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BIODEGRADATION TREATABILITY STUDY REPORT

BIOTREATABILITY SOIL PILE STUDIES

METACHEM PRODUCTS
NEW CASTLE, DELAWARE

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CONESTOGA-ROVERS
& ASSOCIATES

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March 23, 2001

Reference No. 14246

Mr. Hilary Thornton
United States Environmental Protection Agency
Region III
Mail Call 3HS23
1650 Arch Street
Philadelphia, Pennsylvania 19103

Dear Mr. Thornton:

Re: Results of Biodegradation Treatability Study
Standard Chlorine of Delaware Site
EPA Order No. III-96-73-DC

Transmitted with this letter are three (3) copies of the report on the results of the laboratory treatability study for soil at the Standard Chlorine of Delaware (SCD) Site in Delaware City, Delaware. Conestoga-Rovers & Associates, Inc. (CRA) conducted the laboratory treatability study in accordance with the May 1998 Biodegradation Treatability Study Work Plan, and a supplement to that work plan, dated October 16, 1998.

Six test conditions, including a control condition that was not subject to any treatment, other than to be maintained under anaerobic conditions, were performed. The variables in the treatability conditions included: airflow rates; the addition of bulking agents, inorganic nutrients, organic substrate, and microbes; and, creating sequential anaerobic and aerobic conditions. All six test conditions, including the control, showed some degree of removal of the compounds of concern. Under the laboratory conditions, all have been projected to meet cleanup criteria in timeframes less than 7 years.

Under optimized laboratory conditions, soil vapor extraction (SVE) and sequential anaerobic/aerobic biodegradation treatments were shown to be the most effective potential remedial alternatives in reducing contaminant concentration in the soil and meeting cleanup criteria. The results of the laboratory treatability studies are being considered in developing the work plan for a field pilot test. We are focusing on a field program that would further test the effects of variable airflow and the addition of microbes to optimize the on-site biodegradation treatment scheme. The timeframe for meeting cleanup criteria under actual field conditions (versus the controlled and idealized laboratory conditions) will be assessed during the field pilot test. Two treatment technologies would be tested using the soil pile soils:

i) Sequential anaerobic/aerobic degradation (low airflow); and
ii) High airflow SVE.

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Sequential anaerobic/aerobic degradation was effective in reducing the concentrations of all the chlorobenzenes. The chlorobenzenes were degraded biologically to non-toxic products. The time to reach the USEPA Record of Decision (ROD) criteria was longer than SVE for the laboratory test, but times for all treatments are likely to be much longer under field conditions and the relatively small time improvement for SVE is likely to be lost. SVE requires the installation and operation of energy intensive high flow aeration equipment and will generate a spent carbon waste stream for disposal. Sequential anaerobic/aerobic degradation would reduce the equipment cost by reducing the airflow and carbon requirements.

EPA's comments to this submittal will be considered as we further develop the Field Pilot Test Work Plan.

We look forward to your review and comments to this submittal. Please do not hesitate to contact either of us (Alan Weston at 716-297-6150 or aweston@craworld.com; Dan Erdman 610-363-3868 or derdman@craworld.com) if there are any questions.

Yours truly,

CONESTOGA-ROVERS & ASSOCIATES

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BIODEGRADATION TREATABILITY STUDY REPORT

BIOTREATABILITY SOIL PILE STUDIES

METACHEM PRODUCTS
NEW CASTLE, DELAWARE

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EXECUTIVE SUMMARY

A Biodegradation Treatability Study Work Plan (BTSWP) for the Standard Chlorine of Delaware Site (Site) in Delaware City, Delaware was submitted to the United States Environmental Protection Agency (USEPA) by Harding Lawson Associates (Harding) on May 21, 1998. The BTSWP proposed two types of laboratory scale biodegradation treatability studies: a microcosm study intended to assess the feasibility of using indigenous microorganisms to degrade the Site Compounds of Concern (COCs) which, if proven feasible, would lead to a column study to evaluate the effectiveness of biological and combined biological/physical technologies. On reviewing the preliminary results of the microcosm study in conjunction with an assessment of the physical nature of the target soils (soils/sediments in the soil piles and sedimentation basin, and undisturbed upland vadose zone soils) and the characteristics of the COCs, it was determined that the experimental design should simulate the application of soil vapor extraction (SVE) and bioventing technologies. A supplement to the BTSWP was prepared by Harding and submitted to USEPA on October 16, 1998. The supplement presented the experimental design of biopile and bioventing technologies.

Bench-scale soil piles were selected for the experimental design to most closely simulate these technologies. The soil piles and sediments consolidated in the basin contain very high concentrations of COCs (up to 150,000 milligrams per kilogram [mg/kg], or 15 percent by weight) in a fine-grained mix. The upland soils contain much lower but still significant concentrations of the COCs, ranging from hundreds to thousands of mg/Kg. The use of biopiles to treat these soils would allow for both abiotic stripping of the COCs as well as aerobic and anaerobic biodegradative processes. In addition, the soil piles could be manipulated through the use of bulking agents and supplemental inorganic nutrients to improve biological and system performance. The biotreatability tests were considered to be remedy screening level tests, and the results were used only to establish the feasibility of biological and combined biological/physical treatment effectiveness.

The specific objectives of the soil pile experiments were to:

i) evaluate the feasibility of using supplied air to promote aerobic biodegradation of chlorobenzenes;
ii) evaluate the reduction in COC concentrations due to biological activity versus abiotic stripping;
iii) assess the ability of bulking agents and/or nutrients to enhance aerobic biological processes;

iv) assess if the soil pile can be converted to anaerobic conditions after the aeration phase and, if so, determine the resulting biological effects on the COCs; and

v) assess whether one or more of the experimental conditions can meet the Site Record of Decision (ROD) Criteria for Site Cleanup (USEPA, Standard Chlorine ROD, 1995).

The soil pile studies conducted evaluated six different test conditions. Test Condition 1 was conducted on upland soils. Test Conditions 2 through 6 were conducted on-Site soil pile materials.

<u>Test Condition 1</u> - designed to simulate standard bioventing technology in upland soils using a constant high airflow rate. Air exiting the soil pile was passed through an adsorptive medium to capture volatilized COCs.

<u>Test Condition 2</u> - evaluated standard bioventing technology in soil pile materials using a constant high airflow rate. As described for Test Condition 1, air exiting the soil pile was passed through an adsorptive medium and the mass of COCs was quantified analytically to provide an estimate of removal via volatilization.

<u>Test Condition 3</u> - evaluated the impact of adding bulking agents, inorganic nutrients, organic substrate, and microbes in conjunction with reduced airflow rate on COC removal. A high airflow rate was used for the first month to allow for maximum COC removal by volatilization and reduce microbial toxicity. The airflow rate was reduced for the next five months and the system was switched to bioventing treatment.

<u>Test Condition 4</u> - intended to produce sequential anaerobic and aerobic conditions. The soil pile was amended as described for Test Condition 3. A high airflow rate was used for the first month to allow for maximum COC removal by volatilization and reduce microbial toxicity. The soil pile was inundated with water and allowed to stand without aeration for three months to enhance anaerobic conditions and reductive dehalogenation. A low airflow rate was used for five months to establish bioventing conditions and allow for aerobic biodegradation.

<u>Test Condition 5</u> - intended to study the effectiveness of bioventing without the addition of bulking agents, nutrients, and microbes. The soil pile was not amended. A high airflow rate was used for the first month to allow for maximum COC removal by volatilization and to reduce microbial toxicity. The airflow rate was reduced for the next five months to establish bioventing and allow for aerobic biodegradation.

Test Condition 6 - used as a control test and was not subject to any treatment. It was included in the study for comparison purposes.

All of the Site soils were screened to a uniform size and mixed with hand implements to apparent homogeneity before being placed in the test soil piles. Soil mixing reduced the variation in COC concentration within individual test piles and provided preliminary information on the effectiveness of material handling techniques for providing homogeneous soils for future pilot and full-scale treatment evaluations. However, it is expected that soil mixing and handling facilitated the loss of some COCs by volatilization.

All six test conditions were conducted for 9.5 months. Air samples from each test condition were analyzed on a weekly basis. Soil samples were collected each month and analyzed for COCs. At the end of the test period, the carbon traps were analyzed for COCs.

All six test conditions, including the control, showed some degree of COCs removal. The removal rates and the main pathway of removal of individual COCs varied depending on the test conditions. The following conclusions are made based on the results of the study:

i) the feasibility of using supplied air to promote aerobic biodegradation was demonstrated;

ii) both stripping and biological degradation occurred when air was supplied;

iii) the addition of microbial inoculum, nutrients, and bulking agents increased the rate of biological degradation;

iv) sequential anaerobic/aerobic treatment enhanced the degradation of the higher chlorinated benzenes; and

v) SVE provided the shortest treatment time for the soil pile soils to reach the USEPA ROD cleanup criteria.

The USEPA ROD specified cleanup criteria for on-Site soils and sediments at the Site based on the findings of the human-health risk assessment. The cleanup criteria were based on the risk to a future worker and are 625 mg/Kg for total COCs with a ceiling concentration of 450 mg/Kg for 1,4-dichlorobenzene (DCB). The treated soil must also pass the Toxicity Characteristic Leaching Procedure (TCLP) criteria (7.5 milligrams per liter [mg/L] for 1,4-DCB). The rate-limiting component was 1,4-DCB. Therefore, the aerobic treatments that reduced the amount of 1,4-DCB were the most effective

(11 months for upland soil and 25 months for soil pile soil). High airflow (SVE) reduced the cleanup time by approximately 1 year when compared to low airflow (bioventing). However, the use of bioventing resulted in higher biodegradation rates of COCs and therefore would be expected to consume less granular activated carbon.

Under optimized laboratory conditions, SVE and sequential anaerobic/aerobic biodegradation treatments were shown to be effective as potential remedial alternatives to reduce COC concentrations in the soil and meet cleanup criteria. Field pilot tests using larger volumes of soil (e.g., 10 to 20 yd^3) are therefore recommended.

Two treatment technologies would be tested using the soil pile soils:

i) sequential anaerobic/aerobic degradation (low airflow); and
ii) high airflow SVE.

Sequential anaerobic/aerobic degradation was effective in reducing the concentrations of all the chlorobenzenes. The chlorobenzenes were degraded biologically to non-toxic products. The time to reach the ROD criteria was longer than SVE for the laboratory test, but times for all treatments are likely to be much longer under field conditions and the relatively small time improvement for SVE is likely to be lost. SVE requires the installation and operation of energy intensive high flow aeration equipment and will generate a spent carbon waste stream for disposal. Sequential anaerobic/aerobic degradation would reduce the equipment cost by reducing the airflow and carbon requirements.

A plan for the Field Pilot Treatability Test will be developed on the basis of the findings of this report. The Field Pilot Test Work Plan will be prepared for USEPA's review by April 30, 2001, provided USEPA's comments to this report are provided by mid-April 2001.

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1.0 INTRODUCTION

A Biodegradation Treatability Study Work Plan (BTSWP) for the Standard Chlorine of Delaware (SCD) Site (Site) in Delaware City, Delaware was submitted to the United States Environmental Protection Agency (USEPA) by Harding Lawson Associates (Harding) on May 21, 1998. The BTSWP proposed two types of laboratory scale biodegradation treatability studies: a microcosm study intended to assess the feasibility of using indigenous microorganisms to degrade the Site Compounds of Concern (COCs) which, if proven feasible, would lead to a column study to evaluate the effectiveness of biological and combined biological/physical technologies. The results of the microcosm study were reported to USEPA in an interim report dated August 28, 1998.

On reviewing the preliminary results of the microcosm study in conjunction with an assessment of the physical nature of the target soils (soils/sediments in the soil piles and sedimentation basin, and undisturbed upland vadose zone soils) and the characteristics of the COCs, it was determined that the experimental design should simulate the application of SVE and bioventing technologies. A supplement to the BTSWP was prepared by Harding and submitted to USEPA on October 16, 1998. The supplement presented the experimental design of SVE and bioventing technologies. USEPA conditionally approved the supplement on December 11, 1998 and provided Metachem with their comments. These comments were addressed in a letter to USEPA from Metachem dated January 22, 1999.

A combination of soil vapor extraction (SVE) and bioventing was chosen for the treatability testing.

SVE systems rely on abiotic stripping of volatile components to achieve a reduction in the concentration of chemicals in soil. SVE systems typically use high airflows in an effort to increase the amount of chemicals stripped from the soil. SVE is capable of reducing high contaminant concentrations to levels where biological degradation can occur under bioventing conditions. Bioventing system applications and design, in contrast to SVE systems, utilize soil venting systems for oxygen transfer to stimulate in situ aerobic biodegradation of contaminants rather than contaminant stripping. Bioventing entails the use of low airflows for the transport of oxygen to the subsurface, where indigenous organisms are stimulated to aerobically metabolize organic components. Bioventing systems are designed and configured to optimize oxygen transfer and oxygen utilization efficiency. Bioventing is a biological treatment approach and therefore requires the management of environmental conditions to ensure maintenance of bioactivity. Management of soil moisture and soil nutrient levels to avoid inhibition of microbial respiration within the vadose zone is necessary and can be used to optimize contaminant biodegradation. Bioventing has been used primarily on sites contaminated with hydrocarbon fuels and polyaromatic hydrocarbons (DuPont 1993, USEPA 1999).

It has been demonstrated that indigenous soil microbial communities are able to biodegrade dichlorobenzenes and monochlorobenzene present in the soil under aerobic conditions (Nishino 1993, Thompson 1999). If the aerobic conditions are sustained, the microbial population will expand and the degradation rates for the mono- and dichlorobenzenes will increase. A soil medium that can promote the diffusion of air or oxygen will allow higher degradation rates than a tight soil that does not allow for diffusion throughout the matrix. Degradation is also dependent upon the presence of nitrogen and phosphorus nutrients. These may need to be supplemented in order to maintain an increased degradation rate. Highly chlorinated aromatic compounds such as hexachlorobenzene, pentachlorobenzene, tetrachlorobenzenes, and trichlorobenzenes can be degraded faster under anaerobic conditions to produce lower chlorinated benzenes (Ramanand et al., 1993) by a process known as reductive dehalogenation. The lower chlorinated benzenes can subsequently be rapidly degraded under aerobic conditions. Anaerobic conditions could be used to degrade the higher chlorinated benzenes in the Metachem soil and convert them into low chlorinated compounds which are readily degradable under aerobic treatment.

The soil piles and sediments consolidated in the basin contain very high concentrations of COCs (up to 150,000 milligrams per kilogram [mg/kg], or 15 percent by weight) in a fine grained mix. The use of biopiles to treat these soils would allow for both abiotic stripping of the COCs as well as aerobic and anaerobic biodegradative processes. The concentrations of COCs in the upland soils are much lower but still significant, ranging from hundreds to thousands of mg/Kg. In selected areas of the Site, upland soils may be amenable to in situ remedial technologies such as bioventing.

Bench-scale soil piles were selected for the experimental design to most closely simulate these technologies. In addition, the soil piles were manipulated through the use of bulking agents and supplemental inorganic nutrients to improve biological and system performance. The biotreatability tests were considered to be remedy screening level tests, and the results were used only to establish the feasibility of biological and combined biological/physical treatment effectiveness.

In November 1999, Metachem contracted with Conestoga-Rovers & Associates (CRA) to carry out the work described in the supplement to the BTSWP. CRA reviewed the supplement and suggested some modifications to improve the original design. The list of modifications and the rationale for each modification were provided to USEPA in a letter from Metachem dated January 4, 2000. These modifications are presented in Appendix A.

This report presents a description of the activities conducted during the treatability study, the results obtained, conclusions, and recommendations for full-scale application.

2.0 OBJECTIVES

The specific objectives of the soil pile experiments were to:

i) evaluate the feasibility of using supplied air to promote aerobic biodegradation of chlorobenzenes;

ii) evaluate the reduction in COC concentrations due to biological activity versus abiotic stripping;

iii) assess the ability of bulking agents and/or nutrients to enhance aerobic biological processes;

iv) assess whether the soil pile can be converted to anaerobic conditions after the aeration phase and, if so, determine the resulting biological effects on the COCs; and

v) assess whether one or more of the experimental conditions can meet the Site Record of Decision (ROD) criteria for Site cleanup (USEPA, Standard Chlorine ROD 1995).

The cleanup levels specified in the ROD for the on-Site soils are 625 mg/Kg for total COCs, with a maximum concentration of 450 mg/Kg for 1,4-decachlorobiphenyl (1,4-DCB), specifically. In addition, the treated soil must also pass the Toxicity Leachate Characteristic Procedure (TCLP) analysis.

3.0 EXPERIMENTAL DESIGN

The soil pile studies conducted evaluated six different test conditions:

Test Condition 1: The first test condition was designed to simulate standard SVE technology in upland soils using a constant high airflow rate. Air exiting the soil was passed through an adsorptive media to capture volatilized COCs. The mass of adsorbed COCs was quantified analytically to provide an estimate of COCs removed from the soil via volatilization. This remediation approach is potentially suitable for use at selected upland portions of the Site.

Test Condition 2: The second test condition evaluated standard SVE technology in soil pile materials using a constant high airflow rate. As described for Test Condition 1, air exiting the soil was passed through an adsorptive media and the mass of COCs was quantified analytically to provide an estimate of removal via volatilization.

Test Condition 3: In the field, airflow through the soil pile materials may be limited by consolidation and compaction that has occurred over a number of years. The third test condition therefore evaluated the impact of adding bulking agents, inorganic nutrients, organic substrate, and microbes in conjunction with reduced airflow rate on COC removal. Bulking agents were added to increase the soil permeability. Fertilizers were added in solid form to further stimulate biological activity. A high airflow rate was used for the first month to allow for maximum COC removal by volatilization and to reduce microbial toxicity. The airflow rate was reduced for the next 5 months to maintain biological activity. This bioventing treatment method was considered applicable to the soil pile materials.

Test Condition 4: The fourth test condition used was intended to produce sequential anaerobic/aerobic conditions. Past studies indicated that as more chlorine atoms are substituted on the aromatic ring (i.e., tri- and tetrachlorobenzene), the more difficult it is for the compound to be aerobically metabolized. Standard biopile aeration will only enhance the transformation of compounds that can be degraded by aerobic biodegradative processes. By creating anaerobic conditions within the soil pile, the polyhalogenated chlorobenzenes were expected to be successively dehalogenated by anaerobic metabolic processes. Once air was returned to the system, the less halogenated chlorobenzenes were expected to be degraded aerobically. This treatment method was considered applicable to the soil pile materials.

While the transformation from an aerobic to an anaerobic environment may elicit a lag period in biological activity, the presence of facultative anaerobes would most likely accommodate this major environmental change without appreciable delay. The soil pile was amended as described for Test Condition 3. A high airflow rate was used for the first month to allow for maximum COC removal by volatilization and to reduce microbial toxicity. The soil pile was then inundated with water and allowed to stand without aeration for 3 months to enhance anaerobic conditions and reductive dehalogenation. A low airflow rate was subsequently used for 5 months to reestablish aerobic conditions.

Test Condition 5: The fifth test condition was intended to study the effectiveness of bioventing without the addition of bulking agents, nutrients, and microbes. The soil pile was not amended. A high airflow rate was used for the first month to allow for maximum COC removal by volatilization and to reduce microbial toxicity. The airflow rate was reduced for the next five months to allow biological activity. This treatment method was considered applicable to the soil pile materials.

Test Condition 6: The sixth test condition was a control test and was not subject to any treatment. It was included in the study for comparison purposes.

The soil used for Test Condition 1 contained COC concentrations representative of those COC concentrations expected in upland soil. The soil used for Test Conditions 2, 3, 4, 5, and 6 contained COC concentrations representative of those concentrations expected in the existing Site soil piles. All of the soils were screened to a uniform size and mixed with hand implements to apparent homogeneity before being placed in the test soil piles. Soil mixing reduced the variation in COC concentration within individual test piles and provided preliminary information on the effectiveness of material handling techniques for providing homogeneous soils for future pilot and full-scale treatment evaluations. Soil screening, mixing, and handling also enhanced the conditions for COC losses via volatilization.

Each experimental condition was sampled each month over the testing period to evaluate the removal of total COCs. In addition, soil pile gases were collected for estimating COC removal via volatilization and monitoring for biological activity.

Due to the high concentrations of COCs in the soil pile materials (up to 150,000 mg/Kg), the testing program was extended to 9.5 months.

4.0 FIELD SAMPLE COLLECTION

Sample collection was performed in accordance with the procedures specified in the Field Sampling Plan (FSP) and Quality Assurance Project Plan (QAPP). One composite Site soil pile sample and one composite upland soil sample were collected for use in the Phase I biotreatability soil pile tests. The basis for this sampling rationale was to provide soil samples with high COC concentrations to assess possible inhibitory effects that high concentration levels might have on degradation rates and to determine if removal could be enhanced through physical treatment.

Sample documentation including sample location, collection date and time, and analysis were recorded on a label affixed to each sample container.

Chain of Custody records were filled out by field and laboratory personnel and included sample designation, collection date and time, media, and analysis. The Chain of Custody record accompanied the analytical samples at all times. A copy of the Chain of Custody for the samples received by CRA are included as Appendix B.

4.1 SITE SOIL PILES

The Site soil pile sample used in the treatability study was collected from soil pile "B" located north of the SCD (Seep 1) facility. The sample was intended to represent the high COC concentrations (10,000 to 150,000 mg/Kg) that are present throughout these existing soil piles as indicated by the sample results reported in the Remedial Investigation Report (Weston 1994). The sample was received at the CRA Treatability Laboratory in Niagara Falls, New York, in four 55-gallon steel drums on November 1, 1999.

4.2 UPLAND SOILS

Upland soils used for the soil treatability study were collected from selected upland locations that had been shown to historically represent the target concentration range of 1,000 to 10,000 mg/Kg. Approximately 100 pounds of soil was collected and packaged in one 55-gallon steel drum. It was received at the CRA Treatability Laboratory on November 1, 1999.

5.0 SOIL PILE STUDY

5.1 PREPARATION OF TEST SOILS

Solid pieces of chlorobenzenes (predominantly 1,4-DCB) were known to exist within the soil piles. These solid pieces were not likely to be bioavailable and were, therefore, less relevant to the soil pile biotreatability study. Additionally, it was likely that treatment of the soil piles would include mechanical screening to remove these solids as well as other large debris. In order to simulate this screening process, all large solids observed in the soil samples (the Site soil pile soils and the upland soils) were removed by hand in the laboratory to the extent practicable prior to testing. The remaining soils were sieved separately through a #8 (2.36 millimeters [mm]) screen and then each soil was mixed manually with hand tools to apparent homogeneity. The removed material was stored until the end of the experiment and then properly disposed of along with other test materials. The final total amount of soil pile material was approximately 400 pounds.

5.2 SOIL CHARACTERIZATION

Once each soil had been homogenized, two four-point composite samples were collected from each homogenized pile. These samples were analyzed for several physical and chemical characteristics including:

i) total organic carbon (TOC);

ii) ammonia nitrogen and orthophosphate phosphorus;

iii) microbial counts;

iv) water holding capacity;

v) soil moisture content (American Society for Testing and Materials (ASTM) Method D 2216-92); and

vi) concentrations of the following target COCs:
   - *volatile organic compounds (VOCs)* - benzene, toluene, chlorobenzene, 1,2-DCB, 1,3-DCB, and 1,4-DCB, and
   - *semi-volatile organic compounds (SVOCs)* - 1,2,3- and 1,3,5-trichlorobenzene; 1,2,3,4- and 1,2,4,5-tetrachlorobenzene; pentachlorobenzene; hexachlorobenzene; and nitrobenzene.

These analyses followed standard USEPA analytical methodologies, except where otherwise noted, and the data provided a baseline assessment of COC concentrations and background nutrient concentrations. The results of the initial characterization are presented in Table 5.1.

5.3 EXPERIMENTAL SET-UP

The soil pile tests were conducted at the bench-scale. A schematic of the apparatus is provided on Figure 5.1. The laboratory set-up is shown pictorially on Figure 5.2.

Each test condition soil pile was assembled in the following manner. A stainless steel tank 12 inches in diameter and 14 inches in height was used for each test condition. Each tank had a 3-inch high rack at the bottom. Below the rack was a spiral copper tube with air exit holes. A nylon bag slightly larger than 12 inches square was packed with 2 pound of glass beads (6 mm in diameter). The bag was placed on the rack and a layer of glass wool was placed on top of the bag. Following screening and mixing, 15 Kg of the soil was placed on top of the glass wool. The tank was capped with a stainless steel lid. A Teflon gasket was used to seal the lid to the tank. The lid was held in place with clamps. The air inlet was in the middle of the lid. The inlet air was pretreated to remove impurities by passing it through 20 pound of granular activated carbon (Calgon BPL 4x10, Calgon Carbon Corporation, Pittsburgh, PA) in a plastic drum before the air was introduced into the tanks. Air was pulled through the soil using a vacuum pump and exited the tank via the copper tube. On the exit side of the soil treatment tank was a flow meter, a pressure gage, and a flow control needle valve. The air then passed through a plastic pail containing 2 Kg granular activated carbon and through the vacuum pump.

Airflow through each soil pile was controlled by two valves: one on the flow meter and one on the needle valve. The needle valve was used for fine control of the airflow. A sampling port was placed in-line after the flow meter and before the pressure gage.

Following the screening and mixing of the soil samples, 15 Kg of homogenized upland soil was placed in a treatment tank to represent Test Condition 1. For Test Condition 2, 15 Kg of homogenized soil from the soil pile was placed in a treatment tank and left unamended.

The homogenized soil from the soil pile samples used in Test Conditions 3 and 4 were amended with organic and inorganic nutrients, microbial stock, and a bulking agent. The nutrients used were urea (60 grams) and potassium phosphate, dibasic (18 grams). The purpose of the nutrients was to provide sufficient sources of inorganic nitrogen and phosphorus for microbial metabolism. A liquid solution (1 liter) of microbial culture (prepared from in-house proprietary chlorobenzene degrading culture) was prepared in a nutrient medium for 72 hours. The resulting microbial populations in the culture were 1.65×10^5 and 3.46×10^4 colony forming units/milliliter (CFUs/mL) (colony forming units per milliliter) for the total and specific microbial counts, respectively. The purpose of the microbial addition was to provide metabolically active microorganisms to the test soil to reduce the lag time before initiation of active metabolism. A bulking agent in the form of vermiculite (1579 grams) was also added to the mixture at a rate of approximately 5 percent by weight. Vermiculite has a platelet type structure, high porosity, high void volume to surface area ratio, low density, a large range of particle sizes, and is insoluble in water. The purpose of the bulking agent was to increase the permeability of the soil and to enhance airflow throughout the soil pile. The above components were mixed with soil pile soil (30 Kg). The amended soil was divided into two equal portions (approximately 16 Kg per pile) to represent Test Conditions 3 and 4, and each portion was placed in a treatment tank.

For Test Condition 5, 15 Kg of homogenized soil from the soil pile was placed in a treatment tank and was not amended with bulking agents or nutrients. It acted as a control for Test Conditions 3 and 4.

An unamended sample from the homogenized soil pile soil (15 Kg) was placed in a treatment tank to represent Test Condition 6. This was intended as a control for Test Conditions 2, 3, 4, and 5 and was not amended with bulking agents or nutrients.

The amendments used for each test condition are summarized in Table 5.2. Following placement of soil into each of the treatment tanks, two four-point composite samples were collected from each tank. These samples were initially analyzed for pH, moisture content, TOC, ammonia, nitrate, orthophosphate phosphorus, and microbial populations. These data were used as the baseline throughout the test period, and the results are reported as time T = 0 months in Tables 5.3 through 5.8.

5.4 OPERATION OF TREATMENT TANKS

Test Conditions 1 and 2 were operated under continuous airflow conditions. Airflow was adjusted to replace a void volume of air in the soil pile 10 times each day.

Test Condition 3 was operated under continuous airflow conditions. Airflow was adjusted to replace a void volume of air in the soil pile 10 times each day for the first month. The high airflow was necessary to reduce the concentrations of the COCs and reduce their toxicity to the microbial population. After one month the airflow was adjusted to replace a void volume once per day (10 mL/min) and a microbial culture (750 mL, or 5 percent by weight) containing nutrients (30 grams urea and 9 grams potassium phosphate) was sprayed onto the soil and mixed with the soil. The total and specific microbial counts for the culture were 1.39×10^7 and 1.64×10^6 CFUs/mL, respectively.

Test Condition 4 was operated under continuous airflow conditions for one month. Airflow was adjusted to replace one void volume of air in the soil pile 10 times each day. After one month the airflow was terminated and a microbial culture (2250 mL) containing molasses (37.5 grams), urea (15 grams), and potassium phosphate (4.5 grams) was sprayed onto the soil and mixed with the soil. The culture additions produced a liquid content in the soil representing 70 percent of the water holding capacity. The system was allowed to stand for three months without any airflow to allow anaerobic degradation conditions to be maintained. After 3 months the airflow was introduced at the rate of one void volume per day to initiate bioventing. This airflow was maintained for 5.5 months.

Test Condition 5 was operated under the same airflow conditions as Test Condition 3. No amendments were added.

Test Condition 6 was operated as a control with no airflow.

All the test conditions were monitored for a total of 9.5 months. The airflow and amendments for all test conditions are summarized in Table 5.2.

5.5 EXPERIMENTAL SAMPLING AND ANALYSIS

Monthly soil samples were collected from each treatment tank. Two four-point composite samples were collected. One sample was analyzed between months 2.5 and 9.5 for VOC and SVOC concentrations. The other sample from each composite was analyzed each month for pH, soil moisture, microbial populations, ammonia nitrogen, and orthophosphate phosphorus. These samples were analyzed by the CRA analytical laboratory. The data are provided in Tables 5.3 through 5.8 (all soils data are presented on a dry weight basis). The carbon traps from each test condition were analyzed for VOCs and SVOCs at the end of the test period by the Metachem analytical laboratory. The carbon trap data are presented in Table 5.9.

Temperature and airflow were recorded on a weekly basis for each of the test conditions. Air samples were analyzed for oxygen, carbon dioxide, and methane on a weekly basis for each test condition using a Land Tec Infrared Gas Analyzer Model GA-90. Photoionization detector (PID) and Lower Explosive Limit (LEL) readings were also taken. These data are presented in Tables 5.10 through 5.15. Air samples were also collected from the sampling ports (see Figure 5.1) in Tedlar bags and analyzed for dichlorobenzenes on a weekly basis for each test condition. These data are presented in Table 5.16. A sampling pump was used to extract air from Tank 6.

6.0 DISCUSSION OF RESULTS

Table 5.1 shows the results of the initial sample characterization, including general parameters and COC results. Total chlorobenzene concentrations exceeded 20,000 mg/Kg. Review of the general parameter data indicates that the soils had sufficient moisture content, TOC, ammonia nitrogen, and orthophosphate phosphorus to support microbial degradation. The total microbial population was 1.6×10^5 and 4.7×10^4 CFUs/grams for the soil pile and upland soils, respectively. Chlorobenzene-degrading specific microbial populations were 3.7×10^3 and 2.7×10^3 CFUs/grams, respectively, for the soil pile and upland soils. These counts suggested that both soils contain healthy microbial populations that can potentially be stimulated. However, the concentration of 1,4 DCB (20,000 mg/Kg) in the soil pile soil was likely to cause inhibition of the growth of the microbial population. Therefore, high airflow aeration was used to reduce the initial 1,4-DCB concentration and reduce potential microbial toxicity. The chlorobenzene concentrations in the upland soils were lower and were not expected to cause inhibition of the growth of the microbial population.

Moisture content in Test Condition 1 (the upland soil with high airflow) was reduced over the course of the test, but remained within acceptable range for biodegradation. Ammonia nitrogen and orthophosphate phosphorus were present in sufficient concentration to support microbial growth, but the microbial population declined. The decline in microbial counts followed the decline pattern observed in VOC concentrations suggesting that the decrease in microbial population may have been the result of the decrease in the available carbon source. The high airflow was expected to produce abiotic loss by volatilization as the major mechanism for reduction of the COCs. 1,4-DCB was reduced by greater than 99 percent over the course of the test (see Table 6.1). The lack of decline in concentration of the higher chlorinated SVOCs such as 1,2,4,5-tetrachlorobenzene and pentachlorobenzene support this mechanism.

Moisture content also declined as expected in Test Condition 2, the soil pile with high airflow, but it was not reduced sufficiently to impact microbial degradation. Nutrient levels remained relatively stable. The microbial population declined but not to the same extent as in Test Condition 1. 1,4-DCB was reduced by 86 percent, which left 2878 mg/Kg of readily degradable substrate in the soil. Therefore, the lower decrease in microbial population was expected. The high airflow produced volatilization as the major reduction pathway for COCs. Losses of the higher chlorinated benzenes were low.

The Test Condition 3 moisture content increased at month 4 after the microbial culture and nutrients were added and the airflow was reduced. The microbial population increased at month 5, but did not rebound to its original levels. The reduction in airflow reduced the amount of 1,4-DCB removed to 82 percent, showing that abiotic removal had been inhibited. The trichlorobenzene reductions increased, but the higher chlorinated benzene reduction did not, as expected. The reduced airflow and microbial inoculation increased aerobic degradation but not degradation of the SVOCs.

The Test Condition 4 moisture content followed the same trend as Test Condition 3. Nutrient levels increased after month 3 and so did the microbial population at month 5. The population remained high through the remainder of the test. 1,4-DCB reduction was the same as in Test Condition 3 (82 percent) reflecting the effect of reduced abiotic removal. The reduction of all the SVOCs increased. The tetrachlorobenzene and pentachlorobenzene reductions increased dramatically demonstrating that anaerobic degradation had become a significant contributor and that aerobic degradation was also enhanced.

Moisture content and microbial population were reduced over the test period in Test Condition 5, suggesting that low airflow alone was not enough to stimulate growth of the microbial population. The reduction in 1,4-DCB concentration (74 percent) was the lowest for any of the tests with airflow. This reduction showed that enhanced aerobic degradation contributed to 1,4-DCB loss in Test Conditions 3 and 4. Trichlorobenzene losses were similar to the other low airflow tests and, as expected, anaerobic degradation of the higher chlorinated benzenes was not enhanced.

Test Condition 6 was the control without airflow. Moisture content remained constant but the aerobic microbial population was reduced, suggesting that high COC concentrations may be a factor in slowing the growth of the microbial population. It is likely that the lack of sufficient air limited microbial growth. The loss of 1,4-DCB was 47 percent, showing that abiotic loss was a major pathway for 1,4-DCB reduction. The SVOCs were reduced to similar levels to those observed in Test Condition 5; therefore, low airflow was not necessary to produce the losses of SVOCs observed.

The carbon trap results give an indication of the COC losses by volatilization that could be the result of abiotic reduction. Test Condition 4 resulted in the least COC concentrations in the carbon trap, reflecting the high microbial activity and confirming that biodegradation was the major pathway for COC removal.

The temperature for all test conditions was maintained between 21 and 23 degree Centigrade (°C) for the duration of the test period. The flows were maintained at the appropriate rates for each test condition. Oxygen remained constant in all the test conditions at approximately 20 percent throughout the test period. It was not recorded

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for Test Condition 4 during the anaerobic phase. Carbon dioxide, methane, and LEL were not detected in any test condition during the test period, except for carbon dioxide in Test Condition 4, which was detected above 2 percent after 30 weeks reflecting the enhanced microbial activities. PID readings were performed with a meter calibrated with isobutylene therefore the amounts detected cannot be directly related to the likely levels of chlorobenzenes in the air, but the measured concentrations can be used for comparison purposes. PID readings in Test Condition 1 decreased from 600 to 250 parts per million (ppm) over the test period. They decreased in Test Condition 2 from greater than 2000 to 929 ppm over the test period. Test Conditions 3, 4, and 5 PID readings decreased from greater than 2000 to 380, 876, and 950 ppm, respectively. Test Condition 6 decreased from greater than 2000 to 1910 PPM. The results show that stable aerobic conditions were maintained in all the test conditions over the course of the test, except for Test Condition 4 during its anaerobic period. Volatile organic levels in the outlet airflow dropped by more than 50 percent in all the active test conditions. Test Condition 3 showed the greatest decrease. A small decrease was observed in the control.

The concentrations of the dichlorobenzenes in the outlet airflow that contacted the soil decreased in all test conditions over the test period. Figures 6.1 through 6.3 represent the accumulated loss of the dichlorobenzenes over the test period. As expected, the losses were higher over the first 4 to 5 months of the tests. Total DCB losses for the test period ranged from approximately 300 mg for the upland soils (Test Condition 1) to approximately 2000 mg for some soil pile test conditions. However, the air quality data was not sufficiently reliable to allow for mass balance calculations. Test Condition 5 appeared to generate the highest levels of dichlorobenzenes, which is not consistent with the soils analysis data.

7.0 DATA MANAGEMENT

7.1 DATA QUALITY OBJECTIVES

Data collected during the soil pile study was used for screening purposes only. Screening data provide analyte identification and quantification, although the quantification may be imprecise (USEPA 1993). The Quality Assurance/Quality Control (QA/QC) elements, specified in USEPA 1993, were a part of the data collection process and are discussed in the data validation/usability report (presented as Appendix C). The data quality was assessed based on final sample results, laboratory blank results, laboratory duplicates, blank spike, and surrogate recoveries. Significant quality control problems were not observed during the review and sample results reported were judged acceptable for their intended use.

7.2 DATA INTERPRETATION

The data obtained during the soil pile experiments were used to evaluate each test condition described in Section 3.0. This section evaluates the data in terms of how they satisfy each of the study objectives.

7.2.1 OBJECTIVE 1

Objective 1 of the study was to evaluate the feasibility of using supplied air to enhance the removal of chlorobenzenes by SVE and biodegradation.

Supplied air was used in Test Conditions 1 through 5 to promote SVE and aerobic degradation of chlorobenzenes. When airflow alone was the treatment, a high airflow (Test Conditions 1 and 2) was more effective than low airflow (Test Condition 5) for the removal of 1,4-DCB. The low airflow was equally effective at treating the higher chlorinated benzenes. Microbial populations were decreased over the course of the test for all three Test Conditions 1, 2, and 5. This may have been due to the reduction in the chlorobenzene concentration, reflecting the depletion of available carbon source. The carbon dioxide and methane evolution levels in the outlet airflow were too low (below percent levels) to be detected by the analytical equipment employed, suggesting that volatilization was the major pathway in the DCB removal under these test conditions.

7.2.2 OBJECTIVE 2

Objective 2 of the study was to evaluate the reduction in COC concentrations due to biological activity versus abiotic stripping.

The results of the analyses of the carbon traps, the PID readings, and DCB analyses on air emitted from the soil all showed that abiotic stripping occurred in all 5 active test conditions (see Tables 5.9 through 5.16). The concentrations of chlorobenzenes trapped on the carbon show that the dichlorobenzenes were the most likely to be lost by stripping, although the higher dichlorobenzenes were also lost but in smaller amounts. The difference between the COC mass removed in the vent stream and the total mass removed from the test soil was calculated and is shown in Table 7.1. This amount was assumed to be the amount lost by abiotic processes. It was assumed that the remainder of the COC loss in each test condition was by biological degradation. Forty-three percent of the total COCs were lost by stripping from Test Condition 1 as compared to 15 percent from Test Condition 2. However, approximately the same amount of COCs was lost from both test conditions showing that airflow and not concentration was the limiting factor for abiotic loss. For Test Condition 5, 14 percent of the COCs was lost suggesting that low and high airflow did not have a large affect on abiotic loss. The addition of a bulking agent increased the loss to 19 percent, showing that improved airflow increased abiotic loss. Test Condition 4 showed only a 4.7 percent loss; this test included a period without aeration; therefore, there was less time for stripping to occur. This period enhanced biological degradation, which may also account for the lower percentage of COCs found on the carbon. A detailed evaluation of the mechanisms of abiotic losses is beyond the scope of the experimental goals and is not presented.

7.2.3 OBJECTIVE 3

Objective 3 of the study was to assess the ability of bulking agents and/or nutrients to enhance aerobic biological processes.

Test condition 3 was amended with a microbial culture, nutrients, and a bulking agent (vermiculite). A high airflow was used during the first month, after which time a low airflow was used. Test Condition 5 was run under identical conditions except that it was not amended. Comparison of the percent reduction of the COCs in the two test conditions showed that 1,4-DCB decreased by 82 percent and 74 percent in Test Conditions 3 and 5, respectively. The SVOC concentrations decreased by very similar amounts, but Test Condition 5 decreases were slightly greater for several of the SVOCs.

These data indicate that the aerobic degradation of the VOCs may have been enhanced by the amendments whereas degradation of the SVOCs was not enhanced.

7.2.4 OBJECTIVE 4

Objective 4 of the study was to assess whether the soil pile can be converted to anaerobic conditions after the aeration phase and, if so, to determine the resulting biological effects on the COCs.

Test Condition 4 was allowed to stand without airflow during months 2 through 4 of the study. This dormant period was intended to encourage the establishment of anaerobic conditions, which are known to enhance the degradation of the higher chlorinated benzenes. Test Condition 4 was amended and can be compared to Test Condition 3 to determine the biological effects resulting from the dormant phase. As expected, the percent reduction of 1,4-DCB in both test conditions was approximately the same (82 percent). The reduction of trichlorobenzenes was slightly higher in Test Condition 4. However, the reduction in the higher chlorinated benzenes such as tetrachlorobenzenes and pentachlorobenzene was significantly improved. The reduction of 1,2,3,4-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, and pentachlorobenzene increased by 16, 22, and 30 percent, respectively, in Test Condition 4 compared to Test Condition 3. Therefore, the enhancement of anaerobic conditions significantly stimulated reductive dechlorination and did not adversely impact the subsequent aerobic degradation.

7.2.5 OBJECTIVE 5

Objective 5 of the study was to assess whether one or more of the experimental conditions can meet the Site ROD criteria for Site cleanup (USEPA, Standard Chlorine ROD 1995).

All six test conditions, including the control, showed some degree of COCs removal (see Table 6.1). The removal rates and the main pathway of removal of individual COCs varied depending on the test conditions. The USEPA ROD specified cleanup criteria for on-Site soils and sediments at the Site based on the findings of the human-health risk assessment (see Section 5.3.3, p.16 of the ROD). The cleanup criteria were based on the risk to a future worker and are 625 mg/Kg for total COCs with a ceiling concentration of 450 mg/Kg for 1,4-DCB. Also, the on-Site soils must pass the TCLP analysis.

The data generated by this study were used to estimate the concentrations of total COCs and 1,4-DCB versus time using regression analysis. These data are presented on Figures 7.1 through 7.6. The regression curves were used to calculate removal rates for COCs and 1,4-DCB, and to predict the time required for each of the test condition treatments to reach the cleanup criteria. The calculated treatment times and estimated degradation rates for each test condition are shown in Table 7.2. These times have been calculated to allow comparison of the different treatments. They should not be used to predict the actual field cleanup times because they were obtained under optimized laboratory conditions and actual field conditions will affect them. Also, it would be necessary for the soil to meet the TCLP criteria in order to fulfill all cleanup criteria. The "20 Rule" was used for the purposes of this analysis i.e., it was assumed that if the concentration of 1,4-DCB in mg/Kg was below 20 times the TCLP criterion (7.5 mg/L), then it was likely that the sample would pass the TCLP test.

Test Condition 1, the upland soil, would meet either the USEPA ROD health based cleanup criteria or the TCLP criteria after 11 months of treatment. The soil pile soil treated by Test Condition 2 would meet the USEPA ROD health based cleanup criteria after 19 months. This treatment would take an additional 6 months (total 25 months) to reach the TCLP criteria. Test Conditions 3, 4, and 5 would meet the USEPA criteria after 21, 25, and 27 months, respectively. In order to reach the TCLP criteria, these treatments would require 28, 33, and 35 months, respectively. The control (no amendments but maintained under anaerobic conditions) would meet the USEPA criteria after 65 months and the TCLP criteria after 83 months. It is likely that the treatment duration under field conditions would be much longer than these estimations because of the aggressive soil processing (soil sieving and mixing) prior to use. Soils in their natural condition may not be as responsive to aeration due to the lack of pathways for aeration in a more consolidated soil mass. The results of field pilot tests will be used to determine the duration of treatment for more consolidated soil.

8.0 CONCLUSIONS

The following conclusions are made based on the results of the study:

i) the feasibility of using supplied air to promote aerobic biodegradation was demonstrated;

ii) both abiotic stripping and biological degradation occurred when air was supplied;

iii) the addition of microbial inoculates, nutrients, and bulking agents increased the rate of aerobic degradation;

iv) the addition of molasses, inundating the soil, and removing the airflow for a period enhanced the reductive dechlorination of the higher chlorinated benzenes. Subsequent aerobic degradation was not adversely affected; and

v) the high airflow condition provided less biodegradation but the shortest time for the soil pile soils to reach the USEPA ROD or TCLP cleanup criteria. Under the experimental laboratory conditions, the treatment duration to meet TCLP criteria was approximately 11 months for the Upland soil and up to 3 years for the soil pile soil, which could be compared to 7 years for untreated soil in the control test.

The rate-limiting component is 1,4-DCB and therefore, the treatments that reduce the amount of 1,4-DCB are the most effective. High airflow reduced the cleanup time by approximately 1 year when compared to low airflow. An evaluation of the cost of high airflow versus low airflow relative to cleanup time will be considered through the field pilot test stage of this project. The addition of microbial cultures, nutrients, and bulking agents is recommended for the low airflow test. The development of specific design information is beyond the scope of the experimental goals and is not presented.

9.0 RECOMMENDATIONS AND SCHEDULE

Under optimized laboratory conditions, SVE, and sequential anaerobic/aerobic biodegradation treatments were shown to be effective as potential remedial alternatives to reduce COC concentrations in the soil and meet cleanup criteria. Field pilot tests using larger volumes of soil (e.g., 10 to 20 yd^3) are therefore recommended.

Two treatment technologies would be tested using the soil pile soils:

i) sequential anaerobic/aerobic degradation (low airflow); and

ii) high airflow SVE.

A control study with no treatment would also be included in order to allow comparison of the results of the pilot studies.

Sequential anaerobic/aerobic degradation was effective in reducing the concentrations of all the chlorobenzenes. The chlorobenzenes were degraded biologically to non-toxic products. The time to reach the ROD criteria was longer for the laboratory test, but times for all treatments are likely to be longer under field conditions and the relatively small time improvement for SVE is likely to be lost. SVE requires the installation and operation of energy intensive high flow aeration equipment and will generate a spent carbon waste stream for disposal. Sequential anaerobic/aerobic degradation would reduce the equipment cost by reducing the airflow and carbon requirements.

The pilot tests would be performed in order to:

i) assess treatment effectiveness under field conditions;

ii) assess reliability of the process and potential problems during scale-up (e.g., air channeling);

iii) assess treatment duration;

iv) assess capital and operation costs;

v) develop/identify appropriate methods for large-scale soil handling (screening, mixing, irrigation/nutrient supplementation, etc.);

vi) determine the optimum design parameters;

vii) develop full-scale design; and

viii) assess the cost of the full scale treatment.

A plan for the Field Pilot Treatability Test will be developed on the basis of the findings of this report. The Field Pilot Test Work Plan will be prepared for USEPA's review by April 30, 2001, provided USEPA's comments to this report are provided by mid-April 2001.

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FIGURES

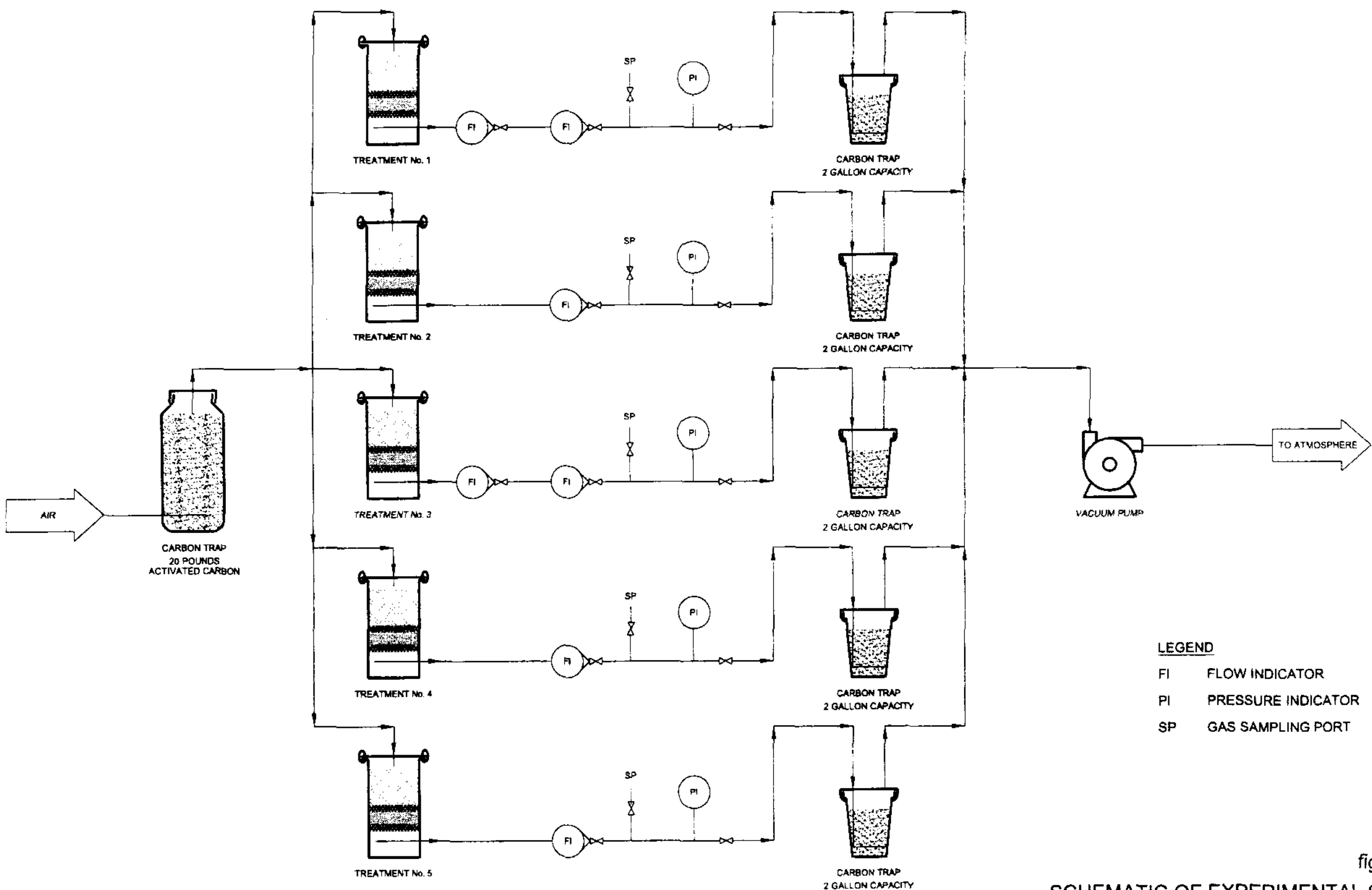

figure 5.1

SCHEMATIC OF EXPERIMENTAL SET-UP
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METACHEM PRODUCTS
New Castle, Delaware

14246-00(001)GN-NF001 MAR 26/2001

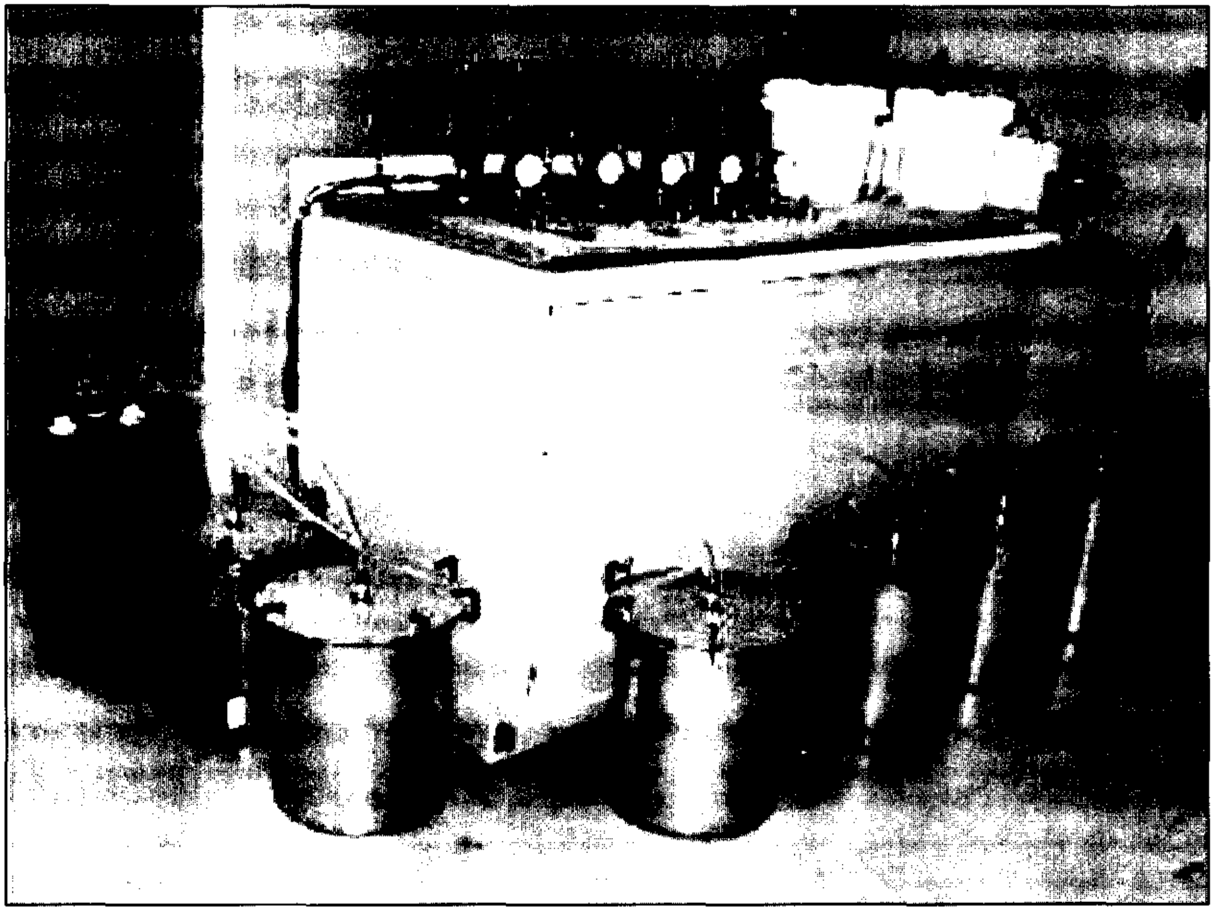

figure 5.2

EXPERIMENTAL SET-UP
BIODEGRADATION TREATABILITY STUDY
METACHEM PRODUCTS
New Castle, Delaware

CRA

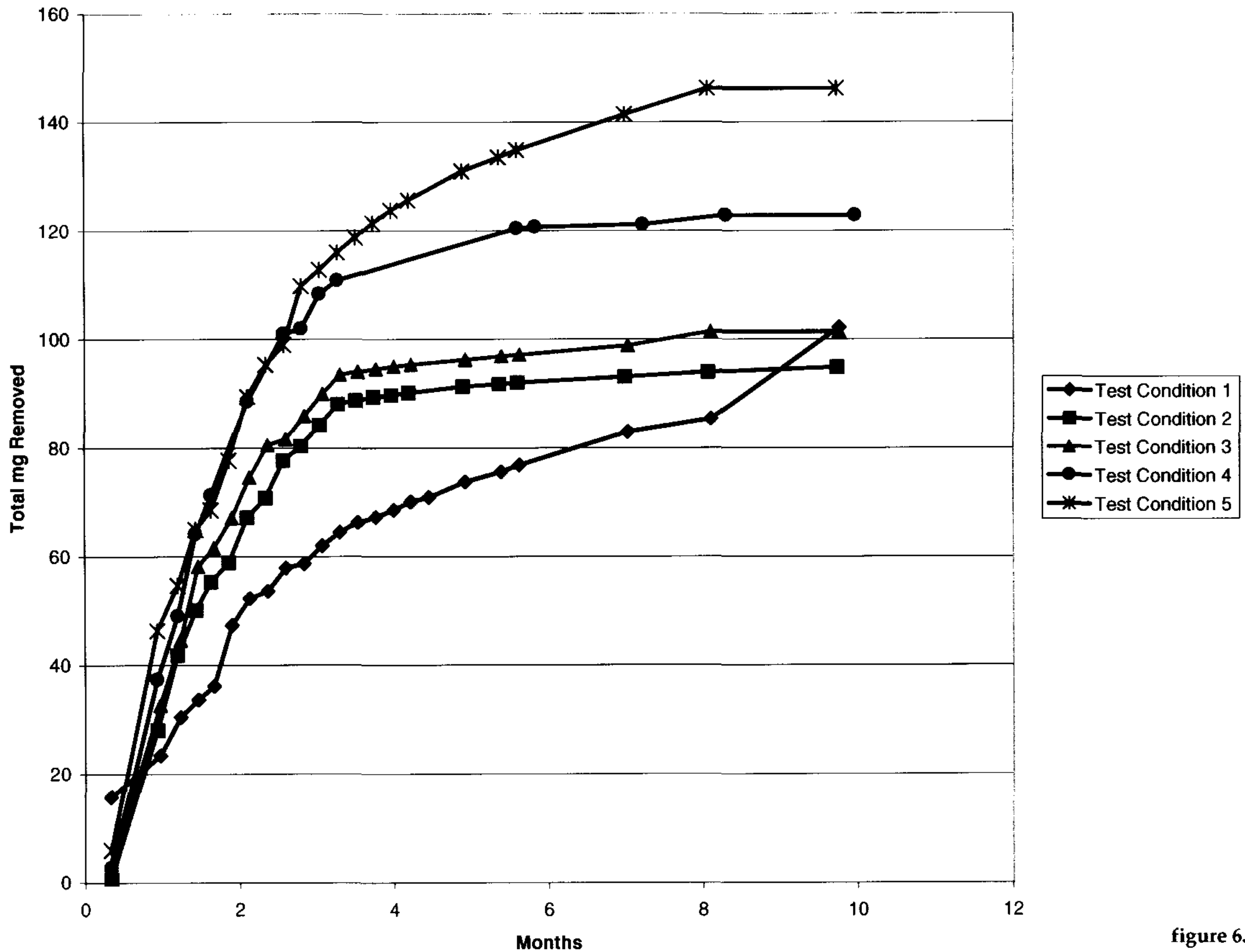

figure 6.1
ACCUMULATED LOSS OF 1,2-DICHLOROBENZENE
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BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

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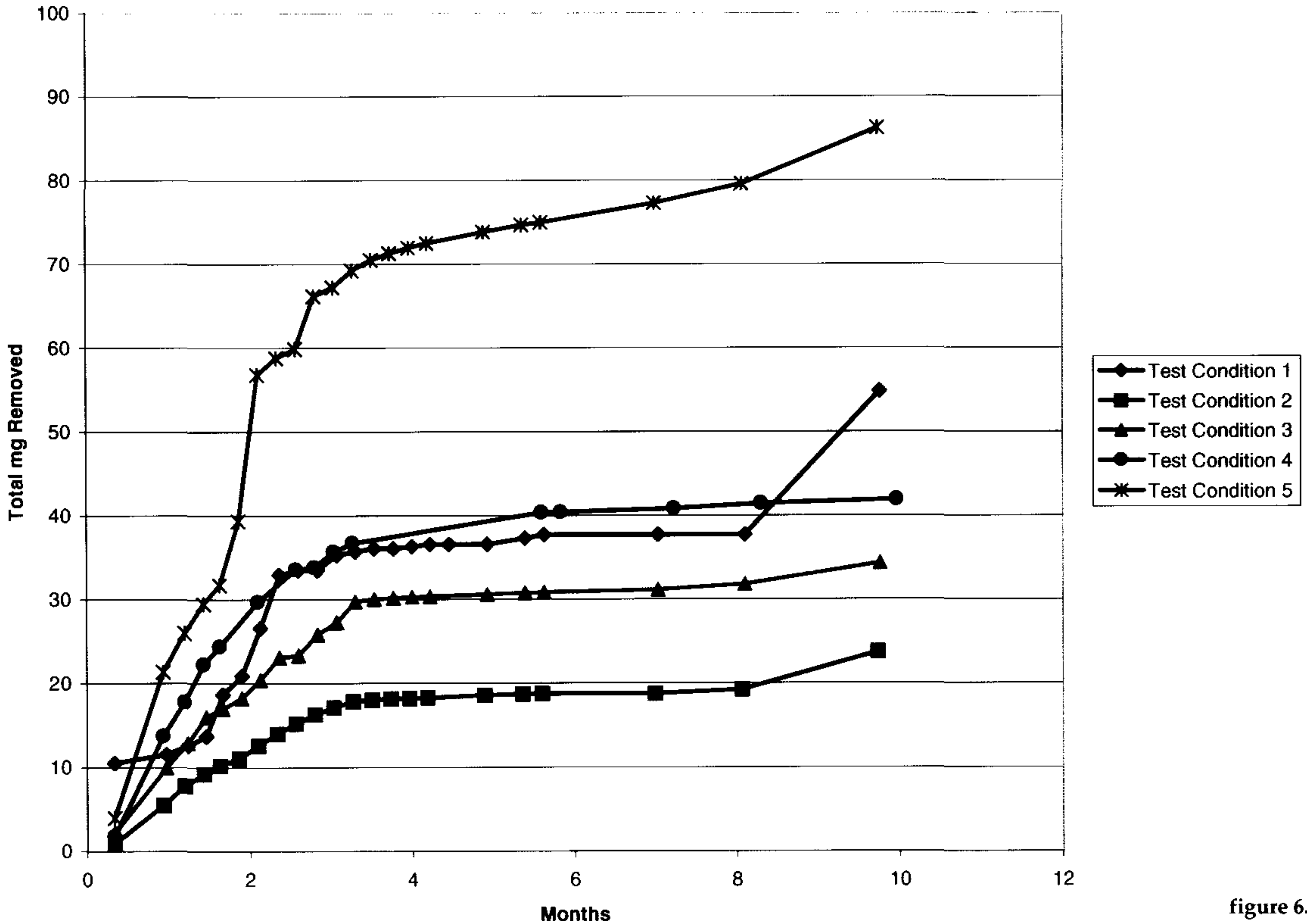

figure 6.2
ACCUMULATED LOSS OF 1,3-DICHLOROBENZENE
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Metachem Products, New Castle, Delaware

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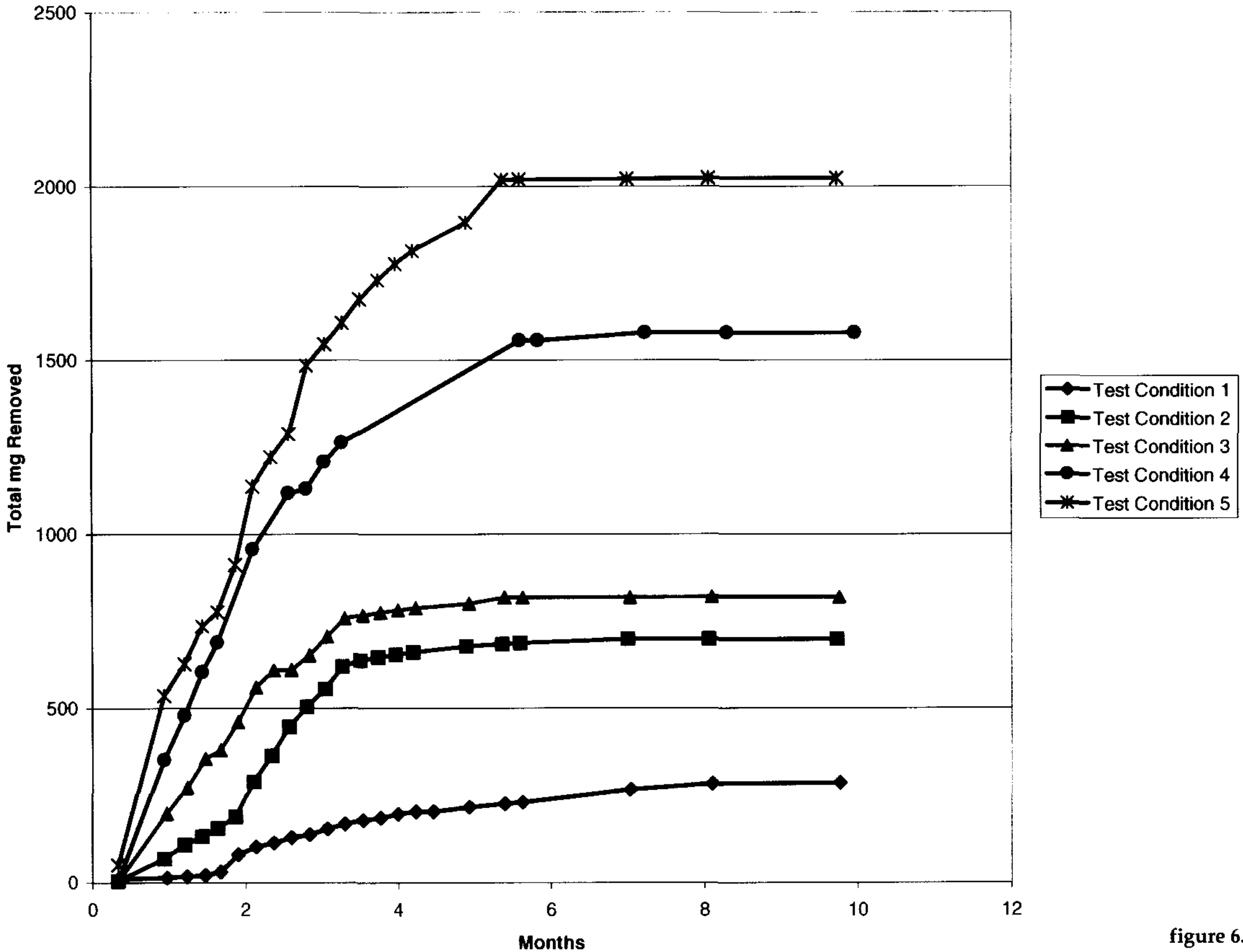

figure 6.3
ACCUMULATED LOSS OF 1,4-DICHLOROBENZENE
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BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

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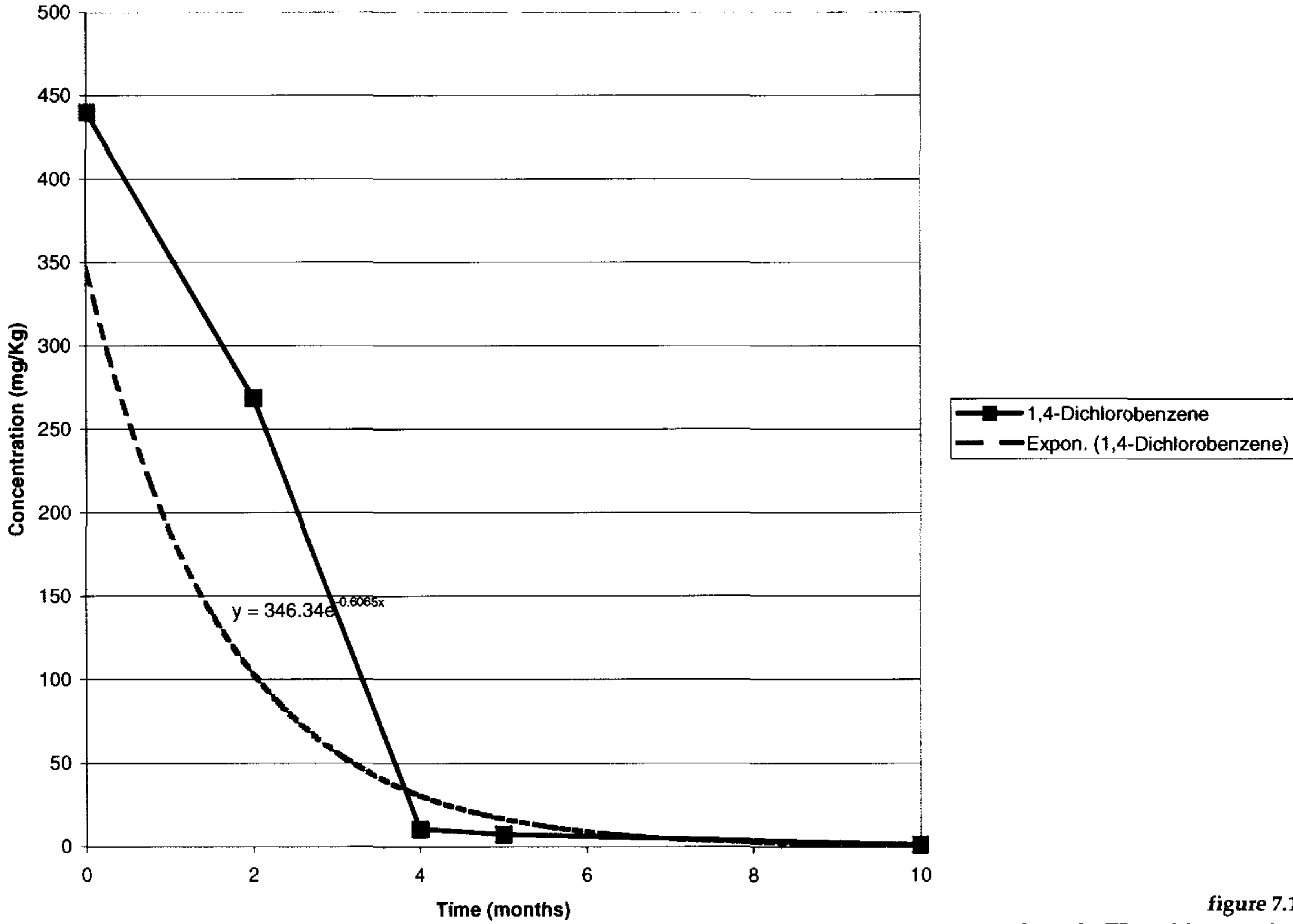

figure 7.1A

1,4-DICHLOROBENZENE RESULTS - TEST CONDITION 1

BIODEGRADATION TREATABILITY STUDY

BIOTREATABILITY SOIL PILE STUDIES

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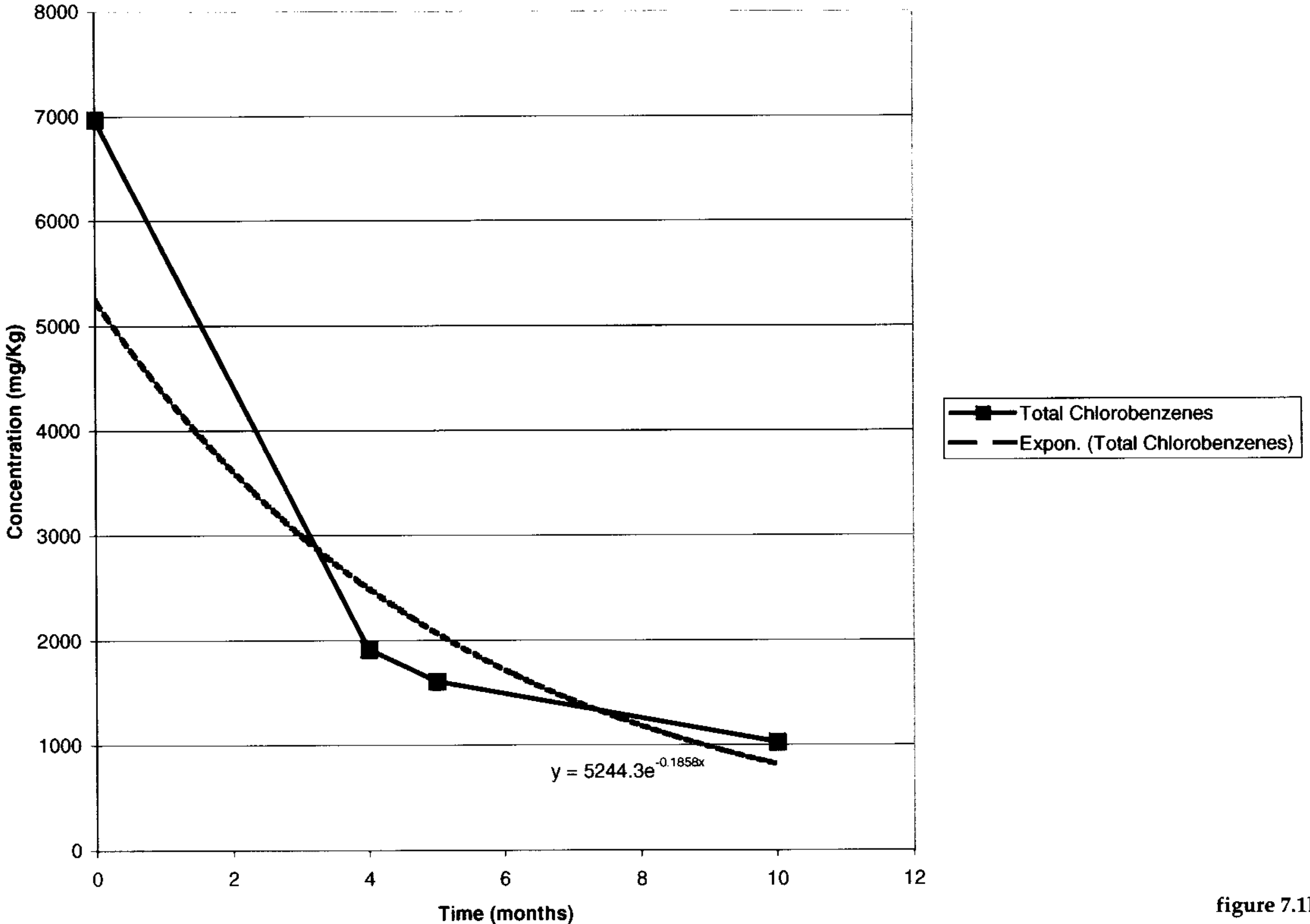

figure 7.1B
TOTAL CHLOROBENZENES RESULTS - TEST CONDITION 1
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

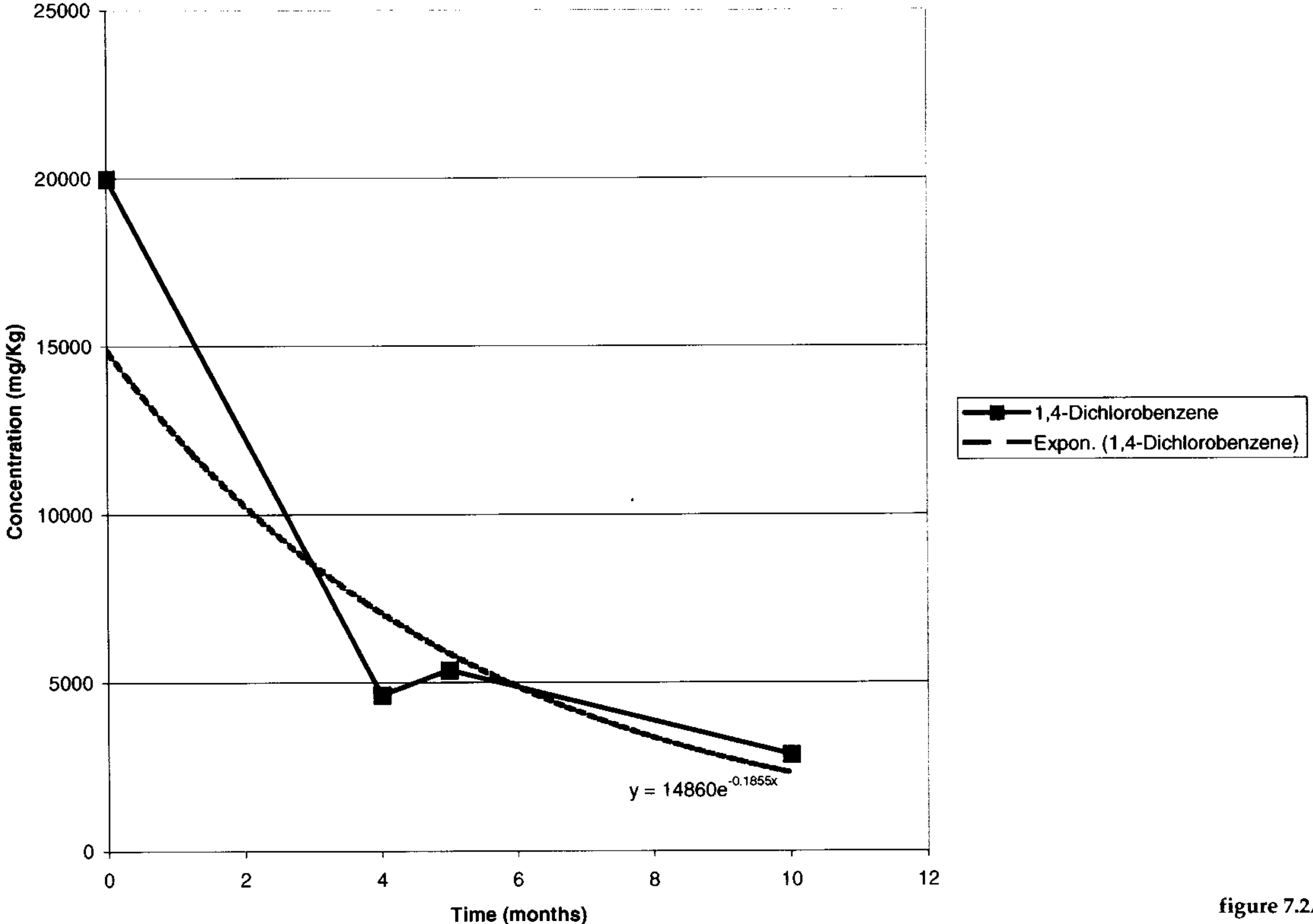

figure 7.2A
1,4-DICHLOROBENZENE RESULTS - TEST CONDITION 2
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BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

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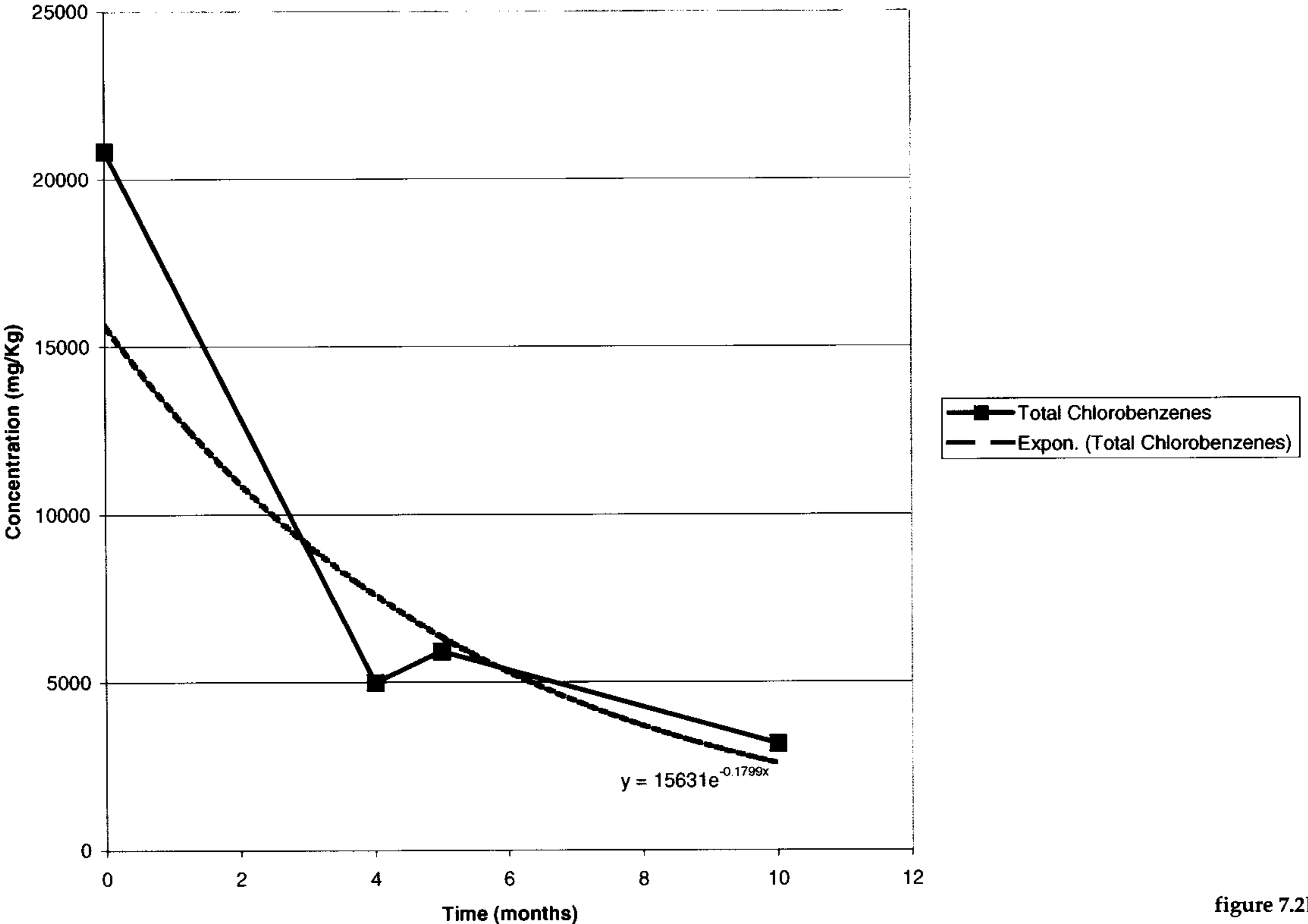

figure 7.2B
TOTAL CHLOROBENZENES RESULTS - TEST CONDITION 2
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BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

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CRA 14246 (1)

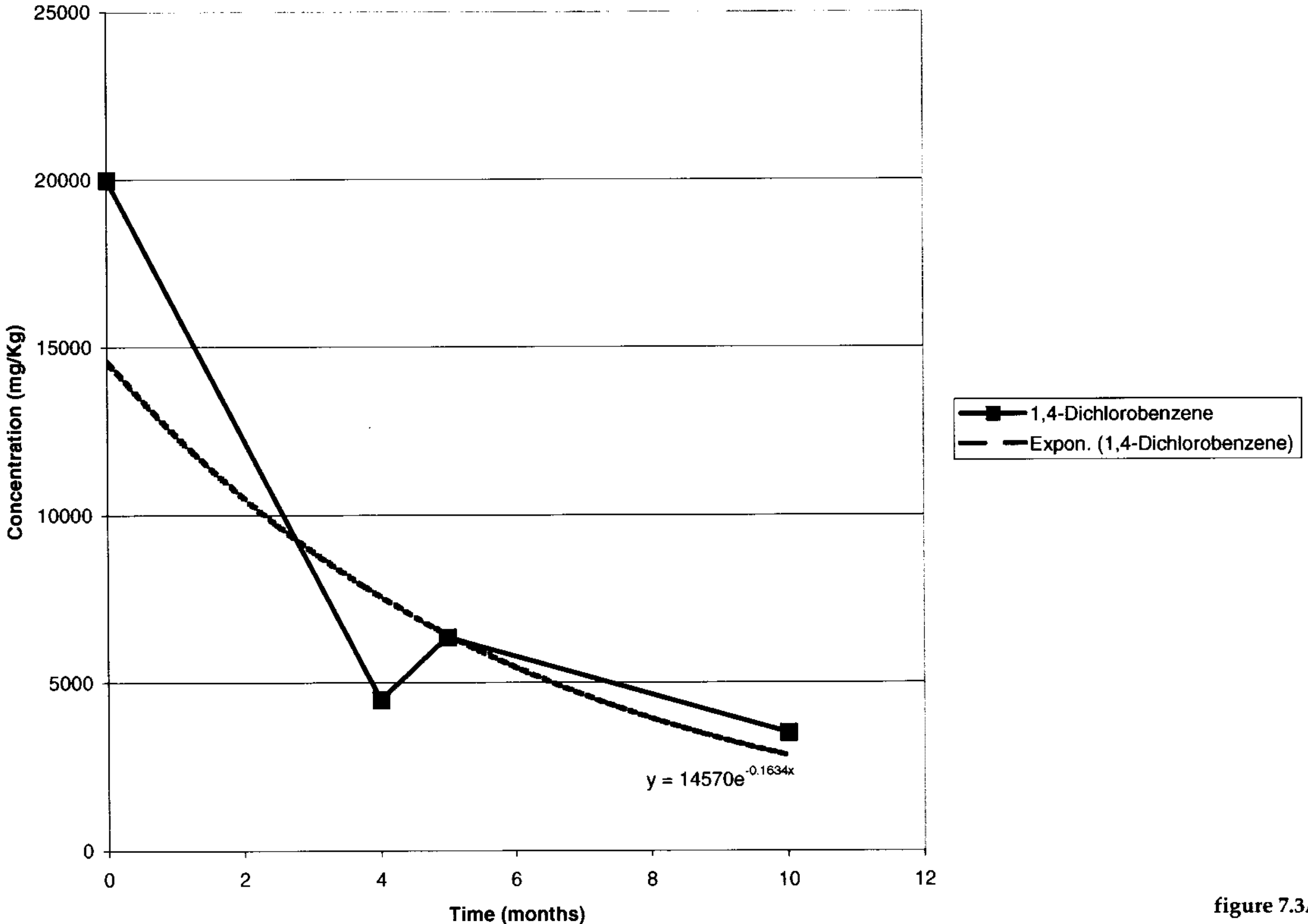

figure 7.3A
1,4-DICHLOROBENZENE RESULTS - TEST CONDITION 3
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

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CRA 14246 (1)

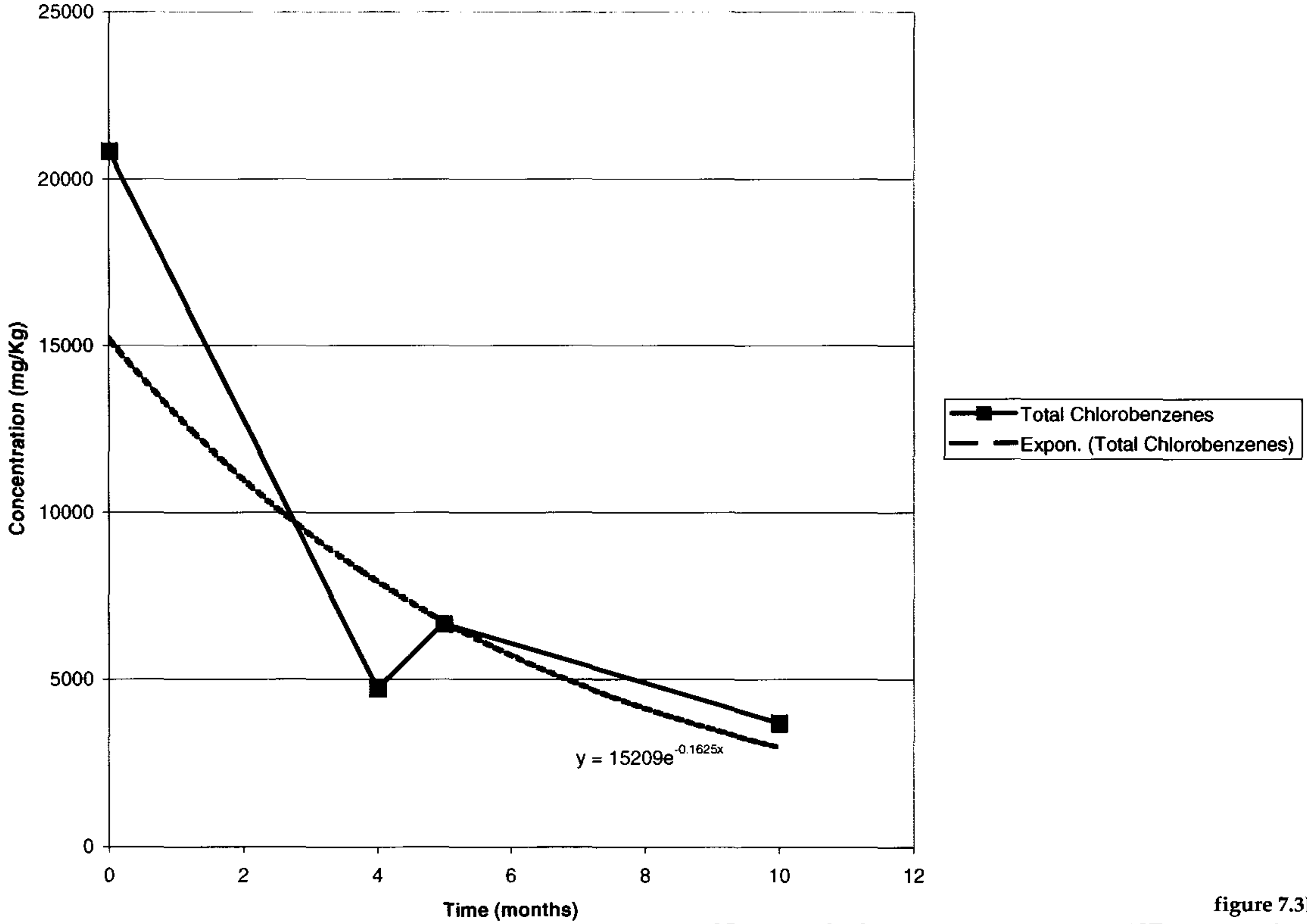

figure 7.3B
TOTAL CHLOROBENZENES RESULTS - TEST CONDITION 3
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

CRA 14246 (1)

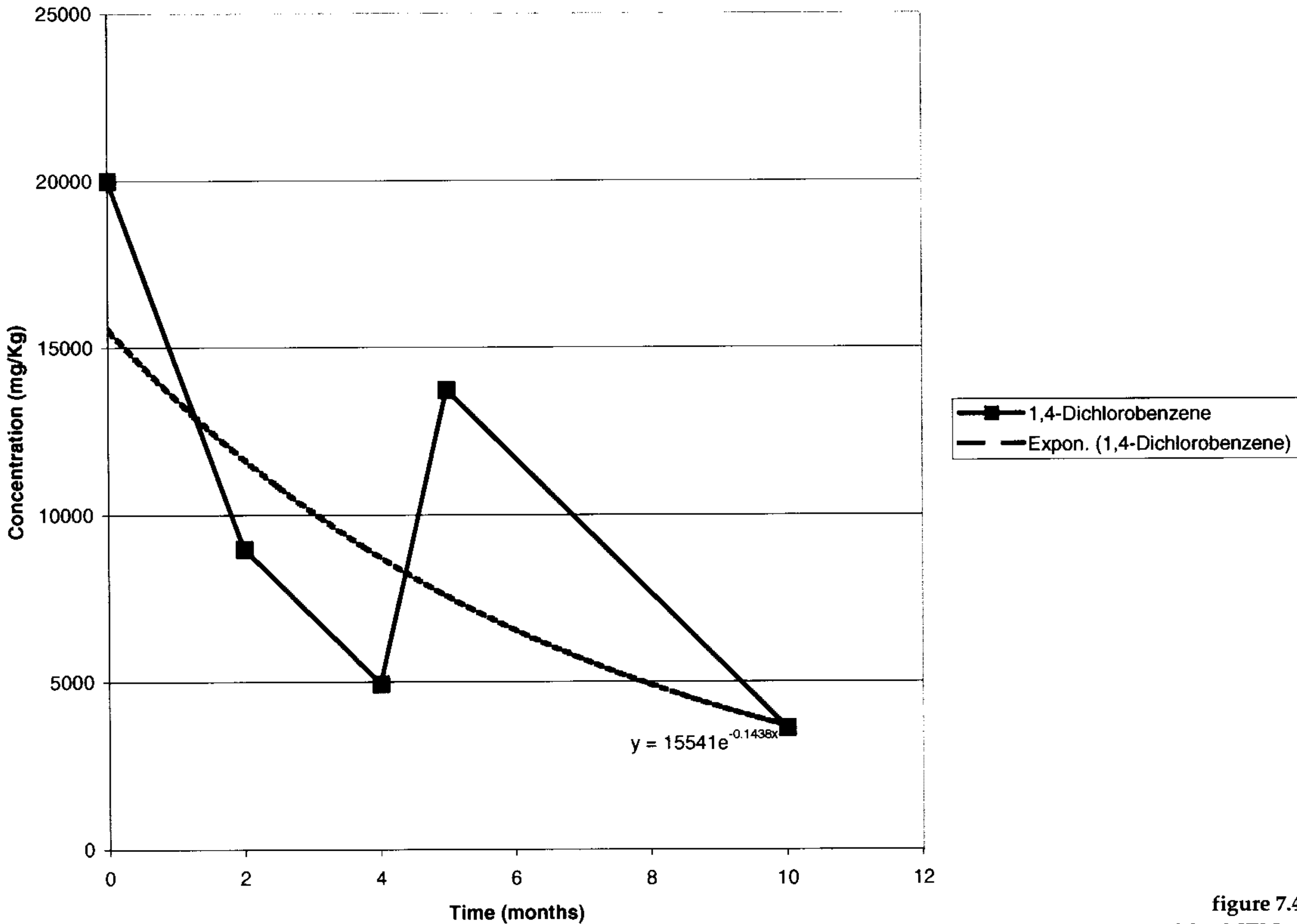

figure 7.4A
1,4-DICHLOROBENZENE RESULTS - TEST CONDITION 4
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

CRA 14246 (1)

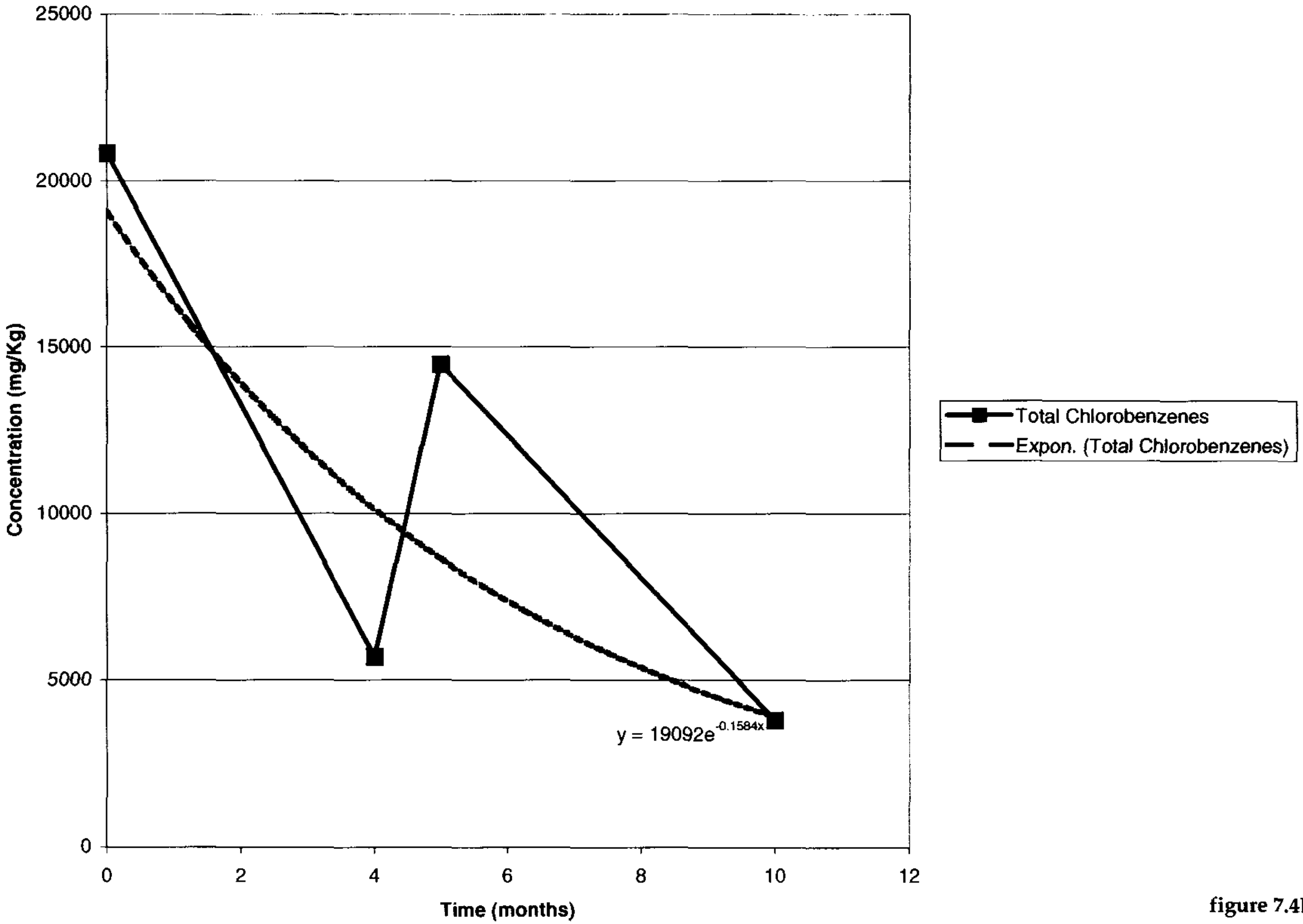

figure 7.4B
TOTAL CHLOROBENZENES RESULTS - TEST CONDITION 4
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

CRA 14246 (1)

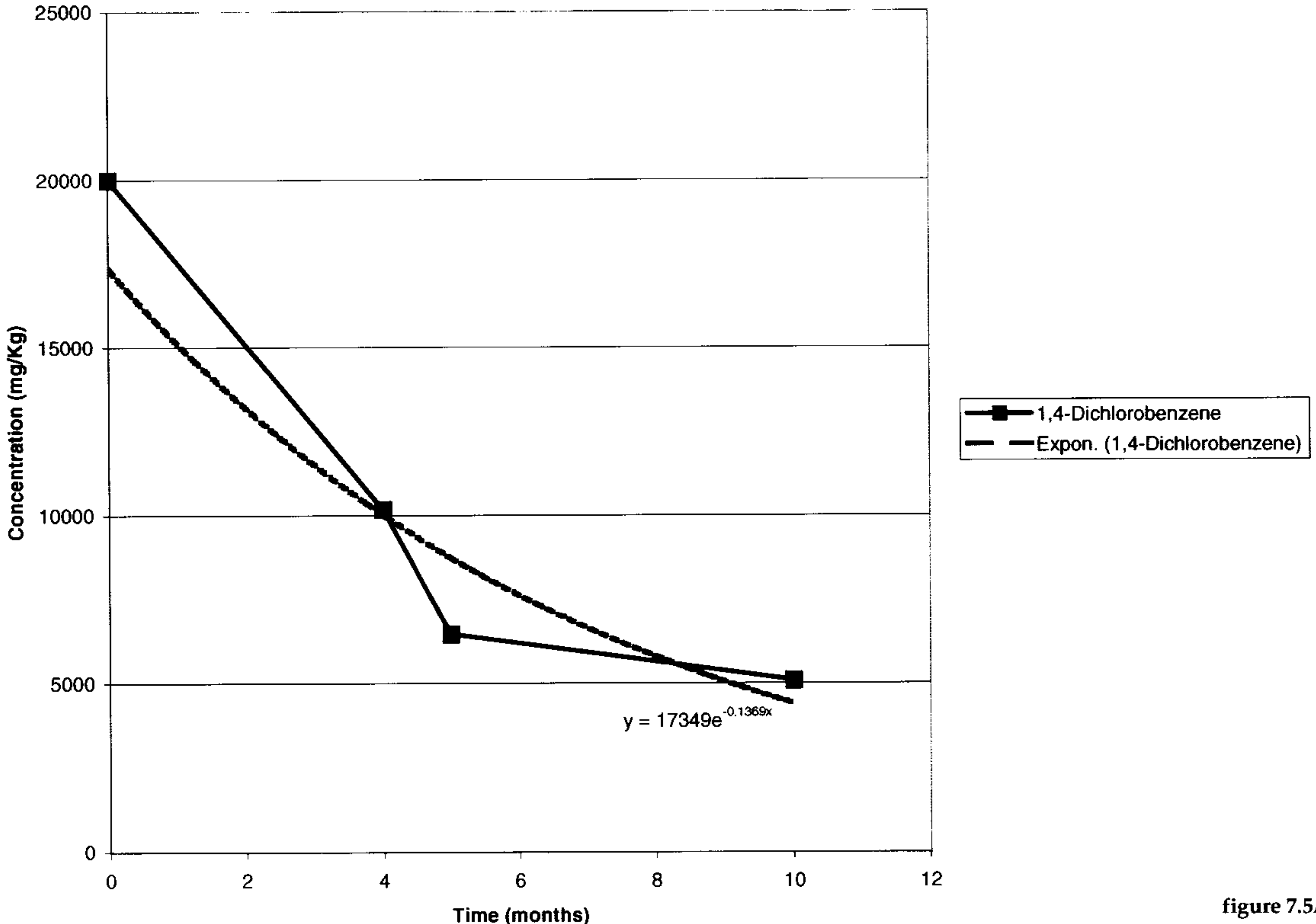

figure 7.5A
1,4-DICHLOROBENZENE RESULTS - TEST CONDITION 5
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

AR300050

CRA 14246 (1)

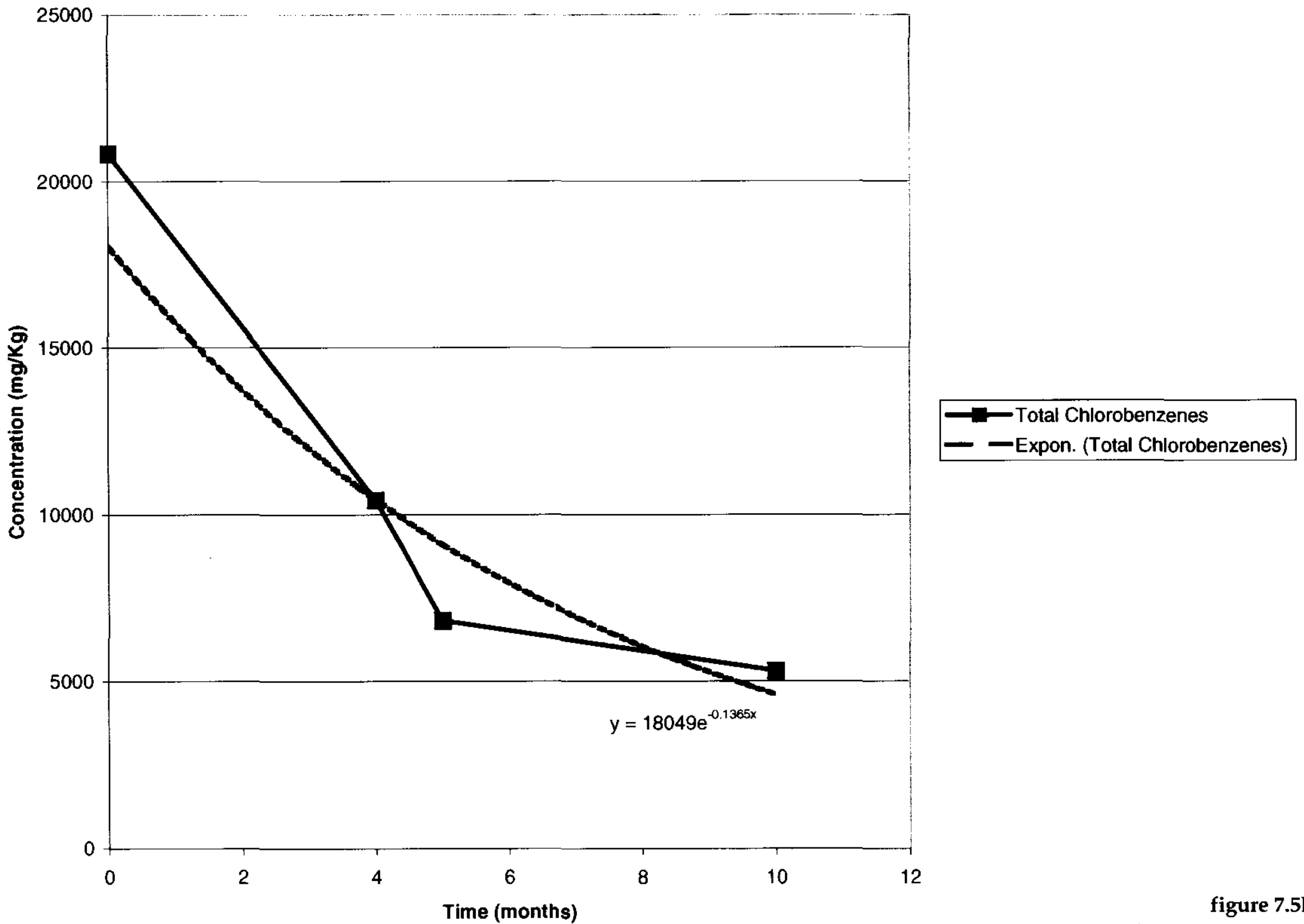

figure 7.5B
TOTAL CHLOROBENZENES RESULTS - TEST CONDITION 5
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

AR300051

CRA 14246 (1)

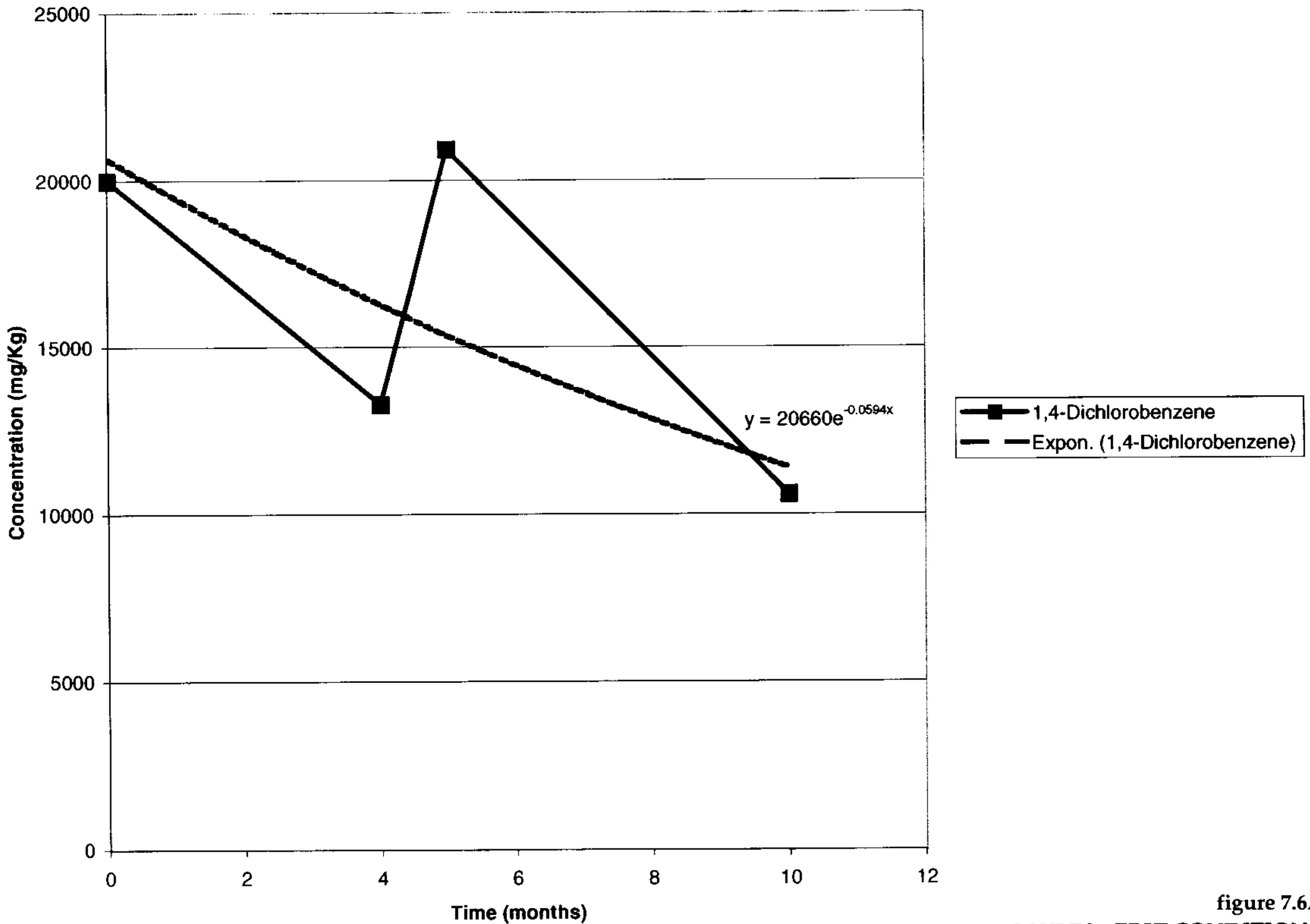

figure 7.6A
1,4-DICHLOROBENZENE RESULTS - TEST CONDITION 6
BIODEGRADATION TREATABILITY STUDY
BIODEGRADATION SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

AR300052

CRA 14246 (1)

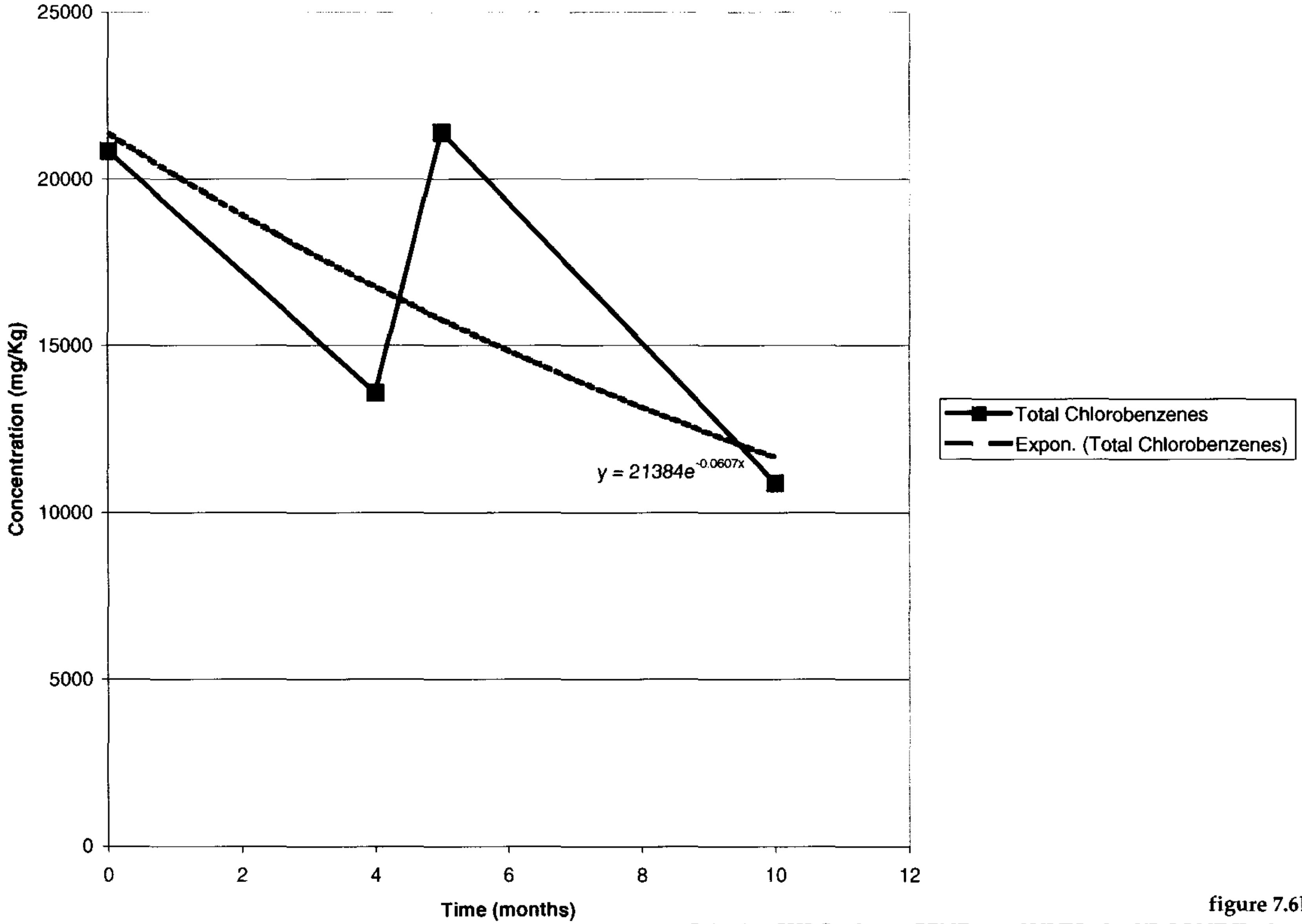

figure 7.6B
TOTAL CHLOROBENZENES RESULTS - TEST CONDITION 6
BIODEGRADATION TREATABILITY STUDY
BIODEGRADATION SOIL PILE STUDIES
Metachem Products, New Castle, Delaware

AR300053

CRA 14246 (1)

TABLES

TABLE 5.1

INITIAL CHARACTERIZATION
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

Parameters	Units	Soil Pile	Soil Pile (Duplicate)	Upland Soil	Upland Soil (Duplicate)
Sample ID:		*Soil Pile*	*Soil Pile (Duplicate)*	*Upland Soil*	*Upland Soil (Duplicate)*
Collection Date:		*11/11/99*	*11/11/99*	*11/11/99*	*11/11/99*
VOCs					
Benzene	mg/Kg	ND 50	-	ND 25	-
Toluene	mg/Kg	ND 50	-	ND 25	-
Chlorobenzene	mg/Kg	ND 50	-	ND 25	-
1,2-Dichlorobenzene	mg/Kg	66	-	670	-
1,3-Dichlorobenzene	mg/Kg	ND 50	-	17	-
1,4-Dichlorobenzene	mg/Kg	20000	-	440	-
SVOCs					
1,2,3-Trichlorobenzene	mg/Kg	150	160	1200	1300
1,2,4-Trichlorobenzene	mg/Kg	470	470	4000	4000
1,3,5-Trichlorobenzene	mg/Kg	ND 8.3	ND 8.3	0.67J	0.67J
1,2,3,4-Tetrachlorobenzene	mg/Kg	160	150	550	470
1,2,4,5-Tetrachlorobenzene	mg/Kg	23	23	86	93
Pentachlorobenzene	mg/Kg	35	34	21	20
Hexachlorobenzene	mg/Kg	0.90J	0.63J	0.25J	0.20J
Nitrobenzene	mg/Kg	ND 8.3	ND 8.3	ND 8.3	ND 8.3
General Chemistry					
pH	S.U.	5.5	5.5	5.7	5.6
Moisture Content	%	18.7	19	15.4	15.3
Total Organic Carbon	%	6.2	6.2	3.1	3.1
Ammonia Nitrogen	mg/Kg	172.6	160.5	109.5	110.8
Orthophosphate Phosphorus	mg/Kg	7.8	8	7.3	7.3
Water Holding Capacity	%	52.3	47.7	40.7	44.4
Total Microbial Population	CFUs/gm	1.8×10^5	1.4×10^5	4.4×10^4	4.9×10^4
Specific Microbial Population	CFUs/gm	4.0×10^3	3.3×10^3	3.1×10^3	2.2×10^3

Notes:

CFUs	Colony Forming Units
J	Estimated
ND	Non-detect at associated value
S.U.	Standard Units
SVOCs	Semi-volatile organic compounds
VOCs	Volatile organic compounds

TABLE 5.2

TEST CONDITION AMENDMENTS
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

Initial Amendments

Test Condition	*Soil* (Kg)	*Carbon* (Kg)	*Air Flow* Month 1 (mL/min)	Months 2-4 (mL/min)	Months 5-9.5 (mL/min)	*Nutrients* *Urea* (g)	*Phosphorus* (g)	*Vermiculite* (g)	*Microbial Culture* (mL)	*Molasses* (g)
1	15	2.3	100	100	100	0	0	0	0	0
2	15	2.3	100	100	100	0	0	0	0	0
3	15	2.3	100	10	10	30	9	790	500	0
4	15	2.3	100	0	10	30	9	790	500	0
5	15	2.3	100	10	10	0	0	0	0	0
6	15	0	0	0	0	0	0	0	0	0
Supplemental Amendments after 4 Months										
3						30	9	0	750	75
4						30	9	0	2250	75

TABLE 5.3

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 1
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

VOCs							
Benzene	mg/Kg	ND 25		ND 117	ND 116	ND 6	ND 11
Toluene	mg/Kg	ND 25		ND 117	ND 116	ND 6	ND 11
Chlorobenzene	mg/Kg	ND 25		ND 117	ND 116	ND 6	ND 11
1,2-Dichlorobenzene	mg/Kg	670		258	92J	83	58
1,3-Dichlorobenzene	mg/Kg	17		ND 117	ND 116	ND 6	ND 11
1,4-Dichlorobenzene	mg/Kg	440		269	ND 116	ND 6	ND 11
SVOCs							
1,2,3-Trichlorobenzene	mg/Kg	1200				358	481
1,2,4-Trichlorobenzene	mg/Kg	4000				1272	1065
1,3,5-Trichlorobenzene	mg/Kg	0.67J				ND 10	ND 10
1,2,3,4-Tetrachlorobenzene	mg/Kg	550				220	263
1,2,4,5-Tetrachlorobenzene	mg/Kg	86				64	26
Pentachlorobenzene	mg/Kg	21				9.9	10
Hexachlorobenzene	mg/Kg	0.25J				ND 10	ND 10
Nitrobenzene	mg/Kg	ND 8.3				ND 10	ND 10
General Chemistry							
pH	S.U.	5.6	5.4	5.5		5.4	5.1
Moisture Content	%	14.7	14.5	14.6		13.5	12.7
Ammonia Nitrogen	mg/L	4.1					
Orthophosphate Phosphorus	mg/L	2.8	2.6	0.05			13.9
Total Microbial Population	CFUs/mL	4.2×10^4	4.4×10^4	8.3×10^3		2.0×10^3	4.3×10^3
Mix Specific Microbial Population	CFUs/mL	2.5×10^3	3.1×10^3	1.6×10^3		1.4×10^3	5.0×10^2

TABLE 5.3

ANALYTICAL RESULTS SUMMARY - *TEST CONDITION 1*
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

VOCs						
Benzene	mg/Kg	ND 12	ND 11	ND 5	ND 46	ND 46
Toluene	mg/Kg	ND 12	ND 11	ND 5	ND 46	ND 46
Chlorobenzene	mg/Kg	ND 12	ND 11	ND 5	ND 46	ND 46
1,2-Dichlorobenzene	mg/Kg	11	ND 11	ND 5	ND 46	ND 46
1,3-Dichlorobenzene	mg/Kg	ND 12	ND 11	ND 5	ND 46	ND 46
1,4-Dichlorobenzene	mg/Kg	7.6	19	74	53	1.5
SVOCs						
1,2,3-Trichlorobenzene	mg/Kg	296	333	464	311	217
1,2,4-Trichlorobenzene	mg/Kg	957	734	1189	842	490
1,3,5-Trichlorobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 8.3	ND 8.3
1,2,3,4-Tetrachlorobenzene	mg/Kg	265	264	345	196	194
1,2,4,5-Tetrachlorobenzene	mg/Kg	63	81	71	72	72
Pentachlorobenzene	mg/Kg	11	19	15	9.3	11
Hexachlorobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
Nitrobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 8.3	ND 8.3
General Chemistry						
pH	S.U.	5.2	5.2	5.2		5.3
Moisture Content	%	13.2	12.8	12.3	13.3	12.3
Ammonia Nitrogen	mg/L	47	52	51		47
Orthophosphate Phosphorus	mg/L	7.3	3.4	14.3		6.0
Total Microbial Population	CFUs/mL	$2.3x10^3$	$1.9x10^3$	$1.9x10^3$		2.5x10
Mix Specific Microbial Population	CFUs/mL	$1.3x10^3$	$5.5x10^2$	$7.0x10^2$		7.5x10

Notes:
Blank entries indicate data not available.

CFUs	Colony Forming Units.
J	Estimated.
ND	Non-detect at associated value.
S.U.	Standard units.
SVOCs	Semi-volatile organic compounds.
VOCs	Volatile organic compounds.

TABLE 5.4

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 2
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	*0*	*1*	*2*	*2.5*	*3*	*4*
	Collection Date	*11/11/99*	*12/20/99*	*1/18/00*	*1/31/00*	*2/16/00*	*3/20/00*
Parameters	**Units**						
VOCs							
Benzene	mg/Kg	ND 50			ND 120	ND 119	ND 122
Toluene	mg/Kg	ND 50			ND 120	ND 119	ND 122
Chlorobenzene	mg/Kg	ND 50			ND 120	ND 119	ND 122
1,2-Dichlorobenzene	mg/Kg	66			ND 120	ND 119	ND 122
1,3-Dichlorobenzene	mg/Kg	ND 50			ND 120	ND 119	ND 122
1,4-Dichlorobenzene	mg/Kg	20000			6960	3819	4645
SVOCs							
1,2,3-Trichlorobenzene	mg/Kg	150				57	61
1,2,4-Trichlorobenzene	mg/Kg	470				203	171
1,3,5-Trichlorobenzene	mg/Kg	ND 8.3				ND 10	ND 10
1,2,3,4-Tetrachlorobenzene	mg/Kg	160				93	94
1,2,4,5-Tetrachlorobenzene	mg/Kg	23				ND 10	7.5
Pentachlorobenzene	mg/Kg	35				23	21
Hexachlorobenzene	mg/Kg	0.90J				ND 10	ND 10
Nitrobenzene	mg/Kg	ND 8.3				ND 10	ND 10
General Chemistry							
pH	S.U.	5.7	5.6	5.6		5.5	5.2
Moisture Content	%	17.8	17.5	17.4		16.2	18.2
Ammonia Nitrogen	mg/L						
Orthophosphate Phosphorus	mg/L	2.8	2.9	2.5			9.9
Total Microbial Population	CFUs/mL	1.6×10^5	1.7×10^5	1.2×10^4		5.3×10^3	1.3x10
Mix Specific Microbial Population	CFUs/mL	3.7×10^3	3.1×10^3	2.7×10^3		2.9×10^3	5.5x10

TABLE 5.4

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 2
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	5	6	7	8	9.5
	Collection Date	4/18/00	5/23/00	6/20/00	7/18/00	9/8/00
Parameters	Units					
VOCs						
Benzene	mg/Kg	ND 118	ND 118	ND 48	ND 47	ND 48
Toluene	mg/Kg	ND 118	ND 118	ND 48	ND 47	ND 48
Chlorobenzene	mg/Kg	ND 118	ND 118	ND 48	ND 47	ND 48
1,2-Dichlorobenzene	mg/Kg	ND 118	ND 118	ND 48	ND 47	ND 48
1,3-Dichlorobenzene	mg/Kg	ND 118	ND 118	ND 48	ND 47	ND 48
1,4-Dichlorobenzene	mg/Kg	5378	1161	1010	4152	2878
SVOCs						
1,2,3-Trichlorobenzene	mg/Kg	78	82	49	43	49
1,2,4-Trichlorobenzene	mg/Kg	239	160	108	104	121
1,3,5-Trichlorobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
1,2,3,4-Tetrachlorobenzene	mg/Kg	189	142	106	69	88
1,2,4,5-Tetrachlorobenzene	mg/Kg	11	19	14	8.1	12
Pentachlorobenzene	mg/Kg	30	40	29	18	23
Hexachlorobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
Nitrobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
General Chemistry						
pH	S.U.	5.1	5.1	5.1		5.1
Moisture Content	%	15.4	15.6	15.8	15.7	16.6
Ammonia Nitrogen	mg/L	205	198	185		164
Orthophosphate Phosphorus	mg/L	2.3	1.6	9.5		3.8
Total Microbial Population	CFUs/mL	$5.5x10^3$	$4.7x10^3$	$4.8x10^3$		4.5x10
Mix Specific Microbial Population	CFUs/mL	$2.8x10^3$	$1.9x10^3$	$1.7x10^3$		1.4x10

Notes:

Blank entries indicate data not available.

CFUs	Colony Forming Units.
J	Estimated.
ND	Non-detect at associated value.
S.U.	Standard units.
SVOCs	Semi-volatile organic compounds.
VOCs	Volatile organic compounds.

TABLE 5.5

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 3
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	*0*	*1*	*2*	*2.5*	*3*	*4*
	Collection Date	*11/11/99*	*12/20/99*	*1/18/00*	*1/31/00*	*2/16/00*	*3/20/00*
Parameters	**Units**						
VOCs							
Benzene	mg/Kg	ND 50			ND 120	ND 120	ND 133
Toluene	mg/Kg	ND 50			ND 120	ND 120	ND 133
Chlorobenzene	mg/Kg	ND 50			ND 120	ND 120	ND 133
1,2-Dichlorobenzene	mg/Kg	66			ND 120	ND 120	ND 133
1,3-Dichlorobenzene	mg/Kg	ND 50			ND 120	ND 120	ND 133
1,4-Dichlorobenzene	mg/Kg	20000			3360	2584	4509
SVOCs							
1,2,3-Trichlorobenzene	mg/Kg	150				66	34
1,2,4-Trichlorobenzene	mg/Kg	470				228	105
1,3,5-Trichlorobenzene	mg/Kg	ND 8.3				ND 10	ND 11
1,2,3,4-Tetrachlorobenzene	mg/Kg	160				118	68
1,2,4,5-Tetrachlorobenzene	mg/Kg	23				13	2J
Pentachlorobenzene	mg/Kg	35				36	19
Hexachlorobenzene	mg/Kg	0.90J				ND 10	ND 11
Nitrobenzene	mg/Kg	ND 8.3				ND 10	ND 11
General Chemistry							
pH	S.U.	5.6	5.5	5.6		5.5	5.5
Moisture Content	%	17.7	17.3	17.9		16.8	24.6
Ammonia Nitrogen	mg/L						
Orthophosphate Phosphorus	mg/L	14.3	7.1	4.7			7.8
Total Microbial Population	CFUs/mL	1.3×10^5	7.0×10^5	9.1×10^4		5.5×10^3	1.2×10^3
Mix Specific Microbial Population	CFUs/mL	3.3×10^3	2.4×10^4	3.3×10^3		1.7×10^3	6.5×10^2

TABLE 5.5

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 3
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	5	6	7	8	9.5
	Collection Date	4/18/00	5/23/00	6/20/00	7/18/00	9/8/00
Parameters	**Units**					
VOCs						
Benzene	mg/Kg	ND 141	ND 139	ND 55	ND 54	ND 54
Toluene	mg/Kg	ND 141	ND 139	ND 55	ND 54	ND 54
Chlorobenzene	mg/Kg	ND 141	ND 139	ND 55	ND 54	ND 54
1,2-Dichlorobenzene	mg/Kg	ND 141	ND 139	ND 55	ND 54	ND 54
1,3-Dichlorobenzene	mg/Kg	ND 141	ND 139	ND 55	ND 54	ND 54
1,4-Dichlorobenzene	mg/Kg	6369	1664	1241	1182	3518
SVOCs						
1,2,3-Trichlorobenzene	mg/Kg	49	49	28	52	41
1,2,4-Trichlorobenzene	mg/Kg	148	93	69	130	96
1,3,5-Trichlorobenzene	mg/Kg	ND 12	ND 12	ND 11	ND 11	ND 11
1,2,3,4-Tetrachlorobenzene	mg/Kg	96	82	ND 11	92	ND 11
1,2,4,5-Tetrachlorobenzene	mg/Kg	3J	ND 10	4.6	11	9.6
Pentachlorobenzene	mg/Kg	26	26	18	27	26
Hexachlorobenzene	mg/Kg	ND 12	ND 12	ND 11	ND 11	ND 11
Nitrobenzene	mg/Kg	ND 12	ND 12	ND 11	ND 11	ND 11
General Chemistry						
pH	S.U.	5.9	5.9	5.8		5.7
Moisture Content	%	29.2	27.9	27.5	26.4	26.1
Ammonia Nitrogen	mg/L	1961	1715	1698		1493
Orthophosphate Phosphorus	mg/L	18.1	21.0	36.1		9.4
Total Microbial Population	CFUs/mL	$8.3x10^3$	$8.4x10^3$	$8.5x10^3$		$4.5x10^3$
Mix Specific Microbial Population	CFUs/mL	$2.1x10^3$	$2.5x10^3$	$2.6x10^3$		$1.6x10^3$

Notes:
Blank entries indicate data not available.
CFUs Colony Forming Units.
J Estimated.
ND Non-detect at associated value.
S.U. Standard units.
SVOCs Semi-volatile organic compounds.
VOCs Volatile organic compounds.

TABLE 5.6

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 4
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	**0**	**1**	**2**	**2.5**	**3**	**4**
	Collection Date	*11/11/99*	*12/20/99*	*1/11/00*	*1/31/00*	*2/16/00*	*3/20/00*
Parameters	**Units**						
VOCs							
Benzene	mg/Kg	ND 50		ND 30	ND 121	ND 121	ND 100
Toluene	mg/Kg	ND 50		ND 30	ND 121	ND 121	ND 100
Chlorobenzene	mg/Kg	ND 50		ND 30	ND 121	ND 121	ND 100
1,2-Dichlorobenzene	mg/Kg	66		ND 30	ND 121	ND 121	ND 100
1,3-Dichlorobenzene	mg/Kg	ND 50		ND 30	ND 121	ND 121	ND 100
1,4-Dichlorobenzene	mg/Kg	20000		8980	3641	6000	4950
SVOCs							
1,2,3-Trichlorobenzene	mg/Kg	150				90	114
1,2,4-Trichlorobenzene	mg/Kg	470				291	356
1,3,5-Trichlorobenzene	mg/Kg	ND 8.3				ND 10	ND 12
1,2,3,4-Tetrachlorobenzene	mg/Kg	160				158	200
1,2,4,5-Tetrachlorobenzene	mg/Kg	23				21	27
Pentachlorobenzene	mg/Kg	35				44	56
Hexachlorobenzene	mg/Kg	0.90J				ND 10	ND 12
Nitrobenzene	mg/Kg	ND 8.3				ND 10	ND 12
General Chemistry							
pH	S.U.	5.6	5.7	5.6		5.4	5.5
Moisture Content	%	17.1	17.8	17.6		17.5	32.5
Ammonia Nitrogen	mg/L						
Orthophosphate Phosphorus	mg/L	14.4	6.3	5.6			26.7
Aerobic Total Microbial Population	CFUs/mL	$1.6x10^5$	$5.8x10^5$	$8.8x10^4$		$7.5x10^3$	$2.0x10^3$
Anaerobic Total Microbial Population	CFUs/mL						$1.2x10^3$
Aerobic Mix Specific Microbial Population	CFUs/mL	$3.4x10^3$	$3.0x10^4$	$4.5x10^3$		$3.2x10^3$	$9.0x10^2$
Anaerobic Mix Specific Microbial Population	CFUs/mL						$5.5x10^2$

TABLE 5.6

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 4
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	5	6	7	8	9.5
	Collection Date	4/18/00	5/23/00	6/20/00	7/18/00	9/8/00
Parameters	**Units**					
VOCs						
Benzene	mg/Kg	ND 160	ND 61	ND 61	ND 58	ND 58
Toluene	mg/Kg	ND 160	ND 61	ND 61	ND 58	ND 58
Chlorobenzene	mg/Kg	ND 160	ND 61	ND 61	ND 58	ND 58
1,2-Dichlorobenzene	mg/Kg	ND 160	ND 61	ND 61	ND 58	ND 58
1,3-Dichlorobenzene	mg/Kg	ND 160	ND 61	ND 61	ND 58	ND 58
1,4-Dichlorobenzene	mg/Kg	13738	4085	4993	4094	3623
SVOCs						
1,2,3-Trichlorobenzene	mg/Kg	117	68	36	42	30
1,2,4-Trichlorobenzene	mg/Kg	319	139	94	113	83
1,3,5-Trichlorobenzene	mg/Kg	ND 13	ND 13	ND 13	ND 12	ND 12
1,2,3,4-Tetrachlorobenzene	mg/Kg	256	135	ND 13	76	57
1,2,4,5-Tetrachlorobenzene	mg/Kg	4J	17	5.5	8.0	4.3
Pentachlorobenzene	mg/Kg	45	41	18	20	15
Hexachlorobenzene	mg/Kg	ND 13	ND 13	ND 13	ND 12	ND 12
Nitrobenzene	mg/Kg	ND 13	ND 13	ND 13	ND 12	ND 12
General Chemistry						
pH	S.U.	5.6	5.2	5.2		5.2
Moisture Content	%	37.4	33.9	32.9	31.6	31.0
Ammonia Nitrogen	mg/L	1470	1238	1206		1175
Orthophosphate Phosphorus	*mg/L*	37.4	25.2	47.8		72.2
Aerobic Total Microbial Population	CFUs/mL	8.8×10^5	6.6×10^5	6.9×10^5		8.7×10^5
Anaerobic Total Microbial Population	CFUs/mL	7.4×10^3	7.1×10^3			
Aerobic Mix Specific Microbial Population	CFUs/mL	6.4×10^4	5.6×10^4	5.2×10^4		5.7×10^4
Anaerobic Mix Specific Microbial Population	CFUs/mL	3.1×10^3	3.1×10^3			

Notes:
Blank entries indicate data not available.

CFUs	*Colony Forming Units.*
J	Estimated.
ND	Non-detect at associated value.
S.U.	Standard units.
SVOCs	Semi-volatile organic compounds.
VOCs	Volatile organic compounds.

TABLE 5.7

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 5
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

Parameters	Time (months) / Collection Date / Units	0 / 11/11/99	1 / 12/20/99	2 / 1/18/00	2.5 / 1/31/00	3 / 2/16/00	4 / 3/20/00
VOCs							
Benzene	mg/Kg	ND 50			ND 122	ND 121	ND 121
Toluene	mg/Kg	ND 50			ND 122	ND 121	ND 121
Chlorobenzene	mg/Kg	ND 50			ND 122	ND 121	ND 121
1,2-Dichlorobenzene	mg/Kg	66			ND 122	ND 121	ND 121
1,3-Dichlorobenzene	mg/Kg	ND 50			ND 122	ND 121	ND 121
1,4-Dichlorobenzene	mg/Kg	20000			11422	7646	10182
SVOCs							
1,2,3-Trichlorobenzene	mg/Kg	150				89	46
1,2,4-Trichlorobenzene	mg/Kg	470				303	133
1,3,5-Trichlorobenzene	mg/Kg	ND 8.3				ND 10	ND 10
1,2,3,4-Tetrachlorobenzene	mg/Kg	160				121	75
1,2,4,5-Tetrachlorobenzene	mg/Kg	23				16	ND 4
Pentachlorobenzene	mg/Kg	35				28	16
Hexachlorobenzene	mg/Kg	0.90J				ND 10	ND 10
Nitrobenzene	mg/Kg	ND 8.3				ND 10	ND 10
General Chemistry							
pH	S.U.	5.6	5.6	5.6		5.5	5.0
Moisture Content	%	17.4	17.5	17.8		17.6	17.5
Ammonia Nitrogen	mg/L						
Orthophosphate Phosphorus	mg/L	2.1	2.7	0.6			3.9
Total Microbial Population	CFUs/mL	$1.4x10^5$	$1.1x10^5$	$8.7x10^3$		$2.1x10^3$	$1.6x10^3$
Mix Specific Microbial Population	CFUs/mL	$2.5x10^3$	$3.3x10^3$	$1.4x10^3$		$1.4x10^3$	$7.5x10^2$

TABLE 5.7

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 5
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	5	6	7	8	9.5
	Collection Date	*4/18/00*	*5/23/00*	*6/20/00*	*7/18/00*	*9/8/00*
Parameters	**Units**					
VOCs						
Benzene	mg/Kg	ND 120	ND 237	ND 95	ND 47	ND 47
Toluene	mg/Kg	ND 120	ND 237	ND 95	ND 47	ND 47
Chlorobenzene	mg/Kg	ND 120	ND 237	ND 95	ND 47	ND 47
1,2-Dichlorobenzene	mg/Kg	ND 120	ND 237	ND 95	ND 47	ND 47
1,3-Dichlorobenzene	mg/Kg	ND 120	ND 237	ND 95	ND 47	ND 47
1,4-Dichlorobenzene	mg/Kg	6467	4982	794	210	5101
SVOCs						
1,2,3-Trichlorobenzene	mg/Kg	50	57	43	37	33
1,2,4-Trichlorobenzene	mg/Kg	192	107	96	78	75
1,3,5-Trichlorobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
1,2,3,4-Tetrachlorobenzene	mg/Kg	105	116	95	74	81
1,2,4,5-Tetrachlorobenzene	mg/Kg	ND 6	14	12	9.2	10
Pentachlorobenzene	mg/Kg	23	32	26	19	23
Hexachlorobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
Nitrobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
General Chemistry						
pH	S.U.	5.0	5.1	5.1		5.0
Moisture Content	%	16.5	15.7	15.6	14.4	15.7
Ammonia Nitrogen	mg/L	234	262	226		201
Orthophosphate Phosphorus	mg/L	2.8	3.4	3.8		4.5
Total Microbial Population	*CFUs/mL*	$2.5x10^3$	$2.4x10^3$	$2.2x10^3$		$1.9x10^3$
Mix Specific Microbial Population	CFUs/mL	$1.4x10^3$	$9.0x10^2$	$7.0x10^2$		$6.0x10^2$

Notes:
Blank entries indicate data not available.

CFUs	Colony Forming Units.
J	Estimated.
ND	Non-detect at associated value.
S.U.	Standard units.
SVOCs	Semi-volatile organic compounds.
VOCs	Volatile organic compounds.

TABLE 5.8

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 6
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	*0*	*1*	*2*	*2.5*	*3*	*4*
	Collection Date	*11/11/99*	*12/20/99*	*1/18/00*	*1/31/00*	*2/16/00*	*3/20/00*
Parameters	**Units**						
VOCs							
Benzene	mg/Kg	ND 50			ND 122	ND 122	ND 121
Toluene	mg/Kg	ND 50			ND 122	ND 122	ND 121
Chlorobenzene	mg/Kg	ND 50			ND 122	ND 122	ND 121
1,2-Dichlorobenzene	mg/Kg	66			57J	ND 122	ND 121
1,3-Dichlorobenzene	mg/Kg	ND 50			ND 122	ND 122	ND 121
1,4-Dichlorobenzene	mg/Kg	20000			14616	11543	13285
SVOCs							
1,2,3-Trichlorobenzene	mg/Kg	150				89	53
1,2,4-Trichlorobenzene	mg/Kg	470				316	169
1,3,5-Trichlorobenzene	mg/Kg	ND 8.3				ND 10	ND 10
1,2,3,4-Tetrachlorobenzene	mg/Kg	160				112	70
1,2,4,5-Tetrachlorobenzene	mg/Kg	23				13	4J
Pentachlorobenzene	mg/Kg	35				29	17
Hexachlorobenzene	mg/Kg	0.90J				ND 10	ND 10
Nitrobenzene	mg/Kg	ND 8.3				ND 10	ND 10
General Chemistry							
pH	S.U.	5.5	5.5	5.5		5.3	5.1
Moisture Content	%	17.7	17.5	18.1		17.7	17.2
Ammonia Nitrogen	mg/L						
Orthophosphate Phosphorus	mg/L	5.2	2.8	0.8			17.8
Total Microbial Population	CFUs/mL	$1.7x10^5$	$1.4x10^5$	$7.1x10^3$		$6.5x10^2$	$7.5x10^2$
Mix Specific Microbial Population	CFUs/mL	$3.2x10^3$	$3.1x10^3$	$1.4x10^3$		$6.0x10^2$	$4.5x10^2$

TABLE 5.8

ANALYTICAL RESULTS SUMMARY - TEST CONDITION 6
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Time (months)	5	6	7	8	9.5
	Collection Date	4/18/00	5/23/00	6/20/00	7/21/00	9/8/00
Parameters	**Units**					
VOCs						
Benzene	mg/Kg	ND 125	ND 117	ND 48	ND 48	ND 49
Toluene	mg/Kg	ND 125	ND 117	ND 48	ND 48	ND 49
Chlorobenzene	mg/Kg	ND 125	ND 117	ND 48	ND 48	ND 49
1,2-Dichlorobenzene	mg/Kg	ND 125	ND 117	ND 48	ND 48	ND 49
1,3-Dichlorobenzene	mg/Kg	ND 125	ND 117	ND 48	ND 48	ND 49
1,4-Dichlorobenzene	mg/Kg	20914	2804	6514	6667	10597
SVOCs						
1,2,3-Trichlorobenzene	mg/Kg	84	74	52	38	47.5
1,2,4-Trichlorobenzene	mg/Kg	266	175	145	110	140
1,3,5-Trichlorobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
1,2,3,4-Tetrachlorobenzene	mg/Kg	110	113	75	48	77
1,2,4,5-Tetrachlorobenzene	mg/Kg	9J	15	9.3	5.0	9.9
Pentachlorobenzene	mg/Kg	27	33	21	13	22
Hexachlorobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
Nitrobenzene	mg/Kg	ND 10	ND 10	ND 10	ND 10	ND 10
General Chemistry						
pH	S.U.	5.0	5.1	5.1		5.1
Moisture Content	%	20.3	14.4	17.1	17.5	17.9
Ammonia Nitrogen	mg/L	211	204	208		212
Orthophosphate Phosphorus	mg/L	1.4	3.3	3.5		2.2
Total Microbial Population	CFUs/mL	$8.0x10^2$	$7.0x10^2$	$7.5x10^2$		$8.5x10^2$
Mix Specific Microbial Population	CFUs/mL	$4.5x10^2$	$2.5x10^2$	$3.0x10^2$		$2.5x10^2$

Notes:
Blank entries indicate data not available.
CFUs Colony Forming Units.
J Estimated.
ND Non-detect at associated value.
S.U. Standard units.
SVOCs Semi-volatile organic compounds.
VOCs Volatile organic compounds.

TABLE 5.9

ANALYTICAL RESULTS - CARBON TRAPS
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Test Condition	*1*	*2*	*3*	*4*	*5*
	Collection Date	*09/06/00*	*09/06/00*	*09/06/00*	*09/06/00*	*09/06/00*
Parameters	Units					
VOCs						
Benzene	mg/Kg	ND 4.6	ND 4.0	ND 4.0	ND 3.8	ND 4.1
Chlorobenzene	mg/Kg	ND 4.6	10	7.6	ND 3.8	ND 4.1
1,2-Dichlorobenzene	mg/Kg	2450	260	380	105	107
1,3-Dichlorobenzene	mg/Kg	145	135	160	63	65
1,4-Dichlorobenzene	mg/Kg	2100	18000	23000	5650	15000
SVOCs						
1,2,3-Trichlorobenzene	mg/Kg	2200	147	215	35	155
1,2,4-Trichlorobenzene	mg/Kg	12500	800	1180	185	550
1,2,3,4-Tetrachlorobenzene	mg/Kg	33	26	13	ND 7.5	ND 8.3
1,2,4,5-Tetrachlorobenzene	mg/Kg	ND 9.1	18	ND 7.8	ND 7.5	ND 8.3

Notes:
ND Non-detect at associated value.
SVOCs Semi-volatile organic compounds.
VOCs Volatile organic compounds.

TABLE 5.10

WEEKLY AIR MONITORING DATA - TEST CONDITION 1
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 1 Day	T = 1.5 weeks	T = 2.5 weeks	T = 4 weeks	T = 5 weeks	T = 6 weeks	T = 7 weeks	T = 7.5 weeks
	Sample Date	11/19/99	11/29/99	12/6/99	12/17/99	12/25/99	1/1/00	1/7/00	1/11/00
Parameter	*Units*								
Vacuum Pressure	inches Water	18	18	18	28	28	20	11	10.5
Flow	cc/min	40	50	50	51	50	50	150	50
Temperature	°C	22	21	21	21	21	22	23	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	18.2	17.6	20.4	18	18	17.9	18	21
CO_2	%	0.1	0.2	0.2	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	605	617	544	261	242	219	373	380

TABLE 5.10

WEEKLY AIR MONITORING DATA - TEST CONDITION 1
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 8 weeks	T = 8.5 weeks	T = 9 weeks	T = 10 weeks	T = 11 weeks	T = 12 weeks	T = 13 weeks	T = 14 weeks
	Sample Date	1/14/00	1/18/00	1/21/00	1/28/00	2/4/00	2/11/00	2/18/00	2/25/00
Parameter	*Units*								
Vacuum Pressure	inches Water	12	10	6	6	7	10	6	10
Flow	cc/min	50	51	51	49	50	50	50	51
Temperature	°C	23	23	21	22	23	22	22	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.1	20.1	20.4	20.9	20.1	19.9	20	19.9
CO_2	%	0	0	0.1	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	390	381	387.2	379.3	157	200	202	301

TABLE 5.10

WEEKLY AIR MONITORING DATA - TEST CONDITION 1
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 15 weeks	T = 16 weeks	T = 17 weeks	T = 18 weeks	T = 19 weeks	T = 21 weeks	T = 23 weeks	T = 24 weeks
	Sample Date	3/3/00	3/10/00	3/17/00	3/24/00	3/31/00	4/14/00	4/28/00	5/5/00
Parameter	*Units*								
Vacuum Pressure	inches Water	7	6	8	7	6	12	10	15
Flow	cc/min	50	50	50	51	49	50	50	50
Temperature	°C	23	22	22	23	23	23	22	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.6	21	20.4	20.3	20.5	20.6	20.2	20.3
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	296	303	300	305	300	310	251	299

TABLE 5.10

WEEKLY AIR MONITORING DATA - TEST CONDITION 1
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 25 weeks	T = 26 weeks	T = 29 weeks	T = 30 weeks	T = 35 weeks	T = 42 weeks
	Sample Date	5/12/00	5/19/00	6/9/00	6/16/00	7/18/00	9/6/00
Parameter	*Units*						
Vacuum Pressure	inches Water	20	20	21	21	22	22
Flow	cc/min	50	50	52	50	50	50
Temperature	°C	23	21	20	22	21	21
CH_4	%	0	0	0	0	0	0
O_2	%	20.2	20.2	20.2	20.1	20.2	20.1
CO_2	%	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0
PID	ppm	309	286	300	254	260	250

Notes:

cc/min	Cubic centimeters per minute
CH_4	Methane
CO_2	Carbon Dioxide
LEL	Lower Explosive Limit
O_2	Oxygen
PID	*Photoionization Detector*
ppm	Parts per million

TABLE 5.11

WEEKLY AIR MONITORING DATA - TEST CONDITION 2
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 1 Day	T = 1.5 weeks	T = 2.5 weeks	T = 4 weeks	T = 5 weeks	T = 6 weeks	T = 7 weeks	T = 7.5 weeks
	Sample Date	11/19/99	11/29/99	12/6/99	12/17/99	12/25/99	1/1/00	1/7/00	1/11/00
Parameter	*Units*								
Vacuum Pressure	inches Water	18	18	18	26	26	18	10.5	10.5
Flow	cc/min	41	50	51	50	50	50	150	50
Temperature	°C	21	22	21	21	21	23	23	22
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	18.1	17.9	20.4	18	18	17.8	18	19.2
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	>2000	>2000	1514	1213	1160	1702	1611	1952

TABLE 5.11

WEEKLY AIR MONITORING DATA - TEST CONDITION 2
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 8 weeks	T = 8.5 weeks	T = 9 weeks	T = 10 weeks	T = 11 weeks	T = 12 weeks	T = 13 weeks	T = 14 weeks
	Sample Date	1/14/00	1/18/00	1/21/00	1/28/00	2/4/00	2/11/00	2/18/00	2/25/00
Parameter	*Units*								
Vacuum Pressure	inches Water	12	8	6	6	10	10	6	10
Flow	cc/min	51	49	50	50	50	50	51	10
Temperature	°C	23	23	21	22	23	22	22	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.8	20.2	20.6	20.9	20.1	20	20	20
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	>2000	>2000	1853	1709	908	1001	1111	1200

TABLE 5.11

WEEKLY AIR MONITORING DATA - TEST CONDITION 2
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 15 weeks	T = 16 weeks	T = 17 weeks	T = 18 weeks	T = 19 weeks	T = 21 weeks	T = 23 weeks	T = 24 weeks
	Sample Date	3/3/00	3/10/00	3/17/00	3/24/00	3/31/00	4/14/00	4/28/00	5/5/00
Parameter	*Units*								
Vacuum Pressure	inches Water	7	7	8	8	7	12	12	15
Flow	cc/min	10	9	10	10	10	9	10	10
Temperature	°C	23	22	22	23	23	23	22	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.7	20.8	20.4	20.5	20.5	20.6	20.1	20.2
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	1300	1211	1272	1250	1309	1350	633	752

TABLE 5.11

WEEKLY AIR MONITORING DATA - TEST CONDITION 2
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 25 weeks	T = 26 weeks	T = 29 weeks	T = 30 weeks	T = 35 weeks	T = 42 weeks
	Sample Date	5/12/00	5/19/00	6/9/00	6/16/00	7/18/00	9/6/00
Parameter	*Units*						
Vacuum Pressure	inches Water	20	20	22	21	22	22
Flow	cc/min	10	10	9	10	10	10
Temperature	°C	23	22	20	20	21	21
CH_4	%	0	0	0	0	0	0
O_2	%	20.2	20.2	20.4	20.2	20.2	20.1
CO_2	%	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0
PID	ppm	741	777	790	940	922	929

Notes:

cc/min	Cubic centimeters per minute
CH_4	Methane
CO_2	Carbon Dioxide
LEL	Lower Explosive Limit
O_2	Oxygen
PID	Photoionization Detector
ppm	Parts per million

TABLE 5.12

WEEKLY AIR MONITORING DATA - TEST CONDITION 3
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 1 Day	T = 1.5 weeks	T = 2.5 weeks	T = 4 weeks	T = 5 weeks	T = 6 weeks	T = 7 weeks	T = 7.5 weeks
	Sample Date	11/19/99	11/29/99	12/6/99	12/17/99	12/25/99	1/1/00	1/7/00	1/11/00
Parameter	*Units*								
Vacuum Pressure	inches Water	18	18	18	28	28	20	10.5	10.5
Flow	cc/min	40	50	50	50	51	50	150	50
Temperature	°C	22	21	21	21	21	23	23	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	18	18	20.4	18	18	17.8	18	18.2
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	>2000	>2000	1502	1480	990	1071	999	1007

TABLE 5.12

WEEKLY AIR MONITORING DATA - TEST CONDITION 3
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 8 weeks	T = 8.5 weeks	T = 9 weeks	T = 10 weeks	T = 11 weeks	T = 12 weeks	T = 13 weeks	T = 14 weeks
	Sample Date	1/14/00	1/18/00	1/21/00	1/28/00	2/4/00	2/11/00	2/18/00	2/25/00
Parameter	*Units*								
Vacuum Pressure	inches Water	12	8	6	6	10	9.5	9.5	7
Flow	cc/min	51	50	49	50	50	50	51	10
Temperature	°C	23	21	21	22	23	22	22	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.8	20.6	20.6	20.9	20.4	20.1	19.9	21
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	1890	1770	1411	1294	808	665	702	700

TABLE 5.12

WEEKLY AIR MONITORING DATA - TEST CONDITION 3
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 15 weeks	T = 16 weeks	T = 17 weeks	T = 18 weeks	T = 19 weeks	T = 21 weeks	T = 23 weeks	T = 24 weeks
	Sample Date	3/3/00	3/10/00	3/17/00	3/24/00	3/31/00	4/14/00	4/28/00	5/5/00
Parameter	*Units*								
Vacuum Pressure	inches Water	7	7	8	8	7	11	11	20
Flow	cc/min	10	10	9	10	10	10	10	9
Temperature	°C	23	22	22	23	23	23	23	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.6	20.7	20.4	20.4	20.6	20.5	20.2	20.2
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	677	649	667	680	679	669	1384	807

TABLE 5.12

WEEKLY AIR MONITORING DATA - TEST CONDITION 3
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 25 weeks	T = 26 weeks	T = 29 weeks	T = 30 weeks	T = 35 weeks	T = 42 weeks
	Sample Date	5/12/00	5/19/00	6/9/00	6/16/00	7/18/00	9/6/00
Parameter	***Units***						
Vacuum Pressure	inches Water	20	20	22	22	22	22
Flow	cc/min	10	10	10	10	10	10
Temperature	°C	23	21	20	20	21	21
CH_4	%	0	0	0	0	0	0
O_2	%	20.2	20.2	20.1	20.2	20.2	20.1
CO_2	%	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0
PID	ppm	873	800	566	375	340	380

Notes:

cc/min	Cubic centimeters per minute
CH_4	Methane
CO_2	Carbon Dioxide
LEL	Lower Explosive Limit
O_2	Oxygen
PID	Photoionization Detector
ppm	Parts per million

TABLE 5.13

WEEKLY AIR MONITORING DATA - TEST CONDITION 4
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 1 Day	T = 1.5 weeks	T = 2.5 weeks	T = 4 weeks	T = 5 weeks	T = 6 weeks	T = 7 weeks	T = 7.5 weeks
	Sample Date	11/19/99	11/29/99	12/6/99	12/17/99	12/25/99	1/1/00	1/7/00	1/11/00
Parameter	*Units*								
Vacuum Pressure	inches Water	18	18	18	27	27	20	9.5	9.5
Flow	cc/min	40	50	50	51	50	50	150	51
Temperature	°C	22	21	21	21	21	23	23	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	18	18	20.5	18.1	18	17.8	17.9	20
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	>2000	>2000	1520	1305	1024	1261	1876	1835

TABLE 5.13

WEEKLY AIR MONITORING DATA - TEST CONDITION 4
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 8 weeks	T = 8.5 weeks	T = 9 weeks	T = 10 weeks	T = 11 weeks	T = 12 weeks	T = 13 weeks	T = 14 weeks
	Sample Date	1/14/00	1/18/00	1/21/00	1/28/00	2/4/00	2/11/00	2/18/00	2/25/00
Parameter	*Units*								
Vacuum Pressure	inches Water	12	8	6	6	9	9	9	NA
Flow	cc/min	50	49	50	50	51	50	50	NA
Temperature	°C	21	21	21	22	23	22	22	23
CH_4	%	0	0	0	0	0	0	0	NA
O_2	%	20.9	20.7	20.7	20.5	18.7	20.1	20	NA
CO_2	%	0	0	0	0	0	0	0	NA
LEL	%	0	0	0	0	0	0	0	NA
PID	ppm	>2000	1801	1600	1222	905	999	925	NA

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TABLE 5.13

WEEKLY AIR MONITORING DATA - TEST CONDITION 4
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 15 weeks	T = 16 weeks	T = 17 weeks	T = 18 weeks	T = 19 weeks	T = 21 weeks	T = 23 weeks	T = 24 weeks
	Sample Date	3/3/00	3/10/00	3/17/00	3/24/00	3/31/00	4/14/00	4/28/00	5/5/00
Parameter	*Units*								
Vacuum Pressure	inches Water	NA	NA	NA	NA	NA	NA	NA	16
Flow	cc/min	NA	NA	NA	NA	NA	NA	9	10
Temperature	°C	NA	22	NA	22	NA	NA	22	23
CH_4	%	NA	NA	NA	NA	NA	NA	0	0
O_2	%	NA	NA	NA	NA	NA	NA	20.1	20.2
CO_2	%	NA	NA	NA	NA	NA	NA	0	0
LEL	%	NA	NA	NA	NA	NA	NA	0	0
PID	ppm	NA	NA	NA	NA	NA	NA	1264	1201

TABLE 5.13

WEEKLY AIR MONITORING DATA - TEST CONDITION 4
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 25 weeks	**T = 26 weeks**	**T = 29 weeks**	**T = 30 weeks**	**T = 35 weeks**	**T = 42 weeks**
	Sample Date	5/12/00	5/19/00	6/9/00	6/16/00	7/18/00	9/6/00
Parameter	***Units***						
Vacuum Pressure	inches Water	16	16	17	22	22	22
Flow	cc/min	10	9	10	10	9	10
Temperature	°C	23	21	20	20	21	21
CH_4	%	0	0	0	0	0	0
O_2	%	20.3	20.2	20.2	18.4	19	20.2
CO_2	%	0	0	0	2.8	2.2	2
LEL	%	0	0	0	0	0	0
PID	ppm	1194	1111	809	799	882	876

Notes:

cc/min	Cubic centimeters per minute
CH_4	Methane
CO_2	Carbon Dioxide
LEL	Lower Explosive Limit
O_2	Oxygen
PID	Photoionization Detector
ppm	Parts per million

TABLE 5.14

WEEKLY AIR MONITORING DATA - TEST CONDITION 5
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 1 Day	T = 1.5 weeks	T = 2.5 weeks	T = 4 weeks	T = 5 weeks	T = 6 weeks	T = 7 weeks	T = 7.5 weeks
	Sample Date	11/19/99	11/29/99	12/6/99	12/17/99	12/25/99	1/1/00	1/7/00	1/11/00
Parameter	*Units*								
Vacuum Pressure	inches Water	18	18	18	27	27	20	9.5	10
Flow	cc/min	41	50	50	51	50	50	150	49
Temperature	°C	21	21	21	21	21	23	23	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	18	18	20.6	18.2	18	17.8	17.9	20
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	>2000	>2000	1474	1329	1499	1029	956	1257

TABLE 5.14

WEEKLY AIR MONITORING DATA - TEST CONDITION 5
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 8 weeks	T = 8.5 weeks	T = 9 weeks	T = 10 weeks	T = 11 weeks	T = 12 weeks	T = 13 weeks	T = 14 weeks
	Sample Date	1/14/00	1/18/00	1/21/00	1/28/00	2/4/00	2/11/00	2/18/00	2/25/00
Parameter	***Units***								
Vacuum Pressure	inches Water	12	8	6	6	10	9.5	9	8
Flow	cc/min	50	51	51	50	50	50	50	51
Temperature	°C	23	20	20	22	23	22	22	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.8	20.5	20.6	20.8	19	20	20.2	20.1
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	>2000	1338	1171	990	965	1001	1009	1212

TABLE 5.14

WEEKLY AIR MONITORING DATA - TEST CONDITION 5
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 15 weeks	T = 16 weeks	T = 17 weeks	T = 18 weeks	T = 19 weeks	T = 21 weeks	T = 23 weeks	T = 24 weeks
	Sample Date	3/3/00	3/10/00	3/17/00	3/24/00	3/31/00	4/14/00	4/28/00	5/5/00
Parameter	*Units*								
Vacuum Pressure	inches Water	6	7	6	6	6	11	13	16
Flow	cc/min	50	50	50	50	51	50	50	50
Temperature	°C	23	22	22	23	23	23	23	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.7	20.7	20.5	20.6	20.4	20.5	20.5	20.4
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	991	997	985	1001	996	1000	1532	1233

TABLE 5.14

WEEKLY AIR MONITORING DATA - TEST CONDITION 5
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 25 weeks	T = 26 weeks	T = 29 weeks	T = 30 weeks	T = 35 weeks	T = 42 weeks
	Sample Date	5/12/00	5/19/00	6/9/00	6/16/00	7/18/00	9/6/00
Parameter	*Units*						
Vacuum Pressure	inches Water	16	16	18	22	22	21
Flow	cc/min	50	50	51	50	50	50
Temperature	°C	23	21	20	20	21	21
CH_4	%	0	0	0	0	0	0
O_2	%	20.2	20.2	20.3	20.3	20.2	20.1
CO_2	%	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0
PID	ppm	1301	1350	1205	921	910	950

Notes:

cc/min Cubic centimeters per minute
CH_4 Methane
CO_2 Carbon Dioxide
LEL Lower Explosive Limit
O_2 Oxygen
PID Photoionization Detector
ppm Parts per million

TABLE 5.15

WEEKLY AIR MONITORING DATA - TEST CONDITION 6
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 1 Day	T = 1.5 weeks	T = 2.5 weeks	T = 4 weeks	T = 5 weeks	T = 6 weeks	T = 7 weeks	T = 7.5 weeks
	Sample Date	11/19/99	11/29/99	12/6/99	12/17/99	12/25/99	1/1/00	1/7/00	1/11/00
Parameter	*Units*								
Vacuum Pressure	inches Water	NA	NA	NA	NA	NA	NA	NA	NA
Flow[(1)]	cc/min	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	21	21	21	21	21	23	23	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.5	20.4	20.6	18.1	18	17.8	17.8	19.1
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	>2000	>2000	1440	1392	1936	1879	1942	1959

TABLE 5.15

WEEKLY AIR MONITORING DATA - TEST CONDITION 6
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 8 weeks	T = 8.5 weeks	T = 9 weeks	T = 10 weeks	T = 11 weeks	T = 12 weeks	T = 13 weeks	T = 14 weeks
	Sample Date	1/14/00	1/18/00	1/21/00	1/28/00	2/4/00	2/11/00	2/18/00	2/25/00
Parameter	*Units*								
Vacuum Pressure	inches Water	NA	NA	NA	NA	NA	NA	NA	NA
Flow(1)	cc/min	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	23	20	19	22	23	22	22	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.8	20.5	20.7	20.6	20.1	20.1	20.2	20.1
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	>2000	1974	1762	1633	1524	1777	1805	1911

TABLE 5.15

WEEKLY AIR MONITORING DATA - TEST CONDITION 6
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 15 weeks	T = 16 weeks	T = 17 weeks	T = 18 weeks	T = 19 weeks	T = 21 weeks	T = 23 weeks	T = 24 weeks
	Sample Date	3/3/00	3/10/00	3/17/00	3/24/00	3/31/00	4/14/00	4/28/00	5/5/00
Parameter	*Units*								
Vacuum Pressure	inches Water	NA	NA	NA	NA	NA	NA	NA	NA
Flow(1)	cc/min	NA	NA	NA	NA	NA	NA	NA	NA
Temperature	°C	23	20	22	23	23	23	22	23
CH_4	%	0	0	0	0	0	0	0	0
O_2	%	20.8	20.7	20.5	20.6	20.5	20.5	20.2	20.2
CO_2	%	0	0	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0	0	0
PID	ppm	1881	18.3	1800	1872	1866	1880	1488	1562

TABLE 5.15

WEEKLY AIR MONITORING DATA - TEST CONDITION 6
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

		T = 25 weeks	T = 26 weeks	T = 29 weeks	T = 30 weeks	T = 35 weeks	T = 42 weeks
	Sample Date	5/12/00	5/19/00	6/9/00	6/16/00	7/18/00	9/6/00
Parameter	***Units***						
Vacuum Pressure	inches Water	NA	NA	NA	NA	NA	NA
Flow(1)	cc/min	NA	NA	NA	NA	NA	NA
Temperature	°C	23	21	20	20	21	21
CH_4	%	0	0	0	0	0	0
O_2	%	20.2	20.2	20.1	20.2	20.2	20.2
CO_2	%	0	0	0	0	0	0
LEL	%	0	0	0	0	0	0
PID	ppm	1588	1536	1377	1010	1172	1910

Notes:

(1) *There was no flow passing through* the tank for the duration of this study.

cc/min Cubic centimeters per minute

CH_4 Methane

CO_2 Carbon Dioxide

LEL Lower Explosive Limit

O_2 Oxygen

PID *Photoionization Detector*

ppm Parts per million

TABLE 5.16

WEEKLY AIR MONITORING DATA - DICHLOROBENZENES
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

Test Condition 1

Parameter	*Units*	11/28/99	12/17/99	12/25/99	01/01/00	01/07/00	01/14/00	01/21/00	01/28/00	02/04/00	02/11/00	02/18/00	02/25/00	03/03/00
Collection Date:														
1,2-DCB	µg/L of air	27	5.5	12	6.3	5.6	7.4	9.9	2.5	8.6	1.6	6.5	4.9	3.4
1,3-DCB	µg/L of air	18	0.75	1.7	2.3	12	1.4	11	12	1.1	0	3.6	0.80	0.69
1,4-DCB	µg/L of air	17	3.0	6.3	7.2	22	32	46	21	31	15	35	25	23

Test Condition 2

Collection Date:		11/19/99	11/28/99	12/17/99	12/25/99	01/01/00	01/07/00	01/14/00	01/21/00	01/28/00	02/04/00	02/11/00	02/18/00	02/25/00	03/03/00
1,2-DCB	µg/L of air	0	1.5	21	24	16	12	7.0	16	7.0	14	5.4	7.7	7.4	7.4
1,3-DCB	µg/L of air	0	1.6	3.5	4.0	2.7	2.5	1.6	3.0	2.8	2.4	2.2	1.7	1.4	1.5
1,4-DCB	µg/L of air	0	9.7	49	72	46	54	67	190	150	170	110	100	120	170

Test Condition 3

Collection Date:		11/19/99	11/28/99	12/17/99	12/25/99	01/01/00	01/07/00	01/14/00	01/21/00	01/28/00	02/04/00	02/11/00	02/18/00	02/25/00	03/03/00
1,2-DCB	µg/L of air	1.7	5.8	21	21	26	7.8	11	14	12	2.1	8.4	8.1	6.9	5.2
1,3-DCB	µg/L of air	1.4	3.8	5.7	5.1	6.1	2.2	2.5	4.2	5.3	0.56	4.9	2.8	4.9	2.8
1,4-DCB	µg/L of air	11	3.8	140	130	160	58	160	190	98	4.0	82	110	100	90

Test Condition 4

Collection Date:		11/18/99	11/28/99	12/17/99	12/25/99	01/01/00	01/07/00		01/21/00	01/28/00	02/04/00	02/11/00	02/18/00
1,2-DCB	µg/L of air	2.7	4.9	26	20	30	16		17	12	1.9	12	4.8
1,3-DCB	µg/L of air	2.5	3.1	9.0	7.0	8.9	4.8		5.3	3.9	0.54	3.6	2.0
1,4-DCB	µg/L of air	5.4	4.2	260	220	250	200		260	160	26	150	110

Test Condition 5

Collection Date:		11/18/99	11/28/99	12/17/99	12/25/99	01/01/00	01/07/00	01/14/00	01/21/00	01/28/00	02/04/00	02/11/00	02/18/00	02/25/00	03/03/00
1,2-DCB	µg/L of air	2.3	10	31	14	20	8.3	18	23	11	7.2	22	5.9	6.3	5.4
1,3-DCB	µg/L of air	2.2	6.8	13	8.0	6.9	5.2	15	35	3.8	2.2	12	2.0	4.0	2.5
1,4-DCB	µg/L of air	9.1	86	380	160	220	93	270	450	160	130	390	120	120	130

Test Condition 6

Collection Date:		12/17/99	12/25/99	01/01/00	01/07/00	01/14/00	01/21/00	01/28/00	02/04/00	02/11/00	02/18/00	02/25/00	03/03/00
1,2-DCB	µg/L of air	51	20	41	2.8	23	30	30	17	32	29	25	24
1,3-DCB	µg/L of air	19	14	12	1.1	15	15	19	6.7	24	11	10	8.6
1,4-DCB	µg/L of air	601	392	471	54	399	450	563	315	658	542	529	561

TABLE 5.16

WEEKLY AIR MONITORING DATA - DICHLOROBENZENES
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

Test Condition 1

Parameter	*Units*											
Collection Date:		03/10/00	03/17/00	03/24/00	03/31/00	04/10/00	04/28/00	05/05/00	06/19/00	07/18/00	09/06/00	12/01/00
1,2-DCB	µg/L of air	2.0	2.6	3.1	1.5	2.8	1.9	2.4	2.0	1.0	4.7	0
1,3-DCB	µg/L of air	0	0.52	0.50	0	0	0.70	0.82	0	0	4.8	11
1,4-DCB	µg/L of air	14	21	15	0.75	12	9.0	10	12	7.3	0.93	2.0

Test Condition 2

Parameter	*Units*											
Collection Date:		03/10/00	03/17/00	03/24/00	04/10/00	04/28/00	05/05/00	05/05/00	06/19/00	07/18/00	09/06/00	12/01/00
1,2-DCB	µg/L of air	5.7	4.1	4.6	3.9	2.5	2.8	2.1	1.8	1.8	1.2	3.5
1,3-DCB	µg/L of air	1.1	1.0	0.78	0.85	0.65	0.79	0.54	0	1.1	6.2	16
1,4-DCB	µg/L of air	100	71	66	59	35	32	29	18	0.64	0	0.72

Test Condition 3

Parameter	*Units*											
Collection Date:		03/10/00	03/17/00	03/24/00	04/10/00	04/28/00	05/05/00	05/05/00	06/19/00	07/18/00	09/06/00	12/01/00
1,2-DCB	µg/L of air	5.5	4.4	4.3	2.9	3.0	3.0	4.4	3.0	5.5	0	0
1,3-DCB	µg/L of air	1.3	1.1	1.0	0.71	0.76	0.69	0.96	0.63	1.4	3.5	67
1,4-DCB	µg/L of air	81	67	60	40	88	1.0	1.8	0.71	2.2	0	1.8

Test Condition 4

Parameter	*Units*											
Collection Date:						04/28/00	05/05/00	05/05/00	06/19/00	07/18/00	09/06/00	
1,2-DCB	µg/L of air					1.9	2.0	1.6	0.82	3.6	0	
1,3-DCB	µg/L of air					0.72	0.67	0.80	0.74	1.3	0.76	
1,4-DCB	µg/L of air					58	1.1	0.82	38	1.1	0	

Test Condition 5

Parameter	*Units*										
Collection Date:		03/10/00	03/17/00	03/24/00	04/10/00	04/28/00	05/05/00	05/05/00	06/19/00	07/18/00	09/06/00
1,2-DCB	µg/L of air	5.3	4.6	3.7	3.5	2.6	2.6	3.0	2.1	2.1	0
1,3-DCB	µg/L of air	1.6	1.3	1.1	0.89	0.86	0.53	0.66	0.77	0.99	1.9
1,4-DCB	µg/L of air	110	92	74	53	120	0.91	0.90	0.71	1.3	0

Test Condition 6

Parameter	*Units*										
Collection Date:		03/10/00	03/17/00	03/24/00	04/10/00	04/28/00	05/05/00	05/05/00	06/19/00	07/18/00	09/06/00
1,2-DCB	µg/L of air	27	23	14	12	5.3	5.6	12	5.4	9.2	0
1,3-DCB	µg/L of air	11	9.4	6.1	4.6	2.2	2.6	0.54	0.53	0.69	0
1,4-DCB	µg/L of air	683	563	396	289	224	181	7.1	2.7	4.3	1.9

Notes:
Blank entries indicate data not available.
1,2-DCB 1,2-Dichlorobenzene
1,3-DCB 1,3-Dichlorobenzene
1,4-DCB 1,4-Dichlorobenzene

TABLE 6.1

PERCENT REDUCTION IN COC CONCENTRATIONS
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

Parameters	Units	*Test Condition* 1	2	3	4	5	6
VOCs							
Benzene	%	ND	ND	ND	ND	ND	ND
Toluene	%	ND	ND	ND	ND	ND	ND
Chlorobenzene	%	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	%	100	100	100	100	100	100
1,3-Dichlorobenzene	%	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	%	>99	86	82	82	74	47
SVOCs							
1,2,3-Trichlorobenzene	%	83	68	74	80	79	69
1,2,4-Trichlorobenzene	%	88	74	80	82	84	70
1,3,5-Trichlorobenzene	%	ND	ND	ND	ND	ND	ND
1,2,3,4-Tetrachlorobenzene	%	59	44	48	64	48	51
1,2,4,5-Tetrachlorobenzene	%	23	48	58	81	57	57
Pentachlorobenzene	%	48	40	26	56	35	37
Hexachlorobenzene	%	ND	ND	ND	ND	ND	ND
Nitrobenzene	%	ND	ND	ND	ND	ND	ND

Notes:

ND Non-detect.
SVOCs Semi-volatile organic compounds.
VOCs Volatile organic compounds.

TABLE 7.1

REDUCTION IN COCs AFTER 9.5 MONTHS TREATMENT
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Test Condition	1	2	3	4	5	6
	Units						
Total COCs Concentration in Untreated Soils	mg/Kg	104760	313560	313560	313560	313560	313560
Final COCs Concentration in Treated Soils	mg/Kg	14775	47550	55350	57180	79830	163395
Amount of COCs Lost	*mg/Kg*	89985	266010	258210	256380	233730	150165
Amount of COCs on Carbon	mg/Kg	38856	38790	49910	12076	31754	-
Amount of DCB on Carbon	mg/Kg	4695	18395	23540	5818	15172	-
Amount of DCB detected in Air	µg/L	443	818	954	1744	2255	-
Percent of COC Loss on Carbon	%	43	15	19	4.7	14	-

Notes:
COCs Compounds of Concern
DCB Dichlorobenzene

TABLE 7.2

CALCULATED TREATMENT TIMES AND DEGRADATION RATES
BIODEGRADATION TREATABILITY STUDY
BIOTREATABILITY SOIL PILE STUDIES
METACHEM PRODUCTS
NEW CASTLE, DELAWARE

	Criteria (ppm)	*Test Condition 1*	*Test Condition 2*	*Test Condition 3*	*Test Condition 4*	*Test Condition 5*	*Test Condition 6*
1,4-Dichlorobenzene	450[1]	$y = 346.34e^{-0.6065x}$	$y = 14860e^{-0.1855x}$	$y = 14570e^{-0.1634x}$	$y = 15541e^{-0.1438x}$	$y = 17349e^{-0.1369x}$	$y = 20660e^{-0.0594x}$
Time to Reach Clean up Criteria		< 450 ppm initial	19 months	21 months	25 months	27 months	65 months
Degradation Rates		NA	187 mg/Kg/month	194 mg/Kg/month	137 mg/Kg/month	126 mg/Kg/month	36 mg/Kg/month
Time to Reach "20 Rule" TCLP Criteria[2]	150	NA	25 months	28 months	33 months	35 months	83 months
Total Chlorobenzenes	625[1]	$y = 5244.3e^{-0.1858x}$	$y = 15631e^{-0.1799x}$	$y = 15209e^{-0.1625x}$	$y = 19092e^{-0.1584x}$	$y = 18049e^{-0.1365x}$	$y = 21384e^{-0.0607x}$
Time to Reach Clean up Criteria		11 months	18 months	20 months	22 months	25 months	58 months
Degradation Rates		232 mg/Kg/month	221 mg/Kg/month	217 mg/Kg/month	150 mg/Kg/month	147 mg/Kg/month	45 mg/Kg/month

Notes:
(1) Clean up criteria established by USEPA ROD based on human health risk assessment.
(2) TCLP Criteria for 1,4-DCB = 7.5 mg/L.
"20 Rule" Criteria = 20x7.5=150mg/L=150 ppm.
NA Not applicable
ppm Parts per million
TCLP Toxicity Characteristic Leaching Procedure

APPENDICES

A

APPENDIX A

MODIFICATIONS TO EXPERIMENTAL DESIGN

BENCH-SCALE BIOVENTING TREATABILITY STUDY
MODIFICATIONS TO EXPERIMENTAL DESIGN

ORIGINAL DESIGN	MODIFIED DESIGN	RATIONALE
Test cells constructed of pressure treated wood	Stainless steel containers used for test cells	Avoid possible airflow channeling
Ten percent wood chips used as a bulking agent	Five percent vermiculite used as bulking agent	Eliminate potential inconsistencies in analytical data associated with organic matter in wood
Animal manure used for nutrient amendment	Inorganic fertilizer (dipotassium phosphate and urea) used for nitrogen and phosphorus amendment	Greater uniformity and control of nutrient amendments and reduced potential for inconsistencies in analytical data associated with organic matter
Aerobic samples to be aerated at a rate of 144 soil pore volumes per day	Aerobic samples to be aerated at a rate of 10 soil pore volumes per day for first month and one pore volume per day thereafter[(1)]	Reduce water loss and more closely simulate full-scale operation
Four treatments [aerobic bioventing of upland soils, aerobic bioventing of soil pile material, aerobic bioventing of soil pile material amended with bulking agents and nutrients, pulsed (aerobic/anaerobic) treatment of soil pile material] and one control	Five treatments [soil vapor extraction of upland soils, soil vapor extraction of soil pile material[(2)], aerobic bioventing of soil pile material, aerobic bioventing of soil pile material amended with bulking agents and nutrients, pulsed (aerobic/anaerobic) treatment of soil pile material[(3)]] and one control	Evaluate potential for enhanced treatment through reduction of high concentrations of organic contaminants by soil vapor extraction in conjunction with bilogicla degradation

NOTES:

1. A low microbial count was observed in the pre-test sample analysis which may be attributable to chlorinated benzene toxicity. Initially aerating at the rate of ten pore volumes per day is intended to vapor extract some of the chlorinated benzenes and reduce or eliminate any associated toxicity.
2. Soil vapor treatments will be aerated at a constant rate of ten pore volumes throughout the test program.
3. A low concentration (0.01%) of food grade molasses may be added to accelerate the development of anaerobic conditions.

B

APPENDIX B

CHAIN OF CUSTODY

H... Lav... Assoc...
Two Valley Square Ste. 100
512 Township Line Road
Blue Bell, PA 19422
(215) 646 3344 • FAX (215) 646 4115

C... IN ... CU...OD... OR...

Lab: HLA / Novato

Project Number: 41827.5010.1
Name/Location: Metachem / Delaware City, DE
Project Manager: Greg Albright

Samplers: Steve Brecker
Greg Albright
Recorder: [signature] (Signature Required)

ANALYSIS REQUESTED: EPA 601/8010, EPA 602/8020, EPA 624/8240, EPA 625/8270, METALS, EPA 8015M/TPHg, EPA 8020/BTEX, EPA 8015M/TPHd,o, ADHS BLS-181, Bio-Pile Study

SOURCE CODE	MATRIX: Soil	# CONTAINERS & PRESERV.: Unpres.	DATE Yr	Mo	Day	Time	STATION DESCRIPTION/ NOTES	Bio-Pile Study
49	X	1	99	05	27	0945	BPS-1 (soil piles)	X
49	X	1	↓	↓	↓	1055	BPS-2 (soil piles)	X
49	X	1	↓	↓	↓	1110	BPS-3 (soil piles)	X
~~49~~	~~X~~	~~1~~	↓	↓	↓	~~1135~~	~~BPS-4~~	~~X~~ SKB
49	X	1	↓	↓	↓	1455	BPS-5 (uplands)	X

LAB NUMBER (Yr, Wk, Seq) | DEPTH IN FEET | COL MTD CD | QA CODE | MISCELLANEOUS: Drums

CHAIN OF CUSTODY RECORD

RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature)	DATE/TIME
[signature]	[signature]	5/27 1530
RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature) [signature]	5/28 1300
RELINQUISHED BY: (Signature) [signature]	RECEIVED BY: (Signature)	DATE/TIME
RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature)	DATE/TIME

DISPATCHED BY: (Signature) | DATE/TIME | RECEIVED FOR LAB BY: (Signature) | DATE/TIME

METHOD OF SHIPMENT

SAMPLE CONDITION WHEN RECEIVED BY THE LABORATORY

AR300105

Laboratory Copy White | Project Office Copy Yellow | Field or Office Copy Pink

C

APPENDIX C

DATA VALIDATION/USABILITY REPORT

CONESTOGA-ROVERS & ASSOCIATES
2055 Niagara Falls Blvd., Suite #3
Niagara Falls, New York 14304
Telephone: (716) 297-6150 Fax: (716) 297-2265
www.CRAworld.com

MEMORANDUM

TO:	Alan Weston	REF. NO.:	14246
FROM:	Deborah Andrasko/js/1	DATE:	March 13, 2001
RE:	**Metachem Data Validation/Usability Report**		

INTRODUCTION

Soil samples were collected from November 1999 through November 2000 and analyzed in support of the Metachem treatability study. Samples were analyzed for Site-Specific Parameter List (SSPL) volatile organic compounds (VOCs) and SSPL semi-volatile organic compounds (SVOCs) using modified United States Environmental Protection Agency (USEPA) Methods 8021 and 8121, respectively.

The data quality was assessed based on final sample results, laboratory blank results, laboratory duplicates, and blank spike, and surrogate recoveries.

QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) ASSESSMENT

Initial calibration consisted of a five-point calibration curve in most instances. Some of the VOCs were quantitated using the response of a single level standard or the averaged response of the initial and ending single level standards. Generally, all calibration indicated acceptable instrument sensitivity.

Continuing calibration standards were analyzed for all SVOCs and VOCs with the exception of the VOC single point calibrations. Some of the analytes did not meet method criteria due to decreased or increased response, indicating possible bias of the associated sample results, but in all instances sufficient sensitivity was achieved.

Method blanks were prepared and/or analyzed with each batch of samples. Target analytes were not detected above the reporting limit in the method blanks.

Blank spikes were prepared and analyzed with each batch of SVOC samples and all recoveries were acceptable.

Surrogates were added to all VOC and SVOC samples prior to extraction and/or analysis. SVOC sample surrogate recoveries could not be assessed due to dilutions necessitated by the sample concentrations of target analytes. SVOC analytical efficiency was judged to be acceptable based on good surrogate recoveries for the blanks and blank spikes. All VOC recoveries were acceptable indicating good laboratory accuracy.

Laboratory duplicates were prepared and analyzed for most of the SVOC analytical batches and results were comparable, indicating acceptable laboratory precision.

REGISTERED COMPANY
ISO 9001
ENGINEERING DESIGN

CONCLUSION

Significant quality control problems were not observed during the review and sample results reported were judged acceptable for their intended use.