REMEDICON : Remediation
Consulting
Ltd.

Microbial and Fixation Technologies for Hydrocarbon and Metal Contaminated Soils

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Manitoba Environment
Dangerous Goods Section
Environmental Operations Branch
Bldg. 2, 139 Tuxedo Ave,
Winnipeg, Manitoba
R3N 0H6

File No. CGS 6.01

May 9, 1996

RECEIVED
MAY 13 1996
DANGEROUS GOODS

Attention: Mr. Edwin Yee

Dear Sir:

RE: APPROVAL FOR THE BIOREMEDIATION OF PAH-CONTAMINATED SOIL AND WATER FROM CENTRA GAS OPERATIONS BUILDING WINNIPEG, MANITOBA

Remedicon: Remediation Consultants Ltd. was requested by Centra Gas Manitoba Inc. to obtain written approval from Manitoba Environment for the Remedicon process to treat polyaromatic hydrocarbon (PAH) contaminated soils from the Centra Gas site in Winnipeg. Remedicon and Mid Canada Soil Treatment Ltd. are working together to obtain the contract to treat the soil from Centra Gas at the Mid Canada site in Sanford, Manitoba. It is our understanding that Mid Canada Soil Treatment operates under a license from Manitoba Environment to treat contaminated soils from industrial sites in Manitoba.

It is anticipated that the treatment of the PAH soils will begin by the end of May. This letter will provide you with background information on the contaminants identified in the Centra Gas soil, the treatability study conducted by Remedicon, Remedicon's process for PAH treatment, location of the treatment, treatment controls and other information to assists Manitoba Environment in evaluating the proposed treatment.

1. Background Information- Centra Gas

According to Centra Gas consultant, Agra Earth and Environmental Ltd., approximately 902 tonnes of PAH impacted soil and 62,000 liters of PAH impacted water were generated during excavation for the construction of an elevator addition at the Centra Gas Operations Building at 35 Sutherland Avenue site in Winnipeg, Manitoba. Analytical tests on the soil have indicated that the concentrations of a number of PAH constituents are above the CCME Commercial/Industrial criteria and therefore cannot be disposed of at any location in the Province of Manitoba. Analytical tests performed on water samples indicate PAH concentrations exceeding the allowable discharge limits for the local water treatment system.

The soil was stockpiled on poly tarps at the Centra Gas site from November 1995 to March 1996. During this time period, the water was stored in 200 liter barrels and in 1 m^3 wet sacks at the same location, and in a water tanker located within a garage at a neighbouring Centra site. In March 1996, all of the soil and a portion of the water (the barrels and water sacks) were transported from the Sutherland Avenue site to the Mid Canada Soil Treatment Ltd. facility in Sanford, Manitoba. Once at the Sanford site, the soil and water was placed in a lined cell and covered. The water in the tanker truck was not transferred to the Sanford site and currently remains at the Centra Gas property. This additional water will be transferred to the Sanford site once the remediation project commences.

The soil transported to the Sanford site was placed in a lined cell, approximately 40 m by 20 m in plan dimensions. The cell is surrounded by a 600 mm high sand berm. The liner used at the site is an Oil Resistant Polyethylene Liner (ORPE), supplied by Layfield Plastics. Within the soil, it is estimated that there are up to 200 tonnes of rubble materials such as bricks, concrete rubble, wire, etc. The size of the rubble pieces vary considerably from as small as 100mm diameter pieces to as large as 2 m long, 300mm diameter precast concrete pieces.

2. Treatability Study

Remedicon received a sample of soil from Centra Gas on February 5, 1996 for the purpose of conducting a treatability study on the contaminated soils. The treatability study was conducted in ASL Analytical Services Laboratory, Vancouver (ASL) under ASL supervision. The final report was prepared by ASL. A copy of the study is attached as Appendix A.

The purpose of the study was to evaluate the effectiveness of three bioremediation treatment processes used by Remedicon. The treatability study determined that the nutrient/bacteria/enzyme/solvent (SBT) approach would reduce the PAH components in a representative soil sample to below commercial/industrial land use criteria quickly and cost efficiently. The bacteria supplement used in the treatability study is referred to as BacTerra 650™ (BT650). BT650 is discussed in the Remedicon Approach section.

2.1 Treatability Methodology

Remedicon designed the treatability study based on PAH levels in the subject site soils as analyzed in samples S1 and S2 (AEE Lab Ref. F95-1465, November 23, 1995). Remedicon received a 5 gallon pail containing soil and a 5 gallon pail containing 2 liters of water on February 2, 1996 from Agra Earth Environment Ltd. The treatability study, conducted at ASL in Vancouver, B.C. began on February 5, 1996.

The study used four bioreactor columns designed and built by ASL. Following homogenization of the representative PAH soil sample and the addition of contaminated water, baseline chemical analysis determined the initial PAH levels. The soil was placed into four identical bioreactor columns, three of which were stimulated in the treatability study and the fourth was retained as a control sample unit. Soil samples were collected from each of the three active columns, at two weeks after initiation of the study and at four weeks after the completion of the study. The soil samples were analyzed for PAH and chlorinated phenols. The data is contained in Appendix A.

The active bioreactor column studied three treatment approaches used by Remedicon. Column B was designated for a BacTerra 650™/nutrient bioaugmentation treatability test, Column C utilized a BacTerra 650™/REM98™ bioaugmentation assessment, and soil remediation in Column D was stimulated with a mixture of an organic solvent, REM98™ and BacTerra 650™ (SBT). Nutrients were added to each of the stimulated columns. Column A contained the control column soils. Due to the low PAH levels identified in the initial sample, Column A was used as the reference initial sample in Table 1.

As part of the proposed remediation design, stockpiled groundwater at the site would be incorporated into the soil treatment system as moisture on an as-needed basis (up to 30%). Following addition of the homogenized sample to the four bioreactor columns, the representative water sample was added to these systems to maintain a 30% moisture content. This procedure most closely approximates the full-scale remediation of the stockpiled soil and groundwater at the Winnipeg site. This procedure facilitates groundwater remediation along with soil remediation.

2.2 Potential Breakdown Products Concerns

In order to address the possibility of production of hazardous or controlled materials following breakdown of the PAHs in the column material, a two-part sampling procedure was designed. Three representative soil samples were analyzed for volatile organic carbon (VOC) constituents, and a representative leachate sample was subjected to a microtox bioassay analysis at the conclusion of the study. At the completion of the treatability study, PAH and PAH breakdown product levels were analyzed. Additional samples were analyzed for chlorinated phenols at the initiation and conclusion of the treatability study. The control column was sampled at the conclusion of the study. PAH soil analyses was conducted in accordance with U.S. Environmental Protection Agency Method Code EPA 3550/8080. Water from the control and the column showing the highest level of PAH reduction was tested for PAH content. Toxicity analysis using the microtox bioassay analysis focused on the groundwater toxicity component. Thus both controlled substances and toxicity concerns were addressed.

2.3 Study Results

Extreme variability in the sample material presented problems in preparing homogenous samples for the columns study. This problem is reflected in the higher than average naphthalene values for Column C.

Concentrations of PAHs in soil can decrease due to volatilization, soluablization and degradation. The experiment consisted of two sampling events and the data is therefore limited. Increased sampling may have better demonstrated trends.

The two week progress results are presented in Table 1. The final results are presented in Table 2. Samples were collected from the middle port in each of the columns. Generally at least a fifty percent reduction was observed in Column B and C. The sample results indicate that a 72% to 82% reduction in contaminant levels occurred in Column D. This reduction occurred in a twelve day period using the solvent solution(SBT). This reduction is illustrated in Figure 1.

In comparing the effectiveness of the three options, the combination used in Column D (SBT) showed the greatest decrease overall for the study period. No non-halogenated volatiles were detected in Column D indicating a more complete remediation. The PAHs detected in the leachate were lower in this column. The microtox results indicated that the leaching solutions had a low level of toxicity (>90% IC_{50}).

3. Background Information - Remedicon

Remedicon specializes in the treatment of contaminated soils using bioremediation methodology. It operates a commercial bioremediation facility in Delta and has treated several thousand tonnes of hydrocarbon contaminated soils over the past three years. Remedicon operates under BC Ministry of Environment, Lands and Parks Waste Management Permit and Section 41(1) Special Waste Treatment Approval. A copy is attached as Appendix B.

Remedicon carries $1,000,000 Environmental Impairment Liability Insurance, Contractors Impairment Liability Insurance and Errors and Omissions Insurance. These insurance policies cover Remedicon's activities across Canada. A copy of insurance coverage is attached as Appendix C.

Over the past year, Remedicon has transferred technologies developed at the Remedicon Facility in Delta to client sites. In some cases the soil is excavated and placed in engineered cells on the client site and then treated. In other cases, the soil is treated in-situ without disturbing the client operation.

Over the past four years, Remedicon has conducted numerous bioremediation projects including:

- Hydrocarbons - gasoline, diesel, waste oil (ex situ and in situ)
- PAHs, PCP, heavy metals and perchloroethylene
- PCBs (initial studies)

3.1 Remedicon Treatment Approach

Remedicon treats contaminated soils from client sites using a multi-stage bioaugmentation treatment process. Through expertise developed from on-site bioremediation, ex-situ and in-situ projects, Remedicon has developed techniques and technology for timely, cost-effective biological solutions to complex treatment problems.

Remedicon uses nutrients, enzymes and oxygen as the main ingredients for the stimulation of natural bacteria in the soil. When the concentrations of chemicals being treated are toxic to the natural bacteria or are not easily degraded by natural bacterial populations, a bioaugmentation program is implemented.

Bioaugmentation is the addition of natural bacteria mixtures in concentrations which accelerate the decomposition of toxic chemicals. The addition of the bacteria is required until the levels of toxicity are reduced and a stable population of degrading bacteria is maintained. This results in the degradation of chemical compounds at a greater rate and reduced treatment times.

BacTerra™ 650 is a mixture of anaerobic and aerobic microorganisms which occur naturally in the environment. This mixture contains non-cloned, non-genetically altered 100% natural micro-organisms including Achromobacter, Nitrobacter and Nitrosonma Family of Organisms. The exact makeup of BacTerra is proprietary. The Microtox Assay results provide confirmation of the non-toxic nature of the material.

4. Location of Treatment

Treatment will be conducted on the Mid Canada Soil Treatment Ltd. site located in Sanford, Manitoba. This site is licensed by Manitoba Environment and operates under permit requirements. Manitoba Environment will be notified and their approval obtained prior to the disposal of any treated soil or water from the facility.

5. Treatment of PAH soils

The treatment approach used at the Sanford site will approximate the schedule and concentration tested at ASL. Variations may occur as a result of the non-homogenous nature of the soils

The soils are presently stored in a ORPE lined cell however this cell is not suitable for treatment of the PAH soils using the Remedicon process. The contaminated soil will be removed from the existing storage cell and placed into a new cell. The new cell is constructed as an engineered, chemically resistant 30 mil (ORPE) lined cell and covered. The specifications are identified in Appendix D.

The large rubble pieces will be removed from the contaminated soil during the soil transfer. The large rubble pieces will be washed and decontaminated. The wash water mixture will be left in the original storage cell. The remaining contaminated water from the Centra Gas site will be added to this cell. The water will then receive a nutrient and bacterial treatment.

The contaminated water will be used as a moisture source and treatment of a limited amount of the water will occur in the engineered treatment cell together with the soil. Water in excess to the treatment process will be treated in the existing ORPE lined cell.

As the soil is placed into the cell, nutrients are added to the contaminated soils. After the soil is loaded into the cell, the REM solution (mixture determined in the Treatability Study) is injected into the soil. A soil sample is obtained and tested with a PAH field test kit. Twenty four hours later, the bacterial supplement (BT650) is injected into the soil. The solution is injected under pressure on a one meter square grid to ensure an equal distribution under the surface of the soil. A final surface spray is conducted after the injection. Water in the sump and water from the storage cell is circulated to the top of the soil pile. This water assists in the movement of the nutrients and bacteria through the soil. The initial nutrient solution injected into the soil moves through the soil dissolving the nutrients placed into the soil and stimulating the native bacteria. The

BT650 added meets this zone, increasing the beneficial microbe population which degrade the PAHs.

Two weeks after the initial treatment, a second injection of BT650 is conducted. The PAH soil samples are obtained one week later and analyzed using a PAH field test kit. This sample will be used to determine the concentration of nutrients and bacteria to be added for the third treatment. The contaminated water is circulated from the sump to the cell on a weekly schedule. Remedicon estimates that three to four treatments may be required to reduce the contamination levels.

The REM solution acts as a vapour suppressant. Odours are reduced after the initial treatment. To ensure that odours are minimized the treatment cell is covered except during treatment activity.

When it has been determined that the soil and water are suitable for disposal, a confirmation analytical program is conducted. One sample for each 200 m^3 of soil is collected and analyzed for PAH compounds. Water samples are collected and analyzed for PAH compounds. A final report is prepared and submitted to Manitoba Ministry of Environment for approval. Once the approval is obtained, the soil and water will be disposed as directed by Manitoba Ministry of Environment.

5.1 Laboratory to Full Scale

The problems of moving from laboratory scale to full scale depend on determining the total quantity of treatment chemicals required. This problem is overcome by adding nutrients to the contaminated soils when it is placed into the cell. This ensures an even distribution of nutrients throughout the soil. The REM mixture is applied to the soil to achieve an even moisture content. By circulating the water, the movement of nutrients and soil degrading bacteria are ensured and oxygen is supplied to the bacteria.

5.2 PAH Break Down Products

From the tests conducted during the treatability study, no breakdown products were detected. It appears that carbon dioxide is the main byproduct produced in the reduction of the PAH compounds. Attached in Appendix E is the abstract from a recent conference on the Biological Remediation of Contaminated Sediments, With Special Emphasis on the Great Lakes. This paper discusses the breakdown of PAHs by use of a specific bacteria and illustrates the major pathways of bacterial oxidation.

5.3 Monitoring and Evaluation

Soil remediation progress is monitored using a PAH Field Test kit (DTech TK1006S-1) and laboratory analysis. Soil and water sampling will be conducted according to Ministry of Environment guidelines. No materials will be discharged without approval from the Ministry of Environment.

We trust that the information provided by Remedicon is sufficient to assist the Ministry of Environment in approving the treatment process. Should you have any questions please contact (604) 987-5659.

Sincerely,
REMEDICON

Albert Holtz

Al Holtz, B.Sc.
President

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COPY

REMEDICON: Remediation Consulting Ltd.

1996 COLUMN STUDY OF POLYCYCLIC AROMATIC HYDROCARBON CONTAMINATED SOIL

Prepared For:

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April 02, 1996

Specialists in Environmental Chemistry

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April 02, 1996

Mr. Al Holtz
Remediation Consulting Ltd.
2620 Hoskins Road,
North Vancouver, B.C.
V7J 3A3

Dear Mr Holtz:

Re: Final Report on Column Study: 1996 Column Study of Polycyclic Aromatic Hydrocarbon Contaminated Soil

Attached is one copy of our final report for ASL File No. F7284 containing column study approach, data tables, methodology, and discussion.

We trust that this completes our analytical assignment with respect to this project. If you require any additional information, please call either of the undersigned at (604) 253-4188.

Sincerely yours,

ASL ANALYTICAL SERVICE LABORATORIES LTD.
per:

Joyce S. Chow, B.Sc.
Project Chemist

Scott Hannam
Manager, Laboratory Operations

COPY

TABLE OF CONTENTS

1.0 INTRODUCTION

The column study was designed to show the effects of various bioremediating solutions on soils with elevated levels of Polycyclic Aromatic Hydrocarbons in a controlled environment. The creosote contaminated soil was submitted to ASL on February 05, 1996, and was initially analysed for Polycyclic Aromatic Hydrocarbons and Chlorinated Phenols. The soil was put through a small scale bioremdiation experiment and samples were taken periodically to check for levels of Polycyclic Aromatic Hydrocarbons and Volatile Organic Compounds. The final leachate was analysed for Polycyclic Aromatic Hydrocarbons and Microtox.

2.0 ANALYTICAL METHODOLOGY

All methods employed by ASL use state-of-the-art equipment and instrumentation for the preparation and analysis of samples. A high degree of quality assurance was incorporated in all testing procedures to ensure that only credible data is produced.

2.1 Column Preparation

ASL designed and built the columns (diagram 1) used in the small scale bioremediation study. The columns were constructed of PVC pipe and fittings to ensure no leaks. The columns had an inside diameter of 10 cm and were 30 cm high. The bottom of the columns contained stainless steel filters to allow separation of the lechachate from the soil. A drain made from 1 cm diameter PVC tubing was attached to the bottom of the columns to allow leachate to be collected and recirculated. The top of the column contained a self-sealing septum. Three sealable holes were situated equidistantly along each column to allow a sampling device (diagram 2) to be inserted into the column for sample collection. These holes were labelled 1,2 and 3 from top to bottom in each of the columns.

2.2 Sampling Procedure

The creosote contaminated soil was submitted to ASL on February 05, 1996. An initial sample that did not undergo any treatments in the experiment was subsampled and analysed for Polycyclic Aromatic Hydrocarbons and Chlorinated Phenols. This sample is identified as "Initial" and data appears in the results of analysis section (Appendix A). The soil was placed into four identical columns, identified as A,B,C and D. The soil was allowed to settle for 2 days before the addition of any nutrients or solutions.

On February 07, 1996, Mr. Al Holtz of Remedicon Remediation Consulting Ltd. added various amounts of nutrients or distilled/deionized water were added to the columns. The leachate water was recycled on several occasions by Remediation Consulting Ltd. throughout the experiment.

Samples were taken at two week and four week intervals from of each column. Soil Samples were taken on February 22 and March 07 and the results are located in Appendix A. After the last sampling date the leachate water was drained from each of the columns and analysed for Polycyclic Aromatic Hydrocarbons and Microtox. A table highlighting the Column Study follows:

COPY

Column Design Study

PAH STUDY	Column A	Column B	Column C	Column D
Description	Control	BacTerra650	REM98	BacTerra650 REM98
Soil:	2/3 Full 96/02/05	2/3 Full 96/02/05	2/3 Full 96/02/05	2/3 Full 96/02/05
Additions:	750ml Water 96/02/07	500ml Nutrients 96/02/07	500ml REM98 96/02/07	100ml Nutrients 400ml REM98 96/02/07
Soil Sampling:	96/02/22 PAH 96/03/07 PAH	96/03/22 PAH 96/03/07 PAH 96/03/07 VOC	96/02/22 PAH 96/03/07 PAH 96/03/07 VOC	96/02/22 PAH 96/03/07 PAH 96/03/07 VOC
Leachate Sampling:	96/03/07 PAH	96/03/07 Microtox	96/03/07 Microtox	96/03/07 PAH 96/03/07 Microtox
Borehole:	3*	2	2	2

* Sampled from Borehole 3 because the soil level was below Borehole 2

DIAGRAM 1

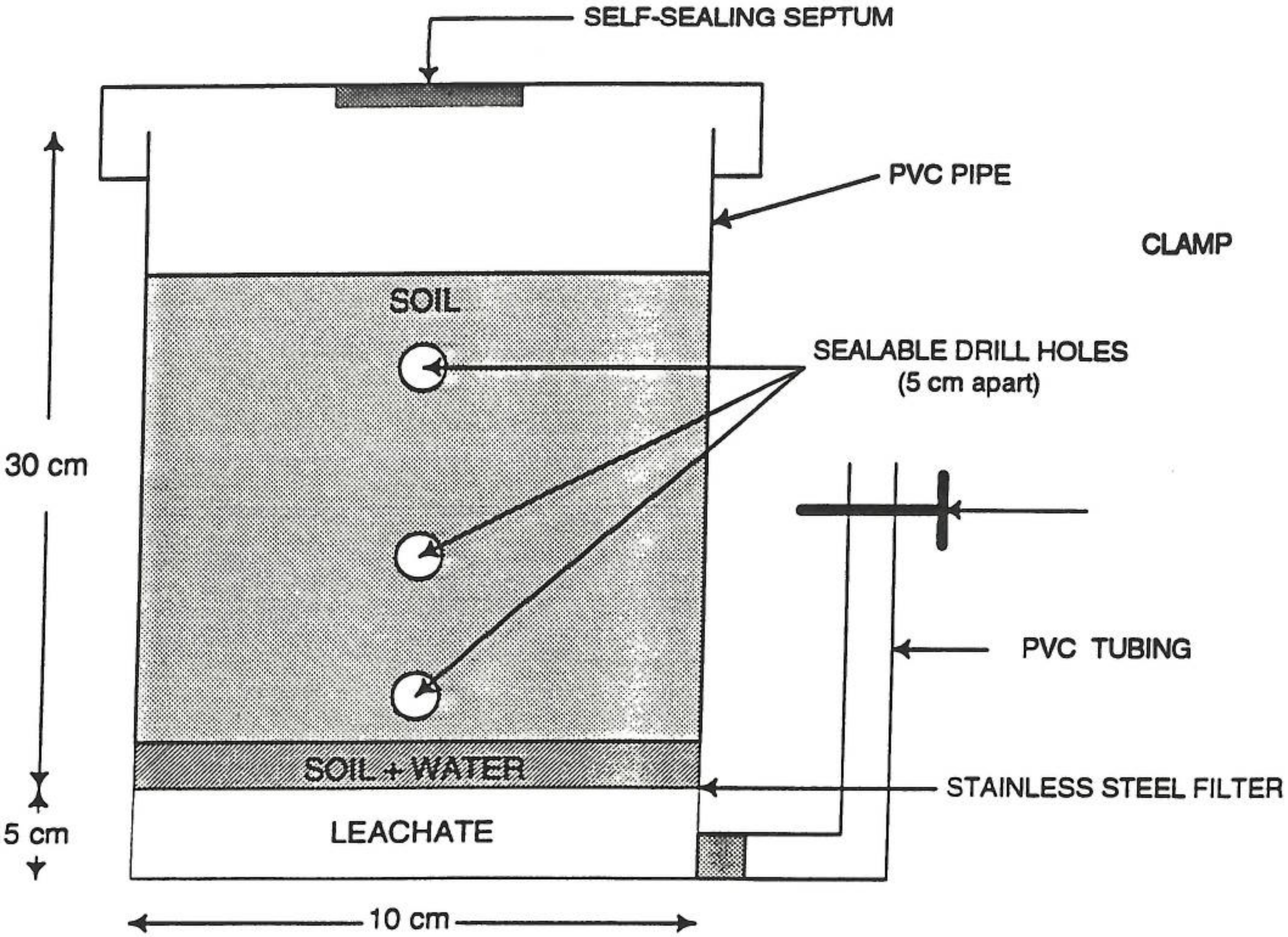
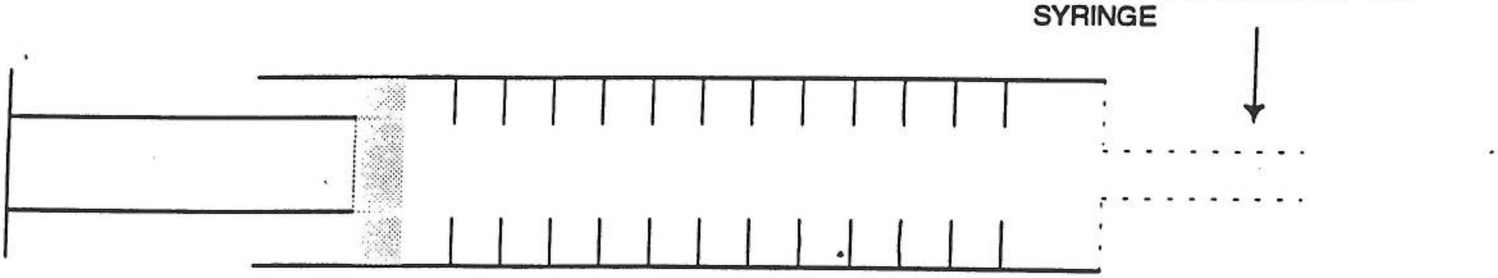


DIAGRAM 2



DOTTED LINES INDICATE THE REMOVED SECTION OF THE SYRINGE

2.3 Organic Parameters in Soil

Polyaromatic Hydrocarbons in Soil

This analysis was carried out using a procedure adapted by ASL from U.S. EPA Methods 3500, 2630, and 8270 (Publ. # SW-846, 3rd ed., Washington, DC 20460). The procedure involves a microwave assisted extraction with dichloromethane followed by a clean-up using silica gel column chromatography, This clean-up procedure has been found to efectively remove aliphatic and heterocyclic hydrocarobns which could potentially interfere with the analysis. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection.

Volatile Organic Compounds in Soil

This analysis was carried out in accordance with U.S. Environmental Protection Agency Methods 5030 and 8240 (Publ. # SW-846, 3rd Ed., Washington, DC 20460). This method involves a purge and trap extraction of the volatile compounds and subsequent analysis by capillary column gas chromatography with mass selective detection.

Chlorinated Phenols in Soil

This anlaysis is carried out using a procedure adapted by ASL from U.S. EPA Methods 3500 and 8041 (Publ. #SW-846, 3rd ed., Washington, DC 20460). The sample is extracted with basic methanol followed by an acid-base clean-up and back extraction to hexane. The final extract is derivatized and analysed by capillary column gas chromatography with electron capture detection.

2.4 Organic Parameters in Leachate

Polyaromatic Hydrocarbons in Leachate

This analysis is carried out using a procedure adapted by ASL from U.S. EPA Methods 3510, 3630 and 8270 (publ. #SW-846, 3rd Ed., Washington, DC 20460). The procedure involves the extraction of the sample with methylene chloride followed by silica column chromatography cleanup. This cleanup procedure has been found to effectively remove aliphatic and heterocyclic hydrocarbons which could potentially interfere with the analysis. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection.

Volatile Organic Compounds in Leachate

This analysis was carried out in accordance with U.S. EPA Methods 3810/8020 and 3810/8015 (Publ. #SW-846, 3rd ed., Washington, DC 20460). The procedure involves the use of a headspace technique in which the volatile non-halogenated conpounds volatilise into the headspace of a sealed vial. A portion of this gaseous headspace is then analysed by capillary column gas chromatography with photoionization and flame-ionization detection. Samples requiring further confirmation are re-analysed in accordance with U.S. EPA Methods 5030/8240. This procedure uses a purge and trap extraction, with subsequent analysis by capillary column gas chromatography with mass spectrometric detection.

2.5 Bioassay

Microtox in Leachate

This analysis were performed on the Beckman Model 500 Microtox Toxicity Analyser System using the methods described in "Microtox Manual, A Toxicity Testing Handbook" 1992. This analysis was performed by Integrated Resource Consultants.

2.6 Quality Assurance/Quality Control(QA/QC)Program

ASL's routine QA/QC Program was implemented throughout the analysis for this study. This includes the use of Method Blanks, Reference Materials, Matrix Spikes, Check Standards, Surrogate Standards and Laboratory Replicates. These quality control samples are part of ASL's internal QA/QC program and are used to monitor method performance, contamination control, precision and accuracy. Data for the two laboratory replicates is included in the results of analysis section (Appendix A).

3.0 RESULTS OF ANALYSIS

The results for the initial sample, the soil and leachate column study analysis are located in Appendix A. Graphs summarizing the data for the Total, Light and heavy Molecular Weight PAH concentrations are located in Appendix B.

4.0 DISCUSSION

The table in Appendix B show the trends in the changes for the Polycyclic Aromatic Hydrocarbon concentrations for the column study samples. The graphs compare Total concentration, Heavy Molecular Weight PAHs and Light Molecular Weight PAHs. There are some major processes to consider when evaluating the effects on the column study. Concentrations of PAHs in the soil can decrease due to volatalization, soluablization,and degradation. Heterogenaity of the samples may also be a cause of variability in the data. The relative concentrations of the Total, Heavy or Light PAHs can also increase as a result of breakdown products of more complex PAHs.

This experiment consisted of two sampling events and the data is somewhat limited. Increased sampling events may have been useful to further demonstrate any trends. An evaluation is based on the data as determined by the analysis. Another consideration is the possibility of changes in concentrations of other products and compounds that were not measured in the scope of this experiment.

Note that the moisture was assumed to be the same for the column study samples as that which was determined in the initial sample. In actual fact the moisture leves were probably higher in the column samples due to the addition of nutrients, distilled/deionized water etc. and may lead to slightly higer results than reported.

Initial

The Initial Sample and the replicate show good precision for the subsamples taken. The Total and Heavy PAHs are lower than the concentrations found for some of the samples that underwent the column study and could possibly be due to heterogenaity, availability, extractability and age of the sample. The Light PAHs are in general higher than in the samples that underwent the column study. No Chlorinated Phenols were detected in the Initial sample.

Control - Column A

Column A at two weeks indicates higher relative Heavy PAHs than in the initial sample. This could be explained by the degradation of heavier molecular weight PAHs that are not included in standard PAH analysis. These compounds can be broken down more readily due to size, surface area, and weakness of chemical bonds to produce the Heavy Molecular Weight PAHs detected. Column A at the four week indicates a decrease in Light, Heavy and Total PAHs from the two week event and may show evidence of natural biodegradation through indigenous bacteria.

Bacterra - Column B

Column B at two weeks indicates similar trends to that of Column A at two weeks. Higher relative Heavy PAHs and lower Light PAHs relative to the Initial sample. Column B at four weeks indicates a decrease in Light, Heavy and Total PAHs from the two week sample which may indicate degradation processes. Overall results for Column B are lower than the control Column A at both the two week and four week intervals and may indicate that the addition of BacTerra may increase the activity of bioremediation. The presence of Non-Halogenated volatiles may indicate that the PAHs are breaking down to these simpler forms through the degradation process. Chloroform detected is likely attributed to the water used to make the nutrient solution.

REM - Column C

The Light PAHs in both the two week and four week results are approximately the same as in the initial sample. The Heavy PAHs are higer in Column C than in the Initial and may again indicate breakdown of heavier PAHs that were not measured previously as in Column A and Column B. The change in the two week and four week isn't as marked as in the other columns and may indicate that REM on its own may not be as effective for remediation. A slight latency period may be present or the indigenous bacteria may be consuming the REM rather than the contaminants. The presence of Non-Halogenated volatiles may indicate that the PAHs are breaking down to these simpler forms through the degradation process. Chloroform detected is likely attributed to the water used to make the REM.

BacTerra and REM - Column D

The Light and Heavy PAHs for Column D show the greatest decrease overall for the two week and four week period. This may indicate that the combination of BacTerra and REM may be the most effective and thourough as a bioremediation process. No Non-Halogenated volatiles were detected and may be as a result of a more complete remediation associated with the combination of the BacTerra and REM. Chloroform detected is likely attributed to the water used to make the Nutrients and REM.

Leachate

The PAHs detected in the Leachate were lower in Column D (BacTerra + REM) compared to the Control. This may be explained by greater degree of remediation activty in column D. The microtox results indicated that the leaching solutions had a low level of toxicity (>90% IC_{50}).

Appendix A

Results of Analysis

RESULTS OF ANALYSIS - Sediment/Soil[1]

File No. F7284

	Initial	B-2	C-2	D-2
	96 02 05	96 03 07	96 03 07	96 03 07
Physical Tests				
Moisture %	22.4	-	-	-
Halogenated Volatiles				
Bromodichloromethane	-	<0.010	<0.010	<0.010
Bromoform	-	<0.010	<0.010	<0.010
Carbon Tetrachloride	-	<0.010	<0.010	<0.010
Chlorobenzene	-	<0.010	<0.010	<0.010
Chloroethane	-	<0.010	<0.010	<0.010
Chloroform	-	0.010	0.020	0.011
Chloromethane	-	<0.010	<0.010	<0.010
Dibromochloromethane	-	<0.010	<0.010	<0.010
1,2-Dichlorobenzene	-	<0.010	<0.010	<0.010
1,3-Dichlorobenzene	-	<0.010	<0.010	<0.010
1,4-Dichlorobenzene	-	<0.010	<0.010	<0.010
1,1-Dichloroethane	-	<0.010	<0.010	<0.010
1,2-Dichloroethane	-	<0.010	<0.010	<0.010
cis-1,2-Dichloroethylene	-	<0.010	<0.010	<0.010
trans-1,2-Dichloroethylene	-	<0.010	<0.010	<0.010
1,1-Dichloroethylene	-	<0.010	<0.010	<0.010
Dichloromethane	-	<0.050	<0.050	<0.050
1,2-Dichloropropane	-	<0.010	<0.010	<0.010
cis-1,3-Dichloropropylene	-	<0.010	<0.010	<0.010
trans-1,3-Dichloropropylene	-	<0.010	<0.010	<0.010
1,1,1,2-Tetrachloroethane	-	<0.010	<0.010	<0.010
1,1,2,2-Tetrachloroethane	-	<0.010	<0.010	<0.010
Tetrachloroethylene	-	<0.010	<0.010	<0.010
1,1,1-Trichloroethane	-	<0.010	<0.010	<0.010
1,1,2-Trichloroethane	-	<0.010	<0.010	<0.010
Trichloroethylene	-	<0.010	<0.010	<0.010
Trichlorofluoromethane	-	<0.010	<0.010	<0.010
Vinyl Chloride	-	<0.010	<0.010	<0.010
Non-halogenated Volatiles				
Benzene	-	<0.010	<0.010	<0.010
Ethylbenzene	-	<0.010	0.015	<0.010
Styrene	-	<0.010	0.021	<0.010
Toluene	-	<0.010	<0.010	<0.010
meta- & para-Xylene	-	0.013	0.079	<0.010
ortho-Xylene	-	0.013	0.066	<0.010

< = Less than the detection limit indicated.

[1] Results are expressed as milligrams per dry kilogram based on the assumption that moisture for all the samples was the same as the "Initial" sample.

COPY

RESULTS OF ANALYSIS - Sediment/Soil[1]

File No. F7284

	Initial 96 02 05	Column A-3 96 02 22	Column B-2 96 02 22	Column C-2 96 02 22	Column D-2 96 02 22
Polycyclic Aromatic Hydrocarbons					
Acenaphthene	0.39	0.37	0.28	0.54	0.28
Acenaphthylene	3.31	4.63	3.15	3.66	1.80
Anthracene	1.51	4.81	1.99	2.15	1.46
Benz(a)anthracene	2.62	12.4	4.18	3.74	2.18
Benzo(a)pyrene	2.49	13.3	5.86	4.63	2.66
Benzo(b)fluoranthene	2.77	15.4	6.99	5.57	3.29
Benzo(ghi)perylene	2.58	15.1	7.22	4.95	3.04
Benzo(k)fluoranthene	1.07	5.39	2.38	1.96	1.18
Chrysene	2.94	11.4	4.04	3.64	2.20
Dibenz(a,h)anthracene	0.38	1.98	0.92	0.70	0.44
Fluoranthene	4.53	24.1	9.55	7.87	4.82
Fluorene	1.60	1.48	1.15	1.85	0.97
Indeno(1,2,3-cd)pyrene	2.35	15.6	7.08	4.99	3.03
Naphthalene	43.5	24.2	24.0	40.9	6.79
Phenanthrene	6.58	9.04	7.18	8.88	4.66
Pyrene	7.24	33.3	15.3	11.3	7.28
Chlorinated Phenols					
2,3,4-Trichlorophenol	<0.020	-	-	-	-
2,3,5-Trichlorophenol	<0.020	-	-	-	-
2,4,5-Trichlorophenol	<0.020	-	-	-	-
2,4,6-Trichlorophenol	<0.020	-	-	-	-
2,3,4,5-Tetrachlorophenol	<0.020	-	-	-	-
2,3,4,6-Tetrachlorophenol	<0.020	-	-	-	-
2,3,5,6-Tetrachlorophenol	<0.020	-	-	-	-
Pentachlorophenol	<0.020	-	-	-	-

< = Less than the detection limit indicated.

[1] Results are expressed as milligrams per dry kilogram based on the assumption that moisture for all the samples was the same as the "Initial" sample.

RESULTS OF ANALYSIS - Sediment/Soil[1]

File No. F7284

	A-3	B-2	C-2	D-2
	96 03 07	96 03 07	96 03 07	96 03 07
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	0.22	0.08	0.29	0.10
Acenaphthylene	1.86	0.89	2.28	0.79
Anthracene	1.60	0.42	2.78	0.64
Benz(a)anthracene	3.53	2.02	6.42	1.92
Benzo(a)pyrene	2.86	1.30	5.60	1.59
Benzo(b)fluoranthene	3.35	2.06	7.19	2.40
Benzo(ghi)perylene	2.77	1.22	7.50	1.73
Benzo(k)fluoranthene	1.31	0.85	2.66	1.00
Chrysene	3.65	1.30	6.23	1.80
Dibenz(a,h)anthracene	0.31	0.16	0.84	0.22
Fluoranthene	5.70	2.70	12.5	3.15
Fluorene	1.05	0.35	1.40	0.40
Indeno(1,2,3-cd)pyrene	2.89	1.25	8.05	1.97
Naphthalene	10.5	7.15	25.2	2.40
Phenanthrene	7.40	2.06	10.4	2.17
Pyrene	9.30	4.61	15.8	4.42

< = Less than the detection limit indicated.

[1] Results are expressed as milligrams per dry kilogram based on the assumption that moisture for all the samples was the same as the "Initial" sample.

RESULTS OF ANALYSIS - Leachate[1]

	A	D	C	B
	96 03 07	96 03 07	96 03 08	96 03 08
Polycyclic Aromatic Hydrocarbons				
Acenaphthene	<0.0005	0.0009	-	-
Acenaphthylene	0.0013	0.0008	-	-
Acridine	0.00008	0.00010	-	-
Anthracene	0.0004	0.0002	-	-
Benz(a)anthracene	0.00106	0.00050	-	-
Benzo(a)pyrene	0.00197	0.00076	-	-
Benzo(b)fluoranthene	0.00229	0.00087	-	-
Benzo(ghi)perylene	0.0024	0.0009	-	-
Benzo(k)fluoranthene	0.00088	0.00039	-	-
Chrysene	0.0013	0.0006	-	-
Dibenz(a,h)anthracene	<0.00001	<0.00001	-	-
Fluoranthene	0.0015	0.0008	-	-
Fluorene	0.0025	0.0011	-	-
Indeno(1,2,3-cd)pyrene	0.00207	0.00077	-	-
Naphthalene	0.0012	0.0003	-	-
Phenanthrene	0.0008	0.0003	-	-
Pyrene	0.00252	0.00153	-	-
Bioassays				
Microtox[2]	-	>90%	>90%	>90%

< = Less than the detection limit indicated.

[1] Results are expressed as milligrams per litre except where noted.

[2] Highest concentration tested.

COPY

QUALITY CONTROL - Replicates

File No. F7284

Sediment/Soil[1]	**Initial**	**Initial**
	96 02 05	QC # 54643
Polycyclic Aromatic Hydrocarbons		
Acenaphthene	0.39	0.30
Acenaphthylene	3.31	2.65
Anthracene	1.51	1.24
Benz(a)anthracene	2.62	2.82
Benzo(a)pyrene	2.49	2.75
Benzo(b)fluoranthene	2.77	3.10
Benzo(ghi)perylene	2.58	2.65
Benzo(k)fluoranthene	1.07	1.14
Chrysene	2.94	3.30
Dibenz(a,h)anthracene	0.38	0.42
Fluoranthene	4.53	5.14
Fluorene	1.60	1.16
Indeno(1,2,3-cd)pyrene	2.35	2.45
Naphthalene	43.5	35.1
Phenanthrene	6.58	5.64
Pyrene	7.24	7.46

< = Less than the detection limit indicated.

[1] Results are expressed as milligrams per dry kilogram based on the assumption that moisture for all the samples was the same as the "Initial" sample.

QUALITY CONTROL - Replicates

File No. F7284

Sediment/Soil[1]	**Column B-2** 96 02 22	**Column B-2** QC # 55965
Polycyclic Aromatic Hydrocarbons		
Acenaphthene	0.28	0.28
Acenaphthylene	3.15	3.14
Anthracene	1.99	1.46
Benz(a)anthracene	4.18	3.76
Benzo(a)pyrene	5.86	5.58
Benzo(b)fluoranthene	6.99	7.34
Benzo(ghi)perylene	7.22	7.13
Benzo(k)fluoranthene	2.38	2.42
Chrysene	4.04	5.04
Dibenz(a,h)anthracene	0.92	0.87
Fluoranthene	9.55	11.6
Fluorene	1.15	1.05
Indeno(1,2,3-cd)pyrene	7.08	6.89
Naphthalene	24.0	22.3
Phenanthrene	7.18	7.36
Pyrene	15.3	17.1

< = Less than the detection limit indicated.

[1] Results are expressed as milligrams per dry kilogram based on the assumption that moisture for all the samples was the same as the "Initial" sample.

IRC
Integrated Resource Consultants Inc.

Suite 160
14480 River Road
Richmond, BC
Canada V6V 1L4
Tel. (604) 278-7714
Fax (604) 278-7741

COPY

DATE: 12 March 1996

REPORT TO:
Ms. Liana Campbell
ASL Ltd.
1988 Triumph St.
Vancouver, B.C. V5L 1K5

MICROTOX BIOASSAY RESULTS

Purchase Order:	F7284
Date, time received:	12 March 1996; 1145 hrs.
Shipping details:	By ground via UPS
Received by:	MZ
Date, time tested:	12 March 1996; 1340 hrs.
Lab technician:	MZ
Bacteria Lot #:	ACV001-3

METHODS

The Microtox bioassay measures toxicity based on light emission from a bioluminescent bacteria in the presence or absence of a toxicant. The bacteria are exposed to different concentrations of a sample and the light loss over time is recorded; the IC_{50} is the concentration of sample causing a 50% reduction in bioluminescence.

RESULTS

Sample Name F7284-11 (D)
Date collected: 7 March 1996
Amount, Container: 1 x 500ml brown glass container with 100ml of sample.
Physical description: Pale yellow colour with some fine solids.
RESULTS: **5 minute IC_{50} (95% confidence interval):** > 90%*
15 minute IC_{50} (95% confidence interval): > 90%*

Sample Name F7284-12 (C)
Date collected: 8 March 1996
Amount, Container: 1 x 250ml clear glass container with 50ml of sample.
Physical description: Pale yellow colour with some fine solids.
RESULTS: **5 minute IC_{50} (95% confidence interval):** > 90%*
15 minute IC_{50} (95% confidence interval): > 90%*

Sample Name F7284-13 (B)
Date collected: 8 March 1996
Amount, Container: 1 x 250ml clear glass container with 50ml of sample.
Physical description: Clear pale yellow colour.
RESULTS: **5 minute IC_{50} (95% confidence interval):** > 90%*
15 minute IC_{50} (95% confidence interval): > 90%*

*highest concentration tested.

Reference toxicant information:
Chemical used: Phenol
IC_{50}: 15.9ppm, with a 95% confidence interval between 14.9ppm and 17.0pm.
Lab Mean: 17.5ppm ± 4.0ppm (two standard deviations).

Bioassays are performed on the Beckman Model 500 Microtox Toxicity Analyzer System using the methods described in "Microtox Manual, A Toxicity Testing Handbook" 1992.

Please call should you have any questions.

IRC Integrated Resource Consultants Inc.

Marian Zazzi
Biologist
b079

Appendix B

Graphical Results and Summary

COPY

MATRIX	SOIL		SOIL		SOIL		SOIL		SOIL	
SAMPLE	Initial	Initial Dup.	A-3	A-3	B-2	B-2	C-2	C-2	D-2	D-2
DATE COLLECTED	5-Feb-96	22-Feb-96	22-Feb-96	7-Mar-96	22-Feb-96	7-Mar-96	22-Feb-96	7-Mar-96	22-Feb-96	7-Mar-96
UNITS	mg/kg dry	mg/kg dry	mg/kg dry	mg/kg dry	mg/kg dry	mg/kg dry	mg/kg dry	mg/kg dry	mg/kg dry	mg/kg dry
Naphthalene	43.50	35.10	24.20	10.50	24.00	7.15	40.90	25.20	6.79	2.40
Acenaphthene	0.39	0.30	0.37	0.22	0.28	0.08	0.54	0.29	0.28	0.10
Acenaphthylene	3.31	2.65	4.63	1.86	3.15	0.89	3.66	2.28	1.80	0.79
Fluorene	1.60	1.16	1.48	1.05	1.15	0.35	1.85	1.40	0.97	0.40
Phenanthrene	6.58	5.64	9.04	7.40	7.18	2.06	8.88	10.40	4.66	2.17
Anthracene	1.51	1.24	4.81	1.60	1.99	0.42	2.15	2.78	1.46	0.64
Fluoranthene	4.53	5.14	24.10	5.70	9.55	2.70	7.87	12.50	4.82	3.15
Pyrene	7.24	7.46	33.30	9.30	15.30	4.61	11.30	15.80	7.28	4.42
Benzo(a)anthracene	2.62	2.82	12.40	3.53	4.18	2.02	3.74	6.42	2.18	1.92
Chrysene	2.94	3.30	11.40	3.65	4.04	1.30	3.64	6.23	2.20	1.80
Benzo(b)fluoranthene	2.77	3.10	15.40	3.35	6.99	2.06	5.57	7.19	3.29	2.40
Benzo(k)fluoranthene	1.07	1.14	5.39	1.31	2.38	0.85	1.96	2.66	1.18	1.00
Benzo(a)pyrene	2.49	2.75	13.30	2.86	5.86	1.30	4.63	5.60	2.66	1.59
Dibenzo(a,h)anthracene	0.38	0.42	1.98	0.31	0.92	0.16	0.70	0.84	0.44	0.22
Benzo(ghi)perylene	2.58	2.65	15.10	2.77	7.22	1.22	4.95	7.50	3.04	1.73
Indeno(1,2,3-cd)pyrene	2.35	2.45	15.60	2.89	7.08	1.25	4.99	8.05	3.03	1.97
Light PAH's	56.9	46.1	44.5	22.6	37.8	11.0	58.0	42.4	16.0	6.5
Heavy PAH's	29.0	31.2	148.0	35.7	63.5	17.5	49.4	72.8	30.1	20.2
Total PAH's	85.9	77.3	192.5	58.3	101.3	28.4	107.3	115.1	46.1	26.7
Chlorophenols	0.000	NA	NA	NA	NA	NA	NA	NA	NA	NA
VOC-Halogenated	NA	NA	NA	NA			NA		NA	
Chloroform						0.010		0.020		0.011
VOC-Non-Halogenated	NA	NA	NA	NA			NA		NA	
Ethylbenzene						0.000		0.015		0.000
Styrene						0.000		0.021		0.000
m,p-Xylene						0.013		0.079		0.000
o-Xylene						0.013		0.066		0.000

COPY

MATRIX		LEACHATE	LEACHATE
SAMPLE		A	D
DATE COLLECTED		7-Mar-96	7-Mar-96
UNITS		mg/L	mg/L
Naphthalene		0.0012	0.0003
Acenaphthene		0.0000	0.0009
Acenaphthylene		0.0013	0.0008
Fluorene		0.0025	0.0011
Phenanthrene		0.0008	0.0003
Anthracene		0.0004	0.0002
Fluoranthene		0.0015	0.0008
Pyrene		0.0025	0.0015
Benzo(a)anthracene		0.0011	0.0005
Chrysene		0.0013	0.0006
Benzo(b)fluoranthene		0.0023	0.00087
Benzo(k)fluoranthene		0.00088	0.00039
Benzo(a)pyrene		0.002	0.00076
Dibenzo(a,h)anthracene		0.0000	0.0000
Benzo(ghi)perylene		0.0024	0.0009
Indeno(1,2,3-cd)pyrene		0.0021	0.00077
Light PAH's		0.006	0.004
Heavy PAH's		0.016	0.007
Total PAH's		0.022	0.011
Chlorophenols		NA	NA
VOC-Halogenated		NA	NA
Chloroform			
VOC-Non-Halogenated		NA	NA
Ethylbenzene			
Styrene			
m,p-Xylene			
o-Xylene			

PAH Column Study Summary

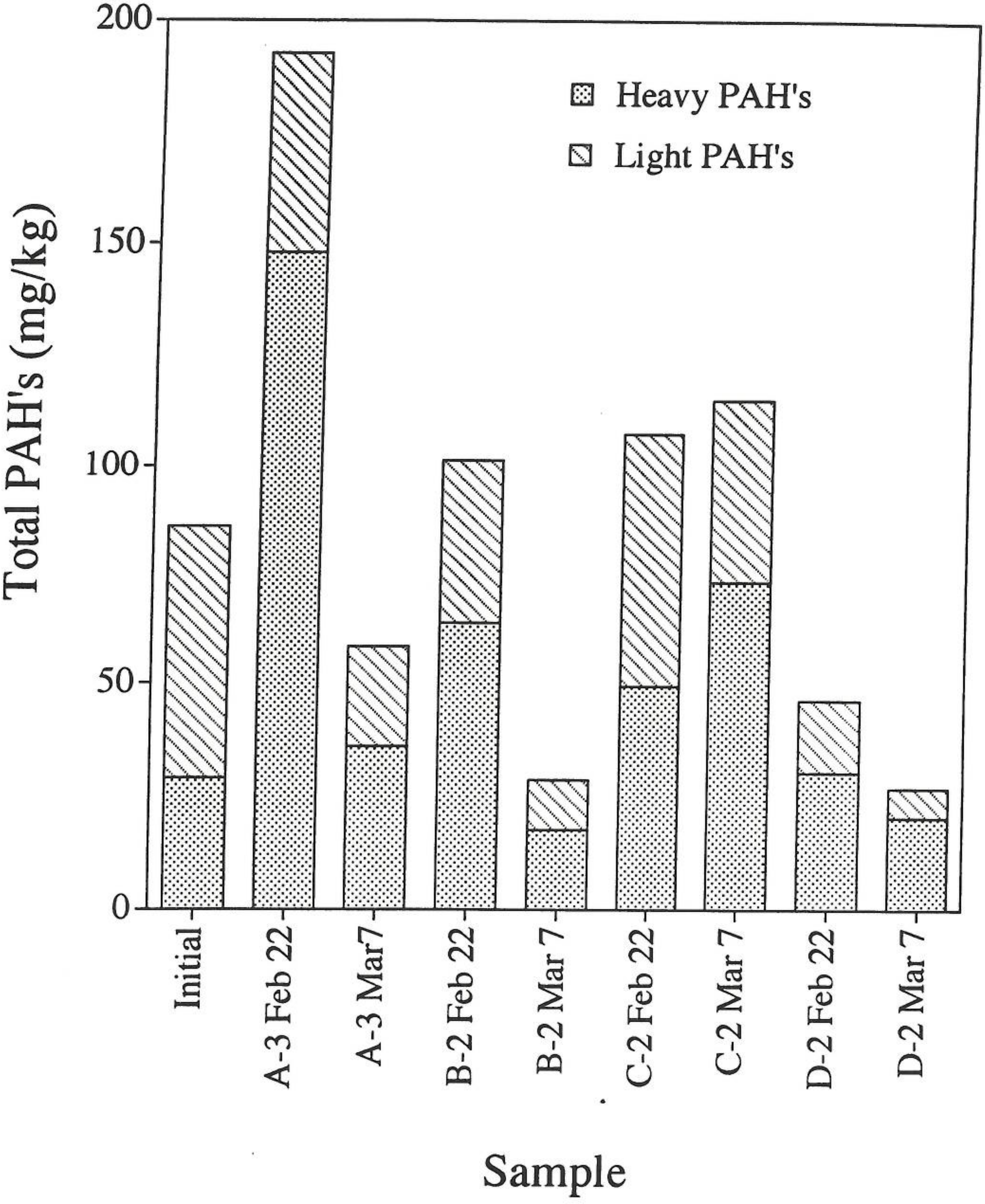


FIGURE 1: PAH REDUCTION COMPARISON BETWEEN COLUMN A AND OTHER COLUMNS, AFTER 4 WEEKS

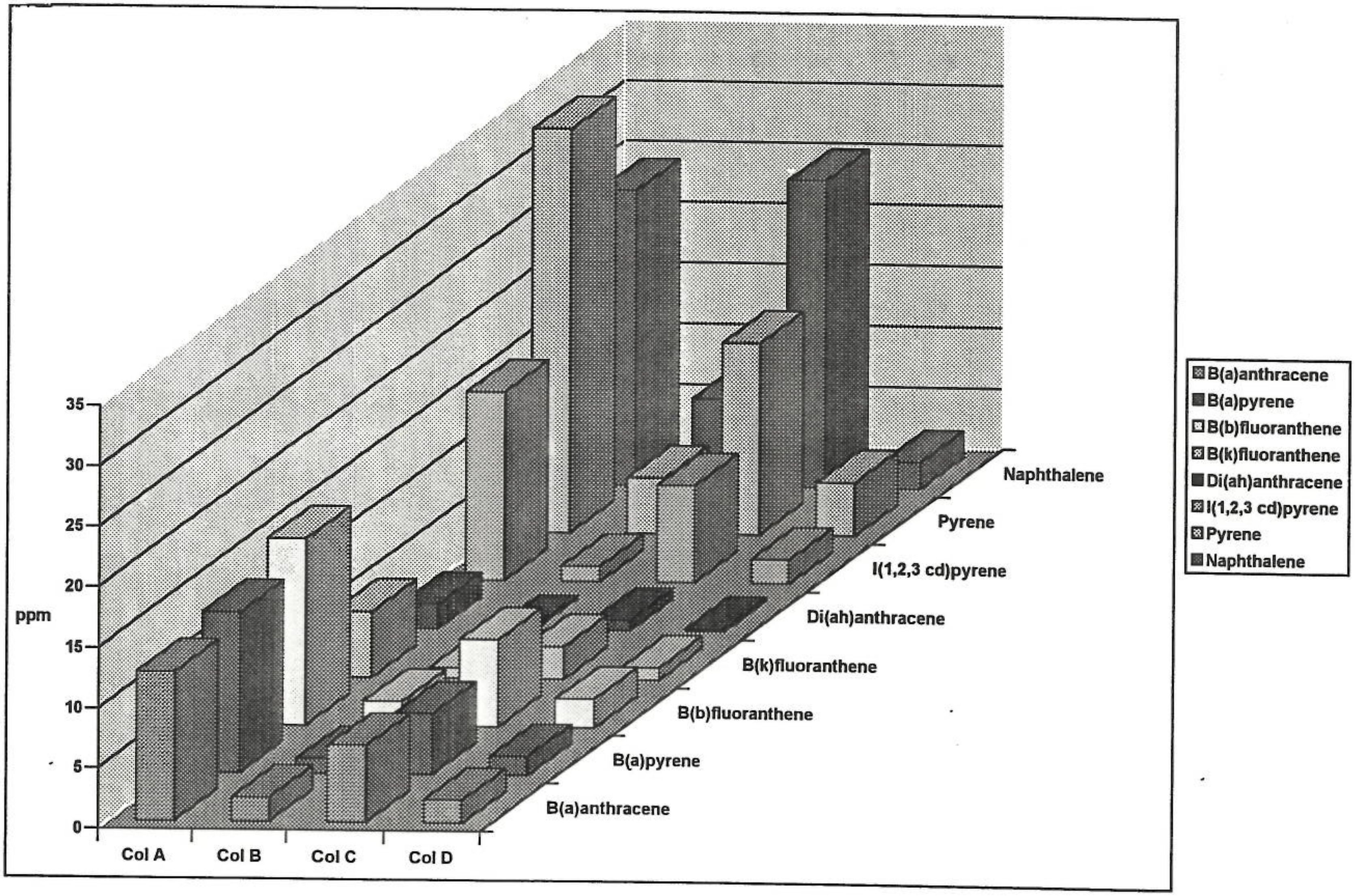


TABLE 1 - Comparison of Measured Contaminant Levels in Columns - 2 weeks

Remediation Criteria		**Columns**					
Parameter	*CCME Criteria C/I*	*Sample S1 Initial*	*Col. A*	*B*	*C*	*D*	*% change D/A*
naphthalene	50	41.2	24.2	24.0	40.9	6.79	72%
acenaphthylene	N.S.	32.4	4.63	3.15	3.66	1.80	
acenaphthene	N.S.	25.7	0.37	0.28	0.54	0.28	
fluorene	N.S.	11.9	1.48	1.15	1.85	0.97	
phenanthrene	50	13.2	9.04	7.18	8.88	4.66	48%
anthracene	N.S.	8.94	4.81	1.99	2.15	1.46	
fluoranthene	N.S.	19.7	24.1	9.55	7.87	4.82	
pyrene	100	16.6	33.3	15.3	11.3	7.28	78%
benz(a)anthracene	10	8.44	12.4	4.18	3.74	2.18	82%
chrysene	N.S.	11.5	11.4	4.04	3.64	2.20	
benzo(b)fluoranthene	10	**16.4**	15.4	6.99	5.57	3.29	78%
benzo(k)fluoranthene	10	**16.4**	5.39	2.38	1.96	1.18	78%
benzo(a)pyrene	10	**25.4**	13.3	5.86	4.63	2.66	80%
perylene	N.S.	34.6	na	na	na	na	
indeno(1,2,3-cd)pyrene	10	**17.4**	15.6	7.08	4.99	3.03	80%
dibenz(a,h)anthracene	10	**23.0**	1.98	0.92	0.70	0.44	77%
benzo(g,h,i)perylene	N.S.	28.7	15.1	7.22	4.95.	3.04	

Notes:
all concentrations expressed in ppm - milligrams per dry kilogram (soil)
"N.S." - No standards listed for indicated parameter
"*CCME*"- *Canadian Council of Ministers of the Environment*
Values for S1 as indicated in AEE letter dated January 16, 1996
bold - indicates concentrations in excess of *CCME* commercial/industrial land use criteria

TABLE 2 - Comparison of Measured Contaminant Levels in Columns - Final							
Remediation Criteria		**Columns**					
Parameter	*CCME Criteria C/I*	*Sample S1 Initial*	*Col. A*	*B*	*C*	*D*	*% change D/A*
naphthalene	50	41.2	10.5	7.15	25.2	2.40	72%
acenaphthylene	N.S.	32.4	1.86	0.89	2.28	0.79	
acenaphthene	N.S.	25.7	0.22	0.08	0.29	0.10	
fluorene	N.S.	11.9	1.05	0.35	1.40	0.40	
phenanthrene	50	13.2	7.40	2.06	10.4	2.17	48%
anthracene	N.S.	8.94	1.60	0.42	2.78	0.64	
fluoranthene	N.S.	19.7	5.70	2.70	12.5	3.15	
pyrene	100	16.6	9.30	4.61	15.8	4.42	78%
benz(a)anthracene	10	8.44	3.53	2.02	6.42	1.92	82%
chrysene	N.S.	11.5	3.65	1.30	6.23	1.80	
benzo(b)fluoranthene	10	**16.4**	3.35	2.06	7.19	2.40	78%
benzo(k)fluoranthene	10	**16.4**	1.31	0.85	2.66	1.00	78%
benzo(a)pyrene	10	**25.4**	2.86	1.30	5.60	1.59	80%
perylene	N.S.	34.6	na	na	na	na	
indeno(1,2,3-cd)pyrene	10	**17.4**	2.89	1.25	8.05	1.97	80%
dibenz(a,h)anthracene	10	**23.0**	0.31	0.16	0.84	0.22	77%
benzo(g,h,i)perylene	N.S.	28.7	2.77	1.22	7.50	1.73	

Notes:
all concentrations expressed in ppm - milligrams per dry kilogram (soil)
"N.S." - No standards listed for indicated parameter
"*CCME*"- *Canadian Council of Ministers of the Environment*
Values for S1 as indicated in AEE letter dated January 16, 1996
bold - indicates concentrations in excess of *CCME* commercial/industrial land use criteria

TABLE 3 - Water - Comparison of Measured Contaminant Levels in Columns - Final

Remediation Criteria		**Columns**					
Parameter	*CCME Criteria C/I*	*Sample S1 Initial*	*Col. A*	*B*	*C*	*D*	*% change D/A*
naphthalene	50	41.2	0.0012	0.0003			72%
acenaphthylene	N.S.	32.4	0.0013	0.0008			
acenaphthene	N.S.	25.7	<0.0005	0.0009			
fluorene	N.S.	11.9	0.0025	0.0011			
phenanthrene	50	13.2	0.0008	0.0003			48%
anthracene	N.S.	8.94	0.0004	0.0002			
fluoranthene	N.S.	19.7	0.0015	0.0008			
pyrene	100	16.6	0.00252	0.00153			78%
benz(a)anthracene	10	8.44	0.00106	0.00050			82%
chrysene	N.S.	11.5	0.0013	0.0006			
benzo(b)fluoranthene	10	**16.4**	0.00229	0.00087			78%
benzo(k)fluoranthene	10	**16.4**	0.00088	0.00039			78%
benzo(a)pyrene	10	**25.4**	0.00197	0.00076			80%
perylene	N.S.	34.6	na	na			
indeno(1,2,3-cd)pyrene	10	**17.4**	0.00207	0.00077			80%
dibenz(a,h)anthracene	10	**23.0**	<0.00001	<0.00001			77%
benzo(g,h,i)perylene	N.S.	28.7	0.0024	0.0009			
Acridine			0.00008	0.00010			

Notes:
all concentrations expressed in ppm - milligrams per dry kilogram (soil)
"N.S." - No standards listed for indicated parameter
"*CCME*"- *Canadian Council of Ministers of the Environment*
Values for S1 as indicated in AEE letter dated January 16, 1996
bold - indicates concentrations in excess of *CCME* commercial/industrial land use criteria

MINISTRY OF ENVIRONMENT AND PARKS

PERMIT

Under the Provisions of the Waste Management Act

7437 HOLDINGS LTD.
Suite #5 - 3046 Edgemont Boulevard
North Vancouver, British Columbia
V7R 2N4

is hereby authorized to discharge refuse from various construction and demolition operations located throughout the Lower Mainland Region in British Columbia to the land at 9356 and 9376 River Road, Delta, British Columbia.

This permit has been issued under the terms and conditions prescribed in the attached appendices: 01, A-1, B-1, B-2, B-3, C-1, C-2 and C-3.

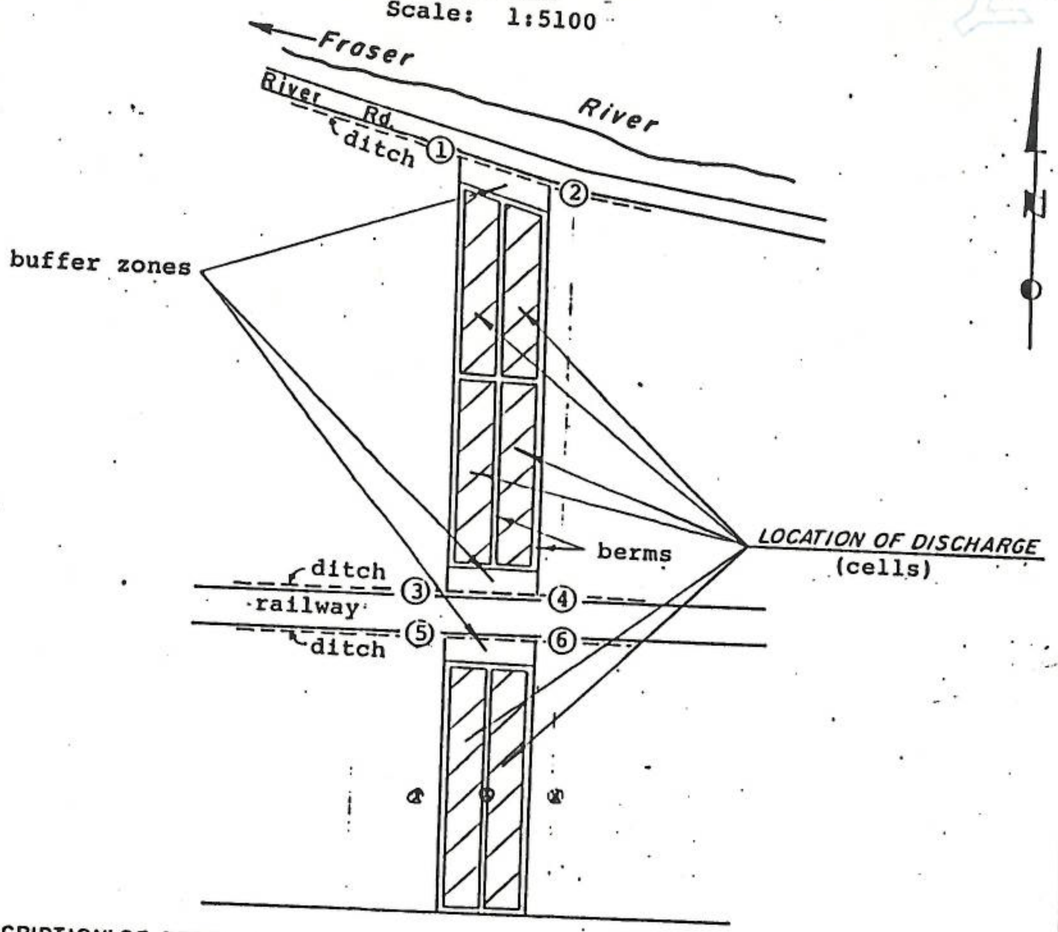
Regional Waste Manager

Permit No. PR-7709

Date Issued June 11, 1987
Date Amended APR 25 1988

SITE PLAN

Scale: 1:5100

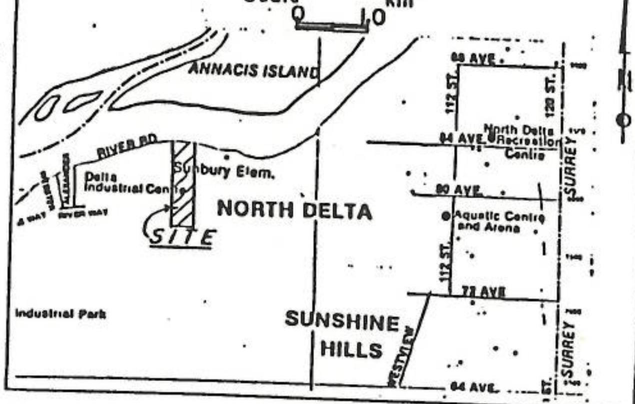


LEGAL DESCRIPTION OF PROPERTY

Lot 10 Except: Firstly: Lot "C" Plan 22258, Secondly: Part on Plan 63382, District Lot 133, Group 2, New Westminster District Plan 852 and Lot 27 Except: Part on Plan 63382, District Lot 133, Group 2, New Westminster District Plan 24821

LOCATION MAP

Scale km 0 10



7437 HOLDINGS LTD.
(Name of applicant(s))

(Date)
(Signature of applicant(s) or agent)

(FOR OFFICE USE ONLY)

JUN 11 1987
Date Issued

Regional Waste Manager

Date Amended

Appendix A-1 to Permit No. PR-7709

Approval No.

ENV 1987

MINISTRY OF ENVIRONMENT AND PARKS

WASTE MANAGEMENT BRANCH

APPENDIX 01

to Permit No. PR-7709

(a) The discharge of refuse to which this appendix is applicable is from various construction and demolition operations.

(b) The rate at which refuse may be discharged is a monthly average of 350 cubic metres per day and a maximum of 76 500 cubic metres per year.

(c) The type of refuse which may be discharged is inert industrial.

(d) The components of the refuse which may be discharged are typical debris from the construction and demolition of building sites consisting of wood, concrete, asphalt, road material and roofing material.

(e) The works authorized are a landfill as directed in Appendices B-1, B-2 and B-3 approximately located as shown on the attached Appendix A-1.

(f) The land to which the refuse is to be discharged and to which this appendix is appurtenant is Lot 10 Except: Firstly: Lot "C" Plan 22258, Secondly: Part on Plan 63382, District Lot 133, Group 2, New Westminster District Plan 852 and Lot 27 Except: Part on Plan 63382, District Lot 133, Group 2, New Westminster District Plan 24821.

(g) The works authorized must be complete and in operation when discharge commences.

Date Issued JUN 11 1987

Date Amended ____________

____

Regional Waste Manager

MINISTRY OF ENVIRONMENT AND PARKS

WASTE MANAGEMENT BRANCH

APPENDIX B-1

to Permit No. PR-7709

A. SITE PREPARATION AND RESTORATION

Provision of fencing, site access, vehicle safety barriers, surface water diversionary works, firebreaks and site restoration as required, shall be carried out to the satisfaction of the Regional Waste Manager. Provide a locked gate on the access road to the landfill and/or take any other measures necessary to prevent the discharge of unauthorized refuse at the site.

B. LANDFILL OPERATION

1. The Permittee shall maintain the landfill authorized in Appendix 01 as a Level "D" operation in accordance with the Pollution Control Objectives for Municipal Type Waste in British Columbia, dated September 1975, which, in normal conditions, requires that cover material be applied once per 20 days of operation and at least once per month. The Regional Waste Manager may vary the frequency of covering when freezing conditions adversely affect normal operation.

   Intermediate cover shall consist of a uniform compacted layer of at least 0.15 metres of relatively impermeable material.

2. The refuse shall be discharged to cells not exceeding 1 hectare in area. Each cell shall be completely encompassed by a relatively impermeable berm constructed to the satisfaction of the Regional Waste Manager prior to discharging any waste within the cell. A final cover shall be placed over the entire surface of each completed cell prior to proceeding onto the next cell. The final cover shall consist of a uniform compacted layer of at least 0.6 metres of relatively impermeable material.

Date Issued JUN 11 1987

Date Amended __________

Regional Waste Manager

MINISTRY OF ENVIRONMENT AND PARKS

WASTE MANAGEMENT BRANCH

APPENDIX B-2

to Permit No. PR-7709

B. LANDFILL OPERATION Cont'd...

3. The following wastes shall not be discharged at the site:
   - (a) Food wastes and other putrescible refuse such as that originating from private dwellings, restaurants and institutions;
   - (b) Hog fuel and sawdust (except for road construction);
   - (c) Bulky wastes such as furniture, household appliances, car bodies and car parts;
   - (d) Liquid or semi-solid wastes resulting from residential, commercial or industrial operations;
   - (e) Gypsum wastes, exceeding 2% of any individual demolition waste load. Intentional addition of gypsum to waste loads is prohibited;
   - (f) Metals, except for minor quantities that are intimately associated with demolition debris such as reinforcement steel embedded in concrete;
   - (g) Wood treated with anti-sapstain chemicals;
   - (h) Asbestos;
   - (i) Special Wastes as defined by the Special Waste Regulation (B.C. Reg. 63/88);
   - (j) Any other waste not covered by section (d) of Appendix 01 of this Permit unless permission has been obtained from the Regional Waste Manager.

4. An attendant shall be present whenever waste is being discharged to monitor the quality of the waste. Any unauthorized refuse shall be removed from the site and disposal of to a site and in a manner approved by the Regional Waste Manager.

5. Maintain a buffer zone of at least 20 metres between the landfill and any ditches. No refuse shall be discharged onto the buffer zone.

6. Erosion of the final cover shall be prevented by grading, seeding with suitable vegetation and/or taking other appropriate measures.

Date Issued June 11, 1987

Date Amended APR 25 1988

Regional Waste Manager

MINISTRY OF ENVIRONMENT AND PARKS
WASTE MANAGEMENT BRANCH

APPENDIX B-3

to Permit No. PR-7709

C. LEACHATE

Should monitoring data or other information obtained by Waste Management indicate that toxic leachate is escaping from the landfill, the Permittee shall install works to collect and treat the leachate to a degree that it is no longer toxic prior to its release into the receiving environment.

D. GROUNDWATER OBSERVATION AND MONITORING WELLS

If required by the Regional Waste Manager, the Permittee shall install not more than 8 groundwater observation wells. The numbers, locations and structural details of these facilities are subject to the approval of the Regional Waste Manager.

E. SURFACE DRAINAGE

Surface drainage shall be diverted away from the landfill and completed sections of the landfill shall be properly graded to allow drainage from and prevent ponding on the surface of the landfill.

F. FUGITIVE DUST CONTROL

The Permittee shall suppress fugitive dust created within the operation area and will maintain, at points designated by the Regional Waste Manager, an ambient air quality in terms of total dustfall equal to or better than 1.75 milligrams per square decimetre per day.

Should this ambient level be exceeded at any of the designated points, the Permittee may be required to provide and implement the additional controls that are considered necessary.

Date Issued June 11, 1987

Date Amended APR 25 1988

Regional Waste Manager

COPY
except.

REMEDICON
Remediation Consultants Ltd.
2620 Hoskins Road
North Vancouver, B.C.
V7J 3A3

March 17, 1993

File No.: NSD200

7437 Holding Ltd. and
North Shore Disposal Service Ltd.
110-80 Orwell St.
North Vancouver, B.C.
V7J 3R5

Attn: Gerry Wild, President

Dear Mr. Wild:

**RE: Letter of Agreement for Lease of North Shore Disposal Service Ltd.
Property - 9376 River Road, North Delta**

It is our understanding that 7437 Holding Ltd. a wholly owned subsidiary of North Shore Disposal Service Ltd. operates a landfill at 9376 River Road, North Delta under Permit Number PR 7709. The landfill has been inspected by Remedicon and determined that the site is suitable for bioremediation of hydrocarbon contaminated soil.

This letter will serve as an agreement for the use of the land located at 9376 River Road. The portion of land proposed for use as bioremediation treatment is that portion of land south and north of the railway right- of- way consisting of approximately 12 acres (Lot 10, D.L.133, Blk GP2, P1852, except PL2258, PL6338). The area for the treatment facility is shown on the Figure attached as Appendix C and may change from time to time with sufficient notice to Remedicon such that any existing cells are allowed to be remediated.

The design and regulatory requirements for operation of the facility are outlined in Appendix C: Typical Remediation Design.

RATE OF COMPENSATION

The agreed rate of compensation for use of the space at NSDS property is outlined in Appendix A: Schedule of Fees. This schedule may be amended from time to time with mutual agreement.

environment or the landfill. No activities will be conducted on this site which could be construed as damaging the environment or the landfill. The report prepared by Piteau Engineering will be used as a baseline of environmental conditions at the facility before remediation projects started.

This agreement replaces all previous agreements. A space is provide below for acceptance of this agreement.

Sincerely,

A. Holtz
REMEDICON
Remediation Consultants Ltd.

This agreement is accepted in its entirety.

G. Wild President
7437 Holding Ltd.
North Shore Disposal Ltd.

Date 03/30/93.

Province of
British Columbia

MINISTRY OF
ENVIRONMENT,
LANDS AND PARKS

BC Environment

LOWER MAINLAND REGION

Environmental Protection
15326 — 103A Avenue
Surrey
British Columbia
V3R 7A2
Telephone: (604) 584-8822
Facsimile: (604) 584-9751

Our File: PR-7709

COPY

JAN 20 1993

DOUBLE REGISTERED

7437 Holdings Ltd.
110-80 Orwell Street
North Vancouver, B.C.
V7J 3R5

Attention: Mr. Gerry Wild

Dear Sirs:

Re: **Requirements for Storage and Treatment of Hydrocarbon Contaminated Soil**

Pursuant to Section 41.1(2)(a) of the Waste Management Act Special Waste Regulation, 7437 Holdings Ltd., operating a landfill at 9356 and 9376 River Road in Delta, B.C., authorized by Waste Management Permit No. PR-7709, shall store and treat hydrocarbon contaminated soil in accordance with all of the following requirements:

(1) The Regional Waste Manager shall be notified at least 14 days prior to delivery of each new batch of contaminated soil. Provisions of the notification shall include suitably tabulated data on the quantity, quality, source site, treatment cell number and date of placement in the cell of the hydrocarbon contaminated soil. No soil shall be accepted that contains contaminants that are present at concentrations in excess of Level C, as specified in *Criteria for Managing Contaminated Sites in British Columbia* (Draft 6) except for parameters which are within the concentrations specified in Section 41.1 of the Special Waste Regulation and light aliphatic hydrocarbons (LAH). All soils shall be placed in a lined treatment facility.

(2) Leachate formation shall be minimized and the discharge of leachate shall be prevented by the installation of a cover consisting of a low permeability liner during the period from November 1 to April 30, and taking any other measures necessary. The cover may be removed temporarily to facilitate the remediation procedures (eg. tilling the soil or adding nutrients) if leachate formation is minimized and discharge of leachate is prevented.

.../2

(3) No effluent shall be discharged from the treatment facility cells, unless it has been tested to confirm its acceptability for discharge to a sewer system or the environment. Records of analyses confirming acceptability shall be kept available for inspection at any time. Notwithstanding local bylaws, effluent discharges from the soil treatment facility are, as a minimum, subject to compliance with the Special Waste Regulation. Approval shall be obtained from the responsible regulatory authorities before any discharge takes place.

(4) The treatment facility synthetic liner shall be made of 30 mil polyethylene or other equivalent impervious material that is compatible with the waste. The liner, in one piece or with sealed impermeable joints, shall be installed in such a manner as to provide support and resistance to pressure gradients above and below and prevent failure due to compression, uplift or settlement.

(5) The liner shall be inspected regularly, including immediately after removal of soil from each treatment facility cell to verify its integrity. In the event of a breach in the liner system, the Regional Waste Manager shall be notified immediately. Repairs to the liner shall be carried out promptly. A record of inspections shall be kept available at the site for inspection at any time.

(6) A vapour evacuation system may be installed for vapour control and to assist in the volatilization process. The extraction line(s) shall be connected to an explosion-proof fan. All necessary air emissions approvals shall be obtained from Greater Vancouver Regional District prior to start-up.

(7) During placement of the hydrocarbon contaminated soil in the treatment facility:

a) Samples shall be obtained on a hexagonal grid basis to adequately characterize the material laterally and vertically and provide a reference condition for monitoring during treatment. The samples shall be tested for benzene, toluene, ethylbenzene and xylene (BTEX); light aliphatic hydrocarbons (LAH); total extractable hydrocarbons (TEH); metals; oil and grease and any other parameters of concern. The results of sampling shall be submitted to the Regional Waste Manager within 45 days of placing the soil in the treatment facility unless otherwise authorized by the Regional Waste Manager.

.../3

b) Suitable amendments, such as inoculum, nutrients, lime and water, shall be added to provide optimum conditions for biodegradation of hydrocarbon soil contaminants.

(8) For the purpose of monitoring the performance of the biodegradation processes, at least two representative samples of the contaminated soil shall be obtained once every three months and assessed using suitable indicator parameters.

(9) Management of the facility shall be carried out to ensure optimum biodegradation of hydrocarbons as well as integrity of the works and shall include, but not be restricted to:

a) Regular inspections pursuant to Section 29.(1) of the Special Waste Regulation performed at least every week;

b) Addition of amendments, such as inoculum, nutrients, lime and water; and

c) Prompt remedial action, to the satisfaction of the Regional Waste Manager, should problems develop.

(10) No soil shall be removed from the treatment facility unless laboratory analyses have confirmed that it meets Level C criteria as specified in the *Criteria for Managing Contaminated Sites in British Columbia* (Draft 6) and the total extractable hydrocarbon concentration does not exceed 2000 mg/kg and is therefore acceptable for deposition in the landfill authorized by the Permit No. PR-7709. Confirmatory sampling analyses shall include the following parameters: BTEX; light aliphatic hydrocarbons; total extractable hydrocarbons; oil and grease and any other parameters of concern. The Regional Waste Manager shall be notified prior to the re-use or disposal of the treated material. Provisions of the notification shall include data of analysis and quantity of the treated soil.

(11) Records indicating the quantity of hydrocarbon contaminated soil received, name of generator and location of source site shall be maintained and provided to the Regional Waste Manager on a quarterly basis. These records shall be cross-referenced to transport manifests for all special waste soil accepted for treatment at the facility.

.../4

(12) Signs shall be posted identifying the cells used to treat hydrocarbon contaminated soils which qualify as Special Waste. Cells shall be numbered to allow easy cross-referencing for locating contaminated soil received. The treatment cells shall be located on top of the bermed landfill authorized by the Permit No. PR-7709. A site plan depicting the location of cells shall be submitted to the Regional Waste Manager.

(13) Unless otherwise authorized by the Regional Waste Manager, the treatment cells shall be constructed in accordance with the drawing entitled 9376 RIVER ROAD DELTA B.C. PLAN AND SECTION THROUGH TYPICAL BIO-REMEDIATION CELL, dated JAN/5/'93 as approved by R.A. Dakin, P. Eng. of Piteau Associates Engineering Ltd.

(14) Submit a contingency plan acceptable to the Regional Waste Manager for responding to all leaks, spills, discharges to the environment or other reasonably foreseeable mishaps which could result in an adverse impact on the environment. In the event of one or more of the above mishaps, the Permittee shall immediately notify:

Provincial Emergency Program (24-hour telephone no.)		1-800-663-3456
Regional Environmental Protection Manager	(telephone)	582-5200
	(Facsimile)	584-9751

and take appropriate remedial action.

(15) A closure plan prepared by a qualified environmental consultant shall be submitted for the approval of the Regional Waste Manager at least six months in advance of the closure of the treatment facility. Any measures necessary to prevent pollution shall be carried out as required by the Regional Waste Manager.

Compliance with these requirements will be determined through periodic inspections by staff from the Surrey office located at 15326 - 103 A Avenue, Surrey, British Columbia, V3R 7A2, telephone 582-5200.

This letter does not authorize entry upon, crossing over, or use for any purpose of private or Crown lands, works, or right-of-ways unless and except as authorized by the owner of such lands, works, or right-of-ways. The responsibility for obtaining such authority shall rest with the Permittee. It is the responsibility of the Permittee to obtain any necessary authorization from the municipality and/or any other agencies.

.../5

Yours very truly,

R. H. Robb
Assistant Regional Waste Manager

REL

cc: Lanny Hubbard - Director, Industrial Waste and Hazardous Contaminants Branch, B.C. Environment
Louise Ouellet - Head, Special Waste Section, B.C. Environment
Mike Stringer - Senior Project Engineer, GVRD
Verne Kucy - Environmental Control Officer, Delta

COPY

JOHN N. BABCOCK INSURANCE AGENCIES LTD.
17TH FLOOR, SUN TOWER, 100 WEST PENDER STREET
VANCOUVER, B.C. V6B 1R8

PHONE: 689-3636
FAX: 689-0291

January 26, 1996

Remedicon: Remediation Consulting Ltd.
2620 Hoskins Road
North Vancouver, B.C.
V7J 3A3

Attention: Mrs. A. Holtz

Dear Sirs,

Re: Liability Insurance Coverages

This follows our recent discussions and confirms the following coverages maintained by your firm and in force to the dates indicated.

A) Policy No. E11 86872 to December 5, 1996
Environmental Impairment liability
Limit $1,000,000.00

B) Policy No. E & O 92218 to December 5, 1996
Environmental Consultants Errors and Omissions liability
Limit $1,000,000.00

C) Policy No. 886526 to November 17, 1996
Commercial General Liability
Limit $1,000,000.00

You may use this as confirmation to clients for the balance of the terms. Should a particular client require independant certificates of coverage, lease have them direct their request to the writer.

Trusting you will find this in order, we remain.

Yours very truly,

W. R. Armstrong, F.I.I.C.
WRA/ln

Province of British Columbia

MINISTRY OF
ENVIRONMENT,
LANDS AND PARKS

BC Environment

Lower Mainland Region

Environmental Protection
15326 - 103A Avenue
Surrey, British Columbia
V3R 7A2
Telephone: (604) 582-5200
Fax: (604) 582-5334

COPY

File: 26250-20/Delta General

January 30, 1995

Remedicon Remediation Consulting Ltd.
2620 Hoskins Road
North Vancouver, BC
V7J 3A3

Attention: Mr. Al Holtz

Dear Sir:

Further to your request of January 26, 1995, this letter will confirm that Remedicon Remediation Consulting Ltd. conducts bioremediation of contaminated soil at 9376 River Road, North Delta, BC. Remedicon has been bioremediating hydrocarbon contaminated soil for two and one half years at this site and is authorised to operate under Section 41.1 of the *Special Waste Regulation*. Remedicon operates on a solid waste landfill authorised under BC Waste Management Permit PR 7709.

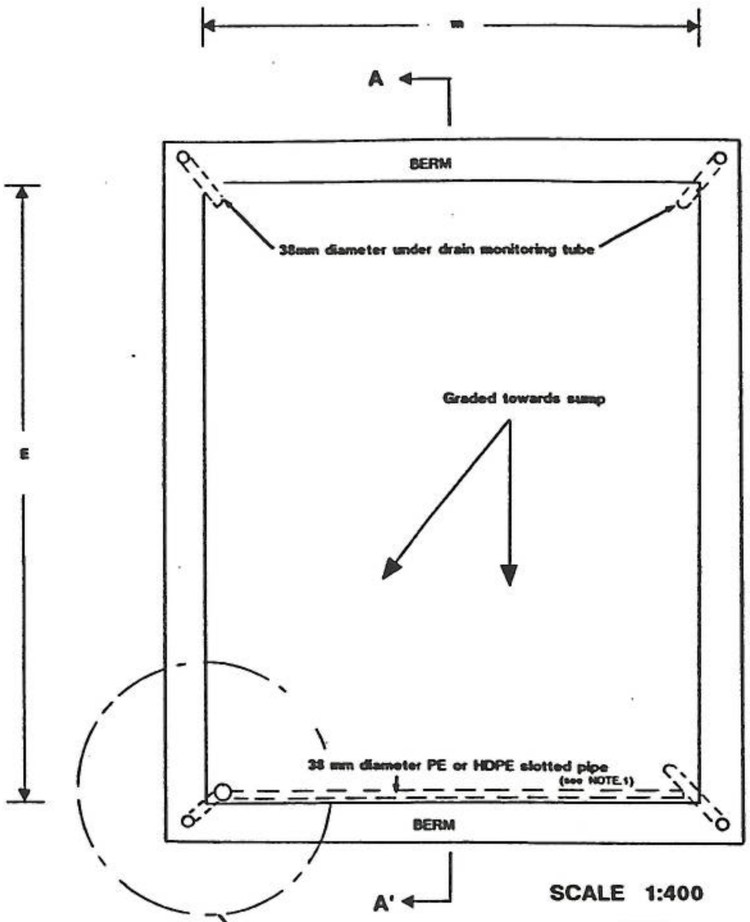
Yours truly,

D. Pope

Douglas T. Pope, P. Eng.
Head, Special Waste Section

Certified a true copy

W. BRAD ADDISON
DuMOULIN & BOSKOVICH
BARRISTERS & SOLICITORS
BOX [illegible] 1095 WEST PENDER ST.
VANCOUVER, B.C. V6E 2M8
PH) 669-5500 FAX) 688-8491



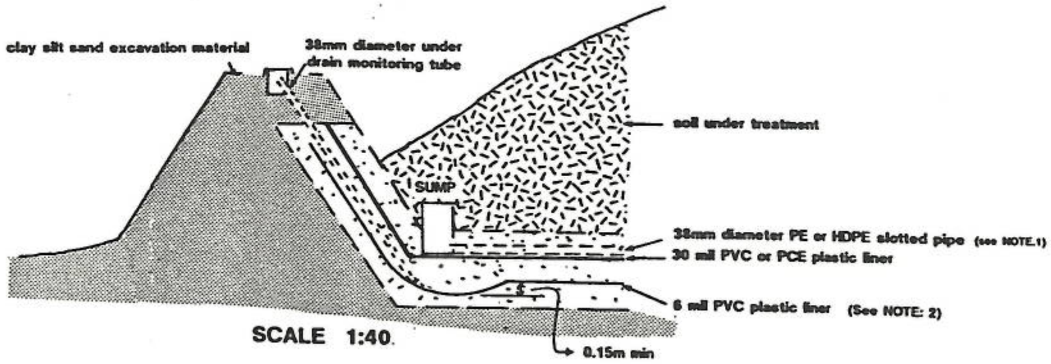
See DETAIL A

SCALE 1:400

SECTION A-A'

SCALE 1:400

DETAIL A



SCALE 1:40

NOTES:
1. Geometry and total length of 38mm diameter PE or HDPE slotted pipe will vary depending on slopes and soil types.
2. 6 mil PVC plastic sheet to be laid down over entire area of the base of the cell and to be extended up the side of the berm.(as per DETAIL A)

⛆	COARSE SAND
▨	CLAY SILT SAND EXCAVATION MATERIAL
⛆	CONTAMINATED SOIL

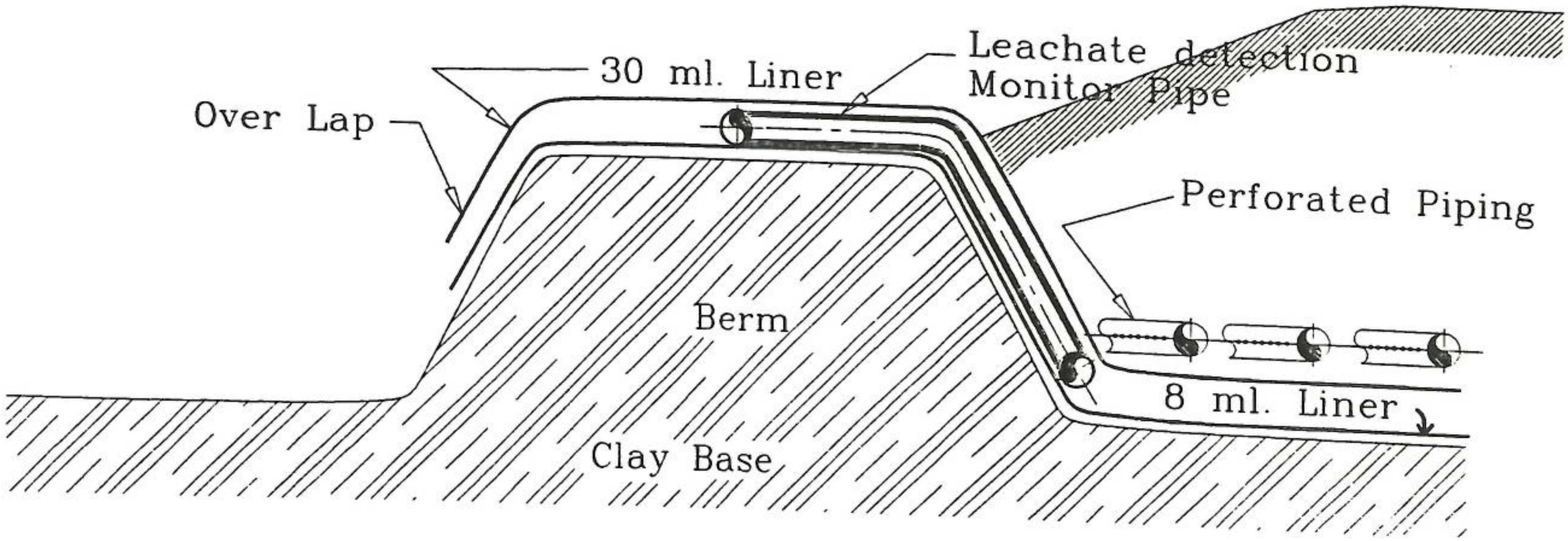
DRAWING REVIEWED AND APPROVED BY:

NAME: R. A. PAKIN P. Eng
Piteau Associates Engineering Ltd

SIGNATURE:

DATE: Aug/27/92

REVISIONS					
DATE	DESCRIPTION		REMEDIATION CONSULTANTS LTD	BY:	DATE: AUG/92
		9376 RIVER ROAD DELTA B.C.	PLAN AND SECTION THROUGH TYPICAL BIO-REMEDIATION CELL	FIGURE:	



CLAY BERM DESIGN

Location of structures on property are approximate
Drawing not to scale.

REMEDICON:
REMEDIATION CONSULTANTS LIMITED
FOR: REMEDICON LANDFILL

CLAY BERM DESIGN
FIGURE-2

DATE: March 5. 1996	SCALE: Not to Scale	ACAD TECH: Ken Parkinson
DRAWN BY: REMEDICON		COMP.FILE I.D.: REMEDF-2

5 POLYCYCLIC AROMATIC HYDROCARBONS

5.1 The Use of a *Mycobacterium* sp. in the Remediation of Polycyclic Aromatic Hydrocarbon Wastes

Carl E. Cerniglia, Ph.D.
Microbiology Division
National Center for Toxicological Research
Food and Drug Administration
Jefferson, Arkansas 72079

Abstract

Recent investigations in my laboratory on the biodegradation of PAHs has led to the isolation of a *Mycobacterium* sp., which was able to extensively degrade PAHs containing up to five fused aromatic rings. This microorganism has been shown to mineralize naphthalene (59.5%), phenanthrene (50.9%), pyrene (63.0%), fluoranthene (89.7%), 1-nitropyrene (12.3%), 6-nitrochrysene (2.0%), and 3-methylcholanthrene (1.6%). Interestingly, the 4-fused ring PAH, pyrene, was metabolized by the *Mycobacterium* sp. to both *cis*- and *trans*-4,5-dihydroxy-4,5-dihydropyrene. $^{18}O_2$ incorporation experiments showed that the formation of *cis*- and *trans*-dihydrodiol isomers were catalyzed by dioxygenase and monooxygenase enzymes, respectively. Similar studies with naphthalene indicated that the *Mycobacterium* initially hydroxylated naphthalene to form *cis*- and *trans*-1,2-dihydroxy-1,2-dihydronaphthalene in a ratio of 20:1, respectively. The *cis*-naphthalene dihydrodiol was further metabolized to ring cleavage products via the classical *meta* cleavage pathway. Initial oxidation of 1-nitropyrene occurred in the 4,5- and 9,10- positions to form *cis*-4,5- and 9,10-1-nitropyrene dihydrodiols. Fluorenone-1-carboxylic acid was identified as a predominant ring cleavage product in the degradation of fluoranthene by the *Mycobacterium*.

The ultimate usefulness of the *Mycobacterium* in the bioremediation of PAH contaminated sediments depends upon its survival and function in diverse ecosystems. The *Mycobacterium* survived and mineralized PAHs in sediment and water microcosms. Microcosms inoculated with the *Mycobacterium* showed enhanced mineralization, singly and as components in a mixture, for 2-methylnaphthalene, phenanthrene, pyrene and benzo[a]pyrene. Studies utilizing pyrene as a sole PAH substrate showed that the *Mycobacterium* survived in microcosms for six weeks in both the presence and absence of PAH exposure. The versatility of the PAH-degrading *Mycobacterium* and its potential for use in the bioremediation of PAH contaminated sediments will be discussed.

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a major class of environmental contaminants originating from both petrogenic and pyrogenic sources (*22,24,25,27,28,34,38,41*). Many PAHs are cytotoxic, mutagenic and carcinogenic to both lower and higher eucaryotic organisms (*13,24,29,33,37*) (Figure 5.1.1). Due to their hydrophobic nature, most PAHs in aquatic ecosystems rapidly become associated with particles and are deposited in sediments. A variety of processes, including volatilization, sedimentation, chemical oxidation, photo-decomposition, and microbial degradation are important mechanisms for environmental loss of PAHs (Figure 5.1.2). Microbial degradation of PAHs can have a significant effect on the PAH distribution in

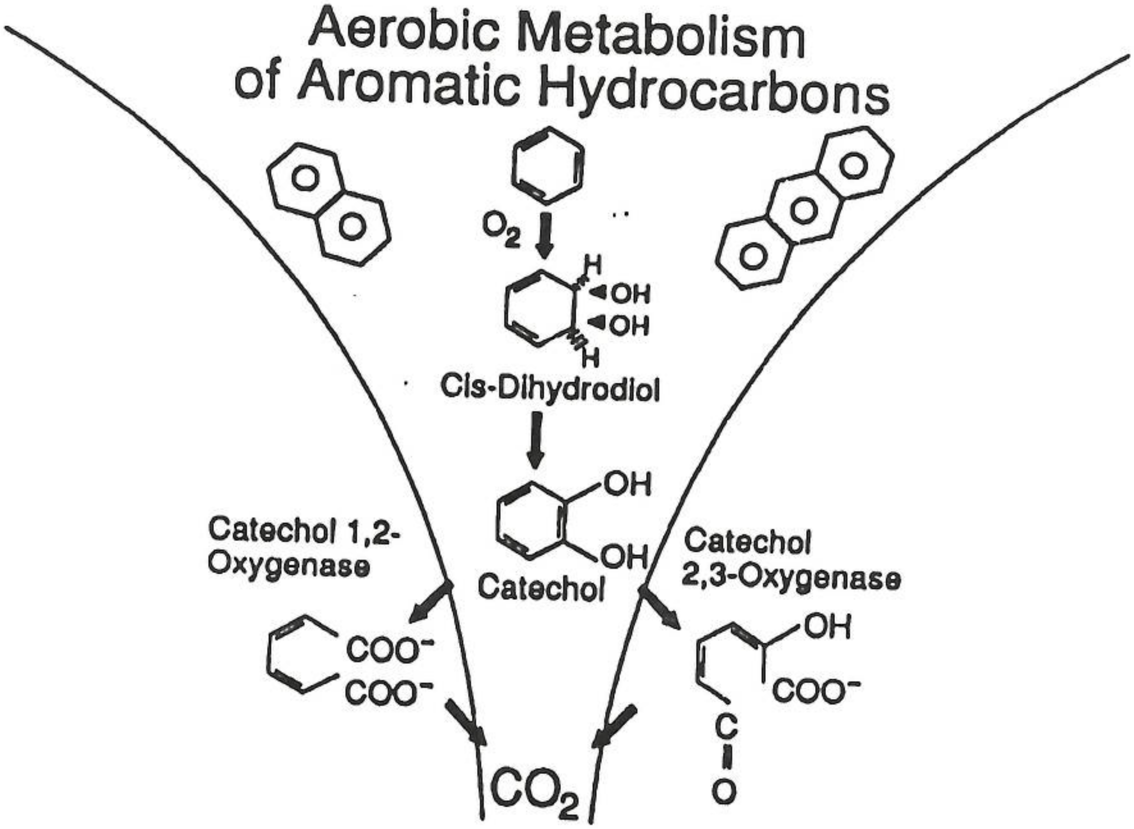


Figure 5.1.3. Major pathways of bacterial oxidation of polycyclic aromatic hydrocarbons.

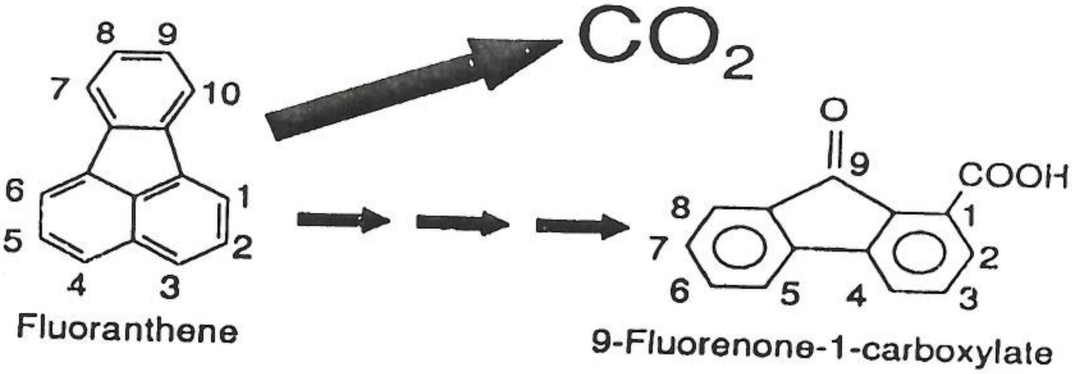


Figure 5.1.8. The pathways utilized by the *Mycobacterium* sp. for the oxidation of fluoranthene.

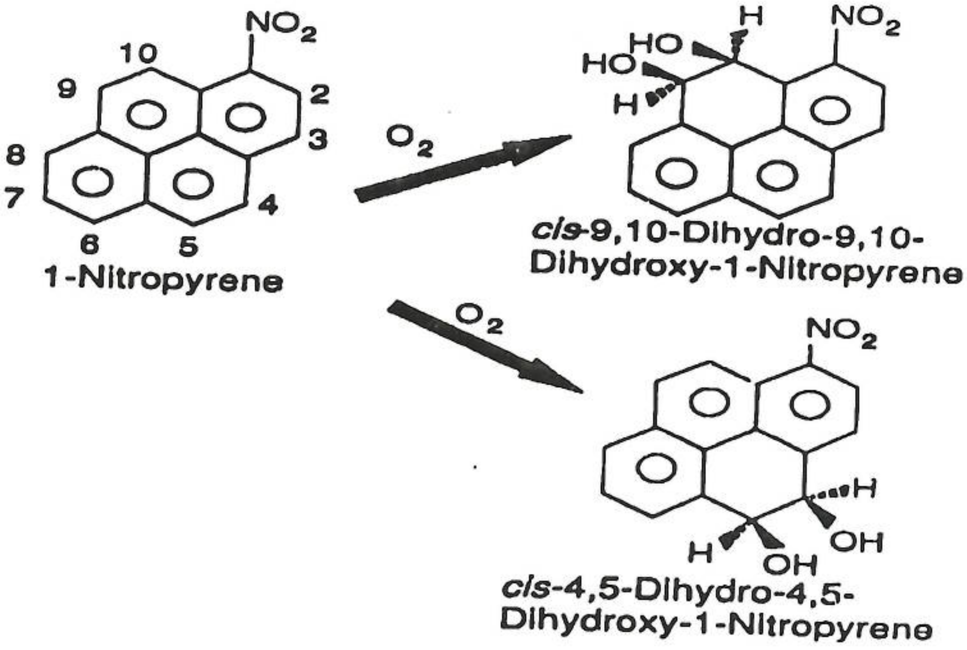


Figure 5.1.9. The pathways utilized by the *Mycobacterium* sp. for the oxidation of 1-nitropyrene.

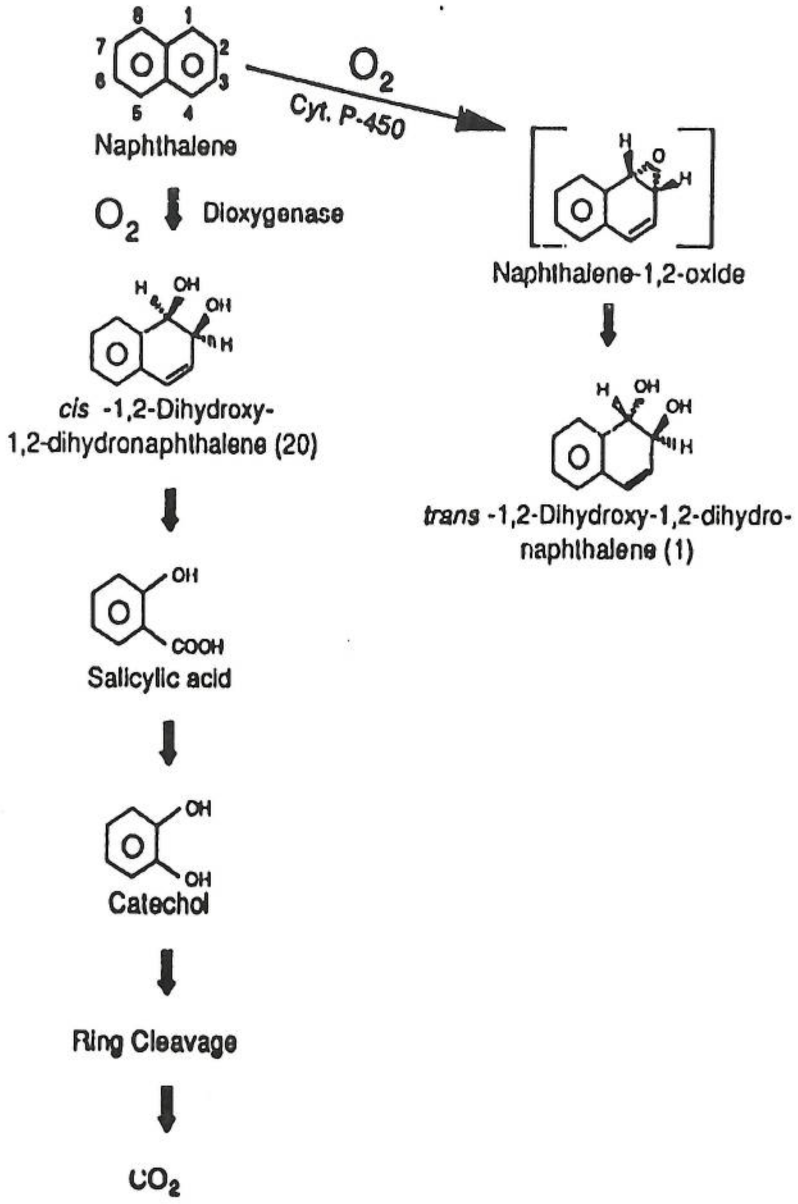


Figure 5.1.7. The pathways utilized by the *Mycobacterium* sp. for the oxidation of naphthalene.

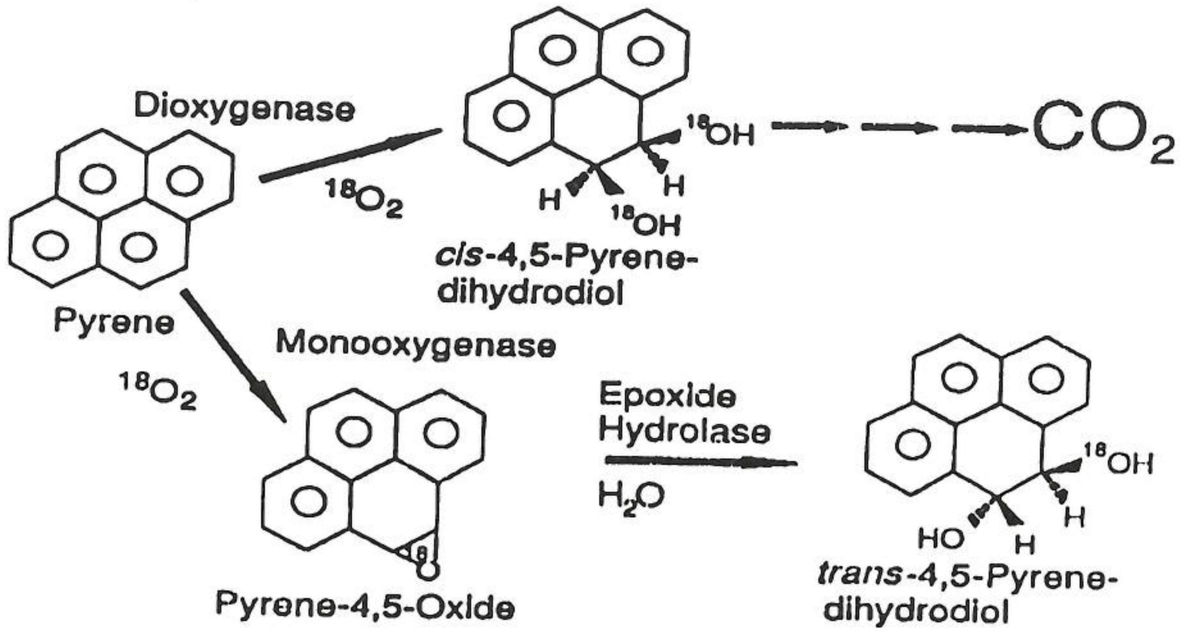


Figure 5.1.6. The pathways utilized by the *Mycobacterium* sp. for the oxidation of pyrene.

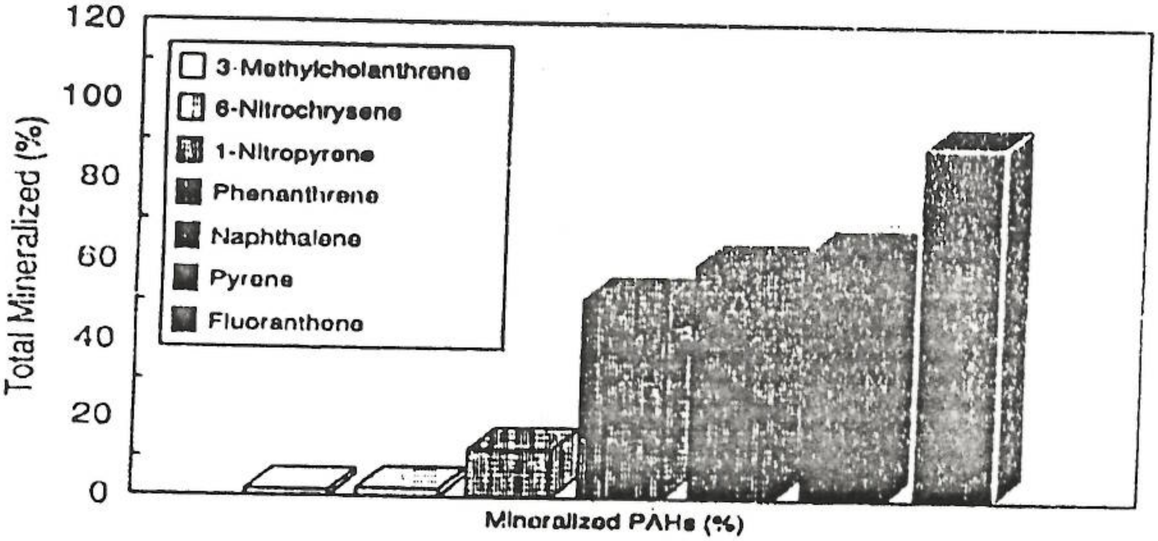


Figure 5.1.5. Mineralization of naphthalene, phenanthrene, pyrene, fluoranthene, 1-nitropyrene, 6-nitrochrysene, and 3-methylcholanthrene by the *Mycobacterium* sp.