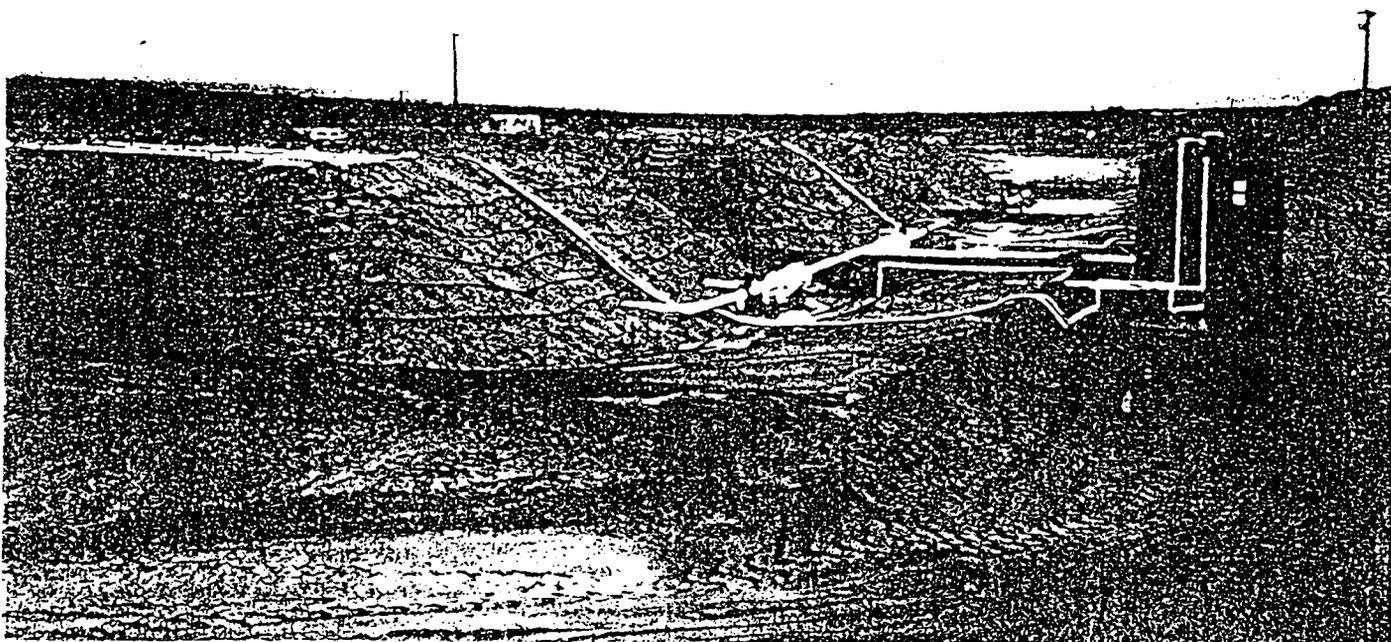
A comprehensive scientific assessment of the soil is performed before the bioremediation of hydrocarbon impacted soil. Laboratory analysis ascertains types of microbes present in impacted soil and optimal conditions for expedient biodegradation. The data generated are helpful in creating an idealized environment in which microorganisms thrive and multiply. Under optimal soil conditions (non-compacted, sandy loam is ideal) indigenous microorganisms use hydrocarbons as a food source and convert them to carbon dioxide and water.

At designated intervals during bioremediation, the levels of end products (carbon dioxide and water) are monitored in conjunction with hydrocarbon levels. As bioremediation progresses, carbon dioxide levels increase and oxygen levels decrease. The air injection system stabilizes oxygen levels necessary for maintenance of the bioremediation process. Upon completion of hydrocarbon degradation, microorganisms become dormant, because they have exhausted their food source.

System monitoring

Treatment piles are monitored at specified intervals throughout remediation. Microbial activity evaluation

This heap pile bioremediation system is similar to the one constructed at MCAS Yuma.



includes enumeration of heterotrophic soil microbes in treated soils using standard microbiological laboratory culturing techniques. Soil vapor probes installed throughout treatment cells monitor soil gas concentrations of carbon dioxide and oxygen.

Treatment cell pipes supply air throughout cell piles. Pressure probes are positioned throughout the treatment cell piles at predetermined depths and locations. The probes provide vacuum monitoring of the cell piles during aeration system operation.

Data collection to monitor system performance begins immediately after startup and continues at designated intervals during the bioremediation. Generated data are used in conjunction with computer-based reconstruction design to determine if adjustments to approach are required.

Probes are constructed using 0.020-inch slotted, 2-inch PVC. Probes are 1 foot in length and placed horizontally at varying depths within each treatment cell. The probes are capped with PVC caps and connected to Tygon tubing leading to the surface of the pile. The end of the Tygon tubing is fitted with a valve to allow vacuum readings and monitoring of oxygen uptake.

During treatment, carbon dioxide and oxygen concentrations in the off-gas from the treatment cell soil piles are monitored to track oxygen use and carbon dioxide evolution. Generated data are used to evaluate nutrient supply requirements and remedial treatment progress. Carbon dioxide in the air stream is monitored with a meter calibrated to 2.5 percent carbon dioxide with a nondispersive infrared (NDIR) light of a specific wavelength. Oxygen in the air stream is monitored with a portable oxygen meter using electrochemical sensors calibrated to atmospheric oxygen concentrations of 21 percent.

The treatment system's design facilitates soil microorganism activity to enhance biodegradation of the hydrocarbon impacted soil in treatment cell soil piles. Microbial population density is measured by using standard plate-count laboratory procedures. Oxygen uptake rates are directly related to microbial activity.

A change in microbial oxygen uptake consumption indicates the system is either nutrient limited or approaching the end point. Oxygen uptake rates are determined by temporarily turning off the aeration system and assessing treatment cell soil pile oxygen and carbon dioxide levels. Oxygen and carbon dioxide concentrations are monitored at six and 24 hour intervals after turning off the aeration system. Acquired data are used in determining oxygen uptake rates to assess the relative "health" of the microbial population.

Biodegradation assessment of petroleum hydrocar-

bons is conducted by soil sampling and analysis. The analysis includes total petroleum hydrocarbons (TPH), and benzene, toluene, ethylbenzene and xylene (BTEX). Soil nutrient conditions, soil pH and soil moisture are also monitored. These analytical methods are used to characterize the soil:

- TPH (EPA Method 8015-modified)
- Soil nutrient conditions
- BTEX by EPA Method 8020
- pH and moisture content

Major points of construction

The major construction steps for a bioremediation facility are:

- Choose a site (level and not in flood plain)
- Prepare site for pad construction
- Lay down HDPE liner and weld all seams
- Install protection over liner to prevent puncture during construction (sand mat or slurry mat)
- Install forms and rebar for slab and containment walls
- Pour and finish concrete
- Install piping for vapor extraction/air injection unit
- Install irrigation/nutrient injection system
- Load soil into cells
- Begin remediation

Bioremediation facilities economically remediate hydrocarbon impacted soils, which typically contain gasoline, diesel and jet fuels. Remediation costs are estimated at \$25 to \$30 per ton, depending upon regulatory requirements. Construction costs range from \$350,000 to \$500,000 for a facility able to process 1,200 tons per cycle. Remediation times vary depending upon hydrocarbon concentrations, nutrients, temperature and microbial conditions. The indigenous microbe soil population is usually sufficient for bioremediation. However, if the indigenous microbe population is low, laboratory cultured exogenous microbes are commercially available. □

For more information, call Jeff O'Connor at Southwest Division, Naval Facilities Engineering Command at (619) 532-2454; Robert Kratzke at the Naval Facilities Engineering Service Center (NFESC) at (805) 982-5844; or John Wollenberg, NFESC, at (805) 982-5844.

Bioremediation of Excavated Petroleum Contaminated Soil

Brian Kamnikar, Project Manager, Minnesota Department of Transportation.

Abstract

The Minnesota Department of Transportation (Mn/DOT) has and will continue to have a need to treat petroleum contaminated soil associated with underground storage tank system failure and/or surface spillage. Mn/DOT's preferred method of soil treatment is landfarming on Mn/DOT Administered property. This reduces potential environmental liability. In recent years, landfarming has become increasingly difficult due to limited suitable Mn/DOT property, public perception, and local government conflicts. Therefore, Mn/DOT developed an alternative technique to remediate impacted soils. The technique was designed to be low-cost, low-tech, and low-maintenance. This pilot study established that the remediation technique reduces treatment costs, reduces future liability, and provides an effective means for treatment of petroleum contaminated soils.

Background

Approximately 560 yards of petroleum contaminated, native, medium grained, sandy soil were excavated during the removal of 9 tanks. The majority of impacted soil was removed in the vicinity of diesel fuel and regular gasoline tanks and a minor amount from the vicinity of a waste oil tank. Field screening of impacted soil with a photoionization device indicated levels ranging from 32 to 543 parts per million (ppm). Laboratory analyses of a soil sample taken from the stockpile contaminated with waste oil revealed 56 ppm Total Petroleum Hydrocarbons (TPH) as fuel oil. Analyses of the two samples taken from the soil stockpile contaminated with diesel fuel and gasoline were 39 and 1300 ppm TPH as fuel oil.

Materials

Following is a list of the materials used to set up the treatment piles:

Manure - 100 yards of fresh sheep manure with bedding, and 40 yards of aged mixed manure were transported to the site. The mixed manure contained sheep, dairy, and chicken wastes.

Wood chips - Approximately 140 yards of wood chips were transported to the site.

Drain tile - Four inch diameter perforated flexible drain tile.

Thermocouple wire and both handheld and continuous recording temperature reading instrumentation.

Polyethylene sheeting, black - 4 mil thickness.

Front end loader.

Bituminous surface large enough to accommodate the mixing and treatment piles - This impermeable surface prevented possible impact to the ground surface during the mixing process and also prevented leaching from the base of the compost piles.

Method

Mixing:

The wood chips and manure were placed in windrows at the site. The chips were then pushed over the manure windrow to reduce the likelihood of odor or insect problems. This effectively mixed the manure and wood chips in a 1:1 ratio.

Two different ratios of soil to manure/wood chips were used. The waste oil contaminated soil was mixed with the manure/wood chips in a 4:1 ratio. The diesel fuel/gasoline contaminated soil was mixed with the manure/wood chips in both 4:1 and 3.5:1 ratios. The mixing of soil, manure, and wood chips was performed upon the impermeable bituminous parking lot.

A front end loader was used to combine the soil and manure/wood chips mixture. The loader removed two buckets of soil from the stockpile and spread the soil on the bituminous surface in a layer approximately six inches thick. The loader then took one bucket from the manure/wood chip pile and spread this on the soil layer. The mixture of material was then lifted and dropped 3-5 times to achieve a homogenous mix.

The soils from the waste oil and fuel stockpiles were kept separate.

Construction:

Once the mixing was completed, the compost piles were constructed. The bioremediation piles were also constructed on a bituminous parking area. The piles were comprised of three lifts (layers) of mixed soil, manure, and wood chips. The three lifts were constructed simultaneously, starting on one end of the pile and continuing until the desired length of the pile was reached. This was done to prevent the loader from driving over the bottom-most layers and compacting the compost.

The first step in constructing the compost pile was to spread a lift approximately 18-24" thick and 18' wide on the bituminous parking area. The second step was to place 20' long sections of drain tile across the width of the pile. The ends of the drain tile extended about 1' beyond each pile edge. This process was repeated until the three lifts, of equal thickness, were completed. The drain tile was spaced at 5' intervals, the upper layer staggered with respect to the lower.

The third step was covering the pile with 4 mil black polyethylene sheeting. Openings were cut in the poly, exposing the drain tile ends. The sheeting was secured by placing tires over the drain

pipe ends and connecting the tires with rope.

Four separate compost piles were built. The first pile was comprised of the waste oil stockpile. The dimension of this pile was approximately 18' x 31' and 5' high. The remaining three piles contained the fuel stockpile, each measuring about 18' x 70-85' and 6' in height. See Figure I for compost pile design.

Monitoring:

Thermocouple wires were placed within the pile during construction. Both a hand held instrument and automated recorder were used in monitoring compost pile temperatures. A total of 35 locations were monitored for temperature.

Sampling:

Twenty-one soil samples were collected from the piles approximately eleven weeks after construction. The sampling was in accordance with EPA statistical sampling method SW846 (Test Methods For Evaluating Solid Waste Physical/Chemical Methods - 2nd Edition). This method is used to determine the number of samples to collect based upon the initial concentration of contaminants and the desired target level of "clean" samples. A random number generator was used to determine the sampling point locations.

Results

Laboratory analyses of the twenty-one compost samples revealed petroleum contamination ranging from no detection above method detection limit to 3.9 ppm THC as gasoline. All samples were also analyzed for Benzene, Ethylbenzene, Toluene, and Xylene. The waste oil compost samples were also analyzed for volatile hydrocarbons. No detection above laboratory method detection limits were found for these parameters.

Temperature readings of the composted piles showed an increase during the initial 11 to 19 days following construction. The piles then maintained a nearly constant temperature throughout the remaining seven to nine weeks of the project. See figure II for a graphical representation of temperature readings. Daily temperature fluctuations were not evident from the chart recordings.

Temperature readings were consistently higher in the upper third of the piles. Some apparent random variation of temperature was evident along the length and width of the pile. The fuel compost pile which was mixed at a ratio of 3.5:1 soil to manure/wood chips, reached higher maximum temperatures than the other piles. In general, the piles maintained temperatures throughout sufficient to support active microbial degradation. Because the pile heated relatively uniformly and did sustain a stabilized maximum temperature, it was felt the piles would not require turning.

Conclusion

Mn/DOT successfully remediated the petroleum impacted soil using bioremediation through composting. The composting process reduced the concentration of contaminants to a nonregulatory level in an eleven week period. The method was low-cost, low-tech, and low-maintenance. The cost was approximately \$13/ yard. This cost is comparable to the average landspread cost to Mn/DOT which ranges from \$10-\$15/yard. The cost of landspreading and composting is a substantial savings over incineration, the most common soil remediation method in the St. Paul/Minneapolis area, which may cost between \$40 and \$60/yard. Because of the increased difficulty in locating suitable landspread sites, and because of the high cost of incineration, composting provides an excellent treatment alternative for Mn/DOT. An added benefit of composting is the end product of this process. The material may be suitable for use as top soil, mulch, or fill material.

Mn/DOT would like to thank the following people and organizations for their assistance in this project:

Philip R. Goodrich, Ph.D., P.E., University of Minnesota -
Agricultural Engineering
U.S. Environmental Protection Agency - Ada, OK
Mn/DOT Arden Hills Maintenance Station
Mn/DOT Environmental Engineering Section
Mn/DOT Environmental Compliance and Investigation Unit
Mn/DOT Environmental Studies Unit

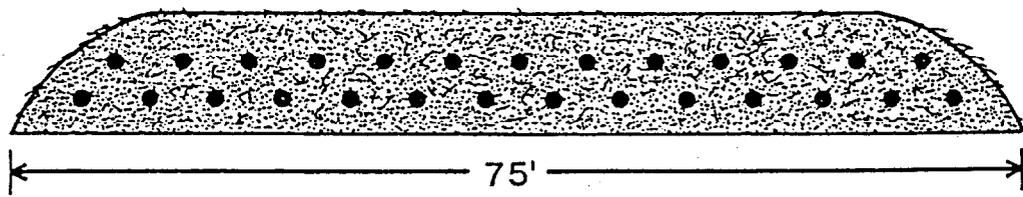
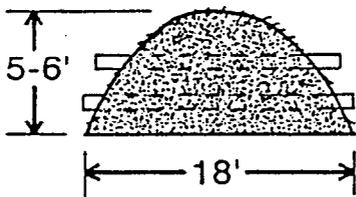
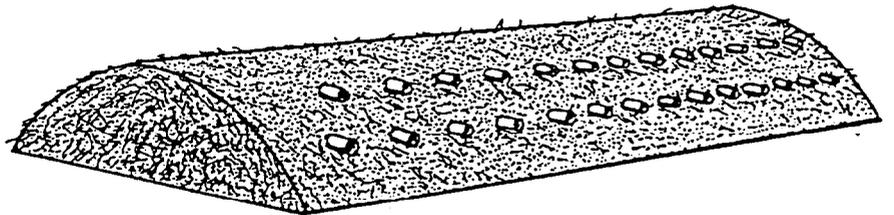
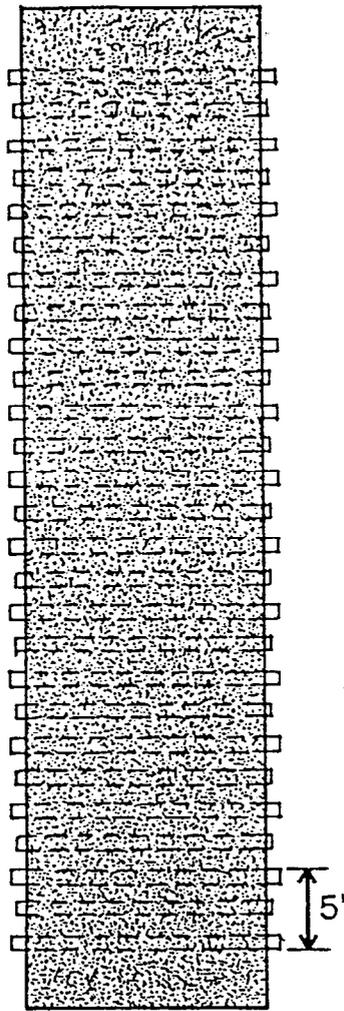
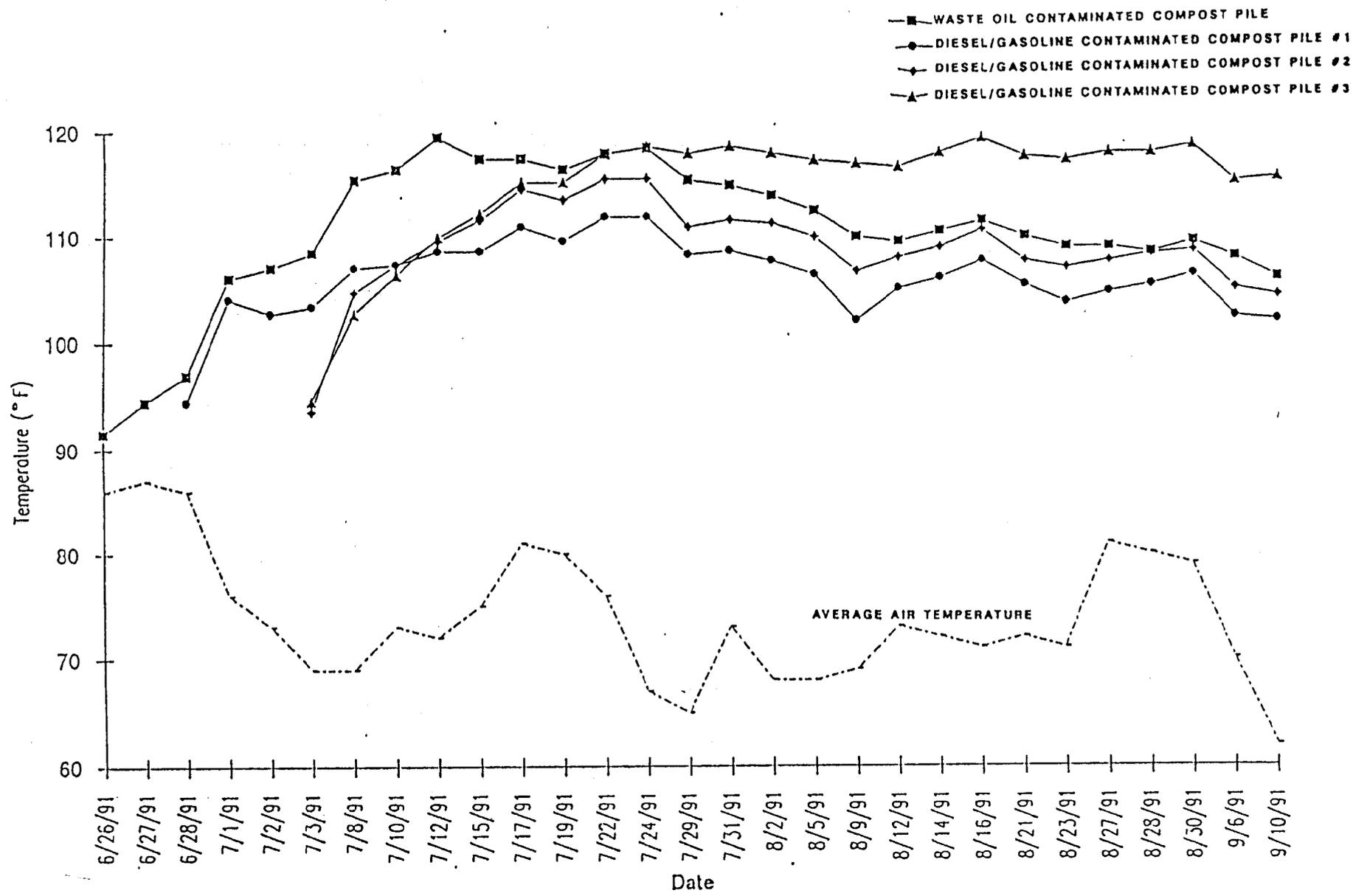


FIGURE I COMPOST PILE DESIGN

COMPOST PILOT STUDY - TEMPERATURE MONITORING



Biomounds pass tests in Minnesota

Field evaluation proves biomounds clean soils economically

By Brian Kamnikar, P.E.

The Minnesota Department of Transportation has developed a low technology composting treatment alternative. They have been recycling petroleum contaminated soil, animal manure and low grade wood chips in an environmentally sound process since 1991. Mn/DOT has successfully treated several thousand cubic meters of excavated petroleum contaminated soils by using the biomound treatment technique. The process has not only been effective but also has the advantage of being generally accepted by local bodies of government and the public with little opposition. Because the process is low maintenance, the

Brian Kamnikar is an environmental engineer for the Minnesota Department of Transportation, Oakdale, Minn. Mn/DOT acknowledges the following organizations for their support and participation in the field evaluation: U.S. Environmental Protection Agency, especially Gerald Phillips, Gilberto Alvarez, Evan Fan; Minnesota Pollution Control Agency, especially Ronald Schwartz; University of Minnesota, especially Charles Christians, Bay West and American Science Corporations, especially Shirley McMaster, Thomas Tweeten, Peter Hanson, Steven Peterson, David Olson, Dennis Littfin; Ramsey County, especially Larry Carlson, John Springman; Minnesota Department of Transportation, especially Charles Vogel and Arden Hills Truck Station crew, Metro Division Staff, Scott Reed, and Office of Environmental Services.

biomound technique has shown substantial cost savings over alternative treatments.

Mn/DOT has removed hundreds of fuel underground storage tanks from their various maintenance facilities, and during highway construction projects since 1988. The majority of these tank removals have encountered petroleum contaminated soil as a result of leaking tank systems or spills experienced during product delivery.

The Minnesota Pollution Control Agency (MPCA) requires treatment of excavated petroleum contaminated soil to a current cleanup threshold for soils treated by landspreading or biomound technology of 10 ppm as total petroleum hydrocarbons. During the late 1980s, Mn/DOT primarily treated the contaminated soil by land application. Minnesota regulations generally allow only a single application of petroleum contaminated soils at an approved landspread location. Therefore, as appropriate landspread locations were used up and as the process became increasingly unpopular with the public, Mn/DOT was faced with the possibility of stockpiling thousands of cubic meters of petroleum contaminated soil with no cost effective treatment alternative available.

In most cases, indigenous bacteria present in petroleum contaminated soil break down petroleum hydrocarbons, which are a source of energy for the bacteria. The advantage of treating petroleum contaminated soils ex-situ is the ability to amend the contaminated

soil with nutrients, bacteria and bulking agents. By amending the contaminated soil, it is possible to construct a biomound with a more conducive environment for bacterial growth, thus accelerating the breakdown of petroleum compounds in the soil as compared to natural attenuation in-situ.

Mn/DOT successfully completed a bioremediation pilot project in 1991. Following success of the pilot project, Mn/DOT used biomound technology to remediate petroleum contaminated soils at a number of sites. In 1993 the EPA expressed interest in Mn/DOT's successes with passive aeration biomounds. With a grant from the EPA, Mn/DOT constructed biomounds with various soil amendments.

The objective of the biomound field evaluation was to measure physical characteristics within the biomounds which are necessary for bacterial growth. Biomounds with four different soil amendment combinations were constructed for the study. The physical characteristics measured were oxygen/carbon dioxide concentrations, nutrient availability, moisture, temperature and pH. Biomound samples were collected during treatment to demonstrate reduction of petroleum hydrocarbons.

In order to sustain efficient rates of hydrocarbon degradation, the biomound environment must provide certain essential elements to promote bacterial population growth. The most efficient form of hydrocarbon degradation is accomplished by aerobic bacteria. To survive, aerobic bacteria need

oxygen, moisture and nutrients.

These elements were provided in the biomound field evaluation as follows:

- Oxygen

Since oxygen is consumed by aerobic bacteria during degradation, a means of replenishing oxygen in the biomound is needed. Aerobic bacteria need a minimum concentration of about 2 percent oxygen to survive. Mn/DOT uses a passive aeration system to supply oxygen to the biomound. Figure 1, right, illustrates the passive aeration system used in the study.

Wood chips were added to all the biomounds as a bulking agent to reduce the bulk density of the soils and enhance diffusion of oxygen in the biomound matrix.

- Nutrients

Petroleum compounds alone do not supply all the nutrients required by soil bacteria. Nutrients already present in the soil vary from one soil type to another. A common ratio to determine appropriate nutrient requirements is 100 parts total carbon to 10 parts nitrogen to 1 part phosphorus. Nutrient amendments varied among the five biomounds. The control biomound received no nutrient amendment. The four remaining biomounds received either sheep manure, granulated fertilizer or a combination of these amendments.

- Moisture

Moisture was increased in the biomounds by mixing moistened wood chips with the contaminated soil. Manure itself may have also been a moisture source.

Bacterial degradation occurs through a range of moisture field capacities of approximately 20 to 80 percent. The optimum moisture field capacity for biomounds is approximately 40 percent. This concentration represents a balance between having an adequate supply of water in the soil matrix pore spaces without preventing effective diffusion of oxygen.

- Temperature

Since bacterial activity increases with warmer temperatures,

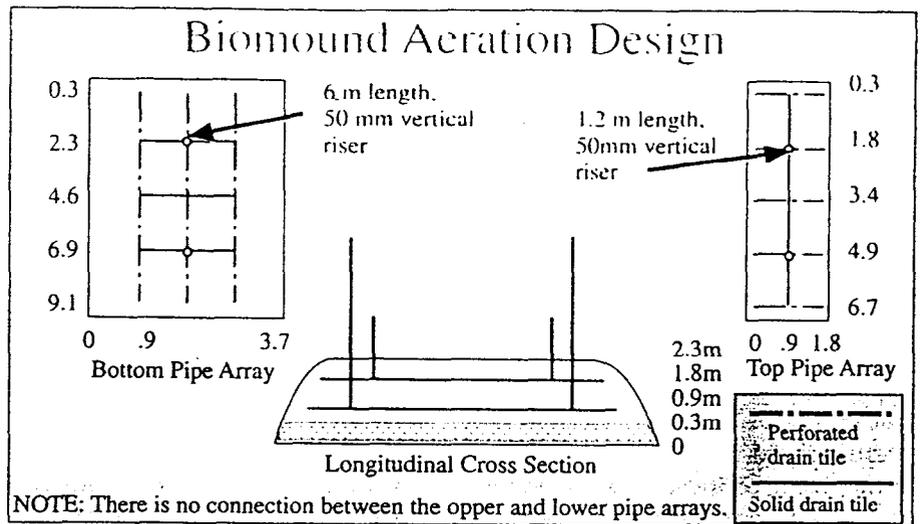


Figure one: biomound design, plan view and cross section

increasing the internal biomound temperature may result in higher rates of petroleum hydrocarbon degradation.

To sustain efficient degradation rates, the essential bacterial requirements discussed above must be provided not only when the biomound is constructed but also during the entire treatment process.

Therefore, it is important that biomound conditions are monitored periodically to ensure that proper conditions are maintained for bacterial growth.

In order to reduce treatment costs, Mn/DOT constructed the biomounds with the most cost

Continues on page 36→

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**Biomounds pass tests,
from page 35**

effective materials and equipment possible. The same passive aeration system was used in all the biomounds. Horizontal piping in the system consisted of 100 mm diameter flexible perforated drain tile. Vertical piping (risers) consisted of 50 mm diameter PVC. Pipe was joined with drain tile tees and PVC side cross outlets. Unions were secured with duct tape. There is no piping connection between the lower and upper horizontal pipe configurations. Any air exchange between the two horizontal configurations must take place by diffusion of air through the biomound matrix.

Type T thermocouple wire and oxygen/carbon dioxide sampling tubes were placed in the biomounds. The oxygen/carbon dioxide sampling tubes consisted of 6.35 mm diameter tygon tubing

inside of a 12.7 mm diameter PVC pipe. A hand held temperature recorder and an oxygen/carbon dioxide field instrument were used to collect the data. Initially, the oxygen/carbon dioxide field instrument could only quantify carbon dioxide concentrations from 0 to 5 percent. When carbon dioxide levels were observed to be greater than 5 percent, a new carbon dioxide detector was installed in the meter capable of quantifying up to 25 percent carbon dioxide.

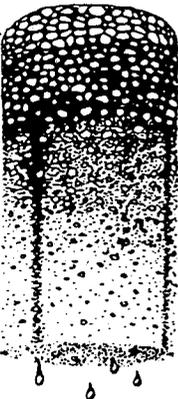
The biomounds were covered with plastic sheeting and secured with sand bags placed around the perimeter of the biomound base. The tall vertical risers were stabilized with guy wires.

Mn/Dot trucks were used to transport contaminated soil and manure to the biomound site. A front-end loader and tractor were used to mix the soil and amendments and construct the biomounds.

Approximately 190 cubic meters of petroleum contaminated soil were excavated from the Maplewood Truck Station during removal of gasoline and diesel underground storage tanks on September 14-15, 1994. Laboratory analyses of stockpile samples detected maximum total petroleum hydrocarbons as gasoline range organics (GRO) and as diesel range organics (DRO) of 2,900 and 540 ppm, respectively. Three additional soil samples were collected from the soil pile prior to biomound construction. Analyses of these samples detected GRO concentrations ranging from 66 to 180 ppm and DRO concentrations ranging from 83 to 260 ppm.

During excavation, the greatest contaminant concentrations are usually found near the leaking tank with decreasing concentrations at greater distances from the tank. Heterogenous concentrations of petroleum contaminants are





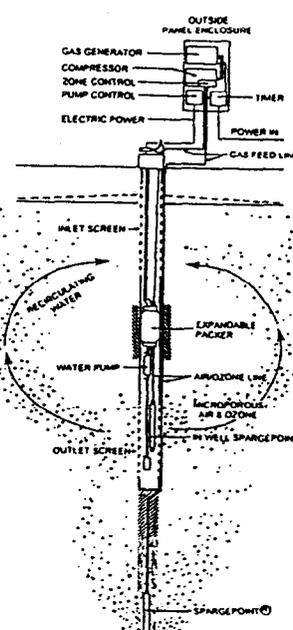
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commonly observed in excavated soil stockpiles. Five biomounds were constructed using this soil stockpile during the period of September 27 through October 6, 1994.

The biomounds were constructed on a bituminous pad. All soil and amendment mixing was accomplished with a front end loader and tractor. The contaminated soil was mixed with wood chips and manure—except biomounds A and B, which did not receive any manure—in batches consisting of approximately six cubic meters of soil. The soil was spread over the bituminous surface approximately 10 to 15 centimeters in thickness. The wood chips and manure were applied by the loader over the thin spread soil. The loader mixed the materials until the batch appeared to be homogenous. This mixing process continued until an adequate volume was generated to construct a biomound.

The biomounds consisted of three layers of mixed soil. The thickness of the lower, middle and upper layers was approximately 0.6, 0.9 and 0.5 meters, respectively. All the biomounds were constructed on top of a 0.3 meter thick wood chip base.

Biomounds B and C received application of granulated fertilizer. A hand operated broadcaster was used to apply the fertilizer after completion of each of the three biomound layers.

Wood chips were added to all the biomounds to improve permeability of the soil matrix. The mixture ratio was four parts soil to one part wood chips, with one exception. Soil left over after completing construction of biomounds A through D was used to construct biomound E. Biomound E was mixed with two parts soil to one part wood chips. The volumes of biomounds A through D ranged from about 37 to 43 cubic meters. Biomound E was approximately 88 cubic meters. Aside from the addition of wood chips, the five biomounds were composed of the following:

1) Biomound A was the control for the study. No nutrient additions were introduced to the biomound.

2) Biomound B included addition of 17-17-17 NPK (nitrogen:phosphorus:potassium) granulated fertilizer at a rate of approximately 0.6 kilograms per cubic meter of soil.

3) Biomound C included addition of sheep manure at a ratio of four parts soil to one part manure. 17-17-17 NPK granulated fertilizer was applied at a rate of approximately 0.6 kilograms per cubic meter of soil/manure mixture.

4) Biomound D included addition of sheep manure at a ratio of four parts soil to one part manure.

5) Biomound E was mixed the same as biomound D except that the content of wood chips was doubled.

A similar passive aeration system was used in each biomound. The aeration system consists of two independent piping arrays. The bottom horizontal piping array was

located between the lower and middle biomound layers. The bottom pipe array was connected to 6 meter vertical risers. The top horizontal piping array was located between the middle and upper biomound layers. The top pipe array was connected to shorter, 1.2 meter vertical risers.

Type T thermocouple wires were placed within the lower and middle layers of the biomounds to monitor internal temperature. Three temperature monitoring points were installed in Biomounds A through D. Four temperature monitoring points were installed in Biomound E. Periodically, some of the thermocouple wires had to be repaired, so there were occasions when temperature reading could not be collected from all the temperature monitoring points.

Air sampling ports consisted of 6.35 mm diameter tygon tubing inside of a 12.7 mm diameter PVC

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sleeve. The end of the PVC sleeve placed within the biomound was perforated to allow collection of gas samples. Two air sampling points were installed in Biomounds A, B, D and E. Air sampling points were located at mid-depth in the lower and middle biomound layers. Biomound C had three air sampling points. An additional air sampling point was located at mid-depth of the upper layer of biomound C.

State regulators in Minnesota require that petroleum contaminated soil piles and biomounds be covered with plastic sheeting to control runoff from the piles and prevent further volatilization of petroleum contaminants. To facilitate in covering the biomounds, the tall riser consisted of two lengths of PVC pipe. The lower length of pipe extended just above the maximum height of the biomound which allowed for easy placement of the plastic cover. Once the cover was in place, the upper length of PVC pipe was attached to complete the tall riser. The tall risers were secured with guy lines.

Sand bags were placed around the perimeter of the biomound and a system of tires and ropes secured the cover. Moisture and heat loss from the soil matrix are minimized by covering the biomound with plastic sheeting.

Temperature measurements, and oxygen and carbon dioxide concentrations were collected from the biomounds approximately once a week. Biomound E oxygen and carbon dioxide readings for the period of March 15 to May 17, 1995 are suspect because of extensive vandalism to the sampling points.

Three samples were collected for moisture and total petroleum hydrocarbon analyses from biomounds A through D at approximately one month intervals from the time the biomounds were constructed until January 1995. Samples could not be collected in January because the biomounds were frozen. The final sampling event was in April 1995.

The samples were collected with a hand auger from the same approximate locations during each sampling event. The sampling depths were approximately 0.6 to 0.8 meters. Figure 2, above, illustrates sampling locations and overall dimensions for each biomound.

Ratios of total carbon to nitrogen were determined and pH measurements collected during biomound construction and during the final sampling event in April 1995.

Oxygen and carbon dioxide measurements were collected from the lower and middle biomound layers on each biomound. Measurements were also collected

Soil Sample Location		
Sample	Distance from North (meters)	Depth (meters)
A-1	2.7-3.7	0.6-1.2
A-2	4.4-5.3	0.8-1.2
A-3	7.5-8.1	0.8-1.2
B-1	2.0-2.9	0.6-1.2
B-2	3.7-4.3	0.8-1.2
B-3	6.2-6.9	0.8-1.1
C-1	1.2-3.0	0.6-1.1
C-2	5.5-6.1	0.6-1.1
C-3	6.9-7.6	0.6-1.2
D-1	2.8-2.9	0.6-0.9
D-2	3.4-4.0	0.8-1.1
D-3	6.4-7.2	0.9-1.2
E-1	3.7	1.2
E-2	7.6	1.1
E-3	14.0	1.1

Figure two

from the upper layer in Biomound C. Carbon dioxide concentrations increased as oxygen levels decreased in each biomound.

The biomounds with manure additions produced the greatest depletions of oxygen in the lower regions of the biomounds. This suggests that the greatest microbial activity took place in biomounds with manure amendment. Minimum oxygen concentrations ranged from 0.5 percent in Biomound B, to 4 percent in Biomound D with manure amendment during times of peak carbon dioxide production. Minimum oxygen concentrations ranged from 10 to 13 percent in biomounds without manure.

Production rates of carbon dioxide were similar in all the biomounds. However, peak production measurements of carbon dioxide could not be quantified for the biomounds because the concentrations exceeded instrument detection capabilities.

Comparisons of production rates of carbon dioxide and depletion of oxygen between biomounds may not be completely valid since the aeration systems in biomounds B, C, and E were vandalized to varying degrees. The aeration systems in biomounds A and D were not vandalized. Minimum oxygen concentrations were 13 percent in Biomound A and 3 percent in Biomound D. These concentrations are greater than the minimum oxygen requirements to support aerobic microbial activity.

Organic carbon to nitrogen ratios and pH values were determined at the beginning and end of the field evaluation. A desirable carbon to nitrogen ratio to support bacterial degradation in the compost mixture is approximately 100 to 10. Biomound A had the least amount of nitrogen available at the start of the study with an average carbon to nitrogen ratio (C:N) of 100:0.8, as compared to biomounds B through D. Biomounds B and C had average C:N ratios of 100:32.4 and 100:18.6, respectively, which was greater than the

desired ratio of 100:10. The average C:N ratio of 100:4.3 for Biomound D was slightly less than the desired ratio.

Published data of nutrient availability in sheep manure were used to calculate the necessary volume of manure amendment. Figure 3, above, depicts percentages of nitrogen, phosphorus and potassium in sheep manure. An average carbon content of 0.47

percent by weight was obtained from analyses of three soil samples before amendment additions. The carbon mass in the soil, including the maximum petroleum contamination of 2,900 ppm detected in the excavated soil, was calculated to be approximately 6.5 kilograms per cubic meter of soil.

It was assumed that 1,000 ppm carbon was present in the sheep manure, based on information provided by the EPA. The carbon mass in the soil and manure mixture was calculated to be approximately 6.8 kilograms per cubic meter of soil. The addition of manure at a ratio of four parts manure to one part soil resulted in a C:N:P ratio of 100:18:8, based on determined nutrient concentrations in sheep manure and the calculated carbon mass in the biomound mass. This nutrient concentration was greater than the desired C:N:P ratio of 100:10:1. Therefore, a smaller volume of manure could have supplied sufficient nutrients to the biomound mass. However, since the process used in blending manure and contaminated soil can not produce a completely homogenous mixture, four parts of manure were added to one part soil (resulting in a C:N:P ratio of 100:18:8) to increase the probability that sufficient nutrients would be available throughout the biomound mass. Also, past experience in constructing biomounds has demonstrated that this manure/soil ratio produces the desired range of internal biomound temperature.

Carbon to nitrogen ratio analyses for biomounds B through D following completion of the project were all less than the 100:10 ratio, indicating depletion of the nitrogen source. The final C:N ratios ranged from 100:1.6 to 100:3.6.

Besides oxygen and nutrients, aerobic bacteria require moisture to survive. During biomound construction, sealed sample containers representing 20 percent and 80 percent maximum field capacity were prepared. These preparations were used as comparisons to estimate moisture content during subsequent sampling events. Soil moisture decreased in all the biomounds over time. The lowest moisture content observed was 30 percent of field capacity in a sample collected from Biomound C.

The highest internal temperatures were measured in biomounds with addition of manure. Maximum average temperatures in biomounds without manure amendment were 21°C in Biomound A, and 23°C in Biomound B. Maximum average temperatures in

Sheep Manure Nutrient Analysis	
Parameter	Percentage (%)
Total Kjeldahl Nitrogen	0.7
Total Phosphorus	0.3
Potassium	0.9

Figure three

biomounds with manure amendment were 43°C in Biomound C, 54°C in Biomound D and 46°C in Biomound E. Minimum average temperatures in Biomounds A through D were -2°C. The minimum average temperature in Biomound E was 1°C.

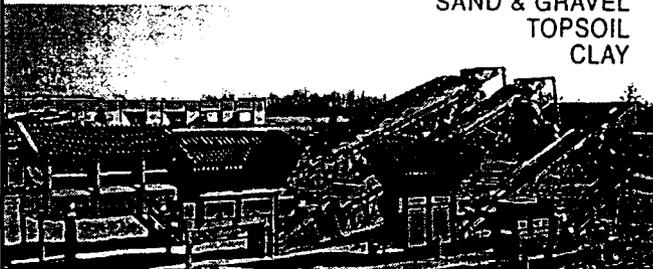
Higher internal temperatures were measured for a longer period of time in Biomounds D and E. Internal temperatures of Biomounds A and B, which did not contain manure, decreased to the point of freezing in approximately early February and mid to late January, respectively. Internal temperatures at or below the freezing point were recorded in biomounds with manure amendment from approximately late February to early to mid March. Biomounds with manure produced internal temperatures above freezing approximately 18 to 47 days longer than biomounds

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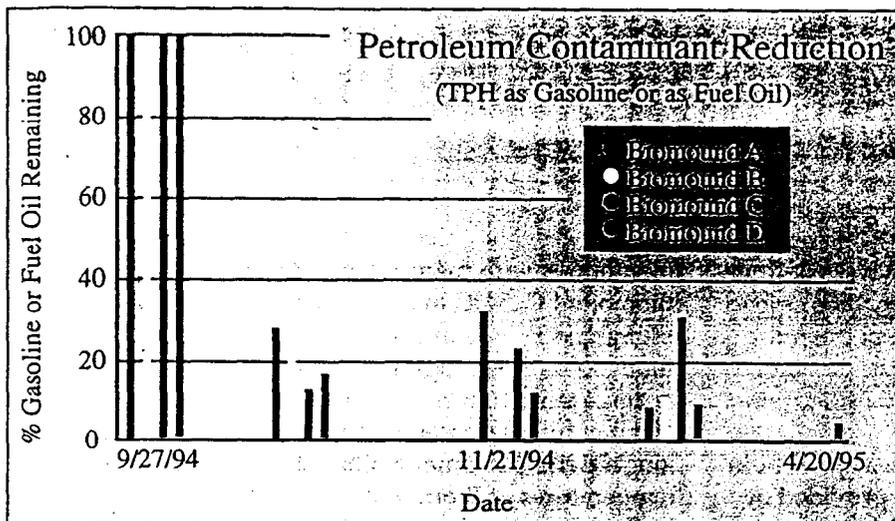


Figure four: petroleum contaminant reduction

without manure.

The pH values were similar for biomounds A through D both at the start and finish of the project. Also, initial and final pH measurements in each biomound did not show significant change over the course of the study. Initially, average pH levels ranged from 7.58 for Biomound B to 8.80 for Biomound C. Final average pH levels ranged from 7.90 for Biomound C to 8.59 in Biomound A.

Final sample analyses indicated degradation of total petroleum hydrocarbons as gasoline/fuel oil (TPH) of 97 to 100 percent (100 percent degradation represents no detection of the analyte above the method detection limit of 5 ppm). Biomound D, with only manure added as a soil amendment, had a hydrocarbon degradation of 97 percent. Final analysis detected 15 ppm TPH in one sample. Biomounds A, B and C had 100 percent hydrocarbon degradation.

Samples collected in September 1994 were analyzed for total petroleum hydrocarbons as diesel range organics (DRO), Wisconsin Modified Method. At about this time, Mn/DOT began to suspect that the DRO analytical procedure was reporting "false positive" petroleum hydrocarbon results. In discussions with EPA and laboratory personnel, it became evident that organic matter present in the soil matrix, such as manure, may have resulted in false positive petroleum concentrations being reported by the laboratory.

To test for possible false positive results, Mn/DOT collected and analyzed samples of manure, uncontaminated soil and uncontaminated soil/manure mixtures for DRO concentrations. Similarly, lab analyses reported petroleum compounds present as DRO in samples containing manure. The control sample, uncontaminated soil without the addition of manure, was reported as not having petroleum

compounds present as DRO, above method detection limits. Lab personnel also stated that gasoline range

organic (GRO) analyses do have the potential to report false positive hydrocarbon results. Therefore, since the method was falsely reporting DRO due to the presence of the manure, Mn/DOT analyzed the remainder of samples collected during the field evaluation for total petroleum hydrocarbons as gasoline/fuel oil (EPA 8020 Modified method).

Air circulation within the biomound was probably driven by two forces. First, air movement probably occurred as a result of convection within the biomound. Internal biomound temperatures recorded in previous Mn/DOT biomound projects demonstrate that

higher temperatures are produced in the lowest portion of the biomound. This results in warmer, less dense air in the bottom of the biomound. Therefore, heat produced during decomposition of organic matter could displace air towards the top of the biomound and force it through the upper pipe system.

Secondly, air circulation may also have been driven by the atmospheric difference present between the short and tall riser openings. The existence of a pressure gradient between the tall and short riser openings created a potential air flow from high to low pressure regions. The passive aeration design used during the project appeared to circulate an adequate amount of oxygen to the biomounds, including the lowest layer where degradation rates were higher, based on measured concentrations of carbon dioxide. Biomounds with aeration systems not subjected to vandalism showed oxygen concentrations equal to or greater than 3 percent. This amount of oxygen is adequate to support biomound bacterial activity. Therefore, it appears that the passive aeration system provided enough oxygen to the biomounds to support microbial activity.

In general, the carbon dioxide levels increased following construction of the biomounds until about the beginning of January when levels began to decrease. This was probably a result of decreased bacterial activity within the biomound as the interior of the compost mass cooled during the winter season. Carbon dioxide levels began increasing once again in late April, along with depletion of oxygen.

Higher concentrations of carbon dioxide and lower concentrations of oxygen were measured in the lower layer of the biomounds, as compared to the middle or upper biomound layers. This may be attributed to

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greater rates of decomposition in the lower regions of the biomound or greater efficiency of air circulation in the upper biomound regions.

Comparisons of oxygen depletion among biomounds with and without manure demonstrate significantly higher rates of oxygen usage in biomounds amended with manure. This indicates a greater rate of microbial activity than in those biomounds without manure. This could in turn suggest a higher potential rate of hydrocarbon degradation in biomounds with manure.

Based on the desired carbon to nitrogen ratio of 100:10, nitrogen additions were adequate for promotion of bacterial populations with amendments of granulated fertilizer (Biomound B) and manure with granulated fertilizer (Biomound C). Addition of manure alone resulted in slightly less than the desired C:N ratio. Analyses of samples collected from Biomound B demonstrate the greatest amount of nitrogen available among the four biomounds at the start of the study. This is probably because the only nutrient source added to Biomound B was granulated fertilizer. Thus, the carbon content was not increased in the Biomound B mass, unlike the manure amended biomounds. Biomounds C and D experienced not only an increase in nitrogen but of carbon as well with the addition of manure.

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In general, biomounds amended with manure generate greater internal temperatures than biomounds without manure. Biomounds with manure also remain warmer than biomounds without manure during the onset of cold ambient temperatures. Therefore, manure amended biomounds may have longer effective treatment times during cold weather conditions.

Biomound E retained heat generated during organic compound decomposition for the greatest length of time. This is most likely due to the larger biomound size. Biomound E also produced higher average internal temperatures during treatment than the other biomounds. This is probably due to a decreased surface area associated with the volumetric increase, thus reducing the potential for surficial heat loss as compared to the smaller volume biomounds. The size of Biomound E may represent an approximate minimum critical size, when mixing at a ratio of four parts soil to one part manure, for extending bacterial activity in cold weather climates.

The pH values were fairly consistent among biomounds and did not change significantly during the treatment period.

Moisture content decreased in all the biomounds over time. The lowest moisture content measured was 30 percent of field capacity in a sample collected from Biomound C. This moisture content, while not optimum, is adequate to support bacterial populations. The samples for moisture analysis were collected from a depth of 0.6 to 0.8 meters into the biomound.

Petroleum degradation was observed in all the biomounds including the control. Concentrations of TPH as gasoline or as fuel oil (EPA 8020 Modified method) were reduced by at least 97 percent.

Careful consideration must be given to selection of an analytical method for biomound samples. Biomound samples, especially those containing organic matter such as manure, present some unique quantitation problems when selecting an appropriate analytical method for analysis of petroleum hydrocarbons. The presence of composted manure in the samples can result in reporting of "false positive" petroleum concentrations when certain procedures are used.

According to the laboratory which performed the analyses for this study, the methodologies of total petroleum hydrocarbons as diesel range organics and as gasoline range organics are susceptible to reporting organic matter concentrations as an indication of the presence of petroleum compounds. Since Mn/DOT had originally intended to use DRO and GRO methodologies, an alternative analytical procedure had to be selected.

The soils used in the project were known to be contaminated with a mixture of gasoline and diesel fuel. Therefore, the method to be used had to detect both. Also, budget constraints prevented using more sophisticated techniques such as gas chromatography (GC)/mass spectrometry (MS) for routine analysis.

GC/MS had been used on past studies to positively confirm degradation of benzene, ethylbenzene, toluene and xylene compounds.

The direct injection technique (California Method or Wisconsin DRO Method) includes a solvent extraction that partitions the petroleum hydrocarbons from the soil matrix into a solvent system. The extraction removes other naturally occurring compounds present in the compost which are not commonly present in contaminated soils excavated from an underground storage tank leak site. Many of these compounds elute as peaks within the hydrocarbon area of the chromatogram and can be mistakenly included in the total petroleum hydrocarbon (TPH) peak summation calculation. This can result in reporting erroneously high TPH values. In addition, the extraction and direct injection procedure can result in the loss of some of the lighter petroleum hydrocarbon components. This was a concern because of the potential presence of gasoline contamination in the biomound soil.

The diesel hydrocarbon range is defined as C10 to C28 by the Wisconsin DRO method. However, this method has been established to determine a wide range of petroleum contaminants including motor oils. Diesel fuels consist of hydrocarbons in the lower end of that hydrocarbon range—typically C10 to C22. The purge and trap GC technique does not cover the entire hydrocarbon range. However, since the same analytical conditions are used for calibration using a diesel fuel standard and sample, complete recovery of the full hydrocarbon range is not critical for effective quantitation analysis. In addition, less interference from non-hydrocarbon—manure compost—compounds has been observed compared to the direct injection GC technique.

A purge and trap gas chromatography procedure (EPA method 8020 modified) was selected as the primary method of analysis for the following reasons:

1) The purge and trap procedure has been effectively able to quantitatively determine hydrocarbons in both gasoline and fuel oil in biomound studies completed over the past four years;

2) The organic compounds present in the manure compost do not interfere with quantitation to the extent that has been observed with direct injection procedures;

3) The longer chain petroleum hydrocarbons can be accounted for through the quantitation process using a standard diesel fuel as a calibration material. The fraction of diesel hydrocarbons that may not be detected by the purge and trap method are less soluble in water and thus are relatively immobile in soil as compared with lighter hydrocarbon compounds.

Therefore, the risk to possible receptors in the environment associated with heavier hydrocarbon components is not as significant as the risk associated with lighter hydrocarbon components since the heavier components are not as mobile.

Biomounds amended with manure showed increased

microbial activity compared to biomounds without manure. This is evidenced by greater magnitudes of oxygen depletion and greater internal biomound temperatures. This may be attributed to one or a combination of the following reasons: the manure provided not only nutrients, but additional bacteria as well which may also have consumed petroleum hydrocarbons; the manure reduced the bulk density of the soil matrix allowing for more efficient diffusion of air through the biomound mass.

The addition of manure in biomounds has resulted in Mn/DOT's beneficial reuse of the soil following successful treatment. Once the soil is cleaned to regulatory standards, the composted soil is used as top soil amendment on highway construction projects. Biomounds amended with manure effectively recycle not only petroleum contaminated soil but animal waste and wood chips as well. This process has benefited producers of animal wastes, especially in metropolitan areas where disposal of manure can be difficult and expensive.

Mn/DOT will continue to use biomound technology to remediate excavated petroleum contaminated soils and plans to further investigate analytical techniques for composted soils and examine air flow within biomounds on future projects.■

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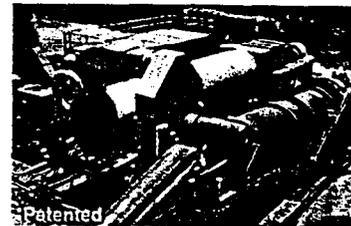
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