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THE EFFECT OF SOIL
MOISTURE ON THE OZONATION
OF PYRENE IN SOILS

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James E. Day

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Susan J. Masten
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THE EFFECT OF SOIL MOISTURE ON THE OZONATION
OF PYRENE IN SOILS

By

James Edward Day

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ABSTRACT

THE EFFECT OF SOIL MOISTURE ON THE OZONATION OF PYRENE IN SOILS

By

James E. Day

This study demonstrates the feasibility of in-situ ozone vapor stripping. The ability to satisfy the ozone demand of several soils was demonstrated, and the effect of soil moisture on the oxidation of pyrene was studied.

Ozone breakthrough was achieved in Ottawa sand and a Metea soil (from Michigan) in experiments conducted in 10 cm. soil columns. The ozone demand for these systems could be satisfied as the effluent ozone concentration from the soil column increased from zero to the ozone concentration in the influent line.

The results obtained from the experiments conducted in pyrene contaminated soils suggest that the decomposition of ozone, and the degradation of pyrene, is dependent on the surface area coverage of the soil particles. The oxidation of 100 ppm pyrene contaminated dry Metea soil using an ozone mass of 28 mg was demonstrated by 82% removal of the contaminant. In moist soil systems, it was demonstrated by the removal of 57% of the pyrene using an ozone mass of 29 mg. The moisture content of the system was approximately 3%, and the experiments were ozone limited batch reactions.

These results suggest that the oxidation of pyrene in dry and moist soil systems is the result of the direct reaction of ozone with the surface adsorbed pyrene. There is no quantifiable improvement in the treatment efficiency due to an indirect reaction mechanism involving OH radicals generated by the reaction of ozone and soil moisture.

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LIST OF ABBREVIATIONS

Abbreviation	Description
PAHs	Polycyclic Aromatic Hydrocarbons
EPA	Environmental Protection Agency
M	Solutes
R	Organic Radical
VOCs	Volatile Organic Compounds
KI	Potassium Iodide
HPLC	High Performance Liquid Chromatography
ASTM	Am. Society for Testing & Materials
BET	Brunauer, Emmet, and Teller
UV/VIS	Ultra-violet/Visible
FID	Flame Ionization Detector
GC	Gas Chromatography
QA/QC	Quality Assurance/Quality Control
tBuOH	Tertiary-Butyl Alcohol
NaOH	Sodium Hydroxide
ppm	part per million
K_2SO_4	Potasium Sulfate
DI	De-Ionized
M	Molarity
SCFM	Standard Cubic Feet per Minute
kWh	kilowatt-hour
SEE	Standard Error of the Estimate
r^2	Coefficient of Determination
SE	Standard Error
OM	Organic Matter
RH	Relative Humidity

CHAPTER I

INTRODUCTION

The environmental importance of polycyclic aromatic hydrocarbons (PAHs) is made apparent by many different factors. These factors include the pathways of introduction into the environment, the extent to which they physically exist in the environment, and the biodegradability and carcinogenicity of these compounds. PAHs are introduced into the environment through many natural processes, as well as through anthropogenic processes. Sources of naturally occurring PAHs are volcanic eruptions and natural wildfires, and anthropogenic sources are primarily fossil fuel combustion processes, such as automobiles, coking plants, and manufacturing processes (1). PAHs have been detected in food, water, soil, and air, where long-range atmospheric transport and deposition of these pollutants have implications for each of these categories (1,2,3). The detection of PAHs in soils has been documented, and the results of one study showed their presence in urban and rural, as well as in forest soils (1). The biodegradability of PAHs has seen limited study, with significant results confined primarily to those compounds with fewer than three rings (4,5). The higher molecular weight PAHs are partially degraded by only a few isolated bacterial strains. Furthermore, the bioaccumulation of PAHs has been documented in a variety of sediment and water residing organisms (5,6). Finally, the U.S. EPA has identified 16 unsubstituted PAHs as priority pollutants, with eight typically considered as possible or probable carcinogens (1).

The determination of quantities of PAHs in each of the sources mentioned above has proven to be a formidable task in terms of the ability to isolate these compounds from natural environmental samples. For the case of soils, the detected levels appear to be highly dependent on the location of sampling, with higher concentrations occurring in the vicinity of the PAH source (3). Relatively uniform concentrations of PAHs have been found in surface soils (1,3), which can be attributed to atmospheric deposition. From data compiled at site investigations by Menzie et al. (1992), the median concentrations of carcinogenic PAHs encountered in the forest, urban, and rural soils tested, ranged from 50 ppb to 1000 ppb.

The purpose of the research described in this paper is to evaluate the use of gaseous ozone for the oxidation of pyrene, under increasingly complex environmental conditions. Previous work with PAHs by Yao (7) has shown that in the presence of dry Metea soil, surface adsorbed PAHs can be significantly degraded using a continuous flow of gaseous ozone through a soil column system. Furthermore, work with chlorinated compounds by Masten (8), has shown that in the presence of humic material, ozone degrades to form secondary oxidants. However, it is uncertain from the surface adsorbed PAH experiments whether it is a direct ozone oxidation of the target compound, or if the degradation of the target compound is due to secondary oxidation by a radical species, such as the OH radical.

The ozone would be applied in the field through the use of a modified vacuum extraction system. Figure 1.1 shows the conventional vapor extraction apparatus. The ozone would be introduced into the unsaturated zone through the use of an injection well, and the flow of ozone can be induced using an extraction well. Because of the relative reactivity and instability of O_3, it is necessary to generate the ozone on site. The presence of a significant quantity of reduced materials in the subsurface environment will exert a significant ozone demand. The natural organic matter is also of concern when

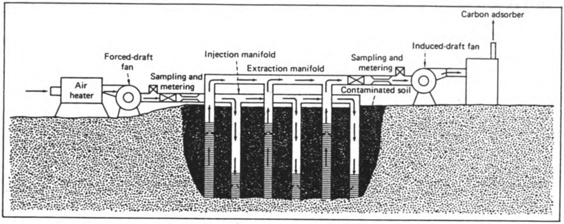


Figure 1.1: Conventional Vapor Extraction System

considering the feasibility of ozone vapor stripping. The ozone demand exerted by these materials may be the determining factor in the cost of remediation. Furthermore, it is necessary to study further the effect of soil moisture on the ozone demand of soils, as well as the effect of moisture content on the removal of surface adsorbed PAHs. The decomposition of ozone in water is known to produce hydroxyl radicals, which are powerful and less selective oxidants. This suggests that the presence of moisture may improve the removal efficiencies of some more recalcitrant PAHs, through the indirect reaction of hydroxyl radicals with the surface adsorbed PAH.

The question of utilizing other treatment techniques to further remediate the site following ozone treatment will not be directly addressed in this research. However, it is entirely feasible that nutrients could be provided to the site following initial oxidation of the target contaminants to stimulate the biological oxidation of the remaining contaminants. It may be necessary to reinoculate the affected area with populations of native microorganisms due to the disinfection capabilities of ozone. Once a population of microorganisms is established, the initially oxidized products of ozonation may be biodegraded further to enhance the overall removal of the PAHs.

CHAPTER II

BACKGROUND

Ozone has been used as an oxidizing agent for years in water and wastewater treatment. It is a very strong oxidant (E_o = 2.06 V) that is more powerful than most oxidants commonly used in water and wastewater treatment.

2.1 Ozone Reaction in the Aromatic System

The reaction of ozone with aromatic compounds has been well documented, however, the precise mechanisms are not well understood (10,11). The majority of organic compounds for which kinetic data is available and which react with ozone appreciably contain unsaturated carbon-carbon bonds (9).

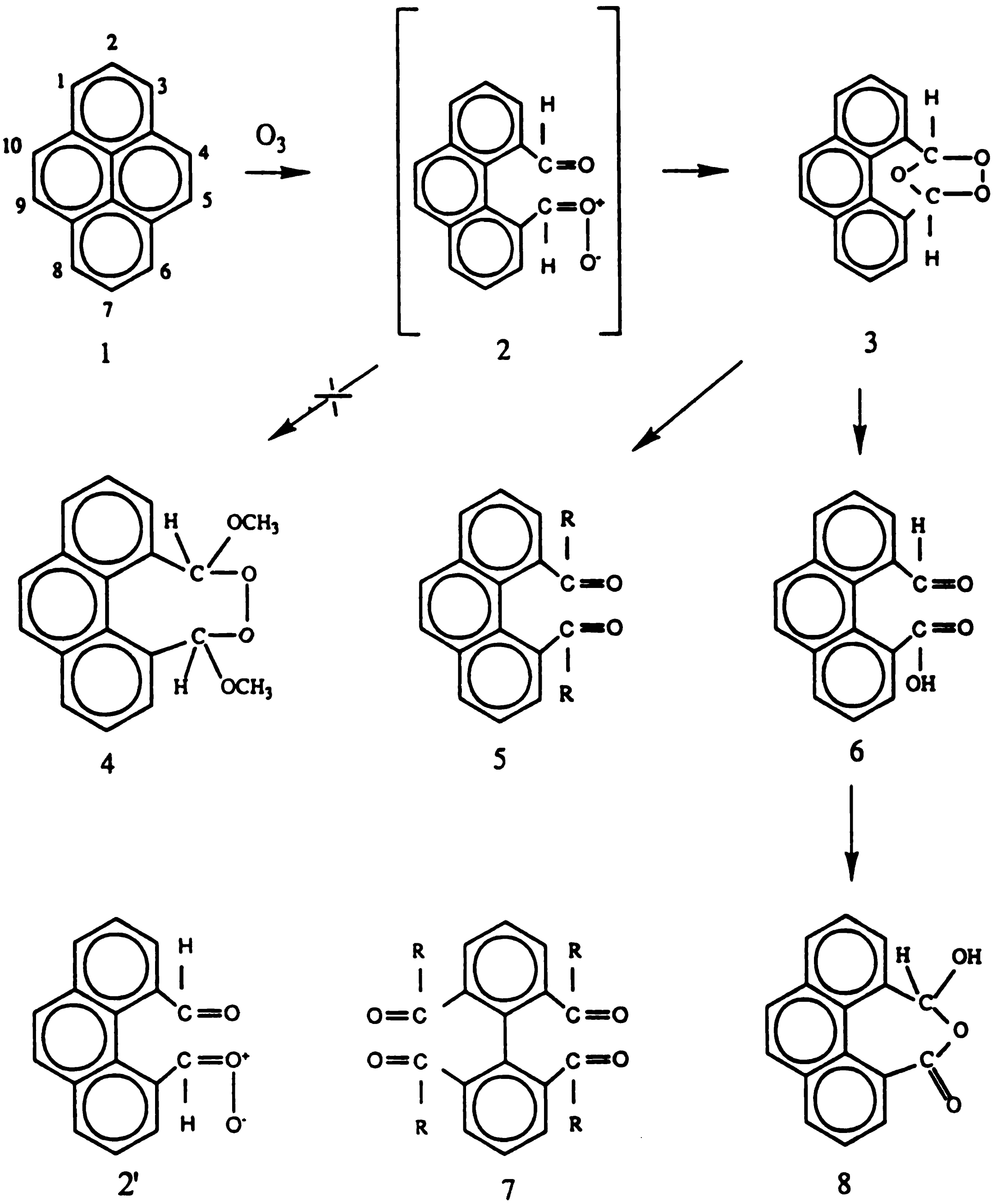
In general, the carbon-carbon double bonds in aromatic compounds are much less reactive with ozone than the double bonds of olefinic compounds (10). This result is attributable to the effects of conjugation present in aromatic compounds, as well as conjugated di- and trialkenes (9). There are two primary mechanisms of interest for the attack of ozone in the aromatic system. The two pathways involved in the direct ozone attack mechanism are electrophilic substitution, and 1,3-dipolar cycloaddition. The electrophilic reaction is restricted to sites with strong electronic densities. Doré and Legube (1983) demonstrated that, as a general rule, simple aromatic products fall into the following two categories: 1) those with electron-donating groups (OH, NH_2) react readily with ozone, and 2) those with electron-withdrawing groups (NO_2, Cl), which react much more slowly. The electron donating groups demonstrate a much stronger electronic density at the molecular site where the ozone attack occurs. The 1,3- dipolar cycloaddition reaction involves the reaction of the dipolar ozone molecule with unsaturated carbon bonds.

The benzene molecule is the classic example of aromaticity. The degree of substitution of the benzene molecule has an important effect on the ability of ozone to attack the compound. The presence of alkyl and other functional groups on the benzene ring facilitate the electrophilic attack by ozone. The mechanism by which benzene and substituted benzene compounds react with ozone is not well understood. For PAHs, the reactivities and mechanisms of these compounds vary considerably; consequently, the characteristics of pyrene will only be discussed in detail.

The proposed reaction pathway for the ozonation of pyrene is shown in Figure 2.1. In pyrene type PAHs, the atom of lowest atom-localization energy is not a part of the bond of lowest bond-localization energy. Therefore, there is competition for the position of initial ozone attack for this reaction. In an aqueous *tert*-butyl alcohol solution, the reaction of pyrene with ozone resulted in a monomeric monozonide *(3)*. The intermediates in this step are carbonyl oxides *(2,4)*, which are similar to the biphenyl carbonyl oxide structure resulting from the ozonation of phenanthrene *(2')*. Further products resulted from treatment with excess ozone *(7)*. Products isolated from the ozonation of pyrene indicate initial cleavage of the 4,5 bond, which is the bond of lowest bond-localization energy. For pyrene, there is no evidence that indicates ozone attack of the atoms of lowest atom-localization energy (11).

2.2 Ozone Decomposition in Water

Another important reaction pertaining to ozone chemistry involves the decomposition of ozone in water. In environmental systems, water will most likely be



a: R = H
b: R = OH

Figure 2.1: Proposed Reaction Pathway for the Ozonation of Pyrene

present. In aqueous systems containing impurities, the decomposition of ozone will result in the formation of secondary oxidants, the most important being $OH^{\bullet}$. In these systems, ozone can directly oxidize the target compound, or the hydroxyl radicals, $OH^{\bullet}$, (generated by the decomposition of ozone) can react with the target compound (12). The decomposition of ozone is affected by the pH of the solution, with the rate of decomposition increasing with increasing pH. Furthermore, as first suggested by Weiss, the decomposition of ozone can be accelerated by a radical-type chain reaction which can be initiated, promoted, or inhibited by the presence of various solutes in a nonpure solution (13). The interaction of radicals, ozone, and substituents of an "impure" water is an extremely complex mechanism. Figure 2.2 shows the reactions of aqueous ozone in the presence of solutes and the interaction of these radical-type chain reactions. The assumptions and mechanisms for these reactions were outlined by Staehelin and Hoigné, 1985 (12).

The first step in the initiation reaction involves the reaction of ozone with OH^- ions leading to the formation of one superoxide anion ($^{\bullet}O_2^-$) and one hydroperoxyl radical ($HO_2^{\bullet}$), which are in acid-base equilibrium (pK_a=4.8). Solutes (M) may also react with ozone directly, thereby consuming the ozone or producing an ozonide ion radical,($^{\bullet}O_3^-$). This radical ion can be protonated, and it will decompose to form hydroxyl radicals which react further with solutes, M. Organic solutes, M, that act as promoters, will react with the hydroxyl radicals to form an organic radical, $R^{\bullet}$, which with addition of O_2 will eliminate ($^{\bullet}HO_2$)/($^{\bullet}O_2^-$) in a base catalyzed reaction. This formation of ($^{\bullet}O_2^-$) will react further with ozone in what may promote a chain reaction. This is known as the propagation step. The termination step involves many other inorganic or organic

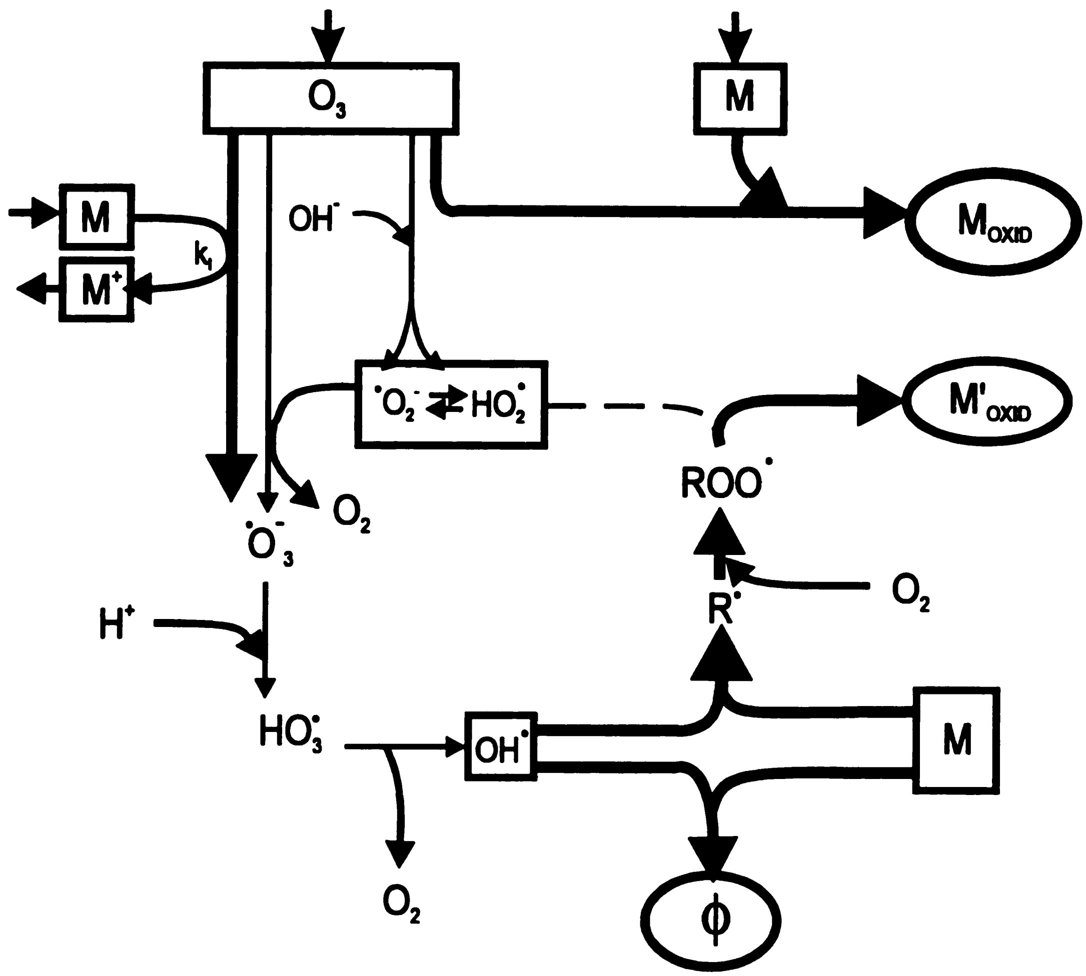


Figure 2.2: Reactions of Aqueous Ozone in the Presence of Solutes

substrates which react with the hydroxyl radicals and do not produce appreciable amounts of ($^{\cdot}HO_2$)/($^{\cdot}O_2^-$). These substrates are called radical scavengers.[1] The presence of substrates (e.g. carbonate and bicarbonate) in the system may behave as radical scavengers, and thereby consume hydroxyl radicals. In systems which the direct ozone reaction predominates, the radical scavenger mechanism may serve the purpose of improving the removal efficiency of specific target compounds in the system, by consuming radicals that would otherwise lead to further decomposition of ozone.

2.3 Ozone Reaction with Organic Matter

The reaction of ozone with naturally occurring organic matter is another important reaction in environmental systems. Soil organic matter is largely comprised of humic and organic acids that form stable complexes with iron and manganese ions. The structure of the humic acid component of humic substances is of primary importance in ozone chemistry, because of its principally aliphatic and aromatic composition randomly linked in a 'backbone' or 'core' structure (14). Ozone will oxidize these components of humic acids, as well as the iron(II) and manganese(II) present in soil, thereby promoting the decomposition of ozone. The implications of the consumption of ozone by a number of substances that exist in natural soils are of primary importance in assessing the feasibility of in-situ ozonation. The most important factor is the ability to transport ozone an "acceptable" distance from the injection well to oxidize target compounds within a treatment area.

[1] For a more complete description of the mechanism described above, see reference 12.

2.4 Surface Adsorption of Organic Chemicals

The accessibility of an organic chemical to ozone in the subsurface environment is dependent on the phase in which the chemical resides. In other words, the interface at which adsorption occurs within the soil matrix affects the accessibility of ozone to the organic molecule.

Research suggests that many organic chemicals, including PAHs, bind onto organic macromolecules such as fulvic acid, humic acid, and organic matter (14). More hydrophobic compounds are readily adsorbed to lipophilic organic matter in soils and, therefore, become relatively immobile (16). This mechanism is commonly referred to as hydrophobic bonding, and for PAHs, it is an important mechanism for describing their fate in soil systems. For more volatile organic chemicals, the portion of the compound that partitions, or dissolves, into the soil organic matter will be increasingly difficult to remove by the vapor extraction mechanisms.

The question arises whether partitioning is the primary mechanism responsible for sorption of organic chemicals. Most active surfaces on soil are negative; however, for the case of dry soil, the surface contains both positive and negative charges. The surface of organic molecules contain small fluctuating dipoles, with no permanent electrostatic polarization on the molecule. The net result of the close proximity of the molecule to the soil surface is momentary electrostatic polarizations, and an attraction between the molecule and the soil surface (16). Consequently, the presence of charged surfaces other than organic matter can affect the distribution of the organic chemical on the soil surface.

The effect of water in the soil system on the distribution of the organic chemical is the final condition that will be briefly discussed. In the case of hydrophobic molecules, such as pyrene, the concentration in the aqueous phase can be considered negligible. However, the coating of surfaces of the soil with water will affect the available sites for adsorption of the chemical. Studies have suggested that, due to cycles of wetting and rewetting of soil surfaces, the polar parts of organic molecules may become oriented towards the soil surface upon drying, and less polar parts become oriented away from it (17). Consequently, available sites for adsorption on the soil surface become increasingly inaccessible to the organic molecule. Furthermore, the uniform monolayer distribution of the organic molecule will increasingly yield clumps of the chemical on available sites.

2.5 Field Application of In-situ Ozonation

The means for transporting air, or oxygen, in conventional vapor stripping is identical to the proposed means for transporting ozone through the subsurface environment. Injection wells introduce fresh air, or oxygen, into the subsurface environment, and, coupled with the extraction wells, induce air flow through the regions of maximum concentration of contamination. These vapor stripping systems are effective for volatile, or semi-volatile contaminants only. However, the extent to which these systems are truly effective has recently come into question.

It has been suggested that vapor stripping as a means for removing volatile organic compounds (VOCs) from the subsurface environment is not as effective as previously thought. At sites where contamination occurred long ago, a significant fraction of the VOCs adsorb to the solid surface, and eventually become trapped inside the soil matrix. This fraction of the contaminant is essentially inaccessible to removal by vapor extraction (15). The most susceptible portion of the volatile contaminant to volatilization is the surface adsorbed component, the component which is dissolved in water, and that which exists as a separate phase.

The need for the use of ozone to oxidize target compounds is apparent from the above discussion. The ability to transport ozone a significant distance between injection and extraction wells has economic implications for the feasibility of ozone vapor stripping; additionally, the consumption of ozone by soil organic matter has treatment efficiency implications as well. In-situ ozone treatment may be economically infeasible as an all encompassing treatment technology; however, the feasibility of employing ozone treatment together with conventional vapor stripping and/or bioremediation is a distinct possibility.

CHAPTER III

MATERIALS AND METHODS

The feasibility of ozone vapor stripping has been previously demonstrated in a limited capacity (7), and this study serves as a continuation of previously completed work. The complexity of the soil system in which these experiments were executed made it necessary to devise a system whereby the study of ozone decomposition could be accomplished. The main goal of experimentation was to examine the effect of ozone on the degradation of the target compound in the presence of field moisturized Metea soil. The field moisture saturation of the soil is between 0-20%.

3.1 Materials

3.1.1 Ozone Generation

The production of ozone was accomplished using an ozone generator (Model T-408, Polymetrics, Inc., San Jose, CA). The generator was water cooled, and a recirculating water bath was maintained at a temperature corresponding to 10°C for this purpose. As a precaution, any excess ozone in the effluent gas from the soil column was trapped using Potassium Iodide (KI) traps.

3.1.2 Preparation of Pyrene and Fluorene Stock Solutions

Stock solutions of the target compound, pyrene, as well as the internal standard compound, fluorene, were prepared in dichloromethane (Mallinckrondt, HPLC grade). Each solution was prepared at a concentration corresponding to 200 ppm, and dilutions were performed as needed.

3.1.3 Preparation of Contaminated Glass Beads and Ottawa Sand

The 6 mm. glass beads were coated with 250 ppm pyrene as described in the following procedure. The demand of ozone by any organic materials adsorbed to the surface of the glass beads was eliminated by soaking the beads for > 24 hrs. in a solution of Nochromix®, which is an inorganic oxidizer, and sulfuric acid. The beads were then rinsed with reverse osmosis/activated carbon filtered, R.O., water > 10 times, and baked in a furnace at approximately 400°C in order to remove any residual organic materials. The entire volume of the sample column was filled with contaminated glass beads. 110 g of glass beads was used for each experiment. The glass beads were contaminated in batch to minimize nonuniform coating of the contaminant. A pyrene solution (Sigma, 99% pure) was prepared using HPLC grade dichloromethane containing 27.5 mg pyrene. This solution was then added to the clean glass beads in a 1000 ml Pyrex beaker. To uniformly coat the beads, a large beaker was used in order to contact the pyrene solution with a single layer of glass beads. The solvent was allowed to volatilize, and the glass beads were mixed together thoroughly.

Ottawa sand has a very uniform and homogeneous particle size. The particle diameter was determined by means of a sieve analysis. The results showed that 25% of the sample was retained on the U.S. sieve #30, which has a sieve opening of 0.60 mm., and 63% of the remainder was retained on the U.S. sieve #40., which has a sieve opening of 0.425 mm (Draft, 1993)(18). Therefore, the particle size distribution of the Ottawa sand used in calculations was 0.42-0.60 mm. The sand was contaminated in a manner similar to the procedure used to contaminate the glass beads, except that a larger mass of Ottawa sand was initially prepared. The Ottawa sand was not soaked in Nochromix®

solution, but was instead ozonated for > 8 hrs., until the decomposition of ozone approached the rate of self-decomposition previously determined for the purpose of rate constant calculations.

3.1.4 Preparation of Contaminated Metea Soil

The soils used were acquired from the southeast side of the Michigan State University campus on research farm property near the Engineering Research Complex. The soil was removed from the B horizon, which was approximately 4-5 ft. below the surface. The soil was spread out and allowed to air dry for approximately one month. Following air drying, the soil was sieved through a series of sieves with a minimum diameter of 1.19 mm, which corresponds to an ASTM sieve #16. The prepared soil was sampled for analysis of physical and chemical characteristics by the Michigan State University Soils Testing Laboratory, as shown in Table 3.1. Additionally, a blank soil sample was extracted to determine the level of PAH contamination present at the time of sampling. The concentration of PAHs in the sample was negligible. A soil sample was also submitted for a total surface area determination using the 2700 BET surface area analysis (19). The calculations from the analysis are given in the appendix, and the total surface area determination was 36.34 m^2/g.

Using the prepared soil, a mass of pyrene was weighed corresponding to the concentration desired in the soil system. For instance, 62.5 mg pyrene was weighed and dissolved into <200 ml dichloromethane. After complete dissolution of the pyrene, the volume of pyrene solution was applied to 250 g of metea soil in a large glass jar. As there was an excess volume of solution in the jar, the soil was effectively slurried. The glass jar was capped and rotated on a mechanical rotator for > 24 hrs. at 30 rev/min.

Table 3.1: Soil Characteristics Results

Category	Result
pH	5.43 ± 0.87
Organic Matter (%)	0.4 ± 0.1
Iron (ppm)	2
Manganese (ppm)	3
Lime Index	71
% Sand	78.9
% Silt	12.5
% Clay	8.6 ± 0.71

Following rotation, the glass jar was opened and the solvent was allowed to volatilize. The soil was then transferred to an aluminum pan, where it was allowed to air dry for 24 hrs.

3.2 Analytical Methods

3.2.1 Ozone Analysis

The concentration of ozone was monitored using a 0.2 cm. pathlength spectrophotometric flow cell and a UV/VIS Spectrophotometer (Model # UV 160, Shimadzu, Kyoto, Japan). The concentration of ozone was calculated according to Beer's Law, with use of an extinction coefficient of $\in = 2900$ L $Mol^{-1}cm^{-1}$ at a wavelength of

258 nm (20).

3.2.2 Spectrophotometric Analysis of Pyrene

The analysis of pyrene was conducted using a UV/VIS Spectrophotometer (Model # UV 160, Shimadzu, Kyoto, Japan) or (Model # 8452A, Hewlett Packard, Palo Alto, CA) following extraction from the glass beads and the Ottawa sand. This form of analysis was chosen for higher sensitivity, and for ease of analysis, when the media contained no organic matter. The wavelength of analysis was chosen by scanning a wavelength range from 250-800 nm and 338 nm was chosen for the analysis.

3.2.3 Fluorimetric Analysis of Pyrene

The analysis of one set of extracts was conducted on a Luminescence Spectrometer (Model # LS50, Perkin Elmer, Norwalk, CT), as a comparative analysis with the UV/VIS spectrophotometric analysis. The excitation and emission wavelengths were determined to be 270 nm and 374 nm, respectively. This form of analysis allows higher sensitivity than the UV/VIS spectrophotometer, and it independently confirms the results of the spectrophotometric analysis.

3.2.4 Gas Chromatography (GC) Analysis of Pyrene

Pyrene was also analyzed (in extracts containing organic matter) using GC/FID. The GC was equipped with a cross-link HP5, 5% Phenyl-Silicone Gum Phase column with dimensions of 30 m x O.53 mm x 2.65 μm. Helium was used as the carrier gas. The samples were injected using the GC direct injection autosampler. Quantification of the peak areas was performed using an integrator (Omega Autosystem Control, Perkin Elmer, Norwalk, CT) or (Turbochrom, PE Nelson, Norwalk, CT). An internal standard method was used with fluorene as the internal standard, and external standard solutions of either every three samples, or every six samples, for quality assurance/ quality control (QA/QC). A pyrene standard was run prior to each set of analyses for verification of optimal operating conditions. The operating conditions of the GC are shown in Table 3.2.

Table 3.2: Gas Chromatography Operating Conditions

Flame Ionization Detector	
Temperature	290°C
Hydrogen Flow Rate	50 ml/min
Air Flow Rate	400 ml/min
Injector	
Injection Volume	1 μL
Temperature	250°C
Oven Conditions and Programming	
Equilibration Time	1 min.
Initial Temperature	170°C
Temperature Program	
Ramp Rate	10°/ min
Final Temperature	290°C

3.2.5 Soil Extraction Technique

Conventional soxhlet extraction techniques were utilized as developed by the EPA (21,22) for the soil extractions in this study. Sample preparation and cleanup was minimized due to the low organic carbon content of the soil. A similar method for the soil extraction was used as developed by Yao (7).

A soil mass of 5 g was used for the extraction, and the samples were weighed directly into a cellulose thimble and freeze dried at < -40°C and at 10 microns Hg vacuum for > 12 hrs. Triplicate samples were taken from the treated and untreated soils. This allowed for any variability in the time of extraction, or the extraction conditions. Following the freeze drying, the samples were transferred to the extraction flask of the soxhlet apparatus.

The solvent system used for the extraction was a 10% methanol/dichloromethane mixture. The total volume of the solvents used was 200 ml, with 20 ml of methanol, and 180 ml dichloromethane. The methanol/dichloromethane mixture was used due to the hydrophobicity of PAH's, which tend to adsorb readily to mineral surfaces. The methanol will coat the mineral surfaces, and this will allow more thorough contact of the dichloromethane with the media on which the PAHs are adsorbed. Previous work has shown that this will increase the recoverabilities of the pyrene. The extraction was allowed to proceed for > 18 hrs.

Following completion of the extraction, the extracts were initially concentrated using the soxhlet apparatus, and then transferred from the soxhlet extraction flask to a Kuderna-Danish concentrating apparatus using a quantitative rinse. The extracts were evaporated to near completion, and then nitrogen was used to dry the remainder of solvent from the sample. Following complete evaporation, 10 ml of 100 ppm fluorene internal standard was added to each extract, and then triplicate samples were prepared for GC analysis.

3.2.6 Moisture Content Determination

The soil moisture content was determined by oven drying the moist soil at 90-100°C for 24 hrs. The sample was weighed before and after oven drying. Upon removal of the soil samples from the oven, the samples were allowed to cool in a desiccator containing drying agents to prevent the transfer of atmospheric moisture to the soil samples.

3.3 Experimental Methods

3.3.1 Ozone Transport Studies

The determination of the ability to transport ozone through the subsurface environment is an extremely important consideration. Ozone transport studies have been conducted in order to evaluate the effectiveness with which ozone can be transported under a variety of conditions. A glass column apparatus was employed in these transport studies to study the effects of soil organic matter, iron, and soil moisture on the ability to transport ozone.

A schematic diagram of the system that was used for the ozone transport studies is shown in Figure 3.1. Spectrophotometric flow cells (Model # 170-QS, Hellma, Germany) and a UV/VIS spectrophotometer (Model # 8452A, Hewlett Packard, Palo Alto, CA) were used for the ozone analysis. The soil column apparatus was comprised of a 10 cm. glass column with a 5.5 cm inside diameter. Stainless steel caps were used along with Teflon® o-rings in order to seal the columns against leakage, and to avoid material that will either adsorb pyrene, or exert an ozone demand. Teflon® or stainless steel tubing was used because they exert no ozone demand.

The soil column was prepared first by packing the column with the soil of interest using a laboratory scale driving mass (hammer). The column was then saturated using the technique shown in Figure 3.2. Initially, the column was de-aired under a vacuum of approximately 500 mbar. After 30 minutes, the valve was released to allow the water solution to completely saturate the packed column. Once the column was saturated, the

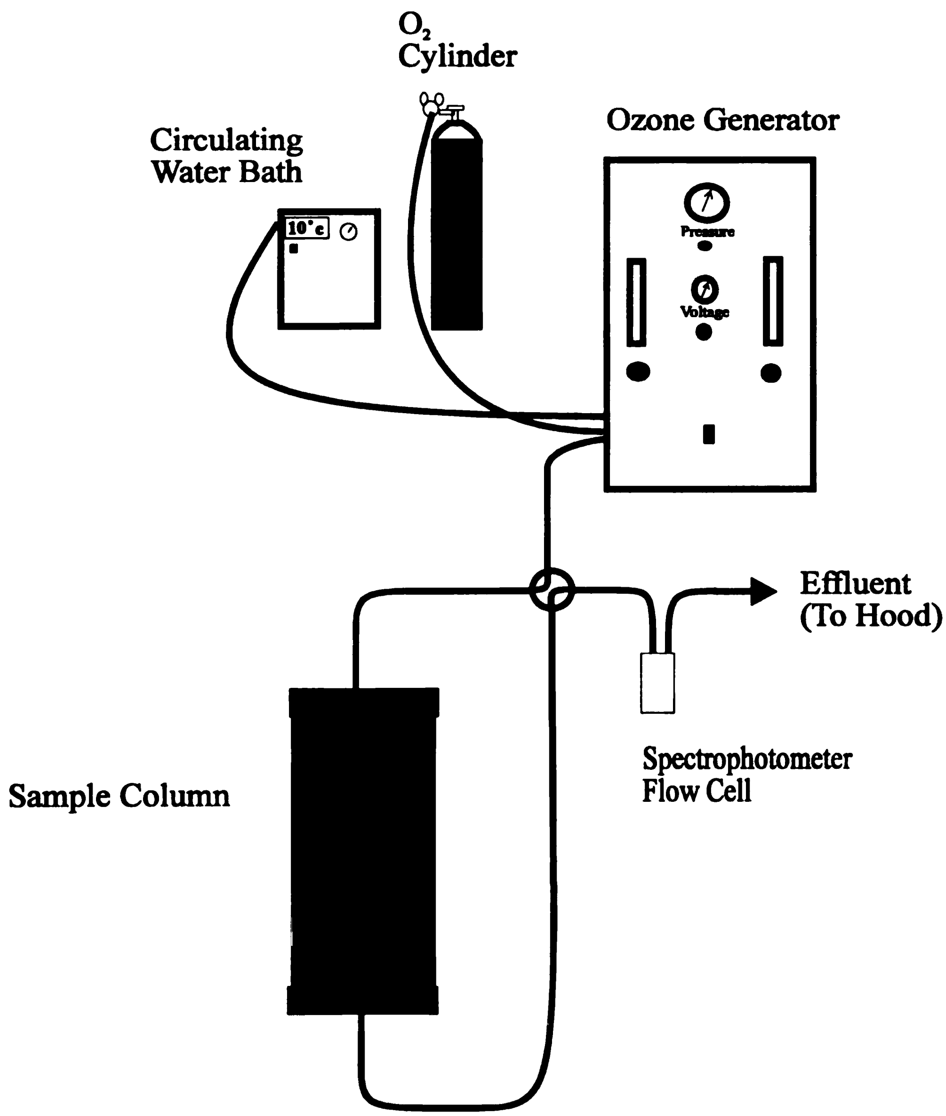


Figure 3.1 : Diagram of Semi-Continuous Flow System

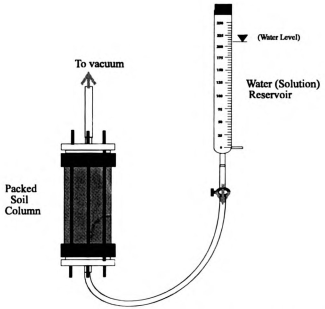


Figure 3.2 : Diagram of Column Saturating Apparatus

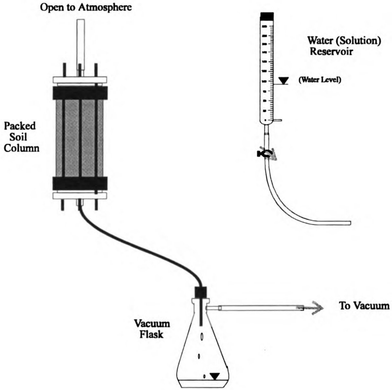


Figure 3.3 : Diagram of Column Draining Apparatus

column was drained to a 0-20% residual saturation level (See Figure 3.3).

The initial column experiments were conducted using Ottawa sand, which contains no organic matter. Control experiments were run to examine the ozone demand of dry Ottawa sand. Subsequently, moisture was added to examine the effect of water on the ozone demand. The effect of tertiary butyl alcohol, a hydroxyl radical scavenger, was studied for comparative purposes. This was an attempt to decrease the ozone consumption by interrupting the chain reaction of involved in the decomposition ozone and hydroxyl radicals. The final experiment was conducted using iron (Fe^{3+}) solutions, and Fe^{3+}-tertiary butyl alcohol solutions in order to examine the effect of likely constituents of the subsurface environment on ozone demand. Ferric sulfate, $Fe_2(SO_4)_3$, was dissolved in aqueous solution and, subsequently, precipitated into solution by raising the pH of the solution using sodium hydroxide, NaOH. This solution was then used to saturate the soil column, and, subsequently, the column was drained to residual saturation.

3.3.2 Kinetic Studies of the Degradation of Pyrene by Ozone

The degradation of pyrene by ozone was studied using the circulating batch system shown in Figure 3.4. These experiments were conducted in batch conditions in order to closely study the rates of ozone decomposition under varying environmental conditions. The system shown was constructed using chromatography columns, with a 271 ml reservoir column (Model # 420830-1520, Kontes, Vineland, NJ), and a 74 ml sample column (Model # 420830-1510, Kontes, Vineland, NJ). The sample column inside diameter was 2.5 cm, and the height of the column was 15 cm. A diaphram pump (Model #7553-20, Cole-Parmer, Chicago, IL) was used as the circulating pump, which has a maximum pumping rate of 800 ml/min, and it was operated at approximately 500 ml/min.

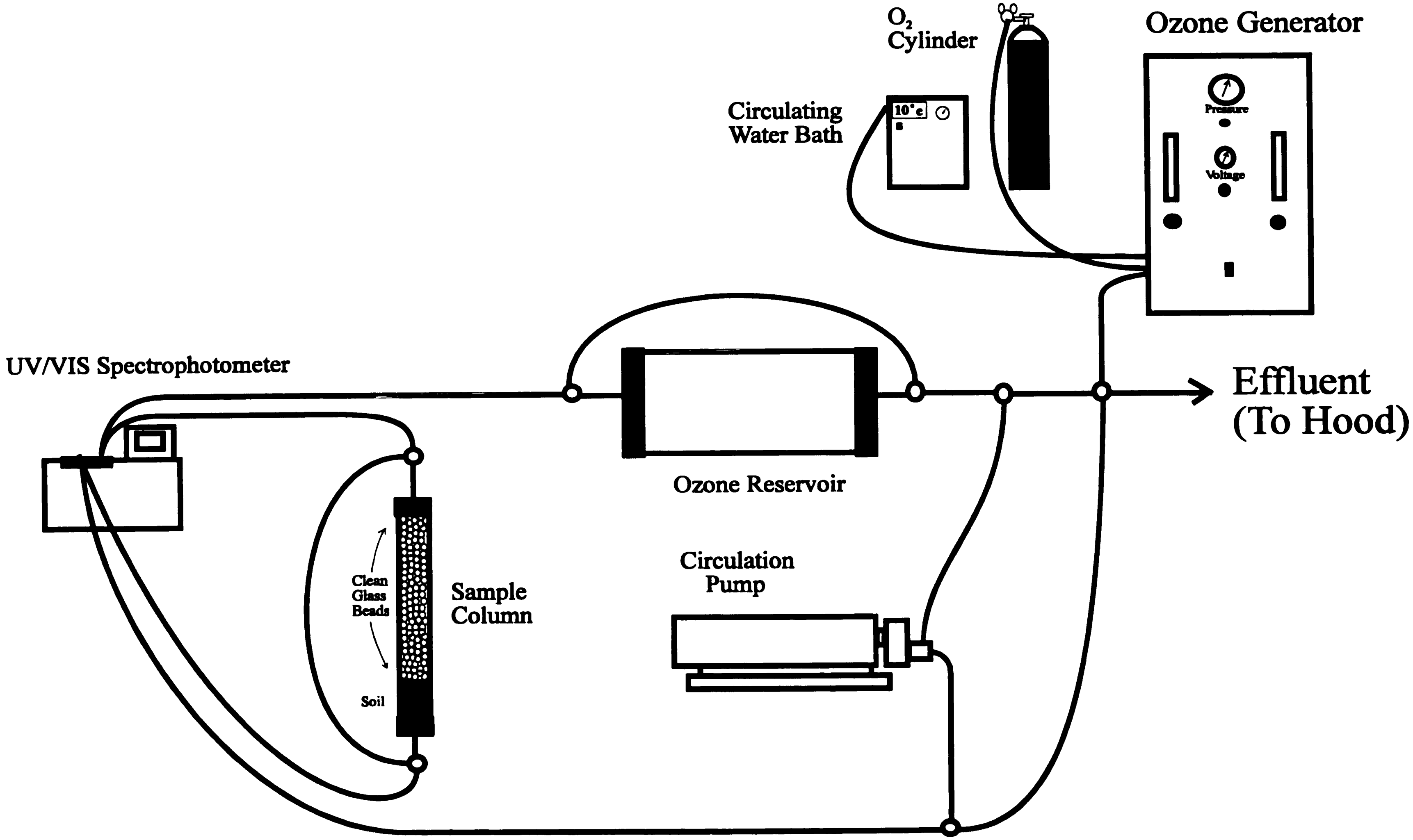


Figure 3.4 : Circulating Batch Treatment System

Furthermore, the ozone concentration was monitored using 2 spectrophotometric flow cells, as described previously, and a UV/VIS spectrophotometer (Model # 1201, Shimadzu,Kyoto, Japan). Initially, the system was operated in order to optimize the performance criteria; for example, the optimal rate of circulation was quantified. For purposes of analysis, it was necessary to minimize the consumption of ozone across the sample column; ideally, the change in the concentration of ozone should be negligible. This was feasible with Ottawa sand, but it was difficult to achieve with the introduction of Metea soil into the sample column. Furthermore, the loss of ozone by leakage throughout the system was minimized or eliminated. This was achieved with use of helium gas and a leak detector (Model # 21-150, GOW MAC Instruments Co., Bridgewater, NJ), which operates on the principle of thermal conductivity of gases. A leak test experiment was conducted following each contaminated media experiment in order to verify the performance of the system. These experiments were conducted over a period of time on the order of the experiment that was conducted. [2]

3.4 Experimental Design

<u>3.4.1 Auto-decomposition of Gaseous Ozone</u>

The initial experiment that was conducted was the quantification of the auto-decomposition of ozone under circulatory conditions within the sample loop. It was necessary to determine this in order to distinguish between the auto-decomposition of ozone, and the consumption of ozone by contaminants, organic matter, and moisture. The

[2] An initial leak test was conducted prior to the introduction of the sample column. The change in absorbance with respect to time was determined and compared to previous experiments. From this number, a determination was made concerning the introduction of the sample column. The entire experiment from initial to final leak test constituted one data set.

mass (concentration) of ozone was varied in order to examine the dependence of the initial concentration in the system on ozone decomposition. It was assumed that the rate of decomposition of gaseous ozone was dependent on the initial concentration of ozone in the system, according to

$$(1) \qquad -\frac{dO_3}{dt} = k_1 \; [O_3]$$

This hypothesis is consistent with the result previously observed by Tomiyasu, et. al. 1985, for aqueous ozone solutions, which is that the order of reaction is pseudo-first order with respect to the concentration of ozone in the system (i.e. $-d[O_3]/dt = k'[O_3]$). The pseudo-first order rate constant, k', accounts for the concentration of hydroxyl radicals generated by the decomposition of ozone in water. However, for these gaseous ozone reactions without the presence of water, the concentration of hydroxyl radicals can be neglected. As the degradation of ozone is affected by the presence of ultraviolet light, the glass ozone reservoir and sample column were wrapped with aluminum foil to reflect any light which may affect the reaction. Four different masses of ozone were examined, with a triplicate run of an intermediate mass in order to ensure the reproducibility of the results.

3.4.2 Treatment of Surface Adsorbed Pyrene

The degradation of pyrene was initially studied with the use of 6 mm diameter solid glass beads. The use of glass beads allowed for the study of the surface catalyzed reaction of ozone with pyrene (in a system without the organic matter present). It has been hypothesized that the reaction rate of PAHs, for higher than monolayer coverage, is independent of the initial amount of PAH (23). This implies that the reaction rate is dependent on the surface area of the media under consideration. Four different masses of ozone were studied, with a triplicate run of an intermediate mass in order to check the reproducibility of the results. The extraction of pyrene from the glass beads was achieved by a solvent wash of the beads in 35 ml centrifuge tubes using dichloromethane.

The hypothesis concerning the dependence of ozone decomposition on the surface area of contact between ozone and pyrene was tested using a material of different particle diameter. The material chosen for testing the hypothesis was Ottawa sand, which is an inert silica sand containing no organic matter. The particle diameter of Ottawa sand is approximately 0.5 mm. This experiment was conducted in triplicate at 250 ppm pyrene, and it was also conducted at 100 ppm pyrene.

3.4.3 Treatment of Pyrene in the Presence of Organic Matter

The decomposition of ozone in the presence of dry Metea soil was studied using uncontaminated soil. Experimental conditions were identical to that used in previous experiments. The soil was then contaminated with 250 ppm, and 100 ppm pyrene. In order to eliminate air stripping as a possible contaminant removal mechanism, an experiment was conducted using 250 ppm pyrene contaminated soil, whereby oxygen was circulated through the loop. The contaminated soil experiments were conducted in an identical manner as the procedure used in the control experiment. Four different masses of ozone were examined, and an intermediate mass of ozone was run in triplicate in order to verify the reproducibility of the results. Following soil treatment, the pyrene was extracted from the soil using soxhlet extraction. An overall rate expression can be developed to describe the reaction of ozone and pyrene in the presence of dry soil using the results from the ozone auto-decomposition experiment, and the decomposition of ozone in the presence of surface adsorbed pyrene.

3.4.4 Treatment of Pyrene in the Presence of Soil Moisture

The decomposition of ozone was examined in the presence of moisturized Metea soil contaminated with pyrene. The soil was moisturized as described previously in section 3.3.1, using the column apparatus and a pressure plate. The reproducibility of the moisture content of the soil was assured with the use of a desiccator containing a salt solution which maintained a constant relative humidity within the desiccator.

Initially, the column was packed with pyrene contaminated Metea soil, and, subsequently, saturated with DI water. The column was then drained to the approximate residual water saturation level. Following sufficient drainage, the moist soil was subdivided, with a triplicate sample taken for soil moisture determination. Twelve moisturized soil samples were placed in the desiccator, which contained a saturated aqueous solution of potassium sulfate, K_2SO_4. The saturated solution was prepared by weighing and dissolving 150 g K_2SO_4 in 1000 ml of DI water. The solution was heated and stirred until complete dissolution of the solid had occurred. According to Greenspan (24), this salt solution corresponds to a relative humidity of 97.88 $\pm$ 0.49 % at a temperature of 25°C. According to Figure 3.5, the use of a solution corresponding to a high relative humidity should result in a moisture content comparable to the original moisture content upon placement into the desiccator. It is desirable to maintain conditions within the desiccator such that the soil suction, h, exerted on the soil samples is high enough to maintain the residual saturation conditions of the soil samples. However, it is also necessary to prevent the condensation of water within the desiccator, and this was accomplished with high relative humidities.

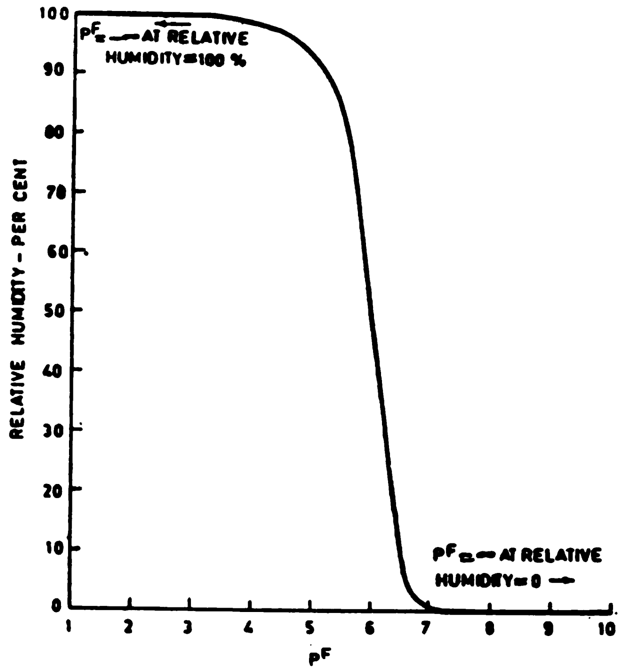


Figure 3.5: Relative Humidity vs. pF

The pF is the logarithm to the base 10 of the soil suction (25). The higher relative humidity values correspond to lower soil suction values. The potassium sulfate solution corresponds to a relative humidity of 98% and should provide enough soil suction to maintain the soil samples at or near the residual saturation value. The vacuum desiccator will be vacated using a vacuum pump at 25-30 in Hg, or approximately 900 mbars. The temperature will be monitored on a daily basis, as well as the pressure within the desiccator using a hand held tensimeter. Upon equilibration of the system, the soil moisture content will be determined from excess soil samples available for soil moisture determination.

When equilibration of the soil samples has been reached, samples will be removed immediately for soil moisture determination, and samples will be removed for experimentation as needed. It is possible that the moisture content from sample to sample will decrease over the course of experimentation, and it is for this reason that a sample will be removed from each individual 25 g soil sample for a moisture content determination. It will also be necessary to conduct these experiments rapidly in order to minimize the ability for water to evaporate from the samples. Each individual moisturized soil experiment will be conducted in an identical manner to the previous experiments. Upon completion of the experiment, the sample will be removed, and immediately weighed and placed into a cellulose extraction thimble used for soxhlet extractions. The thimbles will be placed into a freeze-drying vessel (Model # 7750000, Labconco, Kansas City, MO), and the samples will be freeze dried for > 18 hrs. A control experiment conducted on moisturized soil samples determined that this is sufficient time to remove the moisture in preparation for extraction and gas chromatography analysis, as previously described.

3.5 Modelling of Experimental Results

The development of kinetic rate expressions has been pursued in a limited scope for these experiments. The complexity of the system being studied limits the ability to develop a rate equation which describes the rate of degradation of pyrene. Kinetic rate constants for the decomposition of ozone will be determined using the data from the batch experiments, and a kinetic rate expression will be developed from the proposed experiments. From this expression, an overall rate expression will be developed as a means to determine the decomposition of ozone under similar experimental conditions.

CHAPTER IV

OZONE TRANSPORT STUDY

In a natural soil system, there are many constituents that will react with ozone. It is necessary to attempt to understand the effects of a variety of conditions, and to determine the most significant contribution to the decomposition of ozone within the subsurface environment.

4.1 Ottawa Sand Ozone Transport Experiments

Dry Ottawa sand columns establish the "background" ozone demand of the breakthrough curve in a media with uniform and homogeneous characteristics. Following these initial experiments, saturated Ottawa sand columns were run at two different saturation levels in order to establish the effect of residual saturation on the consumption of ozone. A comparative graph of these three experiments is shown in Figure 4.1.

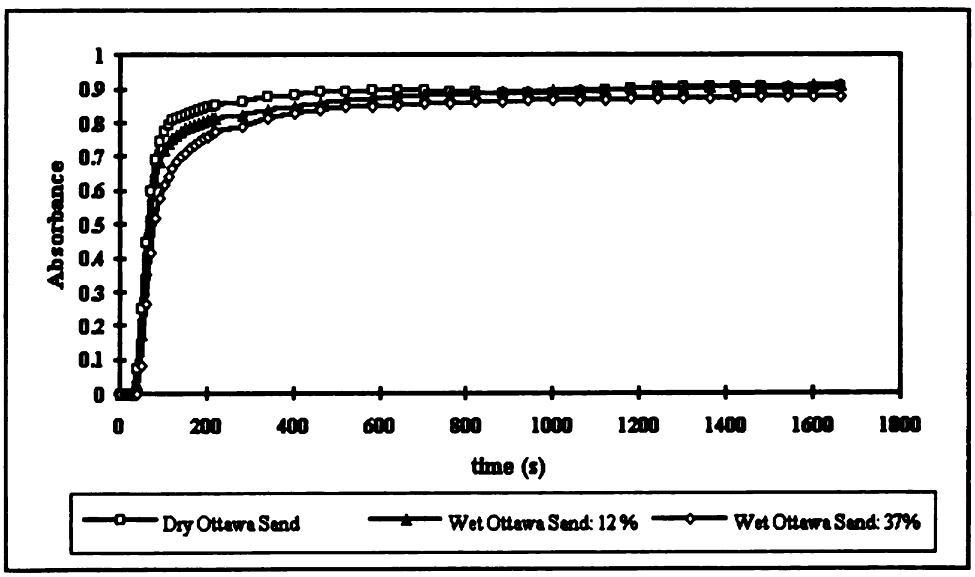


Figure 4.1: Ozone Breakthrough in the Ottawa Sand System

The consumption of ozone was quantified using numerical integration techniques. The mass flux for the experiments was determined using the ozone concentration as determined from the absorbance, at any point in time, using Beer's Law, and the flow rate as determined using a digital flow meter (Model # 1463, J&W Scientific, Folson, CA). The flow rate of ozone for the experiments was 120 ml/min. The results of these experiments, as well as the results of the iron (III) experiment are shown in Table 4.1.

Table 4.1: Ozone Transport in Ottawa Sand Columns

	*η (%)	⊕SAT. (%)	OZONE CONSUMED		% RECOVERED	
			(%)	Mass (mmol/kg soil)	Mass	∓Time
Dry	25	0	6.3	0.76	98.3	0.59
Wet #1	27	12	8	1.0	98.1	0.62
Wet #2	26	37	11	1.3	95.4	0.62
Fe^{3+}	30	N.A.	19	2.26	81.8	0.46

*Porosity calculated using G_s=2.65
⊕Saturation calculated as % of pore volume where V_V = 55 ml
∓Time ratio: (5% Recovery of C_o / 50% Recovery of C_o)

In order to define the breakthrough of ozone further, the % recovered column in Table 4.1 contains mass and time relevant information. The % recovery of mass is defined as the percentage of the influent ozone concentration recovered in the effluent. Additionally, the % recovery of time is the ratio of the time to recover 5% of the influent ozone concentration to the time to recover 50% of the influent ozone concentration. Thisparameter establishes the rate of ozone breakthrough for the respective soil column condition.

Upon examination of the data, it is evident that for an ozone flux of 550 mg/hr used for the dry and moist Ottawa sand columns, the ozone consumption increased with increasing degree of saturation. The background ozone demand of 0.76 mmol/kg soil for the dry Ottawa sand increased 30% to 1.0 mmol/kg soil for 12% saturation, and it increased 70% for 37% saturation. The time parameter indicates the shape of the breakthrough curves for these three conditions. There is no significant effect on the shape of the breakthrough curve for the range of saturations studied.

With the introduction of 400 ppm iron(III) into the soil column, and using a slightly lower ozone flux of 530 mg/hr, the consumption of ozone increased dramatically. Furthermore, for the period of ozonation of the iron(III) system, the effluent ozone concentration reached only 82% of the influent ozone concentration, which suggests that the ozone demand of the system was not met. The time ratio for the iron(III) experiment is significantly lower than that observed for the dry and wet Ottawa sand columns, which is the result of a slower recovery of 50% of the effluent concentration. This result is confirmed by the significant increase in the ozone demand as compared to the dry and wet Ottawa sand columns.

4.2 Modification of Ottawa Sand System

In an attempt to determine if the mass of ozone consumed could be reduced by soil amendments, the soil columns were saturated with a hydroxyl radical scavenger, a 0.08M tertiary-butyl alcohol (tBuOH) solution at a pH = 2. The experiments were conducted using a flow rate of 120 ml/min, and the ozone consumption data was calculated in anidentical manner as the previous Ottawa sand experiments. The results of these experiments are shown in Table 4.2.

Table 4.2: Ozone Transport in Modified Ottawa Sand Columns

	*η (%)	⊕SAT (%)	OZONE CONSUMED		% RECOVERED	
			(%)	Mass (mmol/kg soil)	Mass Ozone	∓Time
tBuOH	31	15	11	1.4	93.7	0.59
Fe^{3+}-tBuOH	30	N.A.	18	2.3	86.7	0.17

*Porosity calculated using G_s=2.65
⊕Saturation calculated as % of pore volume where V_V = 55 ml
∓Time ratio: (5% Recovery of C_o / 50% Recovery of C_o)

There was no appreciable reduction in the consumption of ozone for the tertiary-butyl alcohol experiment, as well as the iron(III)-tertiary butyl alcohol experiment. The tBuOH experiment resulted in 94% recovery of the influent concentration which is comparable to the previous experiments, and the iron(III)-tBuOH experiment showed 86 % recovery of the influent concentration, which is also comparable to the previous iron(III) experiment. Furthermore, the time ratio data for the tBuOH experiment is the same as the ratios determined for the dry and wet Ottawa sand columns. However, the time ratio data for the Fe^{3+}-tBuOH experiment is significantly lower than the previous iron(III) experiment.

4.3 Metea Soil Ozone Transport Experiments

The duration of time needed to reach ozone breakthrough was substantially longer for the Metea soil system, as compared to that required in Ottawa sand. The results of the dry Metea soil column experiment were inconclusive due to experimental difficulties. However, the ozone breakthrough curve was conducted successfully for the residual saturation soil column, as well as the 0.08 M tBuOH residual saturation soil column. Figure 4.2 shows the ozone breakthrough curve for the residual water saturated Metea soil column. There is evidence in this figure of short-circuiting, or fingering, which may be due to small scale heterogeneities in the packing of the soil column (26).

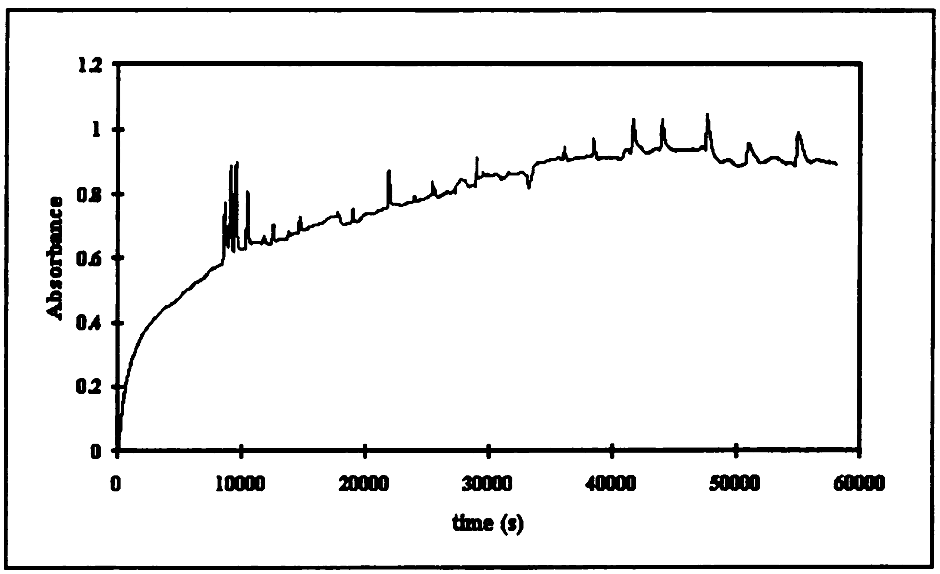


Figure 4.2: Ozone Breakthrough in the Metea Soil System

The results of the residual saturation Metea soil experiments are shown in Table 4.3. An ozone mass consumption of 30 mmol/kg soil and 62 mmol/ kg soil for water and tBuOH, respectively, indicates a greater ozone demand by the tBuOH system. The percent recovery of the influent ozone concentration was nearly complete for each experiment. The recovery time ratios of 0.025 and 0.27 for water and tBuOH, indicates a much quicker recovery of the influent concentration for the tBuOH saturated column as compared to the water saturated column. The recovery of 5% of the influent

Table 4.3: Metea Soil Ozone Transport Experiments

	*η (%)	⊕SAT (%)	OZONE CONSUMED		% RECOVERED	
			(%)	Mass (mmol/kg soil)	Mass	∓Time
Wet	32	35	11	75.8	99.7	0.025
tBuOH	34	25	33	160	97.8	0.27

*Porosity calculated using G_s=2.65
⊕Saturation calculated as % of pore volume where V_V = 55 ml
∓Time ratio: (5% Recovery of C_o / 95% Recovery of C_o)

concentration occurred sooner in the wet Metea soil experiment, than in the tBuOH experiment. However, the time to reach 50% recovery of the influent concentration in the effluent from the column took considerably longer in the wet Metea soil experiment than in the tBuOH experiment. This suggests that a larger initial ozone demand is needed to establish breakthrough in the tBuOH soil column, as compared to the wet Metea soil column. And once the ozone demand is met, the result suggests that ozone transport occurs more readily in the tBuOH system than in the water system.

The most significant result of these Metea soil ozone transport experiments lies in the recoverability of the ozone concentration in the effluent of the soil columns. The wet Metea soil system exerted a very significant ozone demand, as evidenced by the very gradual breakthrough of ozone in the soil column effluent. Furthermore, the difficulty in reaching 100% recovery of the influent ozone concentration represents an "infinite" demand by the Metea soil system. This tailing effect has negative implications for transporting ozone through soil systems that contain much greater than 0.5% organic matter.

4.3.1 Cost Considerations for In-Situ Ozone Vapor Stripping

Capital costs and the expense of generating ozone on site are two of the most important cost considerations in the design of in-situ ozone venting systems. The data for the consumption of ozone can be used to calculate the cost associated with transporting ozone through the subsurface environment.

The cost of producing ozone is dependent on the air flow rate used in venting systems. The air flow rate of vapor extraction systems can range from 50 - 300 ft^3/min (15,27). The operating parameters of a site located in Michigan utilized an air flow rate of 130 SCFM, which is approximately the average of the values associated with the literature. Using this parameter, the ozone mass flux was calculated as 140 lb O_3/day, which was based on 1% ozone in air. To meet these requirements, the power demand for an ozone generator with a 150 lb O_3/day capacity would be 1800 kWh/day. The cost figures can be calculated using these numbers, as well as the experimental ozone consumption numbers. The results are shown below in Table 4.4.

Table 4.4: Energy Consumption Calculations

Material	Energy cost/tonne of soil ($ / tonne)*
Ottawa Sand (12% Sat.)	0.08
Ottawa Sand (37% Sat.)	0.11
Metea Soil (50% Sat.)	2.45

* Energy calculations based on $0.06/kWh

The energy costs associated with in-situ ozone venting, for the soils considered in these experiments, are relatively inexpensive when compared to the cost of $50-100/tonne for typical soil remediation projects (27). However, the effects of tailing may have a substantial effect on the operating costs of a full-scale in-situ ozone treatment system.

CHAPTER V

REACTION KINETICS

The most significant contribution to the consumption of ozone in a natural soil system is an important consideration to be made when designing the treatment system. This determination can be made using kinetic data which reveals the rate of degradation of ozone by various constituents of the subsurface environment.

5.1 Ozone Auto-decomposition in the Circulating Batch System

The "auto-decomposition" of ozone in the circulating batch system was determined to be a function of both the auto-degradation of gaseous ozone, and of small amounts of leakage in the system. It was necessary to quantify the "auto-decomposition" of ozone in a variety of conditions in order to be certain that the system was operating under similar circumstances.

5.1.1 Ozone Auto-decomposition in an Empty System

The "auto-decomposition" of ozone was monitored in the circulating batch system following each experiment. The rate of decomposition of ozone was quantified from a number of these experiments, in which ozone decomposition was determined in an empty soil column. The rate of decomposition is proportional to the ozone concentration, according to the following equation,

$$-\frac{d[O_3]}{dt} = k_{O_3}\ [O_3] \qquad (2)$$

this expression can be integrated to yield,

$$-\ln\left(\frac{O_3}{O_{3_0}}\right) = k_{O_3}\, t \qquad (3)$$

For the graph of $-\ln(C/C_o)$ vs. t, the relationship should be linear with a slope of k_{O3}.

The results of these experiments are shown below in Table 5.1. The standard error of the estimate (S.E.E.), the coefficient of determination, r^2, and the standard error of r^2 (S.E.), are given for comparative purposes. From this data, the average rate constant was determined as $k_{O3} = (4.99 \pm 0.037) \times 10^{-5}\ s^{-1}$ for the rate of ozone self-decomposition in an empty system.

Table 5.1: Ozone Decomposition in Empty System

Experiment	Rate Constant (s^{-1})	S.E.E.	r^2	S.E.
1	5.02×10^{-5}	2.57×10^{-7}	0.9993	2.66×10^{-3}
2	4.97×10^{-5}	3.43×10^{-7}	0.9987	3.54×10^{-3}
3	4.49×10^{-5}	1.65×10^{-7}	0.9992	4.74×10^{-3}
4	4.83×10^{-5}	1.56×10^{-7}	0.9994	4.51×10^{-3}
5	5.05×10^{-5}	1.74×10^{-7}	0.9997	1.71×10^{-3}

5.1.2 Ozone Auto-decomposition with Clean Glass Beads

The quantification of the rate of self-decomposition of ozone in the presence of clean glass beads yielded virtually identical results as that determined in the empty system. The response of the empty system under circulatory conditions compared to the response of the system containing clean glass beads is shown in Figure 5.1.

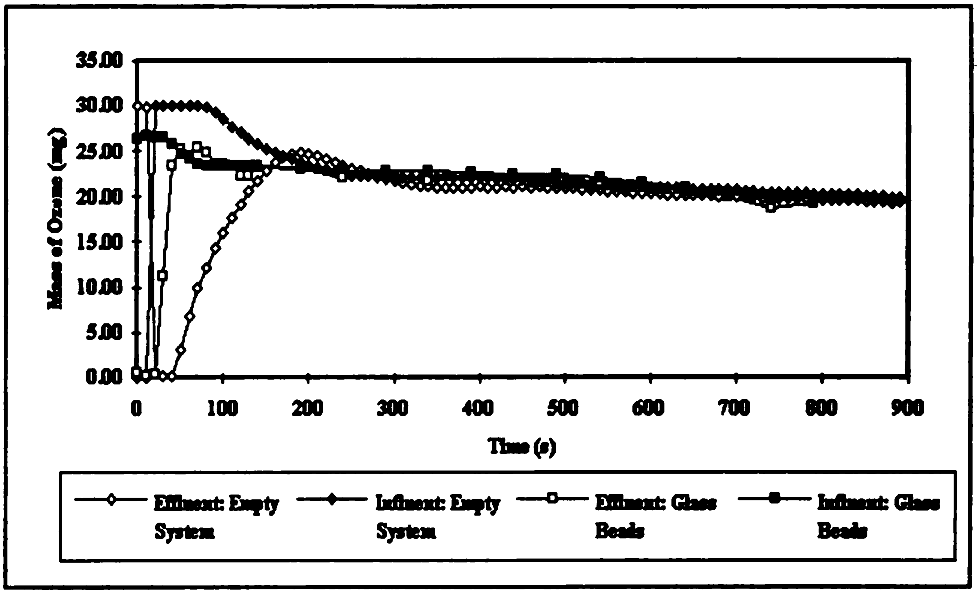


Figure 5.1: Ozone "Auto-degradation"

The rate constant was calculated in the same manner as done in the previous experiments, and the results are shown below in Table 5.2.

The high r^2 values indicate that the rate of ozone decomposition is linear with respect to the ozone concentration in the system with the column packed with clean glass beads. The average rate constant for the experiments was $k_{O3} = (4.96 \pm 0.436) \times 10^{-5}\ s^{-1}$.

Table 5.2: Ozone Decomposition in Clean Glass Beads

Experiment	Rate Constant (s^{-1})	S.E.E.	r^2	S.E.
1	5.13×10^{-5}	8.21×10^{-7}	0.9980	5.69×10^{-3}
2	4.70×10^{-5}	4.74×10^{-7}	0.9992	3.28×10^{-3}
3	4.74×10^{-5}	4.86×10^{-7}	0.9992	3.23×10^{-3}

5.1.3 Ozone Auto-decomposition in Ottawa Sand

The rate of ozone decomposition was also determined in the system with the column packed with Ottawa sand. The results in Table 5.3 show a slight increase in the rate of ozone decomposition, and the increase may be due to a number of reasons. The most likely reason for the increase in ozone decomposition is that there was a increase in the amount of leakage in the system. Leak tests using a helium leak detector were

Table 5.3: Ozone Decomposition with Ottawa Sand

Experiment	Rate Constant (s^{-1})	S.E.E.	r^2
1	7.36×10^{-5}	3.85×10^{-7}	0.9988
2	8.18×10^{-5}	2.84×10^{-7}	0.9996
3	6.28×10^{-5}	1.68×10^{-7}	0.9997

conducted on the system prior to experimentation, and following completion of each experiment. The results have consistently shown rate constant values close to the average value of $k_{O3} = (7.28 \pm 0.954) \times 10^{-5}\ s^{-1}$. Furthermore, the variability in the data, as indicated by the increase in the standard deviation, may be explained by a small ozone demand exerted by the Ottawa sand.

5.2 Pyrene Contaminated Media - No Organic Matter

These experiments establish the effect of surface adsorbed pyrene on the decomposition of ozone, as well as the removal of the target contaminant by ozone. The results show dependence of the rate of ozone decomposition on the surface coverage of pyrene, which for the 0.425 mm diameter Ottawa sand is 2.6 times that of the 6 mm diameter glass beads. Alebic-Juretic and Klasine (1992) hypothesized that the rate of decomposition of ozone is dependent on the surface area coverage of pyrene, and for this system, the rate expression can be written,

$$(4) \qquad -\left(\frac{d[O_3]}{dt}\right) = k_{O_3}[O_3] + k'[O_3]$$

k' is a pseudo first order rate constant comprised of the following relationship,

$$(5) \qquad k' = k_{PY}(S.A.)_{PY}$$

where k_{PY} = first order rate constant for pyrene
$(S.A)_{PY}$ = surface area coverage of pyrene

5.2.1 Pyrene Coated Glass Beads

The glass bead experiments were all conducted at a pyrene concentration of 250 ppm (mg pyrene/kg soil), which corresponds to a pyrene mass of 27.5 mg in 110 g of beads. The surface area coverage was calculated using the diameter of the glass beads, as shown in the appendix, by assuming a uniform, monolayer coverage of pyrene on the glass beads. The surface area of pyrene was 420 cm^2. The results of ozone decomposition are shown in Table 5.4. The extraction results will not be reported here due to experimental difficulties in recovering the pyrene following the treatments. These difficulties have been attributed to the inability to adequately coat the glass beads with

Table 5.4: Ozone Decomposition - Pyrene Coated Glass Beads

Experiment	Ozone Mass (mg)	Rate Constant (s^{-1})	
		Overall	Adjusted
1	11.3	2.50×10^{-4}	2.00×10^{-4}
2	10.8	2.28×10^{-4}	1.78×10^{-4}
3	7.44	2.18×10^{-4}	1.68×10^{-4}
4	4.43	2.28×10^{-4}	1.78×10^{-4}
5	4.61	4.66×10^{-4}	4.16×10^{-4}
6	4.50	3.23×10^{-4}	2.73×10^{-4}

a uniform surface coverage, and, therefore, the inability to obtain a representative sample. The overall rate constant is uncorrected, and the adjusted rate constant accounts for the rate of ozone self-decomposition determined previously as $k_{O3} = 4.96\times10^{-5}$ s^{-1}.

The average adjusted rate constant was calculated as $k' = (2.36 \pm 0.963) \times 10^{-4}$ s^{-1}. The variability in the result as measured by the standard deviation can be attributed primarily to experiment 5, and the glass bead extraction corresponding to that experiment indicates the highest original concentration of pyrene. Consequently, this suggests that the surface coverage of pyrene for this experiment may have been higher, which would result in a faster rate of decomposition of ozone. Negating this result, the average adjusted ozone decomposition rate is $k' = (1.99 \pm 0.43) \times 10^{-4}$ s^{-1}.

5.2.2 Pyrene Coated Ottawa Sand

The surface area of the Ottawa sand was calculated as for the glass beads, and the result for a particle size distribution of 0.425-0.60 mm is an area of 750-1070 cm^2. For an average particle diameter of 0.51 mm, the surface area is 890 cm^2. Figure 5.2 shows the system response to 250 ppm pyrene contaminated Ottawa sand.

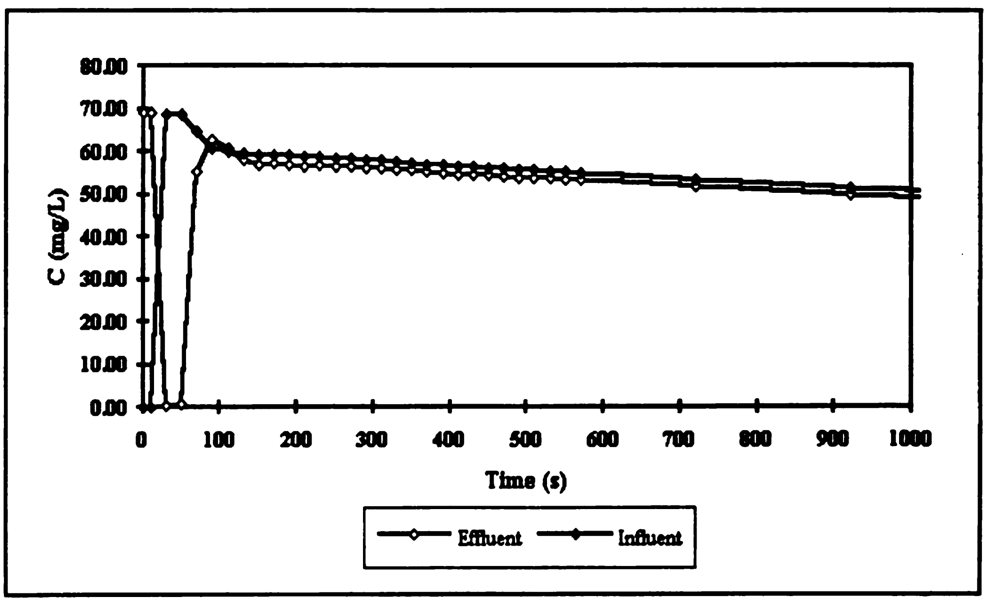


Figure 5.2: 250 ppm Pyrene Contaminated Ottawa Sand

The decomposition of ozone has increased, as evidenced by the difference between influent and effluent concentrations. The surface area hypothesis was tested using two different masses of pyrene. The rate of ozone self-decomposition used for these calculations was $k_{O3} = 7.28\times10^{-5}$ s^{-1}. The ozone decomposition results are shown in Table 5.5.

Table 5.5: Ozone Decomposition-Pyrene Coated Ottawa Sand

Exp	Ozone Mass (mg)	Pyrene		Rate Constant (s^{-1})	
		Conc. (ppm)	Mass (mg)	Overall	Adjusted
1	12.5	250	5	1.96×10^{-4}	1.23×10^{-4}
2	12.5	250	5	1.75×10^{-4}	1.02×10^{-4}
3	23.6	250	5	1.76×10^{-4}	1.03×10^{-4}
4	31.0	100	2	1.63×10^{-4}	9.02×10^{-5}

Upon examining the data, the rate constant that corresponds to a pyrene concentration of 100 ppm is approximately the same as the rate constant corresponding to a pyrene concentration of 250 ppm. This result provides evidence that the ozone decomposition is dependent on surface area coverage of pyrene, rather than the concentration of pyrene. Furthermore, a graph of $-\ln(C/C_o)$ vs. time for all four Ottawa sand experiments is shown in Figure 5.3. The plot that represents the 100 ppm pyreneexperiment shows two distinct linear ranges. Performing a linear regression on these two distinct ranges results in (1) an initial rate constant determination that corresponds to that which is tabulated above, and (2) a rate constant determination which corresponds to the rate of self-decomposition of ozone.

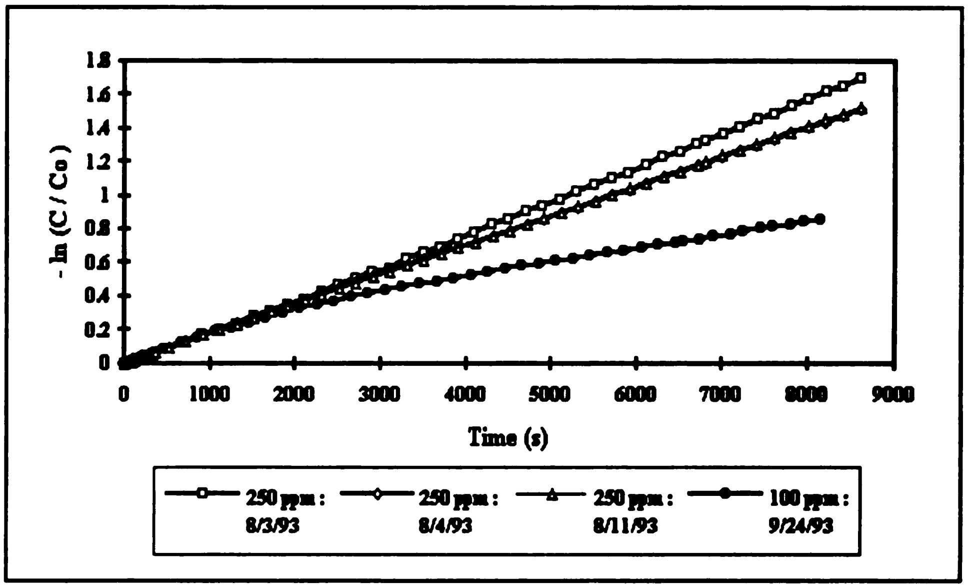


Figure 5.3: Rate Constant Determination - Ottawa Sand

By considering the rate constants as calculated for all four experiments, the average adjusted rate constant for the decomposition of ozone is $k' = (1.04 \pm 0.136) \times 10^{-4}\ s^{-1}$.

The extraction data accumulated in these experiments was more consistent than the glass bead extractions, which may be due to the fact that a more representative sample size was used in the extraction. This may also be due to a more uniform surface coverage of pyrene due to the smaller particle size, as compared to the glass bead surface coverage. The results of these extractions are tabulated below.

Table 5.6: Extraction Data - Pyrene Coated Ottawa Sand

Experiment		**Treatment Efficiency (%)**	
Concentration	#	Spectrophotometer	Fluorimeter
250 ppm	1	67.6	59.6
	2	64.3	----
	3	69.98	----
100 ppm	4	89.9	92.9

The removal efficiencies for pyrene in the 250 ppm experiments are very consistent. The average removal efficiency for pyrene in these experiments is 67.3 $\pm$ 2.86 %, and it is likely that with more available ozone, the removal efficiencies would be higher. To test this hypothesis, an experiment was conducted with ozone in excess. As expected in the experiment using 100 ppm pyrene, the removal efficiency of pyrene increased dramatically. Using the spectrophotometric results, the increase in pyrene removal was 35%. Finally, the analysis of the extracts using the fluorimeter, a more sensitive instrument, confirm the results acquired using the spectrophotometer.

5.3 Metea Soil

Initially, an experiment using a sample of uncontaminated metea soil was conducted in order to examine the effect of the soil on the decomposition of ozone. Again, a linear regression was performed on the natural log transformed data as shown in Figure 5.4.

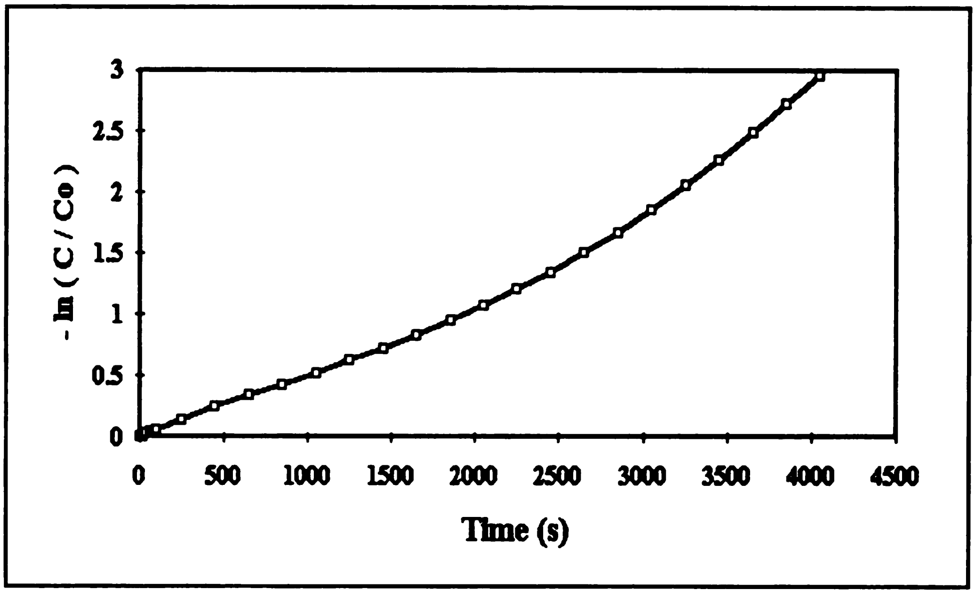


Figure 5.4: Rate Constant Determination - Metea Soil

Upon examination of this graph, it is apparent that the rate of decomposition increases dramatically from its initial rate. This may be the result of the formation of ozone demanding by-products from the oxidation of organic matter present in the natural soil, although no attempt was made to verify this assertion. Consequently, a linear regression was performed on the linear range of this relationship which occurred over the initial 2100 s of the experiment, in order to ascertain the initial rate of decomposition of ozone. The pseudo-first order rate constant, which has been adjusted for the self-decomposition of ozone, is $k'_{OM} = 4.33\times10^{-4}$ s^{-1} with a S.E.E.= 4.35×10^{-6} and $r^2 = 0.9990$.

<u>5.3.1 Pyrene Contaminated Natural Metea Soil</u>

The introduction of soil organic matter into the system had a dramatic effect on the degradation of ozone. The system response to 250 ppm contaminated Metea soil compared to the response for 250 ppm contaminated Ottawa sand is shown in Figure 5.5.

The organic matter consumes a significant amount of the ozone present in the system.

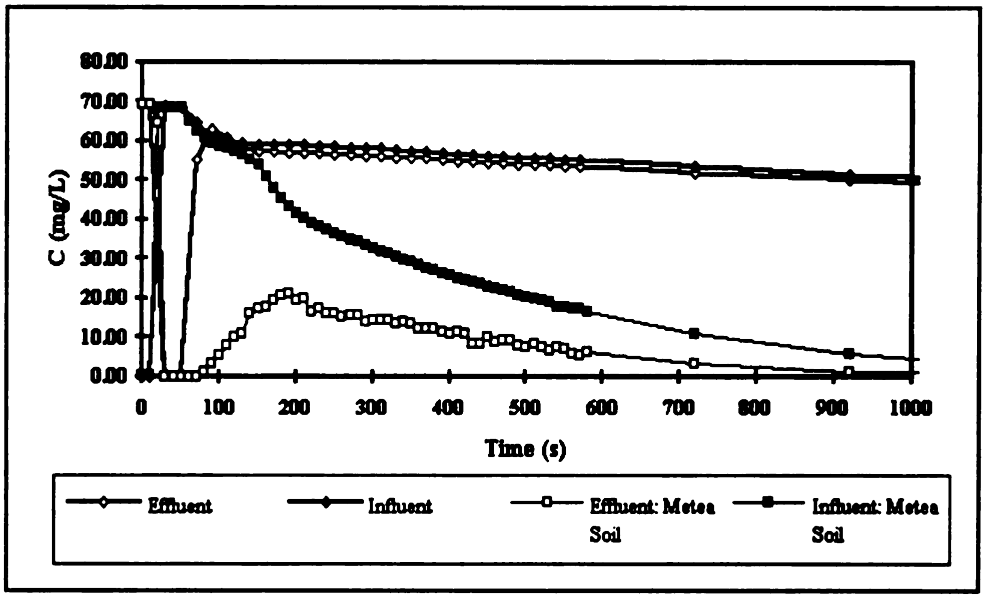


Figure 5.5: 250 ppm Pyrene Contaminated Metea Soil

The variability from sample to sample in the characteristics of the Metea soil, particularly the organic matter content, poses experimental difficulties in reproducing kinetic rate constants. However, considering the variability in the glass bead experiments, the pyrene contaminated metea soil experiments yielded comparatively consistent results. Table 5.7 summarizes the experimental conditions and the results. The results of the uncontaminated natural soil experiment are included in this table for comparative purposes. Furthermore, the results of the control experiment using oxygen indicated that the pyrene is not strippable, and these results are also tabulated in Table 5.7. The rate expression can be formulated using equation 3, as described above, by assuming that the pyrene adsorbs to the organic matter, such that the initial rate is affected only by pyrene.

Table 5.7: Pyrene Contaminated Natural Soil

Exp.	Ozone Mass (mg)	Pyrene		Treatment Efficiency (%)	Rate Constant (s^{-1})	
		Conc. (ppm)	Mass (mg)		Overall	Adjusted
O.M.	26.6	- - -	- -	- - -	5.06×10^{-4}	4.87×10^{-4}
Control	0	250	5	0	- - -	- - -
1	23.6	250	5	63.2	2.40×10^{-3}	2.33×10^{-3}
2	24.3	250	5	59.2	2.30×10^{-3}	2.23×10^{-3}
3	23.8	250	5	67.6	2.00×10^{-3}	1.93×10^{-3}
4	27.5	250	5	60.4	1.60×10^{-3}	1.53×10^{-3}
5	20.3	250	5	65.9	1.64×10^{-3}	1.57×10^{-3}
6	28.0	100	2	81.6	1.62×10^{-3}	1.55×10^{-3}

The removal efficiencies of the pyrene for the 250 ppm experiments show an average value of 63.6 ± 3.55 %. The removal efficiency is not sensitive to small changes in the initial ozone mass present in the system. Consequently, the results have been averaged over all five experiments. This lack of sensitivity may be due to the variability of the soil extraction results. Furthermore, it is likely that the extent of removal of pyrene is ozone limited for these experiments, and with the introduction of a larger mass of ozone, or by providing a continuous flow system, the removal efficiency would increase.

This observation is supported by the extent of removal for the 100 ppm pyrene experiment. By providing an excess of ozone, the removal efficiency increased approximately 30%. This is consistent with the result observed in the 100 ppm pyrene contaminated Ottawa sand experiment, where the removal efficiency increased 35%. The presence of two distinct linear regions in the graph of $-\ln (C / C_o)$ vs t was not evident in the 100 ppm contaminated Metea soil experiments, as observed in the 100 ppm contaminated Ottawa sand.

The rate constant data was calculated in the same manner as described previously. The rate of decomposition of ozone increased dramatically during later times, and the reaction order deviates from the first order assumption. However, the initial rate of decomposition approaches the first order assumption, and the results of these calculations are tabulated above.

5.3.2 Moisturized Pyrene Contaminated Metea Soil

The immediate effect of the addition of moisture into the soil system is demonstrated in Figure 5.6. The ozone introduced into the column was almost completely consumed upon contacting the moist soil. This effect is most probably due to the mass transfer of gaseous ozone into the aqueous phase present in the system. The rate constant determination reveals that the rate of ozone decomposition is linear. The results of these calculations are tabulated below in Table 5.8.

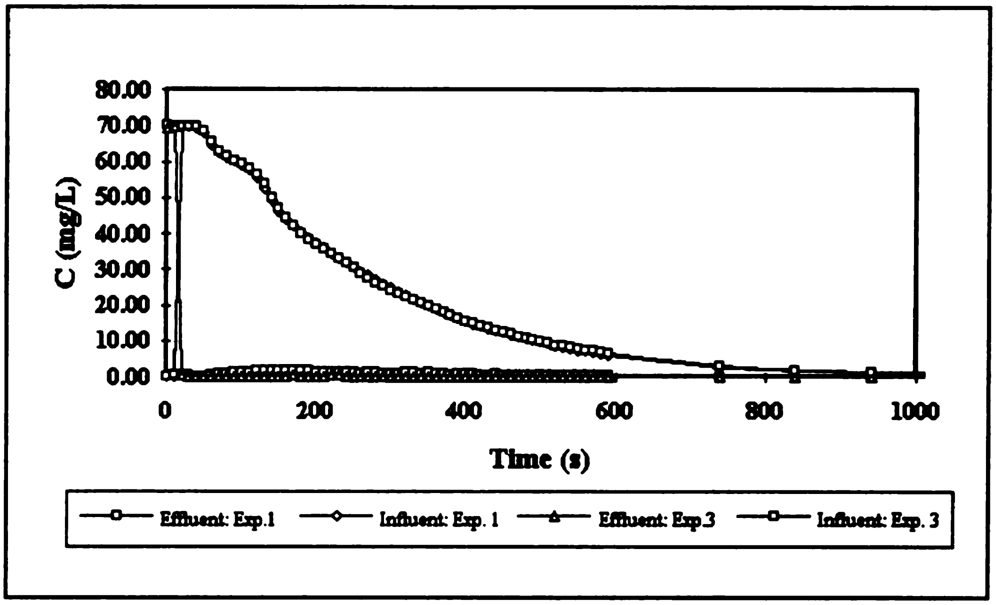


Figure 5.6: System Response to Moist Contaminated Soil

The removal efficiency of pyrene appears to be a function of the ozone mass present in the system, as well as the moisture content of the soil. The moisture content has the effect of reducing the removal efficiency for increasing moisture levels (See Experiments 1,2 and 3 in Table 5.8). The mass of ozone used in these experiments is constant. The removal efficiency of pyrene was observed to increase with decreasing moisture content. Furthermore, an increase in the mass of ozone at a constant moisture content yielded an increase in the removal efficiency (See experiments 3,4,6,7 and 8 in Table 5.8). This result supports the hypothesis that the reaction is ozone limited. Finally, by providing excess ozone (See experiments 9 and 10 in Table 5.8), the removal efficiency increased dramatically which is the same effect as that observed for dry soil. Therefore, the removal efficiency for these experiments was ozone limited.

The rate of ozone decomposition was constant over all of the experiments. The average rate constant can be calculated as $k' = (4.52 \pm 0.28) \times 10^{-3}\ s^{-1}$, with the largest contribution to the deviation coming from experiment 2. This rate is assumed to be pseudo-first order, although it is difficult to ascertain the exact mechanism for the increased rate of ozone decomposition. The most likely mechanism is the dissolution of gaseous ozone into the aqueous phase present in the system.

Table 5.8: Moisturized Metea Soil

Exp	Ozone Mass (mg)	Pyrene Conc. (ppm)	Moisture Content (%)	Treatment Efficiency (%)	Rate Constant (s^{-1})	
					Overall	Adjusted
1	23.9	250	4.4	4.7	4.70×10^{-3}	4.63×10^{-3}
2	23.7	250	3.5	22.2	5.28×10^{-3}	5.21×10^{-3}
3	23.6	250	2.9	29.9	4.51×10^{-3}	4.44×10^{-3}
4	27.6	250	2.8	23.5	4.70×10^{-3}	4.63×10^{-3}
5	20.5	250	2.4	17.5	4.30×10^{-3}	4.23×10^{-3}
6	32.6	250	2.9	35.5	4.43×10^{-3}	4.36×10^{-3}
7	33.1	250	3.1	36.6	4.42×10^{-3}	4.35×10^{-3}
8	32.4	250	3.0	37.3	4.52×10^{-3}	4.45×10^{-3}
9	28.7	100	~ 3	58.2	4.38×10^{-3}	4.31×10^{-3}
10	29.3	100	~ 3	56.8	4.67×10^{-3}	4.60×10^{-3}

CHAPTER VI

DISCUSSION AND CONCLUSIONS

The formulation of the results of this study into a comprehensive predictive model has proven to be difficult. This is due to the uncertainty involved in quantifying the surface characteristics of the adsorption of the organic contaminant, and the nature of the surface coverage of the water. Table 6.1 summarizes the experimental results for reference in the remainder of the discussion and conclusions.

6.1 Surface Coverage of Pyrene

The quantification of the decomposition of ozone is dependent on knowledge of the extent of surface coverage of pyrene. The mass of pyrene necessary for monolayer coverage can be approximated for the media considered in this study. The total surface area of a pyrene molecule was approximated as 250 $Å^2$.(28) By assuming that between 50-100% of the surface adsorbed molecule would be exposed to ozone, a range of pyrene masses was calculated. The approximate masses of pyrene necessary for monolayer coverage are 0.026-0.090 μg, 0.058-0.23 μg, and 390-1560 μg for glass beads, Ottawa sand, and Metea soil, respectively. In each case, there was sufficient mass of pyrene present on the material surface for monolayer coverage. The mass of pyrene that was available in the 250 ppm experiments was 5 mg for both the Ottawa sand and the Metea soil. In the 100 ppm experiments, there was 2 mg of pyrene available for surface coverage on the Ottawa sand and the Metea soil. A 105 g sample size of glass beads was used, therefore, there was 26.25 mg pyrene available in the 250 ppm experiment, and 10.5 mg of pyrene available for surface coverage in the 100 ppm experiment. The uniformity

Table 6.1: Summary of Experimental Results

Experiment	Average Rate Constant	Standard Deviation	Treatment Efficiency C_0	(%)	Standard Deviation
Empty	5.0×10^{-5}	3.7×10^{-7}	N.A.	N.A	N.A.
Clean Glass Beads	5.0×10^{-5}	4.4×10^{-6}	N.A.	N.A.	N.A.
Clean Ottawa Sand	7.3×10^{-5}	9.6×10^{-6}	N.A.	N.A.	N.A.
Dry Metea Soil	4.3×10^{-4}	N.A.	N.A.	N.A.	N.A.
Contaminated Glass Beads	2.4×10^{-4}	9.6×10^{-5}	N.A.	N.A.	N.A.
Contaminated Ottawa Sand	1.0×10^{-4}	1.4×10^{-5}	250	68	2.9
			100	90	N.A.
Contaminated Metea Soil	1.9×10^{-3}	3.6×10^{-4}	250	64	3.6
			100	82	N.A.
Contaminated Moist Metea Soil	4.5×10^{-3}	2.8×10^{-4}	250	36	1.6
			100	58	1.5

of surface coverage is not guaranteed, however, which means that adequate mass of pyrene available is not sufficient for the monolayer assumption.

The assumption of monolayer coverage can be utilized to calculate the rate constant for the decomposition of ozone in the presence of pyrene, k_{PY}. However, the results of these rate constant calculations for glass beads and Ottawa sand are inconclusive. The two materials may have different surface characteristics, which would lead to a different number of active adsorption sites per unit area of material. Furthermore, this discrepancy may be due to the method of contaminating the materials, and there is evidence of this in the variability associated with the glass bead extraction results. The most conclusive evidence which supports the surface coverage hypothesis is the results of the 250 ppm and 100 ppm pyrene experiments. These results reveal an identical rate of ozone decomposition for two different masses of adsorbed pyrene.

The results of this study suggest that the monolayer coverage assumption employed in formulating the rate expression for the decomposition of ozone in the presence of surface adsorbed pyrene does not hold. Furthermore, an accurate quantification of the surface area of adsorbed pyrene is necessary for modeling considerations. However, evidence supports the hypothesis that the rate of decomposition of ozone, and, therefore, the rate of pyrene degradation, is dependent on the surface area of pyrene.[3]

3. The results of the rate constant determination experiments for glass beads and Ottawa sand, shown in Table 6.1, support the surface area dependence hypothesis. Identical concentrations of pyrene were adsorbed to media possessing significantly different surface areas, and the result was substantially different rate constant calculations.

6.2 Surface Coverage of Water

The rate of ozone decomposition due to the presence of water in a subsurface soil system is dependent on the extent of surface coverage. Assuming monolayer surface coverage of water, the rate of decomposition of gaseous ozone will depend on the solubility of ozone in water. The adequacy of this assumption for the soil considered in this study, and the attainment of this condition in the laboratory, as well as in the natural environment, is contingent on a number of considerations. The non-volatile and hydrophobic nature of pyrene, and the soil contamination procedure employed in this study, lead to the assumption of complete adsorption of the contaminant to the soil surface. Consequently, the dissolution of the gaseous ozone into the aqueous phase present in the soil system accounts for the decomposition of ozone as monitored during this study.

Goss (29) showed that the sorption of volatile and semi-volatile organic compounds is dependent on the relative humidity (RH), as well as the temperature, of the system being studied. For experiments conducted in quartz sand systems (i.e. Ottawa sand), a monolayer surface coverage of water would have occurred at a RH of 26%. This corresponded to a mass of 0.18 mg of water/g of sorbent. In these experiments, therefore, the minimum mass of water necessary for a monolayer coverage was 3.6 mg. With a 3% moisture content in the experiments, there was 600 mg of water available, which far exceeds the minimum amount of water required for monolayer coverage. For the soil considered in this study, the mineral component of the soil will affect the sorption of water to the soil surface. The water uptake of the Metea soil will increase considerably due to the polar interactions of water and mineral surfaces, as well as the high internal surface area of mineral surfaces which can act as a water-holding reservoir (30). Therefore, the RH necessary for a monolayer of water to exist on the Metea soil is higher than for the quartz sand system. Experiments conducted on a dry Woodburn soil by Chiou and Shoup (31) suggest that for a soil containing a high mineral content, monolayer coverage of water occurred at a RH of 90%. Their experiment showed that the soil uptake of volatile organic compounds decreased with increasing relative humidities.

These studies suggest that the monolayer water assumption should hold for Metea soil at a RH between 26-90%. The moisturization of the Metea soil samples, as discussed in the materials and methods section of this paper, occurred in a vacuum desiccator using a salt solution previously determined to correspond to a RH of approximately 98%. This evidence suggests that the conditions existing in preparing the soil samples far exceed the conditions necessary to insure a monolayer coverage of water, although the relative humidity in the desiccator was not monitored. Considering the above discussion, the results of the moist Metea soil experiments suggest that the decomposition of ozone corresponds to the dissolution of ozone into the aqueous phase. The aqueous phase ozone subsequently reacted with the surface adsorbed pyrene.

6.3 Implications for In-situ Ozone Vapor Stripping

The implications of this study suggest the feasibility of in-situ ozone vapor stripping. The transport of ozone in residually saturated Metea soil was demonstrated, as well as the oxidation of pyrene in the presence of soil moisture.

The transport of ozone in residually saturated soils under a variety of conditions was demonstrated. The ozone demand of a natural Metea soil system was met, and preliminary cost calculations of the results show competitiveness with alternative soil remediation techniques. The ozone demand of an Ottawa sand system containing 200 ppm iron(III) was not achieved, although breakthrough of ozone in the effluent of the column was accomplished. The environmental significance of such a system has not been demonstrated, as the concentration of iron used was higher than that found in soils. The degree of water saturation was shown to affect the ozone demand of soil systems, as revealed by the residually saturated Ottawa sand systems.

The degradation of surface adsorbed pyrene was achieved, although a significant improvement in the treatment efficiency was not demonstrated for moisturized soil systems. The results suggest that the pyrene (in air-dried systems) reacts directly with ozone. Furthermore, an aqueous phase reaction of ozone and pyrene is suggested by the results of the moist soil experiments.[4] The production of radical species, such as hydroxyl radicals, had no apparent beneficial effect on the removal of pyrene in the system.

6.4 Further Research

The conclusions reached in these experiments suggest a number of possible research topics. One such topic involves the study of different PAHs to determine the role of indirect reactions by radical species due to the presence of soil moisture. Another extremely important topic involves the identification of oxidation byproducts, and the characteristics of these compounds in terms of toxicity, biodegradability, and mobility. The concerns raised regarding the characteristics of these byproducts may ultimately determine the feasibility of ozone treatment of soils.

4. The evidence supporting the direct reaction mechanism is the comparable treatment efficiencies for the contaminated Ottawa sand and Metea soil (See Table 6.1). Furthermore, the glass bead and Ottawa sand experiments demonstrate the effect of the direct reaction mechanism because the production of radical species is unlikely.

As a continuation of these experiments, the effect of varying moisture content on the degradation of PAHs, with careful attention to the monolayer considerations put forth in these experiments, should be pursued. Finally, the results of these experiments suggest the necessity of formulating the results of continued moisture experimentation into a competitive kinetic model.

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APPENDICES

A. Ozone Transport Study

A.1 Ottawa Sand Experiments

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A.3 Metea Soil Experiments

B. Kinetic Rate Constant Data

B.1 Pyrene Contaminated Glass Beads

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D.3 Calculations of Energy Consumption

APPENDIX A: Ozone Transport Study

Table A.1-1

Treatment of Ottawa Sand: DRY

	Breakthrough			
	time (s)	Final Avg.(ABS)	del t (s)	Area
Initial	0	0	10	0
avg(ABS)	10	0	10	0
0.92500459	20	0	10	0
0.92458956	30	0.00355988	10	0.0356
0.92473907	40	0.07322387	10	0.7322
0.92450869	50	0.25085603	10	2.5086
0.92415009	60	0.44962004	10	4.4962
0.92380372	70	0.59947509	10	5.9948
0.92345581	80	0.69282989	10	6.9283
0.92303619	90	0.74641112	10	7.4641
0.92261505	100	0.77706605	10	7.7707
0.92240906	110	0.7955536	10	7.9555
0.92196197	120	0.80790558	10	8.0791
0.92157136	130	0.81445314	10	8.1445
0.9210724	140	0.82083282	10	8.2083
0.92023621	150	0.8267502	10	8.2675
0.91989288	160	0.83212282	10	8.3212
0.91972962	170	0.83657532	10	8.3658
0.91950531	180	0.84058837	10	8.4059
0.919458	190	0.84435273	10	8.4435
0.91914028	200	0.84767	10	8.4767
	210	0.85068055	10	8.5068
0.92215157	220	0.85322113	10	8.5322
	280	0.86666108	60	52
	340	0.87726237	60	52.636
	400	0.88559291	60	53.136
	460	0.89176381	60	53.506
	520	0.89583258	60	53.75
	580	0.89790244	60	53.874
	640	0.89777451	60	53.866
	700	0.89642615	60	53.786
	760	0.8952764	60	53.717
	820	0.89283779	60	53.57
	880	0.88964387	60	53.379
	940	0.88718415	60	53.231
	1000	0.88863398	60	53.318

Breakthrough (cont.)			
time (s)	Final Avg.(ABS)	del t (s)	Area
1060	0.893410493	60	53.60463
1120	0.89818523	60	53.89111
1180	0.902864082	60	54.17184
1240	0.90620117	60	54.37207
1300	0.908193462	60	54.49161
1360	0.90877203	60	54.52632
1420	0.90861029	60	54.51662
1480	0.908168802	60	54.49013
1540	0.905418145	60	54.32509
1600	0.903464762	60	54.20789
1660	0.906297159	60	54.37783
	SUM:		1426.38

Area=	96.0921
Mass Ozone consumed=	0.000757
% Consumed=	6.311583
(ABS)f/(ABS)i=	98.28072

Table A.1-2

Treatment of Ottawa Sand: RO Water #1

	Breakthrough							
	time (s)	Final Avg.(ABS)	del t (s)	Area	time (s)	Final Avg.(ABS)	del t (s)	Area
Initial	10	0.00175476	10	0.017548	1310	0.90515697	60	54.3094179
avg(ABS)	20	0.00195923	10	0.019592	1370	0.90604528	60	54.362717
0.93253327	30	0.00204163	10	0.020416	1430	0.90762381	60	54.4574283
0.93218995	40	0.00215607	10	0.021561	1490	0.90932439	60	54.5594634
0.93181611	50	0.03185883	10	0.318588	1550	0.91041006	60	54.6246033
0.93124695	60	0.17624206	10	1.762421	1610	0.91150412	60	54.690247
0.93094788	70	0.36964113	10	3.696411	1670	0.9119568	60	54.717408
0.93077543	80	0.52869417	10	5.286942				
0.93044587	90	0.62970123	10	6.297012	SUM:			1404.39071
0.93020629	100	0.68724213	10	6.872421				
0.92965851	110	0.72080232	10	7.208023		Area=	129.85	
0.92923432	120	0.7418915	10	7.418915	Mass Ozone consumed=		0.00103	mol / kgsoil
0.92890016	130	0.75650026	10	7.565003		% Consumed=	8.46345	
0.92859193	140	0.76736909	10	7.673691				
0.92831116	150	0.77614897	10	7.76149		(ABS)f/(ABS)i=	98.1359	
0.92743989	160	0.78364868	10	7.836487				
0.92735596	170	0.79011383	10	7.901138				
0.92688142	180	0.795578	10	7.95578				
0.92676699	190	0.8005432	10	8.005432				
0.92664185	200	0.80507051	10	8.050705				
0.92636618	210	0.80919037	10	8.091904				
---------	220	0.81301271	10	8.130127				
0.92927948	230	0.81654663	10	8.165466				
	290	0.82646535	60	49.58792				
	350	0.83964743	60	50.37885				
	410	0.8505305	60	51.03183				
	470	0.86033555	60	51.62013				
	530	0.86838151	60	52.10289				
	590	0.87448375	60	52.46903				
	650	0.87876766	60	52.72606				
	710	0.88203049	60	52.92183				
	770	0.8851738	60	53.11043				
	830	0.88797201	60	53.27832				
	890	0.89120789	60	53.47247				
	950	0.89468436	60	53.68106				
	1010	0.89702251	60	53.82135				
	1070	0.89915416	60	53.94925				
	1130	0.90099794	60	54.05988				
	1190	0.90241471	60	54.14488				
	1250	0.90393626	60	54.23618				

Table A.1-3

Treatment of Ottawa sand: RO Water #2

Breakthrough

Initial avg(ABS)	time (s)	Final Avg.(ABS)	del t (s)	Area
	10	0	10	0
	20	0	10	0
0.92275391	30	0	10	0
0.92234956	40	0	10	0
0.92243805	50	0.00208282	10	0.02083
0.92196809	60	0.08246765	10	0.82468
0.92151797	70	0.26354676	10	2.63547
0.9211258	80	0.42017975	10	4.2018
0.92074584	90	0.51899262	10	5.18993
0.92053834	100	0.57870943	10	5.78709
0.92062532	110	0.61760255	10	6.17603
0.92042085	120	0.64586794	10	6.45868
0.92067564	130	0.66780854	10	6.67809
0.92060241	140	0.68593902	10	6.85939
0.92050171	150	0.70137634	10	7.01376
0.92043763	160	0.71460725	10	7.14607
0.92024689	170	0.7262665	10	7.26267
0.92004091	180	0.73671417	10	7.36714
0.91997833	190	0.74606629	10	7.46066
0.91985933	200	0.75443727	10	7.54437
0.91991002	210	0.76184996	10	7.6185
---------	220	0.76866151	10	7.68662
0.92088087	230	0.77480316	10	7.74803
	290	0.79257966	60	47.5548
	350	0.81502558	60	48.9015
	410	0.83021546	60	49.8129
	470	0.84023082	60	50.4138
	530	0.84742432	60	50.8455
	590	0.85198695	60	51.1192
	650	0.8544215	60	51.2653
	710	0.85739314	60	51.4436
	770	0.86010438	60	51.6063
	830	0.86287892	60	51.7727
	890	0.86546669	60	51.928
	950	0.86729254	60	52.0376

Breakthrough (cont.)

time (s)	Final Avg.(ABS)	del t (s)	Area
1010	0.86884487	60	52.1306919
1070	0.86969351	60	52.1816104
1130	0.87092159	60	52.2552954
1190	0.87158483	60	52.2950898
1250	0.87284698	60	52.370819
1310	0.8745636	60	52.4738161
1370	0.87527212	60	52.5163274
1430	0.87707393	60	52.6244358
1490	0.87820868	60	52.6925207
1550	0.87853115	60	52.7118687
1610	0.87817791	60	52.6906746
1670	0.87816444	60	52.6898663

SUM: 1350.01401

Area= 170.36

Mass Ozone consumed= 0.00135 mol / kgsoil

% Consumed= 11.2052

(ABS)f/(ABS)i= 95.3614

Table A.2-1

Treatment of Ottawa Sand: Fe^{3+}

Breakthrough

	time (s)	Final Avg.(ABS)	del t (s)	Area
Initial	10	0	10	0
avg(ABS)	20	0	10	0
0.90753021	30	0.02510834	10	0.25108
0.9079773	40	0.15196838	10	1.51968
0.90857087	50	0.33714752	10	3.37148
0.90883026	60	0.49527435	10	4.95274
0.90921938	70	0.59756929	10	5.97569
0.90941466	80	0.65783997	10	6.5784
0.90970614	90	0.69316407	10	6.93164
0.91003113	100	0.7148224	10	7.14822
0.91013337	110	0.7289505	10	7.28951
0.91046753	120	0.73834229	10	7.38342
0.91083679	130	0.74465179	10	7.44652
0.91084595	140	0.74862061	10	7.48621
0.91120911	150	0.75111848	10	7.51118
0.91081696	160	0.75235292	10	7.52353
0.91092988	170	0.75283356	10	7.52834
0.91064607	180	0.75291442	10	7.52914
0.91089174	190	0.75272522	10	7.52725
0.91116333	200	0.75263215	10	7.52632
0.91122098	210	0.7522934	10	7.52293
	220	0.75211183	10	7.52112
0.91002325	230	0.75222321	10	7.52223
	290	0.75291545	60	45.1749
	350	0.75553666	60	45.3322
	410	0.75847474	60	45.5085
	470	0.76030324	60	45.6182
	530	0.76115316	60	45.6692
	590	0.7621488	60	45.7289
	650	0.76218211	60	45.7309
	710	0.76107179	60	45.6643
	770	0.75957414	60	45.5744
	830	0.75813116	60	45.4879
	890	0.7561863	60	45.3712
	950	0.75467275	60	45.2804
	1010	0.75383276	60	45.23

time (s)	Final Avg.(ABS)	del t (s)	Area
1070	0.75269318	60	45.1615909
1130	0.75148036	60	45.0888215
1190	0.74961777	60	44.9770664
1250	0.74765498	60	44.8592989
1310	0.74579087	60	44.7474524
1370	0.7443334	60	44.6600039
1430	0.74412537	60	44.6475222
1490	0.74370041	60	44.6220247
1550	0.74342117	60	44.6052704
1610	0.74367244	60	44.6203465
1670	0.74415238	60	44.6491426

SUM: 1218.05617

Area= 284.392

Mass Ozone consumed= 0.00228 mol / kgsoil

% Consumed= 18.9286

(ABS)f/(ABS)i= 81.7729

Table A.2-2

Treatment of Ottawa Sand: t-BuOH

	Breakthrough			
	time (s)	Final Avg.(ABS)	del t (s)	Area
Initial	10	0	10	0
avg(ABS)	20	0	10	0
0.91083069	30	0	10	0
0.91053617	40	0.00060883	10	0.00609
0.90998231	50	0.06309662	10	0.63097
0.90955964	60	0.22773437	10	2.27734
0.9088379	70	0.40740968	10	4.0741
0.908461	80	0.53881686	10	5.38817
0.90832978	90	0.61962129	10	6.19621
0.90786286	100	0.66725617	10	6.67256
0.90774842	110	0.69657899	10	6.96579
0.90754242	120	0.71603394	10	7.16034
0.90729372	130	0.73001709	10	7.30017
0.90710298	140	0.74113005	10	7.4113
0.90691375	150	0.74992371	10	7.49924
0.90648957	160	0.75724944	10	7.57249
0.90621339	170	0.76383668	10	7.63837
0.90606537	180	0.76948853	10	7.69489
0.90591889	190	0.77430878	10	7.74309
0.90546723	200	0.7788437	10	7.78844
0.90515308	210	0.78269349	10	7.82693
---------	220	0.78613281	10	7.86133
0.90770048	230	0.78921356	10	7.89214
	290	0.79812013	60	47.8872
	350	0.80931779	60	48.5591
	410	0.81703847	60	49.0223
	470	0.8237732	60	49.4264
	530	0.82875265	60	49.7252
	590	0.83287965	60	49.9728
	650	0.8360545	60	50.1633
	710	0.83893942	60	50.3364
	770	0.84114304	60	50.4686
	830	0.84340185	60	50.6041
	890	0.84546968	60	50.7282
	950	0.84629543	60	50.7777
	1010	0.84649659	60	50.7898

Breakthrough (cont.)			
time (s)	Final Avg.(ABS)	del t (s)	Area
1070	0.84644089	60	50.7864536
1130	0.84531836	60	50.7191014
1190	0.84461035	60	50.6766207
1250	0.84475352	60	50.6852114
1310	0.84491476	60	50.6948854
1370	0.84515483	60	50.7092899
1430	0.84649684	60	50.7898104
1490	0.84716188	60	50.8297125
1550	0.84848837	60	50.9093023
1610	0.84993414	60	50.9960486
1670	0.85043453	60	51.0260718
SUM:			1330.8834

Area= 167.73

Mass Ozone consumed= 0.0014 mol / kgsoil

% Consumed= 11.1924

(ABS)f/(ABS)i= 93.6911

Table A.2-3

Treatment of Ottawa sand: Fe^{3+} and (t-BuOH)

	Breakthrough				Breakthrough (cont.)			
	time (s)	Final Avg.(ABS)	del t (s)	Area	time (s)	Final Avg.(ABS)	del t (s)	Area
Initial	10	4.5776E-05	10	0.00046	1070	0.72583949	60	43.5503696
avg(ABS)	20	0.10625459	10	1.06255	1130	0.72669398	60	43.6016388
0.89820099	30	0.36092071	10	3.60921	1190	0.72767512	60	43.6605074
0.89777985	40	0.52445373	10	5.24454	1250	0.72753933	60	43.6523597
0.89759523	50	0.61431885	10	6.14319	1310	0.7281924	60	43.6915442
0.89719391	60	0.67138214	10	6.71382	1370	0.72910488	60	43.7462926
0.89690095	70	0.70941165	10	7.09412	1430	0.72933655	60	43.7601932
0.8966614	80	0.73406982	10	7.3407	1490	0.72975897	60	43.7855382
0.89618529	90	0.75023499	10	7.50235	1550	0.72936478	60	43.7618868
0.89594575	100	0.76074524	10	7.60745	1610	0.72875825	60	43.7254949
0.8956955	110	0.76740724	10	7.67407	1670	0.72803675	60	43.6822052
0.89563143	120	0.77155764	10	7.71558				
0.89526978	130	0.77410431	10	7.74104		SUM:		1211.25114
0.8947876	140	0.77543792	10	7.75438				
0.8944046	150	0.77607424	10	7.76074		Area=	267.078	
0.89414826	160	0.77646789	10	7.76468		Mass Ozone consumed=	0.00226	mol / kgsoil
0.89354553	170	0.77651521	10	7.76515		% Consumed=	18.0662	
0.89343719	180	0.77642061	10	7.76421				
0.89331358	190	0.77619476	10	7.76195		(ABS)f/(ABS)i=	86.7069	
0.89303589	200	0.775795	10	7.75795				
0.89313762	210	0.77552187	10	7.75522				
	220	0.77546692	10	7.75467				
0.89541423	230	0.77535707	10	7.75357				
	290	0.77638627	60	46.5832				
	350	0.78482259	60	47.0894				
	410	0.78370667	60	47.0224				
	470	0.7699496	60	46.197				
	530	0.7494512	60	44.9671				
	590	0.72848485	60	43.7091				
	650	0.71798478	60	43.0791				
	710	0.71525065	60	42.915				
	770	0.7158544	60	42.9513				
	830	0.71706874	60	43.0241				
	890	0.72020016	60	43.212				
	950	0.72279053	60	43.3674				
	1010	0.72457505	60	43.4745				

Table A.3-1

Natural soil: RO water

	Breakthrough			
	Time (s)	Final Avg(ABS)	del t (s)	Area
Initial	10	0	10	0
Avg(ABS)	20	0	10	0
0.903822	30	0	10	0
0.90367	40	0	10	0
0.903755	50	1.22E-05	10	0.000122
0.903708	60	0.002686	10	0.026855
0.903448	70	0.0078	10	0.078003
0.903444	80	0.013301	10	0.133011
0.903046	90	0.018904	10	0.189041
0.90256	100	0.024187	10	0.241867
0.902217	110	0.029413	10	0.294128
0.901892	120	0.034592	10	0.345917
0.901407	130	0.039574	10	0.395737
0.901163	140	0.044452	10	0.444519
0.900784	150	0.049075	10	0.490753
0.9	160	0.053783	10	0.537827
0.899406	170	0.058371	10	0.58371
0.89897	180	0.062959	10	0.629593
0.898557	190	0.067484	10	0.674835
0.89852	200	0.071962	10	0.71962
0.896679	210	0.076273	10	0.762726
	220	0.080659	10	0.806595
0.901424	230	0.084886	10	0.848862
	290	0.099075	60	5.944489
	350	0.121743	60	7.30458
	410	0.142016	60	8.520935
	470	0.160343	60	9.62056
	530	0.176716	60	10.60294
	590	0.19183	60	11.50978
	650	0.205579	60	12.33475
	710	0.21826	60	13.09561
	770	0.230107	60	13.80644
	830	0.240917	60	14.455
	910	0.252521	80	20.20168
	970	0.263247	60	15.79483
	1030	0.271984	60	16.31903
	1090	0.280291	60	16.81746
	1150	0.287835	60	17.27011
	1210	0.294483	60	17.66898
	1270	0.300346	60	18.02077
	1330	0.305874	60	18.35242
	1390	0.311958	60	18.71745
	1450	0.317829	60	19.06976

Breakthrough (cont.)			
Time (s)	Final Avg(ABS)	del t (s)	Area
1510	0.323623	60	19.4173742
1570	0.3287	60	19.7219855
1630	0.334284	60	20.0570523
1690	0.33951	60	20.3706211
1750	0.344755	60	20.6853028
1810	0.349826	60	20.9895788
1857	0.3539	47	16.6332984
5577	0.439225	3720	1633.91601
9177	0.581912	3600	2094.88496
12777	0.609931	3600	2195.75111
16377	0.638644	3600	2299.119
19977	0.662219	3600	2383.98744
23577	0.706701	3600	2544.12326
27177	0.728756	3600	2623.52054
30777	0.778376	3600	2802.15454
34377	0.814068	3600	2930.64422
37977	0.856693	3600	3084.09394
41577	0.88402	3600	3182.47103
45177	0.917516	3600	3303.05605
48777	0.933025	3600	3358.8895
52377	0.946693	3600	3408.09449
55977	0.930506	3600	3349.82116
59577	0.911208	3600	3280.34821
63177	0.914169	3600	3291.00954
64017	0.898812	840	755.001957
SUM:		64017	48952.3935

Area=	8754.043	
Mass Ozone consumed=	0.075818	mol / kg soil
% Consumed=	16.72151	
(ABS)f/(ABS)i=	99.71026	

Table A.3-2

Natural soil: t-BuOH

Breakthrough							
Time (s)	Final Avg (ABS)	del t (s)	Area	Time (s)	Final Avg (ABS)	del t (s)	Area
600	0	600	0	61800	0.91376318	3720	3399.199
1200	0	600	0	65400	0.92066777	3600	3314.404
1800	0.001515	600	0.9091	69000	0.92205737	3600	3319.407
2400	0.01255	600	7.5302	72720	0.93103494	3720	3463.45
3000	0.024049	600	14.43				
3600	0.035103	600	21.062		SUM:	72720	50336.57
4200	0.045872	600	27.523			58080	36840.11
4800	0.057591	600	34.555		Area=	18431.72	
5400	0.071629	600	42.978		Mass Ozone consumed=	0.159637	mol /kg soil
6000	0.084412	600	50.647		% consumed=	33.34912	
6600	0.097899	600	58.739				
7200	0.10947	600	65.682		(ABS)f/(ABS)in=	97.83376	
7800	0.126274	600	75.764				
8400	0.143742	600	86.245				
9000	0.162129	600	97.278				
9600	0.180392	600	108.24				
10200	0.200974	600	120.58				
10800	0.222182	600	133.31				
11400	0.240312	600	144.19				
12000	0.265115	600	159.07				
12600	0.281465	600	168.88				
13200	0.302689	600	181.61				
13800	0.323085	600	193.85				
17400	0.393179	3600	1415.4				
21000	0.521895	3600	1878.8				
24600	0.634821	3600	2285.4				
28200	0.744016	3600	2678.5				
31800	0.824618	3600	2968.6				
35400	0.8665	3600	3119.4				
39000	0.8912	3600	3208.3				
42600	0.912446	3600	3284.8				
46200	0.899871	3600	3239.5				
49800	0.907997	3600	3268.8				
54600	0.930914	4800	4468.4				
58080	0.928479	3480	3231.1				

APPENDIX B: Kinetic Rate Constant Data

Table B.1-1

250 ppm Pyrene Contaminated Glass Beads

(Experiment #1)

	Slope	y-intercept
	0.000228502	0.019298167
S.E.E.	1.09627E-06	0.001550292
r^(2)	0.998804533	0.009104699
	43445.65257	52
	Co=	10.39

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	10.39	2.341275161	1	0
10	0.00277778	10.35	2.337286325	0.996019108	0.003988837
20	0.00555556	10.34	2.335686324	0.994426752	0.005588837
30	0.00833333	10.30	2.331675088	0.99044586	0.009600074
40	0.01111111	10.20	2.322793318	0.981687898	0.018481844
50	0.01388889	10.21	2.323604019	0.982484076	0.017671143
60	0.01666667	10.17	2.319543924	0.978503185	0.021731237
70	0.01944444	10.08	2.310553263	0.969745223	0.030721899
80	0.02222222	10.08	2.310553263	0.969745223	0.030721899
90	0.025	10.06	2.30808717	0.967356688	0.033187991
100	0.02777778	10.00	2.302309193	0.961783439	0.038965969
110	0.03055556	9.97	2.29982266	0.959394904	0.041452501
120	0.03333333	9.94	2.296497636	0.956210191	0.044777525
130	0.03611111	9.93	2.29566465	0.955414013	0.045610511
140	0.03888889	9.91	2.293996593	0.953821656	0.047278568
150	0.04166667	9.86	2.288136384	0.948248408	0.053138778
160	0.04444444	9.82	2.284772209	0.945063694	0.056502952
170	0.04722222	9.79	2.281396678	0.941878981	0.059878483
180	0.05	9.77	2.278857532	0.939490446	0.06241763
190	0.05277778	9.75	2.277161179	0.937898089	0.064113983
200	0.05555556	9.70	2.272054785	0.933121019	0.069220377
210	0.05833333	9.69	2.271201178	0.932324841	0.070073983
220	0.06111111	9.69	2.271201178	0.932324841	0.070073983
230	0.06388889	9.69	2.271201178	0.932324841	0.070073983
240	0.06666667	9.67	2.268635978	0.929936306	0.072639184
250	0.06944444	9.57	2.258308864	0.920382166	0.082966298
260	0.07222222	9.56	2.257443437	0.919585987	0.083831724
270	0.075	9.53	2.253974223	0.916401274	0.087300938
280	0.07777778	9.52	2.253105036	0.915605096	0.088170126
290	0.08055556	9.48	2.249620712	0.912420382	0.09165445
300	0.08333333	9.48	2.249620712	0.912420382	0.09165445
310	0.08611111	9.48	2.249620712	0.912420382	0.09165445
320	0.08888889	9.42	2.242615429	0.906050955	0.098659732
330	0.09166667	9.38	2.239094299	0.902866242	0.102180863
340	0.09444444	9.35	2.235560726	0.899681529	0.105714435
350	0.09722222	9.34	2.234675379	0.89888535	0.106599783
500	0.13888889	9.02	2.19952079	0.867834395	0.141754372
700	0.19444444	8.60	2.151601805	0.827229299	0.189673356
900	0.25	8.21	2.105310922	0.789808917	0.23596424
1100	0.30555556	7.80	2.053593089	0.75	0.287682072
1300	0.36111111	7.51	2.015730264	0.722133758	0.325544897
1500	0.41666667	7.14	1.966002505	0.687101911	0.375272656
1700	0.47222222	6.78	1.913671898	0.652070064	0.427603263
1900	0.52777778	6.54	1.87762076	0.628980892	0.463654402
2100	0.58333333	6.26	1.833629191	0.601910828	0.507645971
2300	0.63888889	5.98	1.788997037	0.575636943	0.552278125
2500	0.69444444	5.77	1.752373225	0.554936306	0.588901936
2700	0.75	5.50	1.703869964	0.52866242	0.637405198
2900	0.80555556	5.28	1.663926098	0.507961783	0.677349064
3100	0.86111111	5.04	1.617406082	0.484872611	0.723869079
3300	0.91666667	4.81	1.570338571	0.462579618	0.77093659
3500	0.97222222	4.63	1.531737288	0.445063694	0.809537874
3700	1.02777778	4.44	1.489721975	0.426751592	0.851553186
3900	1.08333333	4.25	1.44586366	0.40843949	0.895411502

Table B.1-2

250 ppm Pyrene Contaminated Glass Beads

(Experiment #2)

	Slope	y-intercept
	0.000465697	-0.002901616
S.E.E.	2.02787E-06	0.0030547
r^(2)	0.998996042	0.018063616
	52738.079	53
	Co=	10.32

Time (s)	Time (hrs.)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	10.32	2.29982266	1	0
10	0.0027778	10.27	2.294830969	0.995189577	0.00482203
20	0.0055556	10.22	2.289814236	0.990379155	0.009667424
30	0.0083333	10.18	2.285614314	0.986370469	0.013723265
40	0.0111111	10.16	2.283085868	0.983965258	0.016164689
50	0.0138889	10.09	2.276311922	0.977551361	0.022704445
60	0.0166667	10.08	2.275461943	0.976749624	0.02352493
70	0.0194444	10.04	2.271201178	0.972740939	0.027637482
80	0.0222222	9.99	2.26606418	0.967930516	0.032594975
90	0.025	9.90	2.256577261	0.959111408	0.04174804
100	0.0277778	9.86	2.252235092	0.955102723	0.045936381
110	0.0305556	9.83	2.249620712	0.952697511	0.048457833
120	0.0333333	9.74	2.239975744	0.943878403	0.057757931
130	0.0361111	9.69	2.234675379	0.939067981	0.062867406
140	0.0388889	9.64	2.2284559	0.933455821	0.068861643
150	0.0416667	9.59	2.223093957	0.928645398	0.074028316
160	0.0444444	9.55	2.219503289	0.92543845	0.077487654
170	0.0472222	9.50	2.214092996	0.920628027	0.082699203
180	0.05	9.49	2.212283041	0.919024553	0.08444244
190	0.0527778	9.42	2.205010282	0.912610656	0.091445934
200	0.0555556	9.34	2.195844315	0.904593285	0.100269845
210	0.0583333	9.33	2.19492308	0.903791548	0.101156533
220	0.0611111	9.25	2.185663755	0.895774177	0.110066932
230	0.0638889	9.24	2.184733089	0.89497244	0.110962354
240	0.0666667	9.20	2.180066725	0.890963755	0.115451532
250	0.0694444	9.13	2.172554953	0.884549858	0.122676398
260	0.0722222	9.13	2.172554953	0.884549858	0.122676398
270	0.075	9.08	2.16688386	0.879739435	0.128129511
280	0.0777778	9.01	2.159272025	0.873325539	0.135446896
290	0.0805556	8.97	2.154485037	0.869316853	0.140047602
300	0.0833333	8.97	2.153524883	0.868515116	0.140970289
310	0.0861111	8.90	2.145810283	0.862101219	0.148382591
320	0.0888889	8.88	2.143872298	0.860497745	0.150244284
330	0.0916667	8.86	2.14095826	0.858092534	0.153043337
340	0.0944444	8.83	2.138035706	0.855687323	0.155850247
350	0.0972222	8.78	2.132164848	0.8508769	0.161487814
500	0.1388889	8.19	2.058886908	0.793151829	0.231740614
700	0.1944444	7.53	1.971779529	0.729814598	0.314964752
900	0.25	6.89	1.87762076	0.667279105	0.404546873
1100	0.3055556	6.29	1.782057383	0.609554034	0.495027681
1300	0.3611111	5.76	1.688695166	0.55824286	0.582961179
1500	0.4166667	5.27	1.592467134	0.510138634	0.673072759
1700	0.4722222	4.82	1.497156954	0.46684483	0.761758345
1900	0.5277778	4.44	1.408123332	0.429964924	0.844051646
2100	0.5833333	4.02	1.301412377	0.389878069	0.941921232
2300	0.6388889	3.66	1.197052361	0.354601637	1.036760269
2500	0.6944444	3.35	1.099990649	0.324937364	1.12412284
2700	0.75	3.02	0.983240138	0.29286788	1.228033692
2900	0.8055556	2.77	0.882341617	0.26801403	1.316715948
3100	0.8611111	2.47	0.750765259	0.239151495	1.430658058
3300	0.9166667	2.21	0.621688217	0.214297645	1.540389366
3500	0.9722222	2.01	0.508892722	0.195055955	1.634468815
3700	1.0277778	1.81	0.376071809	0.175012527	1.742897724
3900	1.0833333	1.59	0.216223108	0.154167363	1.869716496

Table B.1-3

250 ppm Pyrene Contaminated Glass Beads

(Experiment #3)

	Slope	y-intercept
	0.000323431	-0.0052344
S.E.E.	1.30275E-06	0.0020839
r^(2)	0.999124668	0.0124028
	61636.90655	54
	Co=	10.78

Time (s)	Time (hrs)	C (mg/L)	lnC	C / Co	- ln C / Co
0	0	10.78	2.38	1	0
10	0.002777778	10.77	2.38	0.99923195	0.000768344
20	0.005555556	10.70	2.37	0.99308756	0.006936444
30	0.008333333	10.68	2.37	0.99078341	0.009259325
40	0.011111111	10.62	2.36	0.98540707	0.014700458
50	0.013888889	10.58	2.36	0.98156682	0.018605188
60	0.016666667	10.54	2.35	0.97772657	0.022525224
70	0.019444444	10.54	2.35	0.97772657	0.022525224
80	0.022222222	10.48	2.35	0.97235023	0.02803922
90	0.025	10.48	2.35	0.97235023	0.02803922
100	0.027777778	10.42	2.34	0.96697389	0.033583789
110	0.030555556	10.36	2.34	0.96159754	0.039159271
120	0.033333333	10.39	2.34	0.96390169	0.036765971
130	0.036111111	10.34	2.34	0.95929339	0.041558313
140	0.038888889	10.30	2.33	0.95545315	0.045569549
150	0.041666667	10.30	2.33	0.95545315	0.045569549
160	0.044444444	10.26	2.33	0.95238095	0.048790164
170	0.047222222	10.26	2.33	0.95238095	0.048790164
180	0.05	10.21	2.32	0.94777266	0.053640618
190	0.052777778	10.20	2.32	0.94700461	0.05445132
200	0.055555556	10.16	2.32	0.94316436	0.058514714
210	0.058333333	10.15	2.32	0.94162826	0.060144706
220	0.061111111	10.12	2.31	0.93932412	0.062594687
230	0.063888889	10.08	2.31	0.93548387	0.066691374
240	0.066666667	10.06	2.31	0.93394777	0.06833476
250	0.069444444	10.06	2.31	0.93317972	0.069157467
260	0.072222222	10.02	2.30	0.93010753	0.072455079
270	0.075	9.98	2.30	0.92626728	0.076592445
280	0.077777778	9.95	2.30	0.92319508	0.079914708
290	0.080555556	9.93	2.30	0.92165899	0.081579987
300	0.083333333	9.91	2.29	0.92012289	0.083248044
310	0.086111111	9.87	2.29	0.91628264	0.087430401
320	0.088888889	9.83	2.29	0.9124424	0.091630323
330	0.091666667	9.83	2.29	0.9124424	0.091630323
340	0.094444444	9.77	2.28	0.906298	0.098387105
350	0.097222222	9.76	2.28	0.90552995	0.099234922
500	0.138888889	9.34	2.23	0.86635945	0.143455391
700	0.194444444	8.78	2.17	0.81490015	0.204689684
900	0.25	8.28	2.11	0.76804916	0.263901544
1100	0.305555556	7.72	2.04	0.71658986	0.333251622
1300	0.361111111	7.18	1.97	0.66666667	0.405465108

1500	0.416666667	6.71	1.90	0.62288786	0.473388769
1700	0.472222222	6.23	1.83	0.57834101	0.547591595
1900	0.527777778	5.82	1.76	0.53993856	0.616299931
2100	0.583333333	5.35	1.68	0.49615975	0.700857319
2300	0.638888889	4.98	1.61	0.46236559	0.771399377
2500	0.694444444	4.67	1.54	0.43317972	0.836602571
2700	0.75	4.43	1.49	0.4109063	0.889390076
2900	0.805555556	4.15	1.42	0.38556068	0.953056703
3100	0.861111111	3.91	1.36	0.3625192	1.014677837
3300	0.916666667	3.72	1.31	0.34485407	1.064633935
3500	0.972222222	3.48	1.25	0.32334869	1.129023989
3700	1.027777778	3.33	1.20	0.30875576	1.175204734
3900	1.083333333	3.12	1.14	0.28955453	1.239411635
4100	1.138888889	2.94	1.08	0.27265745	1.299539033
4300	1.194444444	2.76	1.02	0.25652842	1.36051583
4500	1.25	2.64	0.97	0.24500768	1.40646572
4700	1.305555556	2.43	0.89	0.22580645	1.488077055
4900	1.361111111	2.34	0.85	0.21735791	1.526209925
5100	1.416666667	2.18	0.78	0.20276498	1.59570772
5300	1.472222222	2.06	0.72	0.19124424	1.654203926
5500	1.527777778	1.93	0.66	0.17895545	1.720618369
5700	1.583333333	1.82	0.60	0.16897081	1.778029276
5900	1.638888889	1.73	0.55	0.16052227	1.829322571
6100	1.694444444	1.64	0.49	0.15207373	1.883389792
6300	1.75	1.51	0.41	0.13978495	1.967650136
6500	1.805555556	1.45	0.37	0.1344086	2.006870849
6700	1.861111111	1.38	0.32	0.12826421	2.05366301
6900	1.916666667	1.32	0.28	0.12288786	2.096483008
7100	1.972222222	1.23	0.21	0.11443932	2.167710517
7300	2.027777778	1.16	0.15	0.10752688	2.2300144
7500	2.083333333	1.07	0.07	0.09907834	2.311844418
7700	2.138888889	1.00	0.00	0.09293395	2.375866277
7900	2.194444444	0.94	-0.06	0.0875576	2.435458374
8100	2.25	0.87	-0.14	0.08064516	2.517696473
8300	2.305555556	0.81	-0.21	0.07526882	2.586689344
8500	2.361111111	0.76	-0.27	0.07066052	2.649868246
8700	2.416666667	0.70	-0.36	0.06451613	2.740840024
8900	2.472222222	0.67	-0.40	0.06221198	2.777207668
9100	2.527777778	0.60	-0.50	0.05606759	2.881197382
9300	2.583333333	0.54	-0.62	0.0499232	2.997269553
9500	2.638888889	0.50	-0.68	0.046851	3.060782959
9700	2.694444444	0.43	-0.84	0.03993856	3.220413104

Table B.1-4

250 ppm Pyrene Contaminated Glass Beads

(Experiment #4)

Slope	y-intercept
0.00021825	0.009578863
1.9305E-06	0.003088136
0.99579242	0.018379742
12779.9842	54
Co=	18.45

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	18.45	2.91489615	1	0
10	0.00277778	18.46	2.91534468	1.000448632	-0.000448531
20	0.00555556	18.37	2.91085029	0.995962315	0.004045859
30	0.00833333	18.28	2.90588302	0.991027367	0.00901313
40	0.01111111	18.27	2.90543022	0.990578735	0.009465926
50	0.01388889	18.28	2.90588302	0.991027367	0.00901313
60	0.01666667	18.17	2.89998062	0.985195155	0.014915531
70	0.01944444	18.11	2.89633098	0.981606101	0.01856517
80	0.02222222	18.11	2.89633098	0.981606101	0.01856517
90	0.025	18.04	2.89266797	0.978017048	0.022228178
100	0.02777778	18.02	2.89129088	0.976671153	0.023605272
110	0.03055556	17.95	2.88760933	0.9730821	0.027286823
120	0.03333333	17.86	2.88252496	0.968147151	0.032371188
130	0.03611111	17.89	2.88437681	0.969941678	0.030519335
140	0.03888889	17.84	2.88159775	0.967249888	0.033298401
150	0.04166667	17.74	2.87601634	0.961866308	0.038879811
160	0.04444444	17.73	2.87508307	0.960969044	0.039813082
170	0.04722222	17.68	2.87227801	0.958277254	0.042618133
180	0.05	17.69	2.87274607	0.958725886	0.042150078
190	0.05277778	17.57	2.86617328	0.952445043	0.048722872
200	0.05555556	17.57	2.86617328	0.952445043	0.048722872
210	0.05833333	17.56	2.86570213	0.951996411	0.049194014
220	0.06111111	17.50	2.86239791	0.948855989	0.052498242
230	0.06388889	17.49	2.86145183	0.947958726	0.053444316
240	0.06666667	17.36	2.8543276	0.941229251	0.060568544
250	0.06944444	17.39	2.85575652	0.942575146	0.059139633
260	0.07222222	17.34	2.85289665	0.939883356	0.061999501
270	0.075	17.27	2.84907072	0.936294302	0.065825426
280	0.07777778	17.25	2.84763222	0.934948407	0.067263931
290	0.08055556	17.20	2.84474899	0.932256617	0.070147162
300	0.08333333	17.15	2.84185742	0.929564827	0.07303873
310	0.08611111	17.11	2.83992505	0.927770301	0.074971098
320	0.08888889	17.11	2.83992505	0.927770301	0.074971098
330	0.09166667	17.08	2.83798894	0.925975774	0.076907207
340	0.09444444	16.97	2.83118289	0.91969493	0.083713261
350	0.09722222	17.00	2.8331322	0.921489457	0.081763943
500	0.13888889	16.33	2.79289832	0.885150292	0.121997827
700	0.19444444	15.53	2.74301785	0.842081651	0.171878297
900	0.25	14.68	2.68657998	0.795872589	0.228316171
1100	0.30555556	13.99	2.63866316	0.75863616	0.276232984
1300	0.36111111	13.27	2.58521997	0.719156572	0.329676181
1500	0.41666667	12.63	2.53599303	0.684611934	0.378903122
1700	0.47222222	12.13	2.4958807	0.657694033	0.419015451
1900	0.52777778	11.64	2.45409189	0.630776133	0.460804261
2100	0.58333333	11.14	2.41048032	0.603858232	0.504415823
2300	0.63888889	10.71	2.37108129	0.580529385	0.543814858
2500	0.69444444	10.34	2.33648664	0.560789592	0.578409503
2700	0.75	9.93	2.29566465	0.538358008	0.619231498
2900	0.80555556	9.55	2.25657726	0.517720951	0.658318886
3100	0.86111111	9.19	2.2186036	0.498429789	0.696292544
3300	0.91666667	8.90	2.18566375	0.482279049	0.729232393
3500	0.97222222	8.57	2.14774452	0.464333782	0.767151628
3700	1.02777778	8.32	2.11833063	0.450874832	0.796565513

3900	1.08333333	8.04	2.08494362	0.436069987	0.829952529
4100	1.13888889	7.77	2.05040329	0.421265141	0.864492854
4300	1.19444444	7.55	2.0212278	0.409152086	0.893668343
4500	1.25	7.29	1.98664544	0.395244504	0.928250707
4700	1.30555556	7.06	1.95434736	0.382682817	0.960548786
4900	1.36111111	6.82	1.91975834	0.369672499	0.995137803
5100	1.41666667	6.60	1.88769641	0.358008075	1.027199736
5300	1.47222222	6.41	1.85715969	0.347240915	1.05773646
5500	1.52777778	6.22	1.82699347	0.336922387	1.087902682
5700	1.58333333	6.04	1.79863235	0.327501122	1.116263799
5900	1.63888889	5.82	1.76094471	0.315388066	1.153951442
6100	1.69444444	5.64	1.73061747	0.305966801	1.184278676
6300	1.75	5.41	1.68869517	0.293405114	1.226200982
6500	1.80555556	5.21	1.65130763	0.282637954	1.263588514
6700	1.86111111	5.02	1.61411661	0.272319426	1.300779542
6900	1.91666667	4.92	1.59246713	0.266487214	1.322429014
7100	1.97222222	4.76	1.55995786	0.257963212	1.354938293
7300	2.02777778	4.61	1.52815305	0.249887842	1.386743093
7500	2.08333333	4.43	1.48785456	0.240017945	1.427041586
7700	2.13888889	4.26	1.44975472	0.231045312	1.465141433
7900	2.19444444	4.07	1.40406653	0.220726783	1.510829617
8100	2.25	3.89	1.35832051	0.210856886	1.556575639
8300	2.30555556	3.71	1.31038105	0.20098699	1.604515101
8500	2.36111111	3.52	1.25767698	0.190668461	1.657219164
8700	2.41666667	3.35	1.20947488	0.181695828	1.705421266
8900	2.47222222	3.21	1.16659315	0.174069089	1.748302994
9100	2.52777778	3.12	1.137833	0.169134141	1.777063146
9300	2.58333333	2.97	1.0889102	0.161058771	1.825985945
9500	2.63888889	2.86	1.04913223	0.154777927	1.865763916
9700	2.69444444	2.76	1.01672881	0.149842979	1.89816734
9900	2.75	2.66	0.97702894	0.144010767	1.93786721
10100	2.80555556	2.52	0.92589959	0.13683266	1.988996557
10300	2.86111111	2.43	0.88916758	0.131897712	2.025728566
10500	2.91666667	2.28	0.82598868	0.123822342	2.088907468
10700	2.97222222	2.16	0.77010822	0.117092867	2.144787926
10900	3.02777778	2.01	0.69864926	0.109017497	2.21624689
11100	3.08333333	1.92	0.65232519	0.104082548	2.262570962
11300	3.13888889	1.81	0.59465954	0.098250336	2.320236604
11500	3.19444444	1.72	0.54312589	0.093315388	2.371770254
11700	3.25	1.60	0.468278	0.086585913	2.446618144
11900	3.30555556	1.51	0.41507397	0.082099596	2.499822181
12100	3.36111111	1.42	0.35308229	0.077164648	2.561813857
12300	3.41666667	1.33	0.28699218	0.072229699	2.627903968
12500	3.47222222	1.27	0.23602574	0.068640646	2.678870412
12700	3.52777778	1.20	0.18232156	0.065051593	2.732574591
12900	3.58333333	1.16	0.14723024	0.062808434	2.767665911
13100	3.63888889	1.10	0.09593694	0.059668013	2.818959205
13300	3.69444444	1.06	0.05761808	0.057424854	2.857278069
13500	3.75	1.00	0.00137836	0.054284432	2.913517788
13700	3.80555556	0.97	-0.0322383	0.052489906	2.947134399
13900	3.86111111	0.95	-0.0494801	0.051592642	2.964376205
14100	3.91666667	0.88	-0.1309731	0.047554957	3.045869239
14300	3.97222222	0.83	-0.189242	0.044863167	3.104138147
14500	4.02777778	0.81	-0.2094447	0.043965904	3.124340855
14700	4.08333333	0.74	-0.3057758	0.039928219	3.220671964
14900	4.13888889	0.70	-0.3517609	0.038133692	3.266657077
15100	4.19444444	0.65	-0.4377034	0.034993271	3.352599507
15300	4.25	0.60	-0.5039527	0.032750112	3.418848892
15500	4.30555556	0.55	-0.5897196	0.030058322	3.504615714
15700	4.36111111	0.50	-0.6835383	0.027366532	3.598434469
15900	4.41666667	0.47	-0.7513609	0.025572005	3.666257066
16100	4.47222222	0.46	-0.7690605	0.025123374	3.683956643

Table B.1-5

250 ppm Pyrene Contaminated Glass Beads
(Experiment #5)

	Slope	y-intercept
	0.0002276	0.002344689
S.E.E.	1.962E-06	0.003138739
r^(2)	0.9960023	0.01868092
	13453.748	54
	Co=	27.38

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	27.38	3.3099891	1	0
10	0.0027778	27.33	3.3078714	0.997884557	0.002117683
20	0.0055556	27.32	3.3075685	0.997582351	0.002420576
30	0.0083333	27.20	3.3033184	0.993351466	0.006670734
40	0.0111111	27.20	3.3033184	0.993351466	0.006670734
50	0.0138889	27.22	3.3039267	0.993955878	0.006062462
60	0.0166667	27.05	3.2978272	0.987911756	0.012161901
70	0.0194444	27.02	3.2966029	0.986702931	0.013386266
80	0.0222222	26.95	3.2941496	0.984285283	0.015839503
90	0.025	26.98	3.2950703	0.985191901	0.014918834
100	0.0277778	26.86	3.2907666	0.980961015	0.01922256
110	0.0305556	26.86	3.2907666	0.980961015	0.01922256
120	0.0333333	26.75	3.2864442	0.97673013	0.023544888
130	0.0361111	26.74	3.2861348	0.976427924	0.023854342
140	0.0388889	26.62	3.2817923	0.972197038	0.028196781
150	0.0416667	26.59	3.2805482	0.970988214	0.029440949
160	0.0444444	26.54	3.278679	0.969174977	0.031310108
170	0.0472222	26.42	3.2739908	0.964641886	0.035998349
180	0.05	26.40	3.273364	0.964037474	0.036625112
190	0.0527778	26.38	3.2724231	0.963130855	0.037565994
200	0.0555556	26.27	3.2683357	0.959202176	0.041653407
210	0.0583333	26.21	3.2661279	0.957086733	0.043861261
220	0.0611111	26.19	3.2654961	0.956482321	0.044492973
230	0.0638889	26.09	3.2616975	0.952855848	0.048291648
240	0.0666667	25.97	3.2569287	0.948322756	0.053060375
250	0.0694444	26.01	3.2585209	0.949833787	0.051468271
260	0.0722222	25.90	3.2540566	0.945602901	0.055932564
270	0.075	25.83	3.2514966	0.943185252	0.058492566
280	0.0777778	25.83	3.2514966	0.943185252	0.058492566
290	0.0805556	25.68	3.2457125	0.937745542	0.064276643
300	0.0833333	25.65	3.2444226	0.936536718	0.06556655
310	0.0861111	25.53	3.2398948	0.932305833	0.070094372
320	0.0888889	25.50	3.2385973	0.931097008	0.071391809
330	0.0916667	25.50	3.2385973	0.931097008	0.071391809
340	0.0944444	25.42	3.2353463	0.928074947	0.074642787
350	0.0972222	25.37	3.2337169	0.926563917	0.076272248
500	0.1388889	24.36	3.1927726	0.889392566	0.11721656
700	0.1944444	22.99	3.1350743	0.839528558	0.174914785
900	0.25	21.84	3.0837432	0.79752191	0.226245971
1100	0.3055556	20.76	3.0332274	0.758235116	0.276761762
1300	0.3611111	19.64	2.9774981	0.717135086	0.332491051
1500	0.4166667	18.70	2.9287079	0.682985796	0.381281216
1700	0.4722222	17.86	2.882525	0.652160774	0.427464162
1900	0.5277778	17.02	2.8345917	0.621637957	0.475397418
2100	0.5833333	16.30	2.7913766	0.595346026	0.518612486
2300	0.6388889	15.61	2.7478013	0.569960713	0.562187845
2500	0.6944444	15.01	2.7088774	0.548201874	0.601111677

2700	0.75	14.42	2.668377	0.526443034	0.641612151
2900	0.8055556	13.90	2.6321369	0.507706256	0.677852236
3100	0.8611111	13.40	2.5951518	0.489271683	0.714837354
3300	0.9166667	12.90	2.5573877	0.471139317	0.752601439
3500	0.9722222	12.42	2.5194746	0.453611363	0.790514476
3700	1.0277778	12.00	2.4849066	0.438198852	0.825082473
3900	1.0833333	11.58	2.4491008	0.42278634	0.860888333
4100	1.1388889	11.23	2.4186195	0.410093684	0.891369648
4300	1.1944444	10.84	2.3833702	0.395889997	0.926618892
4500	1.25	10.52	2.3531471	0.384103959	0.956842037
4700	1.3055556	10.17	2.3195439	0.371411303	0.990445198
4900	1.3611111	9.86	2.2881364	0.359927471	1.021852739
5100	1.4166667	9.58	2.2591735	0.349652463	1.050815581
5300	1.4722222	9.25	2.2248845	0.337866425	1.085104654
5500	1.5277778	8.97	2.194001	0.327591417	1.115988126
5700	1.5833333	8.66	2.159272	0.316409791	1.150717097
5900	1.6388889	8.42	2.1302002	0.307343608	1.179788912
6100	1.6944444	8.18	2.1022821	0.298881837	1.207706976
6300	1.75	7.90	2.0672992	0.28860683	1.242689967
6500	1.8055556	7.66	2.0353816	0.279540647	1.27460757
6700	1.8611111	7.43	2.0057579	0.271381082	1.30423124
6900	1.9166667	7.28	1.9855097	0.265941372	1.3244794
7100	1.9722222	7.02	1.9484685	0.256270777	1.361520672
7300	2.0277778	6.81	1.918544	0.248715624	1.391445107
7500	2.0833333	6.55	1.8788858	0.239045029	1.43110334
7700	2.1388889	6.40	1.8558669	0.233605319	1.454122259
7900	2.1944444	6.17	1.8203134	0.225445754	1.489675708
8100	2.25	5.95	1.7834492	0.217286189	1.52653995
8300	2.3055556	5.77	1.7523732	0.210637655	1.557615897
8500	2.3611111	5.57	1.7173331	0.203384708	1.592655978
8700	2.4166667	5.40	1.6856324	0.19703838	1.624356746
8900	2.4722222	5.21	1.6497191	0.19008764	1.660270051
9100	2.5277778	5.00	1.609162	0.182532487	1.70082711
9300	2.5833333	4.85	1.5789076	0.177092777	1.731081518
9500	2.6388889	4.68	1.5441819	0.171048655	1.76580723
9700	2.6944444	4.53	1.5100366	0.165306739	1.799952505
9900	2.75	4.38	1.4765762	0.159867029	1.833412876
10100	2.8055556	4.21	1.4380358	0.153822907	1.871953291
10300	2.8611111	4.03	1.3938519	0.147174373	1.916137185
10500	2.9166667	3.87	1.3540561	0.141432457	1.955933012
10700	2.9722222	3.72	1.3148354	0.135992747	1.995153725
10900	3.0277778	3.60	1.2809338	0.131459655	2.029055277
11100	3.0833333	3.39	1.221745	0.123904503	2.088244148
11300	3.1388889	3.25	1.1793974	0.118766999	2.130591696
11500	3.1944444	3.10	1.1298436	0.113025083	2.180145511
11700	3.25	2.97	1.0889102	0.108491992	2.221078919
11900	3.3055556	2.84	1.0433183	0.103656694	2.266670861
12100	3.3611111	2.67	0.9832401	0.097612572	2.326748985
12300	3.4166667	2.57	0.9453807	0.093986099	2.364608396
12500	3.4722222	2.47	0.9026813	0.090057419	2.407307821
12700	3.5277778	2.30	0.8332089	0.084013297	2.476780194
12900	3.5833333	2.18	0.7815369	0.079782412	2.528452205
13100	3.6388889	2.10	0.7429221	0.076760351	2.567067041

Table B.1-6

250 ppm Pyrene Contaminated Glass Beads
(Experiment #6)

	Slope	y-intercept
	0.00024954	0.061878868
S.E.E.	2.0136E-06	0.009648095
r^(2)	0.99662552	0.042781598
	15357.7924	52
	Co=	26.06

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	26.06	3.26042804	1	0
10	0.00277778	26.09	3.26169747	1.001270245	-0.001269438
20	0.00555556	25.95	3.2562912	0.995871705	0.00413684
30	0.00833333	25.83	3.25149656	0.991108288	0.008931479
40	0.01111111	25.91	3.25469554	0.9942839	0.0057325
50	0.01388889	25.68	3.24571248	0.985392188	0.014715557
60	0.01666667	25.74	3.24796582	0.987615116	0.012462216
70	0.01944444	25.73	3.24764422	0.987297555	0.012783811
80	0.02222222	25.64	3.24409984	0.983804382	0.0163282
200	0.05555556	24.36	3.19277256	0.934582407	0.067655473
400	0.11111111	22.26	3.10288429	0.854239441	0.157543749
600	0.16666667	20.89	3.03918804	0.801524293	0.221239997
800	0.22222222	19.37	2.96349402	0.743093045	0.296934013
1000	0.27777778	18.35	2.90949802	0.704033026	0.350930011
1200	0.33333333	17.13	2.8408917	0.65735154	0.419536335
1400	0.38888889	16.24	2.78730745	0.623054938	0.473120581
1600	0.44444444	15.35	2.73122779	0.589075897	0.529200246
1800	0.5	14.68	2.68657998	0.563353446	0.573848058
2000	0.55555556	13.94	2.63510866	0.535090505	0.625319378
2200	0.61111111	13.22	2.58209594	0.507462687	0.678332095
2400	0.66666667	12.66	2.53861083	0.48586853	0.721817207
2600	0.72222222	12.09	2.49246423	0.463956812	0.767963809
2800	0.77777778	11.50	2.44192716	0.44109241	0.818500878
3000	0.83333333	11.05	2.40227439	0.423944109	0.85815365
3200	0.88888889	10.43	2.34445481	0.400127024	0.915973221
3400	0.94444444	9.98	2.30065219	0.382978723	0.959775844
3600	1	9.61	2.2626248	0.368688473	0.997803239
3800	1.05555556	9.19	2.2186036	0.352810416	1.041824431
4000	1.11111111	8.79	2.17349702	0.337249921	1.086931019
4200	1.16666667	8.38	2.12527166	0.321371864	1.135156371
4400	1.22222222	8.04	2.08494362	0.308669419	1.175484417
4600	1.27777778	7.66	2.03538155	0.293744046	1.225046484
4800	1.33333333	7.36	1.99568505	0.282311845	1.264742986
5000	1.38888889	7.03	1.95082416	0.269926961	1.309603872
5200	1.44444444	6.74	1.90877593	0.258812321	1.351652108
5400	1.5	6.46	1.86488173	0.247697682	1.395546301
5600	1.55555556	6.13	1.81358844	0.235312798	1.446839596
5800	1.61111111	5.88	1.77085278	0.225468403	1.489575251
6000	1.66666667	5.58	1.71881793	0.214036202	1.54161011
6200	1.72222222	5.35	1.67638732	0.20514449	1.584040717
6400	1.77777778	5.09	1.62721008	0.195300095	1.633217953
6520	1.81111111	4.91	1.59078221	0.18831375	1.669645822
6720	1.86666667	4.68	1.54418189	0.1797396	1.716246143
6920	1.92222222	4.44	1.49158591	0.170530327	1.768842127
7120	1.97777778	4.26	1.44975472	0.163543982	1.81067332
7320	2.03333333	4.06	1.39999321	0.155604954	1.86043483
7520	2.08888889	3.84	1.34547237	0.147348365	1.914955669
7720	2.14444444	3.65	1.29463269	0.140044459	1.965795346
7920	2.2	3.45	1.23867404	0.132422991	2.021753999
8120	2.25555556	3.28	1.18700203	0.125754208	2.07342601
8320	2.31111111	3.08	1.12448167	0.118132741	2.135946367
8520	2.36666667	2.94	1.0777056	0.112734201	2.182722432
8720	2.42222222	2.80	1.02863371	0.107335662	2.231794326
8920	2.47777778	2.65	0.97390881	0.101619562	2.286519225

Table B.2-1

250 ppm Pyrene Contaminated Ottawa Sand
(Experiment #1)

	Slope	y-intercept
	0.000196299	-0.0121199
S.E.E.	4.04245E-07	0.001533389
r^(2)	0.999677798	0.010040343
	235800.8811	76

Co=	29.46

time (s)	time (hrs.)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	29.46	3.383103638	1	0
10	0.002778	29.75	3.392887085	1.009831461	-0.009783446
20	0.005556	29.34	3.378881253	0.995786517	0.004222385
30	0.008333	29.58	3.38702851	1.003932584	-0.003924872
40	0.011111	29.47	3.383384498	1.000280899	-0.000280859
50	0.013889	29.57	3.386748672	1.003651685	-0.003645034
60	0.016667	29.29	3.377187295	0.994101124	0.005916344
70	0.019444	29.35	3.379445269	0.996348315	0.003658369
80	0.022222	29.52	3.385068	1.001966292	-0.001964362
90	0.025	28.98	3.366677327	0.983707865	0.016426311
100	0.027778	29.29	3.377187295	0.994101124	0.005916344
110	0.030556	29.19	3.373790745	0.990730337	0.009312894
120	0.033333	29.11	3.37123574	0.988202247	0.011867899
130	0.036111	28.87	3.362958256	0.98005618	0.020145383
140	0.038889	28.84	3.361811138	0.978932584	0.021292501
150	0.041667	28.83	3.361524152	0.978651685	0.021579486
160	0.044444	28.76	3.358937572	0.976123596	0.024166066
170	0.047222	28.78	3.359512946	0.976685393	0.023590692
180	0.05	28.71	3.357209461	0.974438202	0.025894177
190	0.052778	28.58	3.352586512	0.96994382	0.030517126
200	0.055556	28.48	3.34910522	0.966573034	0.033998418
210	0.058333	28.53	3.350847381	0.968258427	0.032256257
220	0.061111	28.34	3.344444565	0.962078652	0.038659073
230	0.063889	28.44	3.347651097	0.965168539	0.035452541
240	0.066667	28.24	3.340641723	0.958426966	0.042461915
250	0.069444	28.16	3.338000489	0.955898876	0.045103149
260	0.072222	28.00	3.332105983	0.950280899	0.050997655
270	0.075	28.33	3.343860453	0.961516854	0.039243185
280	0.077778	28.11	3.336235783	0.954213483	0.046867856
290	0.080556	28.06	3.334467956	0.95252809	0.048635682
300	0.083333	28.02	3.332992377	0.951123596	0.050111261
310	0.086111	28.03	3.333287667	0.951404494	0.049815971
320	0.088889	27.79	3.324688652	0.943258427	0.058414986
330	0.091667	27.82	3.325581642	0.944101124	0.057521996
340	0.094444	27.82	3.325879128	0.944382022	0.05722451
350	0.097222	27.70	3.321407516	0.940168539	0.061696123
500	0.138889	26.96	3.294456604	0.915168539	0.088647035

700	0.194444	25.90	3.254376098	0.879213483	0.12872754
900	0.25	24.87	3.213620661	0.844101124	0.169482977
1100	0.305556	23.99	3.177708943	0.814325843	0.205394695
1300	0.361111	23.28	3.147594623	0.790168539	0.235509015
1500	0.416667	22.26	3.102884287	0.755617978	0.280219351
1700	0.472222	21.54	3.070007719	0.731179775	0.313095919
1900	0.527778	20.81	3.035615897	0.706460674	0.347487741
2100	0.583333	20.08	2.999586904	0.681460674	0.383516734
2300	0.638889	19.18	2.954047838	0.651123596	0.4290558
2500	0.694444	18.50	2.917584321	0.627808989	0.465519317
2700	0.75	17.78	2.87788027	0.603370787	0.505223368
2900	0.805556	17.15	2.841857418	0.582022472	0.54124622
3100	0.861111	16.67	2.813465888	0.565730337	0.569637751
3300	0.916667	15.81	2.760446335	0.536516854	0.622657303
3500	0.972222	15.19	2.720387575	0.515449438	0.662716063
3700	1.027778	14.74	2.690518098	0.500280899	0.692585541
3900	1.083333	14.10	2.646321522	0.478651685	0.736782116
4100	1.138889	13.55	2.606208392	0.459831461	0.776895246
4300	1.194444	12.91	2.558028915	0.438202247	0.825074724
4500	1.25	12.53	2.528098248	0.425280899	0.85500539
4700	1.305556	11.94	2.480067373	0.405337079	0.903036265
4900	1.361111	11.59	2.450529361	0.393539326	0.932574278
5100	1.416667	11.11	2.407504132	0.376966292	0.975599506
5300	1.472222	10.54	2.355504651	0.357865169	1.027598988
5500	1.527778	10.21	2.323604019	0.346629213	1.059499619
5700	1.583333	9.79	2.281396678	0.332303371	1.10170696
5900	1.638889	9.47	2.247873986	0.321348315	1.135229652
6100	1.694444	9.05	2.202269303	0.307022472	1.180834336
6300	1.75	8.57	2.14774452	0.290730337	1.235359118
6500	1.805556	8.36	2.123293424	0.283707865	1.259810214
6700	1.861111	7.95	2.073562223	0.26994382	1.309541415
6805	1.890278	7.80	2.053593089	0.264606742	1.329510549
7005	1.945833	7.52	2.017932909	0.255337079	1.36517073
7205	2.001389	7.22	1.97752337	0.245224719	1.405580268
7405	2.056944	6.88	1.928217609	0.233426966	1.454886029
7605	2.1125	6.65	1.895187084	0.225842697	1.487916555
7805	2.168056	6.36	1.849377548	0.215730337	1.533726091
8005	2.223611	6.12	1.810885735	0.20758427	1.572217903
8205	2.279167	5.82	1.760944706	0.19747191	1.622158932
8405	2.334722	5.64	1.730617472	0.191573034	1.652486166
8605	2.390278	5.40	1.685632376	0.183146067	1.697471262

Table B.2-2

250 ppm Pyrene Contaminated Ottawa Sand

(Experiment #2)

	Slope	y-intercept
	0.000175161	0.005610804
S.E.E.	2.11227E-07	0.00090638
r^(2)	0.99991421	0.004693824
	687664.3635	59

Co= 31.07

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	31.07	3.386188762	1	0
20	0.00555556	30.98	3.388147078	0.997069792	0.002934509
40	0.01111111	30.89	3.38394598	0.994139584	0.005877655
60	0.01666667	30.80	3.38113541	0.991475759	0.00856078
80	0.02222222	30.70	3.38394598	0.988279169	0.011790062
100	0.02777778	30.51	3.380290697	0.982152371	0.018008819
120	0.03333333	30.38	3.370951447	0.97789025	0.022357834
140	0.03888889	30.25	3.36781888	0.97362813	0.026725845
160	0.04444444	30.12	3.368389168	0.96936601	0.03111302
180	0.05	30.02	3.356921152	0.966169419	0.034416078
200	0.05555556	29.92	3.354033481	0.962972829	0.037730083
220	0.06111111	29.75	3.350847381	0.957645178	0.043277947
240	0.06666667	29.70	3.346194857	0.956046883	0.044948326
260	0.07222222	29.53	3.340641723	0.95045285	0.050816723
280	0.07777778	29.44	3.342106066	0.947522643	0.053904445
300	0.08333333	29.35	3.338588033	0.944858817	0.056719762
320	0.08888889	29.17	3.334467956	0.938998402	0.062941502
340	0.09444444	29.12	3.324390811	0.937400107	0.06464508
360	0.1	29.03	3.329738418	0.934469899	0.067775864
510	0.14166667	28.25	3.292920741	0.909163559	0.095230268
710	0.19722222	27.19	3.262965303	0.875066596	0.133455286
910	0.25277778	26.21	3.226186964	0.843633458	0.170037171
1110	0.30833333	25.30	3.189368883	0.81433138	0.205387895
1310	0.36388889	24.34	3.154679314	0.783431007	0.244072279
1510	0.41944444	23.54	3.110660664	0.757591902	0.277610426
1710	0.475	22.76	3.078804869	0.732551945	0.311221026
1910	0.53055556	21.89	3.044719463	0.704581779	0.350150873
2110	0.58611111	21.18	3.010247111	0.681672882	0.383205381
2310	0.64166667	20.43	2.97791939	0.657698455	0.419008728
2510	0.69722222	19.76	2.939709118	0.63612147	0.452365743
2710	0.75277778	19.08	2.903163161	0.614278103	0.487307516
2910	0.80833333	18.41	2.866644197	0.592434736	0.523514562
3110	0.86388889	17.84	2.835563521	0.574320725	0.554567285
3310	0.91944444	17.26	2.796439938	0.555407565	0.588053083
3510	0.975	16.65	2.771381097	0.535961641	0.623692686
3710	1.03055556	16.07	2.73606781	0.517314864	0.659103568

3910	1.08611111	15.53	2.700574048	0.5	0.693147181
4110	1.14166667	15.05	2.663197104	0.484549814	0.724535039
4310	1.19722222	14.57	2.633921009	0.468833245	0.757508129
4510	1.25277778	14.06	2.595151768	0.45258391	0.792782095
4710	1.30833333	13.56	2.561867691	0.436600959	0.828735638
4910	1.36388889	13.10	2.531395317	0.421683538	0.863500157
5110	1.41944444	12.66	2.497924991	0.407565264	0.897554203
5310	1.475	12.30	2.461179089	0.395844433	0.926733992
5510	1.53055556	11.83	2.43034122	0.380660629	0.965847039
5710	1.58611111	11.41	2.391732119	0.367341502	1.001463339
5910	1.64166667	10.99	2.353147086	0.353755994	1.039147887
6110	1.69722222	10.66	2.322793318	0.343100693	1.06973131
6310	1.75277778	10.22	2.2872964	0.328982419	1.111750968
6510	1.80833333	9.88	2.253974223	0.318060735	1.145512923
6710	1.86388889	9.55	2.218603604	0.307405434	1.17958777
6800	1.88888889	9.40	2.202269303	0.302610549	1.195308618
7000	1.94444444	9.07	2.167831279	0.291955248	1.23115475
7200	2	8.76	2.120318707	0.281832712	1.266441605
7400	2.05555556	8.47	2.092119457	0.272775706	1.299105412
7600	2.11111111	8.18	2.058886908	0.263452318	1.333882886
7800	2.16666667	7.83	2.027785205	0.251997869	1.378334648
8000	2.22222222	7.61	1.98664544	0.245071923	1.406203547
8200	2.27777778	7.36	1.953174341	0.236814065	1.440479982
8400	2.33333333	7.08	1.918544015	0.228023442	1.478306841
8600	2.38888889	6.84	1.878885782	0.220031966	1.513982444

Table B.2-3

250 ppm Pyrene Contaminated Ottawa Sand

(Experiment #3)

	Slope	y-intercept
	0.00017625	0.002261435
S.E.E.	1.4557E-07	0.00062463
r^(2)	0.99995975	0.003234737
	1465937.35	59

Co=	58.92

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	58.92	4.03890475	1	0
20	0.00555556	58.78	4.03963346	0.99747191	0.002531291
40	0.01111111	58.69	4.03334918	0.996067416	0.003940337
60	0.01666667	58.38	4.03802961	0.990730337	0.009312894
80	0.02222222	58.25	4.02805739	0.988623596	0.011441611
100	0.02777778	58.08	4.02835211	0.985674157	0.014429448
120	0.03333333	57.73	4.02273744	0.979775281	0.020432039
140	0.03888889	57.38	4.01947237	0.973876404	0.026470878
160	0.04444444	57.18	4.01738904	0.970365169	0.030082816
180	0.05	56.90	4.00991293	0.965589888	0.035016082
200	0.05555556	56.71	4.00328739	0.9625	0.038221213
220	0.06111111	56.52	4.00268289	0.959129213	0.041729475
240	0.06666667	56.23	3.99859291	0.954213483	0.046867856
260	0.07222222	56.03	3.99631344	0.950842697	0.050406638
280	0.07777778	55.76	3.98576047	0.946348315	0.05514458
300	0.08333333	55.67	3.98591421	0.944803371	0.056778446
320	0.08888889	55.51	3.98468363	0.941994382	0.059755968
340	0.09444444	55.26	3.9805192	0.937780899	0.064238941
360	0.1	55.08	3.9805192	0.934691011	0.067539274
510	0.14166667	53.54	3.94704393	0.908567416	0.095886188
710	0.19722222	51.60	3.91158153	0.875702247	0.132729146
910	0.25277778	49.74	3.87309577	0.844101124	0.169482977
1110	0.30833333	48.11	3.83735891	0.816432584	0.202810937
1310	0.36388889	46.54	3.80233128	0.789747191	0.236042396
1510	0.41944444	44.89	3.76966459	0.761797753	0.272074175
1710	0.475	43.37	3.73193894	0.735955056	0.306586227
1910	0.53055556	41.84	3.69623167	0.71011236	0.342332069
2110	0.58611111	40.43	3.66494001	0.686095506	0.37673844
2310	0.64166667	39.06	3.63000761	0.662921348	0.411098926
2510	0.69722222	37.69	3.59381062	0.639606742	0.446901758
2710	0.75277778	36.49	3.55884931	0.619241573	0.479259819
2910	0.80833333	35.24	3.52408613	0.598033708	0.514108159
3110	0.86388889	34.01	3.48655221	0.577247191	0.549484697
3310	0.91944444	32.86	3.45437855	0.557724719	0.583889773
3510	0.975	31.76	3.41869851	0.539044944	0.617956328
3710	1.03055556	30.62	3.37577347	0.519662921	0.654574906

3910	1.08611111	29.59	3.35113745	0.502106742	0.688942549
4110	1.14166667	28.66	3.31240385	0.486376404	0.72077246
4310	1.19722222	27.61	3.28085936	0.468539326	0.758135241
4510	1.25277778	26.62	3.24216122	0.451825843	0.794458477
4710	1.30833333	25.74	3.20895087	0.436797753	0.828284999
4910	1.36388889	24.84	3.17009118	0.421629213	0.863628992
5110	1.41944444	23.98	3.1390262	0.406882022	0.899232007
5310	1.475	23.17	3.09990588	0.393258427	0.933288308
5510	1.53055556	22.32	3.05647048	0.378792135	0.970767681
5710	1.58611111	21.56	3.0256258	0.365870787	1.00547505
5910	1.64166667	20.81	2.98964482	0.353230337	1.040634922
6110	1.69722222	20.04	2.95404784	0.340168539	1.07831408
6310	1.75277778	19.42	2.9189257	0.329494382	1.110195975
6510	1.80833333	18.71	2.88159775	0.31755618	1.147100532
6710	1.86388889	18.02	2.85146364	0.305898876	1.184500701
6800	1.88888889	17.71	2.83118289	0.300561798	1.202101896
7000	1.94444444	17.09	2.79391149	0.29002809	1.237777499
7200	2	16.48	2.75730003	0.279634831	1.2742707
7400	2.05555556	15.94	2.72038757	0.270505618	1.307462412
7600	2.11111111	15.34	2.68770674	0.260393258	1.345562258
7800	2.16666667	14.82	2.65508582	0.251544944	1.380133602
8000	2.22222222	14.33	2.62076292	0.243117978	1.414208449
8200	2.27777778	13.80	2.58459594	0.234129213	1.451882122
8400	2.33333333	13.32	2.54382596	0.226123596	1.486673546
8600	2.38888889	12.87	2.50200108	0.218398876	1.52143218

Table B.2-4

100 ppm Pyrene Contaminated Ottawa Sand

	Initial Linear Range			Final Linear Range	
	Slope	y-intercept		Slope	y-intercept
	7.44205E-05	0.618542927		0.00016312	0.006214249
S.E.E.	5.90124E-07	0.001130181		2.70416E-06	0.002749999
r^(2)	0.998994958	0.002480892		0.996167244	0.007573829
	15903.73598	16		3638.723668	14
		Co=	74.73		

time (s)	time (hrs)	C	ln C	C / Co	- ln C / Co
0	0	74.73	4.260793689	1	0
20	0.005555556	74.57	4.261727505	0.997785161	0.002217296
40	0.011111111	74.18	4.248810463	0.99269103	0.007335811
60	0.016666667	73.92	4.247864501	0.989147287	0.010912033
80	0.022222222	73.51	4.241812866	0.98372093	0.01641303
100	0.027777778	73.21	4.240025981	0.979623477	0.020586988
250	0.069444444	71.05	4.208534945	0.950719823	0.050535873
450	0.125	68.57	4.175892767	0.917607973	0.085985024
650	0.180555556	66.19	4.13661103	0.885714286	0.121360857
850	0.236111111	63.90	4.10913125	0.85503876	0.156608478
1050	0.291666667	61.88	4.075126592	0.828017719	0.188720725
1250	0.347222222	60.38	4.048625539	0.807973422	0.213226115
1450	0.402777778	58.45	4.017537992	0.782170543	0.245682477
1650	0.458333333	56.75	3.994028772	0.759357697	0.275282339
1850	0.513888889	55.20	3.971202364	0.738648948	0.302932508
2050	0.569444444	53.92	3.946884097	0.721483942	0.326445157
2250	0.625	52.58	3.92113994	0.703543743	0.351625225
2450	0.680555556	51.41	3.902599432	0.687929125	0.374069462
2650	0.736111111	50.26	3.880126577	0.672535991	0.396699651
2850	0.791666667	49.38	3.864106942	0.660797342	0.414308079
3050	0.847222222	48.29	3.839496805	0.646179402	0.436678102
3250	0.902777778	47.31	3.819363104	0.633111849	0.457108175
3450	0.958333333	46.58	3.808224488	0.623366556	0.472620561
3650	1.013888889	45.72	3.789504638	0.611849391	0.49126912
3850	1.069444444	44.90	3.768327821	0.600775194	0.509534468
4050	1.125	44.09	3.752922163	0.590033223	0.527576434
4250	1.180555556	43.22	3.733127298	0.578294574	0.547671897
4450	1.236111111	42.48	3.714950427	0.568438538	0.564862084
4650	1.291666667	41.71	3.69787337	0.558139535	0.583146285
4850	1.347222222	41.09	3.682167323	0.549833887	0.59813907
5050	1.402777778	40.34	3.663243293	0.539756368	0.616637412
5250	1.458333333	39.86	3.650855266	0.533333333	0.628608659
5450	1.513888889	39.10	3.631542525	0.523255814	0.647684806
5650	1.569444444	38.51	3.616753601	0.515282392	0.663040195
5850	1.625	37.95	3.607594596	0.50786268	0.677544183
6050	1.680555556	37.34	3.583978603	0.499667774	0.693811853
6250	1.736111111	36.73	3.571492892	0.491472868	0.710348543
6450	1.791666667	36.20	3.556962521	0.484385382	0.724874445
6540	1.816666667	35.92	3.549379546	0.480620155	0.732678019
6740	1.872222222	35.50	3.536451428	0.475083056	0.744265634
6890	1.913888889	34.88	3.521154298	0.466777409	0.761902776
7090	1.969444444	34.42	3.506613068	0.460575858	0.775277707
7240	2.011111111	33.89	3.491353235	0.453488372	0.79078565
7440	2.066666667	33.37	3.476880467	0.446511628	0.806289837
7590	2.108333333	32.95	3.462454663	0.440974529	0.818768162
7790	2.163888889	32.51	3.449396238	0.434994463	0.832421977
7940	2.205555556	32.12	3.44147854	0.42978959	0.844459515
8140	2.261111111	31.63	3.426528983	0.423255814	0.859778522

Table B.3-1

250 ppm Contaminated Natural Metea Soil
(Experiment #1)

	Slope	y-intercept
	0.0023836	-0.013223051
S.E.E.	1.507E-05	0.003066486
r^(2)	0.9986432	0.009391803
	25025.039	34
Co=	38.07	

time (s)	time (hrs.)	C	ln C	C / Co	- ln C / Co
0	0	38.07	2.8581335	1	0
10	0.0027778	37.18	2.7816852	0.976521739	0.023758267
20	0.0055556	36.37	2.7682691	0.955434783	0.045588772
30	0.0083333	35.69	2.730149	0.937608696	0.064422586
40	0.0111111	34.91	2.7398161	0.916956522	0.086695221
50	0.0138889	34.19	2.7398161	0.898043478	0.107536795
60	0.0166667	33.52	2.6285591	0.880434783	0.127339422
70	0.0194444	32.76	2.6746717	0.860652174	0.150064835
80	0.0222222	32.01	2.668377	0.840869565	0.173318726
90	0.025	31.23	2.6550858	0.820434783	0.197920857
100	0.0277778	30.55	2.6141184	0.802391304	0.220158879
110	0.0305556	29.78	2.6261667	0.782391304	0.245400274
120	0.0333333	29.10	2.6086489	0.764347826	0.268732324
130	0.0361111	28.39	2.4965626	0.745869565	0.29320454
140	0.0388889	27.74	2.497925	0.728695652	0.316499121
150	0.0416667	27.05	2.5067356	0.710652174	0.341572176
160	0.0444444	26.38	2.4252299	0.693043478	0.366662543
170	0.0472222	25.79	2.3970171	0.677391304	0.389506175
180	0.05	25.19	2.4281538	0.66173913	0.412883863
190	0.0527778	24.63	2.3871798	0.646956522	0.435476187
200	0.0555556	24.11	2.1232934	0.63326087	0.456872826
210	0.0583333	23.54	2.1183306	0.61826087	0.480844792
220	0.0611111	22.97	2.294831	0.603478261	0.505045261
230	0.0638889	22.48	2.159272	0.590434783	0.526896094
240	0.0666667	21.92	2.2158997	0.575869565	0.551874093
250	0.0694444	21.45	2.2329023	0.563478261	0.573626525
260	0.0722222	20.96	2.0921195	0.550652174	0.596651932
270	0.075	20.43	2.0024115	0.53673913	0.622243093
280	0.0777778	19.95	2.131183	0.524130435	0.646014704
290	0.0805556	19.40	2.0212278	0.509565217	0.674197432
300	0.0833333	18.97	1.9063189	0.49826087	0.696631505
310	0.0861111	17.98	2.0450643	0.472173913	0.750407901
320	0.0888889	17.59	1.974081	0.462173913	0.771814024
330	0.0916667	17.16	1.7580957	0.450652174	0.79705947
340	0.0944444	17.16	1.7217809	0.450652174	0.79705947
350	0.0972222	16.65	1.8428458	0.437391304	0.826927051
500	0.1388889	10.82	1.135177	0.284130435	1.258321869
700	0.1944444	5.77	0.3235816	0.151521739	1.887026172
900	0.25	2.74	-0.5897196	0.071956522	2.631693207
1100	0.3055556	1.16	-1.9611988	0.030434783	3.49216916
1300	0.3611111	0.46	-----	0.011956522	4.426478397
1500	0.4166667	0.11	-----	0.002826087	5.868862225
1700	0.4722222	0.04	-----	0.001086957	6.82437367
1900	0.5277778	0.00	-----	0	-----

Table B.3-2

250 ppm Pyrene Contaminated Natural Metea Soil
(Experiment #2)

	Slope	y-intercept
	0.002019899	-0.042224744
S.E.E.	2.63525E-05	0.008273216
r^(2)	0.993405594	0.034344912
	5875.103285	39
	Co=	41.83

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	41.83	3.733523102	1	0
10	0.0027778	41.05	3.714748834	0.981400871	0.0187743
20	0.0055556	40.24	3.694792969	0.962010289	0.0387301
30	0.0083333	39.59	3.67862011	0.946576969	0.054903
40	0.0111111	38.94	3.661968866	0.930945786	0.0715542
50	0.0138889	38.31	3.645683955	0.915908192	0.0878391
60	0.0166667	37.69	3.629349061	0.901068461	0.104174
70	0.0194444	37.06	3.612519612	0.886030867	0.1210035
80	0.0222222	36.44	3.59562922	0.871191136	0.1378939
90	0.025	35.83	3.578910635	0.856747131	0.1546125
100	0.0277778	35.15	3.559555945	0.840324495	0.1739672
110	0.0305556	34.56	3.542696944	0.826276217	0.1908262
120	0.0333333	33.93	3.524330067	0.811238623	0.209193
130	0.0361111	33.31	3.505868004	0.796398892	0.2276551
140	0.0388889	32.74	3.488576507	0.78274634	0.2449466
150	0.0416667	32.14	3.469951144	0.768302335	0.263572
160	0.0444444	31.55	3.451497079	0.754254056	0.282026
170	0.0472222	31.02	3.434565458	0.741590819	0.2989576
180	0.05	30.45	3.415984069	0.727938267	0.317539
190	0.0527778	29.90	3.397881546	0.714879304	0.3356416
200	0.0555556	29.40	3.38113541	0.703007519	0.3523877
210	0.0583333	28.89	3.363531321	0.690740008	0.3699918
220	0.0611111	28.38	3.345611767	0.678472497	0.3879113
230	0.0638889	27.86	3.327365234	0.666204986	0.4061579
240	0.0666667	27.37	3.309384527	0.654333201	0.4241386
250	0.0694444	26.92	3.292920741	0.643648595	0.4406024
260	0.0722222	26.42	3.274304007	0.63177681	0.4592191
270	0.075	25.96	3.256610023	0.620696478	0.4769131
280	0.0777778	25.51	3.239246242	0.610011872	0.4942769
290	0.0805556	25.12	3.223554518	0.600514444	0.5099686
300	0.0833333	24.67	3.205601908	0.589829838	0.5279212
310	0.0861111	24.22	3.187321101	0.579145231	0.546202
320	0.0888889	23.80	3.169743533	0.569054214	0.5637796
330	0.0916667	23.34	3.150079978	0.557973882	0.5834431
340	0.0944444	22.94	3.132912175	0.548476454	0.6006109
350	0.0972222	22.55	3.115811521	0.53917689	0.6177116
500	0.1388889	16.54	2.805489774	0.395330431	0.9280333
600	0.1666667	13.35	2.591438892	0.319153146	1.1420842
700	0.1944444	10.60	2.360984116	0.253462604	1.372539
800	0.2222222	8.23	2.107325021	0.1966759	1.6261981
900	0.25	6.26	1.833629191	0.149584488	1.8998939
1000	0.2777778	4.62	1.529946777	0.110407598	2.2035763
1100	0.3055556	3.38	1.21930297	0.080925999	2.5142201
1200	0.3333333	2.42	0.882341617	0.057776019	2.8511815
1300	0.3611111	1.65	0.498892639	0.039374753	3.2346305
1400	0.3888889	1.16	0.147230237	0.027700831	3.5862929
1460	0.4055556	0.94	-0.058213737	0.022556391	3.7917368
1560	0.4333333	0.64	-0.450606764	0.015235457	4.1841299
1660	0.4611111	0.43	-0.843168467	0.01028888	4.5766916
1760	0.4888889	0.32	-1.130850539	0.00771666	4.8643736
1860	0.5166667	0.26	-1.328676283	0.006331619	5.0621994

Table B.3-3

250 ppm Pyrene Contaminated Natural Metea Soil
(Experiment #3)

	Slope	y-intercept
	0.0022907	-0.060921723
S.E.E.	3.525E-05	0.012212929
r^(2)	0.9906154	0.05304087
	4222.3126	40
	Co=	39.78

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	39.78	3.0419576	1	0
10	0.0027778	39.06	3.0984133	0.981901394	0.018264389
20	0.0055556	38.31	3.1021405	0.962970668	0.037732327
30	0.0083333	37.63	3.0451134	0.945912211	0.055605514
40	0.0111111	36.98	3.0513953	0.929685875	0.072908519
50	0.0138889	36.26	3.0757538	0.911587269	0.092567948
60	0.0166667	35.59	3.0462943	0.894736842	0.111225635
70	0.0194444	34.93	3.0232133	0.878094446	0.130001122
80	0.0222222	34.28	3.0110624	0.861660079	0.148894426
90	0.025	33.59	3.0008227	0.844393593	0.169136551
100	0.0277778	32.99	2.9867263	0.829207406	0.187284967
110	0.0305556	32.35	2.9766549	0.813189099	0.206791602
120	0.0333333	31.72	2.9440759	0.797378823	0.226425403
130	0.0361111	31.11	2.8990695	0.781984606	0.245920224
140	0.0388889	29.98	2.8788109	0.753484502	0.283046829
150	0.0416667	29.43	2.8788109	0.739754525	0.301436871
160	0.0444444	28.87	2.8699344	0.725608488	0.320744683
170	0.0472222	28.42	2.8316706	0.71437487	0.336347426
180	0.05	27.94	2.7739671	0.702309133	0.353381612
190	0.0527778	27.45	2.6955587	0.690035365	0.371012429
200	0.0555556	26.97	2.6591497	0.677969628	0.388652789
210	0.0583333	26.47	2.71163	0.66548783	0.407234928
220	0.0611111	26.06	2.7269058	0.655086332	0.422988247
230	0.0638889	25.58	2.7061173	0.643020595	0.441578526
240	0.0666667	25.12	2.6427942	0.631370917	0.459861764
250	0.0694444	24.61	2.6780886	0.61868109	0.480165341
260	0.0722222	24.16	2.6433829	0.607239442	0.498832097
270	0.075	23.64	2.6219663	0.594133555	0.520651144
280	0.0777778	23.20	2.5726649	0.583107968	0.539382917
290	0.0805556	22.78	2.5820959	0.57270647	0.557381963
300	0.0833333	22.29	2.5327111	0.560224672	0.579417375
310	0.0861111	21.88	2.4917795	0.550031204	0.597780267
320	0.0888889	21.50	2.5060606	0.540461827	0.615331271
330	0.0916667	21.04	2.4625905	0.528812149	0.637122016
340	0.0944444	20.61	2.4200922	0.517994591	0.657790478
350	0.0972222	19.42	2.4281538	0.488038278	0.717361439
500	0.1388889	14.80	2.0057579	0.371957562	0.988975512
600	0.1666667	11.68	1.5703386	0.293530268	1.225774516
700	0.1944444	8.99	1.3126107	0.225920533	1.487571967
800	0.2222222	6.76	0.96133	0.169960474	1.772189373
900	0.25	4.93	0.533464	0.123985854	2.087587801
1000	0.2777778	3.51	0.0576181	0.088204701	2.428095013
1100	0.3055556	2.46	-0.1992923	0.061784897	2.784096329
1200	0.3333333	1.69	-0.6200249	0.042438111	3.159708474
1300	0.3611111	1.13	-1.0567426	0.028500104	3.557847542
1400	0.3888889	0.77	-1.2390641	0.019346786	3.945228975
1460	0.4055556	0.46	-1.360425	0.011649678	4.452476777
1560	0.4333333	0.46	-1.5363156	0.011649678	4.452476777
1660	0.4611111	0.33	-1.6163584	0.008321198	4.788949014
1760	0.4888889	0.28	-1.658918	0.007073019	4.951467943
1860	0.5166667	0.23	-1.658918	0.005824839	5.145623958

Table B.3-4

250 ppm Pyrene Contaminated Natural Metea Soil
(Experiment #4)

	Slope	y-intercept
	0.00159973	-0.05797119
S.E.E.	2.1939E-05	0.012726375
R^(2)	0.99142225	0.064745993
	5316.71461	46
	Co=	49.51

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	49.51	3.48705867	1	0
10	0.00277778	48.92	3.52408613	0.987965903	0.012107093
20	0.00555556	48.32	3.42760425	0.975931807	0.024362565
30	0.00833333	47.50	3.45254585	0.959217784	0.041637135
40	0.01111111	46.93	3.49009204	0.947852248	0.053556645
50	0.01388889	46.38	3.4580339	0.936653853	0.065441486
60	0.01666667	45.86	3.4039522	0.926291158	0.076566668
70	0.01944444	45.40	3.37577347	0.916931305	0.086722722
80	0.02222222	44.76	3.41080624	0.904061508	0.100857882
90	0.025	44.13	3.44650036	0.89119171	0.115195712
100	0.02777778	43.66	3.38814708	0.881664717	0.125943435
110	0.03055556	43.04	3.39093804	0.86929634	0.1400712
120	0.03333333	42.44	3.42948319	0.857095103	0.154206395
130	0.03611111	42.02	3.42518327	0.848738091	0.164004631
140	0.03888889	41.38	3.33594136	0.835701153	0.179484202
150	0.04166667	40.93	3.31961326	0.826675581	0.190342945
160	0.04444444	40.33	3.29261329	0.814474344	0.205212351
170	0.04722222	39.65	3.35432262	0.800768845	0.222182957
180	0.05	39.05	3.33976209	0.788734748	0.237325202
190	0.05277778	38.49	3.27242313	0.777369213	0.251839864
200	0.05555556	37.93	3.32290028	0.766003677	0.266568309
210	0.05833333	37.36	3.30392666	0.754471001	0.281738436
220	0.06111111	36.90	3.24280785	0.745278288	0.293997589
230	0.06388889	36.38	3.20694284	0.734748454	0.308227078
240	0.06666667	35.88	3.1903912	0.7245529	0.322200504
250	0.06944444	35.30	3.2288125	0.712853084	0.338479933
260	0.07222222	34.84	3.25149656	0.703660371	0.351459467
270	0.075	34.47	3.18834552	0.696139061	0.362205839
280	0.07777778	33.96	3.18355591	0.685776366	0.377203701
290	0.08055556	33.58	3.19751833	0.678087916	0.38847833
300	0.08333333	33.10	3.18936888	0.668560923	0.402627753
310	0.08611111	32.71	3.10214052	0.660705332	0.41444733
320	0.08888889	32.42	3.08412201	0.654855424	0.423340795
330	0.09166667	31.99	3.07498953	0.645996991	0.436960432
340	0.09444444	31.63	3.12239531	0.638809962	0.448148269
350	0.09722222	31.20	3.10214052	0.63011867	0.461847113
500	0.13888889	25.44	2.84571099	0.513789069	0.665942469
600	0.16666667	22.39	2.62316822	0.452281464	0.793450585
700	0.19444444	19.30	2.49656259	0.389771018	0.942195846
800	0.22222222	16.48	2.38337023	0.332776199	1.100285089
900	0.25	13.81	2.18286916	0.278957045	1.27669747
1000	0.27777778	11.99	1.9136719	0.242186194	1.418048451
1100	0.30555556	9.69	1.65763677	0.19572121	1.63106403
1200	0.33333333	8.10	1.35832051	0.163630286	1.810145751
1300	0.36111111	6.60	1.12448167	0.133210764	2.015822715
1400	0.38888889	5.14	0.99554799	0.103794083	2.265346311
1500	0.41666667	4.25	0.71497615	0.085910079	2.454454128
1600	0.44444444	3.15	0.48879154	0.063680428	2.753878018
1700	0.47222222	2.52	-0.0582137	0.05097777	2.976365617
1800	0.5	1.99	-0.0237276	0.040113655	3.21603847

Table B.3-5

250 ppm Pyrene Contaminated Natural Metea Soil

(Experiment #5)

	Slope	y-intercept
	0.001643732	-0.009972714
S.E.E.	1.57717E-05	0.009079041
r^(2)	0.995782886	0.046055382
	10861.93476	46
	Co=	32.71

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	32.71	3.487817878	1	0
10	0.0027778	31.90	3.462454663	0.97495573	0.025363214
20	0.0055556	31.23	3.44147854	0.954717936	0.046339337
30	0.0083333	30.78	3.426797908	0.940804452	0.061019969
40	0.0111111	30.17	3.40697377	0.922337465	0.080844108
50	0.0138889	29.76	3.39316521	0.909688844	0.094652668
60	0.0166667	29.30	3.377752266	0.89577536	0.110065611
70	0.0194444	28.94	3.365248551	0.884644574	0.122569326
80	0.0222222	28.56	3.352007137	0.873007842	0.13581074
90	0.025	28.11	3.336235783	0.859347331	0.151582095
100	0.0277778	27.62	3.318415293	0.844168986	0.169402585
110	0.0305556	27.14	3.301186516	0.829749557	0.186631362
120	0.0333333	26.77	3.287372021	0.818365798	0.200445856
130	0.0361111	26.33	3.270538706	0.804705287	0.217279172
140	0.0388889	25.99	3.257884314	0.79458639	0.229933564
150	0.0416667	25.58	3.241837757	0.781937769	0.245980121
160	0.0444444	25.18	3.226186964	0.769795092	0.261630913
170	0.0472222	24.82	3.211621993	0.758664306	0.276195885
180	0.05	24.43	3.195826	0.746774602	0.291991878
190	0.0527778	24.04	3.179776484	0.734884898	0.308041394
200	0.0555556	23.70	3.165562342	0.724513028	0.322255535
210	0.0583333	23.40	3.152559172	0.715153048	0.335258706
220	0.0611111	23.02	3.136153669	0.703516317	0.351664209
230	0.0638889	22.73	3.1238525	0.694915254	0.363965377
240	0.0666667	22.34	3.106224427	0.682772578	0.38159345
250	0.0694444	22.05	3.093171846	0.673918543	0.394646032
260	0.0722222	21.63	3.074224709	0.661269922	0.413593169
270	0.075	21.24	3.056080995	0.649380218	0.431736882
280	0.0777778	20.93	3.041167061	0.639767265	0.446650817
290	0.0805556	20.56	3.023213257	0.628383506	0.46460462
300	0.0833333	20.22	3.006569886	0.618011637	0.481247992
310	0.0861111	19.88	2.989644817	0.607639767	0.498173061
320	0.0888889	19.51	2.971156895	0.596508981	0.516660982
330	0.0916667	19.32	2.961354984	0.590690615	0.526462893
340	0.0944444	19.09	2.949291073	0.583607387	0.538526805
350	0.0972222	18.83	2.935323146	0.575512269	0.552494732
500	0.1388889	14.98	2.706669939	0.457880091	0.781147939
600	0.1666667	13.10	2.572664874	0.40045535	0.915153003
700	0.1944444	11.35	2.428883494	0.346825196	1.058934384
800	0.2222222	9.67	2.268635978	0.295471794	1.2191819
900	0.25	8.09	2.090074466	0.24715406	1.397743411
1000	0.2777778	7.08	1.957858191	0.216544397	1.529959687
1100	0.3055556	5.78	1.753806917	0.176574753	1.734010961
1200	0.3333333	4.81	1.570338571	0.14697698	1.917479306
1300	0.3611111	3.89	1.358320509	0.11889704	2.129497369
1400	0.3888889	3.19	1.161425184	0.097647356	2.326392694
1460	0.4055556	2.86	1.049132231	0.087275487	2.438685646
1560	0.4333333	2.04	0.714976151	0.062484189	2.772841727
1660	0.4611111	1.60	0.468278003	0.048823678	3.019539874
1760	0.4888889	1.18	0.161414872	0.035922084	3.326403006
1860	0.5166667	1.01	0.009608859	0.030862636	3.478209019

Table B.3-6

250 ppm Pyrene Contaminated Natural Metea Soil

(Experiment #6)

	Slope	y-intercept
	0.00162	1.813357276
S.E.E.	2.391E-05	0.012766769
r^(2)	0.9982596	0.021721287
	4588.6649	8
	Co=	51.41

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	51.41	3.4809642	1	0
10	0.002777778	50.94	3.4364314	0.990824211	0.009218146
20	0.005555556	50.22	3.3658203	0.97681906	0.023453844
30	0.008333333	49.50	3.4624547	0.962813909	0.037895127
40	0.011111111	48.90	3.4575125	0.951223439	0.050006293
50	0.013888889	48.30	3.4246445	0.93947199	0.062437275
60	0.016666667	47.64	3.4353656	0.926754668	0.0760664
70	0.019444444	47.00	3.4438604	0.914198326	0.089707744
80	0.022222222	46.27	3.4334977	0.900032196	0.105324743
90	0.025	45.74	3.4069738	0.889729556	0.116837732
100	0.027777778	45.10	3.383946	0.877173213	0.1310508
110	0.030555556	44.47	3.3788813	0.865099807	0.144910395
120	0.033333333	43.85	3.3749242	0.853026401	0.158964782
130	0.036111111	43.40	3.3359414	0.844172569	0.169398339
140	0.038888889	42.99	3.2984388	0.83628461	0.178786281
150	0.041666667	42.48	3.2950703	0.826303928	0.190792622
160	0.044444444	41.90	3.3273652	0.815035415	0.204523712
170	0.047222222	41.47	3.3423987	0.80666452	0.214847409
180	0.05	40.97	3.3380005	0.797005795	0.226893329
190	0.052777778	40.44	3.333878	0.786542176	0.240108932
200	0.055555556	39.97	3.2546955	0.777527366	0.251636438
210	0.058333333	39.44	3.2421612	0.767224726	0.264975527
220	0.061111111	38.95	3.261063	0.757566001	0.277644615
230	0.063888889	38.47	3.3081742	0.748229234	0.290045886
240	0.066666667	38.08	3.2827245	0.740663232	0.300209234
250	0.069444444	37.71	3.2301227	0.733580167	0.309818393
260	0.072222222	37.34	3.1732146	0.726336124	0.319742391
270	0.075	36.88	3.1951483	0.717321314	0.332231403
280	0.077777778	36.33	3.1975183	0.706696716	0.347153678
290	0.080555556	35.98	3.2562912	0.69977463	0.356996953
300	0.083333333	35.50	3.2149509	0.690598841	0.370196172
310	0.086111111	35.30	3.2052664	0.686574372	0.376040724
320	0.088888889	34.78	3.1927726	0.676432711	0.390922303
330	0.091666667	34.30	3.1924327	0.667095943	0.4048214
340	0.094444444	33.87	3.2005573	0.658886027	0.417204708
350	0.097222222	33.63	3.1223953	0.654217643	0.424315195
500	0.138888889	28.27	3.0126911	0.549903413	0.598012629
600	0.166666667	25.22	2.8945012	0.490663232	0.711997267
700	0.194444444	22.61	2.7873075	0.439793947	0.821448964
800	0.222222222	20.28	2.6741011	0.394397939	0.930394881
900	0.25	17.91	2.5353375	0.348358017	1.054524544
1000	0.277777778	15.79	2.4022744	0.307147457	1.180427332
1100	0.305555556	13.93	2.2469995	0.270927238	1.30590499
1200	0.333333333	12.41	2.1053109	0.241307147	1.421684686
1300	0.361111111	10.77	1.9786682	0.209433355	1.563349706
1400	0.388888889	9.53	1.7903792	0.185286542	1.685851776
1460	0.405555556	8.15	1.7083779	0.15856407	1.841596543
1560	0.433333333	7.05	1.5477092	0.137153896	1.986651657
1660	0.461111111	6.18	1.3258852	0.120251127	2.118172999
1760	0.488888889	5.30	1.1819387	0.103026401	2.272770008
1860	0.516666667	4.47	1.0577903	0.086928525	2.442669045

Table B.4-1

250 ppm Pyrene Contaminated Moist Soil

(Experiment #1)

	Slope	y-intercept
	0.0046966	-0.025596095
S.E.E.	1.865E-05	0.003796277
r^(2)	0.9994639	0.011626951
	63390.211	34
	Co=	32.09

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	32.09	0.1891944	1	0
10	0.0027778	30.86	0.2360257	0.961578133	0.039179456
20	0.0055556	29.52	-0.0494801	0.919804023	0.08359465
30	0.0083333	28.30	0.3703738	0.881640021	0.125971446
40	0.0111111	27.16	0.2554438	0.846312532	0.166866564
50	0.0138889	26.03	-0.1500213	0.810985044	0.209505667
60	0.0166667	24.87	0.0497749	0.774883961	0.255041989
70	0.0194444	23.79	0.0339016	0.741361527	0.299266883
80	0.0222222	22.74	0.2425404	0.708612687	0.344446182
90	0.025	21.72	0.1823216	0.676895307	0.390238661
100	0.0277778	20.73	-0.0939318	0.645951521	0.437030822
110	0.0305556	19.77	0.1614149	0.616039195	0.484444688
120	0.0333333	18.90	0.0418697	0.588963383	0.529391265
130	0.0361111	17.96	-0.2946025	0.559566787	0.580592389
140	0.0388889	17.18	-0.399963	0.535327488	0.624876592
150	0.0416667	16.34	-0.0237276	0.509283136	0.674751158
160	0.0444444	15.60	-0.0322383	0.486075297	0.721391736
170	0.0472222	14.93	-0.1215834	0.465188241	0.765313135
180	0.05	14.22	-0.3755716	0.443011862	0.814158733
190	0.0527778	13.56	-0.3755716	0.422640536	0.861233257
200	0.0555556	12.97	-0.3057758	0.404074265	0.906156593
210	0.0583333	12.39	-0.4377034	0.386023724	0.951856451
220	0.0611111	11.79	-0.5749045	0.367457452	1.001147743
230	0.0638889	11.18	-0.4506068	0.348375451	1.054474498
240	0.0666667	10.83	-0.7513609	0.337545126	1.08605607
250	0.0694444	10.34	-1.0332121	0.322073234	1.132976326
260	0.0722222	9.83	-0.8431685	0.306343476	1.183048336
270	0.075	9.39	-0.6200249	0.292676637	1.228686906
280	0.0777778	8.90	-0.7690605	0.277204745	1.282998895
290	0.0805556	8.45	-0.5897196	0.263280041	1.334537018
300	0.0833333	7.98	-0.6835383	0.248581743	1.391983541
310	0.0861111	7.61	-0.6835383	0.236977824	1.439788713
320	0.0888889	7.22	-0.7513609	0.225116039	1.49113928
330	0.0916667	6.89	-1.1308505	0.214801444	1.538041194
340	0.0944444	6.55	-1.2680517	0.203971119	1.589776868
350	0.0972222	6.18	-1.1308505	0.192625064	1.647009651
500	0.1388889	2.66	-1.360425	0.083032491	2.48852329
600	0.1666667	1.42	-1.2979046	0.044352759	3.115580359
700	0.1944444	0.83	-2.3095055	0.025786488	3.65790465
800	0.2222222	0.54	-2.0218235	0.016761217	4.088687566
900	0.25	0.37	-2.3095055	0.01160392	4.456412346
1000	0.2777778	0.29	-2.4918271	0.009025271	4.707726774
1100	0.3055556	0.26	-2.3965169	0.007993811	4.829087631
1200	0.3333333	0.32	-2.3095055	0.01005673	4.59951319
1300	0.3611111	0.32	-3.0026527	0.01005673	4.59951319
1400	0.3888889	0.26	-4.7944122	0.007993811	4.829087631

Table B.4-2

250 ppm Pyrene Contaminated Moist Soil

(Experiment #2)

	Slope	y-intercept
	0.005276602	-0.043535806
S.E.E.	3.40516E-05	0.006929875
r^(2)	0.998586059	0.021224298
	24012.26121	34
	Co=	28.87

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	28.87	3.362958256	1	0
10	0.0027778	27.57	3.316615653	0.954714818	0.046342603
20	0.0055556	26.37	3.272109305	0.913155632	0.090848951
30	0.0083333	25.19	3.226515533	0.872456291	0.136442722
40	0.0111111	24.02	3.178743248	0.83175695	0.184215008
50	0.0138889	22.84	3.128573773	0.79105761	0.234384482
60	0.0166667	21.73	3.078804869	0.752651189	0.284153386
70	0.0194444	20.82	3.036013432	0.721123531	0.326944823
80	0.0222222	20.00	2.995870195	0.692748639	0.36708806
90	0.025	19.00	2.944511572	0.658068214	0.418446684
100	0.0277778	18.07	2.894501151	0.625967326	0.468457104
110	0.0305556	17.20	2.844748986	0.595586128	0.51820927
120	0.0333333	16.37	2.795429327	0.56692462	0.567528929
130	0.0361111	15.57	2.745146644	0.539122958	0.617811612
140	0.0388889	14.74	2.690518098	0.51046145	0.672440158
150	0.0416667	13.97	2.63688749	0.483806248	0.726070766
160	0.0444444	13.32	2.588955961	0.461163657	0.774002294
170	0.0472222	12.60	2.533368353	0.436228146	0.829589903
180	0.05	11.93	2.479374132	0.41329894	0.883584123
190	0.0527778	11.20	2.415667443	0.387790198	0.947290813
200	0.0555556	10.69	2.369534499	0.370306678	0.993423757
210	0.0583333	10.12	2.31464995	0.350530238	1.048308305
220	0.0611111	9.53	2.253974223	0.329893952	1.108984032
230	0.0638889	9.03	2.2004378	0.312697048	1.162520455
240	0.0666667	8.57	2.14774452	0.296646604	1.215213735
250	0.0694444	8.16	2.099244169	0.282602465	1.263714087
260	0.0722222	7.70	2.040772401	0.266552021	1.322185855
270	0.075	7.32	1.990044877	0.253367727	1.372913379
280	0.0777778	6.89	1.930621457	0.238750358	1.432336799
290	0.0805556	6.51	1.873816063	0.225566065	1.489142193
300	0.0833333	6.17	1.818972033	0.213528232	1.543986223
310	0.0861111	5.77	1.752373225	0.199770708	1.61058503
320	0.0888889	5.41	1.688695166	0.18744626	1.67426309
330	0.0916667	5.16	1.641738183	0.178847807	1.721220073
340	0.0944444	4.87	1.582314762	0.168529665	1.780643493
350	0.0972222	4.58	1.520945816	0.158498137	1.84201244
500	0.1388889	1.57	0.452611887	0.054456864	2.910346369
600	0.1666667	0.73	-0.317075371	0.025222127	3.680033627
700	0.1944444	0.46	-0.769060495	0.016050444	4.13201875
800	0.2222222	0.35	-1.056742567	0.012037833	4.419700823
900	0.25	0.26	-1.360424981	0.008885067	4.723383237
1000	0.2777778	0.29	-1.239064124	0.010031528	4.60202238
1100	0.3055556	0.22	-1.49857532	0.007738607	4.861533575
1200	0.3333333	0.22	-1.536315648	0.007451992	4.899273903
1300	0.3611111	0.11	-2.229462828	0.003725996	5.592421084
1400	0.3888889	0.22	-1.536315648	0.007451992	4.899273903
1500	0.4166667	0.94	-0.058213737	0.032674119	3.421171993

Table B.4-3

250 ppm Pyrene Contaminated Moist Soil

(Experiment #3)

	Slope	y-intercept
	0.0045062	-0.010404435
S.E.E.	1.746E-05	0.003552684
r^(2)	0.99949	0.010880894
	66632.761	34
	Co=	31.76

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	31.76	-1.4622077	1	0
10	0.0027778	30.43	-1.4985753	0.958051068	0.042854195
20	0.0055556	28.98	-1.4622077	0.912454403	0.091617164
30	0.0083333	27.78	-1.2979046	0.87467431	0.13390368
40	0.0111111	26.47	-1.4622077	0.833507035	0.182113137
50	0.0138889	25.44	-3.1849743	0.800937989	0.221971752
60	0.0166667	24.36	-2.4918271	0.76706618	0.265182197
70	0.0194444	23.40	-2.4918271	0.736842105	0.30538165
80	0.0222222	22.43	-2.2294628	0.706096925	0.348002763
90	0.025	21.43	-1.9040404	0.674570089	0.393679697
100	0.0277778	20.67	-1.7498897	0.650859823	0.429460986
110	0.0305556	19.82	-1.360425	0.624022929	0.471568167
120	0.0333333	18.97	-1.7986799	0.597186034	0.515526599
130	0.0361111	18.02	-1.7498897	0.567483064	0.566544373
140	0.0388889	17.18	-1.9040404	0.540906722	0.614508432
150	0.0416667	16.38	-1.5363156	0.515633142	0.662359731
160	0.0444444	15.69	-2.3095055	0.494007295	0.705204994
170	0.0472222	15.03	-2.3965169	0.473163106	0.748315117
180	0.05	14.38	-2.0218235	0.452840021	0.792216371
190	0.0527778	13.75	-1.7986799	0.432777488	0.837531567
200	0.0555556	13.13	-1.7986799	0.413496613	0.883105956
210	0.0583333	12.54	-1.7498897	0.394736842	0.929535959
220	0.0611111	11.98	-2.2294628	0.377019281	0.97545895
230	0.0638889	11.44	-2.0218235	0.360083377	1.021419672
240	0.0666667	10.92	-1.7986799	0.34392913	1.067319661
250	0.0694444	10.47	-2.5971876	0.329598749	1.109879275
260	0.0722222	10.00	-1.9611988	0.314747264	1.155985298
270	0.075	9.51	-2.3965169	0.299374674	1.206059399
280	0.0777778	8.68	-2.4918271	0.273319437	1.297114068
290	0.0805556	8.68	-2.2294628	0.273319437	1.297114068
300	0.0833333	8.33	-2.2294628	0.262115685	1.338969326
310	0.0861111	7.91	-1.9611988	0.249088067	1.389948764
320	0.0888889	7.60	-2.3965169	0.239187077	1.430509286
330	0.0916667	7.25	-2.3095055	0.228243877	1.477340586
340	0.0944444	6.88	-1.658918	0.21651902	1.530076882
350	0.0972222	6.56	-1.9611988	0.20661803	1.576883455
500	0.1388889	3.15	-4.7944122	0.099270453	2.309907301
600	0.1666667	1.93	-2.3095055	0.060708702	2.801668223
700	0.1944444	1.20	-2.3965169	0.037780094	3.275972934
800	0.2222222	0.76	-2.3095055	0.023970818	3.7309181
900	0.25	0.59	-2.2294628	0.018499218	3.9900268
1000	0.2777778	0.37	-1.658918	0.011724857	4.446044187
1100	0.3055556	0.32	-2.3965169	0.010161542	4.58914503
1200	0.3333333	0.46	-4.7944122	0.01433038	4.245373491
1300	0.3611111	0.40	-4.7944122	0.012506514	4.381505666
1400	0.3888889	0.32	-2.3965169	0.010161542	4.58914503

Table B.4-4

250 ppm Pyrene Contaminated Moist Soil: (Dessicator #1)

(Experiment #4)

	Slope	y-intercept
	0.0046987	-0.024902476
S.E.E.	1.444E-05	0.002938583
r^(2)	0.999679	0.009000071
	105888.66	34
	Co=	40.19

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	40.19	-0.8431685	1	0
10	0.0027778	38.67	-0.1500213	0.962314662	0.03841379
20	0.0055556	37.26	-0.084882	0.927100494	0.075693311
30	0.0083333	35.69	-0.189242	0.888179572	0.118581336
40	0.0111111	34.09	-0.0759133	0.848228995	0.164604638
50	0.0138889	32.53	0.0959369	0.809514003	0.211321207
60	0.0166667	31.02	0.0339016	0.771828666	0.258992689
70	0.0194444	29.58	-0.7513609	0.735996705	0.306529637
80	0.0222222	28.25	-0.4377034	0.702841845	0.352623384
90	0.025	27.04	-0.3057758	0.672775947	0.396342921
100	0.0277778	25.86	-0.3635954	0.643533773	0.440780771
110	0.0305556	24.65	-0.4377034	0.613467875	0.48862738
120	0.0333333	23.54	-0.2405353	0.585667216	0.535003542
130	0.0361111	22.52	-0.7690605	0.560337727	0.579215594
140	0.0388889	21.57	-0.9232112	0.536655684	0.622398575
150	0.0416667	20.58	-0.8823892	0.512149918	0.669137889
160	0.0444444	19.60	-0.6200249	0.487644152	0.718169337
170	0.0472222	18.74	-0.8054281	0.466227348	0.763081893
180	0.05	17.91	-0.7513609	0.445634267	0.808256693
190	0.0527778	17.07	-0.7000676	0.424835255	0.85605382
200	0.0555556	16.30	-0.787079	0.40568369	0.902181511
210	0.0583333	15.51	-1.4622077	0.385914333	0.95213987
220	0.0611111	14.80	-1.2390641	0.368204283	0.999117377
230	0.0638889	14.04	-1.1308505	0.34946458	1.051353068
240	0.0666667	13.33	-0.9232112	0.33175453	1.10335995
250	0.0694444	12.77	-0.9232112	0.317751236	1.14648648
260	0.0722222	12.22	-1.1308505	0.303953871	1.190879328
270	0.075	11.50	-0.8431685	0.286037891	1.25163099
280	0.0777778	10.99	-0.9877497	0.273476112	1.296541003
290	0.0805556	10.48	-1.3286763	0.260708402	1.34435273
300	0.0833333	9.98	-1.4622077	0.248352554	1.392905955
310	0.0861111	9.52	-1.4985753	0.236820428	1.440453111
320	0.0888889	9.10	-1.6163584	0.226317957	1.485814378
330	0.0916667	8.68	-1.9611988	0.216021417	1.532377724
340	0.0944444	8.28	-1.7986799	0.205930807	1.580215054
350	0.0972222	7.86	-1.4985753	0.195634267	1.631508348
500	0.1388889	3.91	-2.2294628	0.097199341	2.330991347
700	0.1944444	2.30	-4.101265	0.057248764	2.860349219
900	0.25	1.27	-3.1849743	0.031507414	3.457532411
1100	0.3055556	0.76	-3.4081178	0.018945634	3.966181756
1300	0.3611111	0.41	-----	0.01009061	4.596150035
1500	0.4166667	0.23	-----	0.005766063	5.155765823
1700	0.4722222	0.17	-----	0.004324547	5.443447895
1900	0.5277778	0.15	-----	0.003706755	-----

Table B.4-5

250 ppm Pyrene Contaminated Moist Soil: (Dessicator #1)

(Experiment #5)

	Slope	y-intercept
	0.004302772	-0.029051503
S.E.E.	2.38697E-05	0.00485775
r^(2)	0.998954743	0.01487795
	32493.8781	34
	Co=	28.23

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	28.23	3.340348597	1	0
10	0.0027778	27.19	3.302709745	0.963060686	0.037638851
20	0.0055556	26.15	3.263915121	0.926414541	0.076433476
30	0.0083333	25.18	3.226186964	0.89211375	0.114161633
40	0.0111111	24.21	3.186637574	0.857519789	0.153711023
50	0.0138889	23.34	3.150079978	0.826737027	0.190268618
60	0.0166667	22.38	3.108075252	0.792729405	0.232273345
70	0.0194444	21.51	3.068469849	0.761946643	0.271878748
80	0.0222222	20.63	3.026829898	0.730870712	0.313518699
90	0.025	19.87	2.989228411	0.70389915	0.351120186
100	0.0277778	19.00	2.944511572	0.673116388	0.395837025
110	0.0305556	18.31	2.907692154	0.648783348	0.432656442
120	0.0333333	17.54	2.864759182	0.621518616	0.475589415
130	0.0361111	16.84	2.823838912	0.596599238	0.516509685
140	0.0388889	16.07	2.777061463	0.569334506	0.563287134
150	0.0416667	15.44	2.737140196	0.54705365	0.603208401
160	0.0444444	14.75	2.691079422	0.522427441	0.649269174
170	0.0472222	14.19	2.652756174	0.502785107	0.687592423
180	0.05	13.60	2.609866932	0.481676928	0.730481664
190	0.0527778	13.01	2.565691787	0.460861917	0.774656809
200	0.0555556	12.46	2.522800223	0.441512753	0.817548374
210	0.0583333	12.00	2.48490665	0.42509528	0.855441947
220	0.0611111	11.40	2.433976266	0.403987101	0.906372331
230	0.0638889	10.93	2.391732119	0.387276459	0.948616478
240	0.0666667	10.40	2.342071023	0.368513632	0.998277574
250	0.0694444	9.95	2.297329929	0.352389329	1.043018667
260	0.0722222	9.52	2.253105036	0.337144532	1.087243561
270	0.075	9.16	2.214996747	0.324538259	1.12535185
280	0.0777778	8.70	2.163085185	0.308120786	1.177263412
290	0.0805556	8.36	2.123293424	0.29610085	1.217055173
300	0.0833333	7.96	2.074602265	0.282028731	1.265746332
310	0.0861111	7.67	2.03754138	0.27176781	1.302807217
320	0.0888889	7.23	1.97866819	0.256229845	1.361680407
330	0.0916667	6.93	1.935411885	0.245382586	1.404936712
340	0.0944444	6.55	1.878885782	0.231896804	1.461462815
350	0.0972222	6.18	1.821653	0.218997361	1.518695597
500	0.1388889	2.47	0.902681301	0.087364409	2.437667296
600	0.1666667	1.24	0.216223108	0.043975374	3.124125488
700	0.1944444	0.63	-0.463678845	0.022280856	3.804027442
800	0.2222222	0.40	-0.923211175	0.01407212	4.263559772
900	0.25	0.27	-1.297904624	0.009674582	4.638253221
1000	0.2777778	0.14	-1.961198842	0.004983876	5.301547438
1100	0.3055556	0.17	-1.798679912	0.005863383	5.139028509
1200	0.3333333	0.14	-1.961198842	0.004983876	5.301547438
1300	0.3611111	0.19	-1.65891797	0.006742891	4.999266566
1400	0.3888889	0.17	-1.798679912	0.005863383	5.139028509
1460	0.4055556	2.42	0.882341617	0.085605394	2.45800698

Table B.4-6

250 ppm Pyrene Contaminated Moist Soil: (Dessicator #2)

(Experiment #1)

Slope	y-intercept
0.0044338	-0.009372022
1.431E-05	0.002911291
0.9996462	0.008916484
96061.425	34
Co=	42.95

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	42.95	-0.8431685	1	0
10	0.0027778	41.15	-0.3170754	0.957996146	0.042911524
20	0.0055556	39.46	-0.7513609	0.918689788	0.084806767
30	0.0083333	37.63	-0.9657708	0.8761079	0.132266022
40	0.0111111	36.03	-0.6200249	0.838921002	0.175638734
50	0.0138889	34.49	-0.8054281	0.802890173	0.219537345
60	0.0166667	33.00	-0.8054281	0.768208092	0.263694629
70	0.0194444	31.63	-0.6672778	0.736416185	0.305959851
80	0.0222222	30.31	-0.787079	0.705780347	0.348451213
90	0.025	28.96	-0.6200249	0.674181118	0.394256484
100	0.0277778	27.88	-0.787079	0.649132948	0.432117733
110	0.0305556	26.59	-1.1055327	0.619075145	0.479528617
120	0.0333333	25.60	-1.3286763	0.595953757	0.517592203
130	0.0361111	24.47	-1.1308505	0.569749518	0.562558456
140	0.0388889	23.54	-0.9657708	0.547976879	0.601522185
150	0.0416667	22.56	-1.1308505	0.525240848	0.643898364
160	0.0444444	21.63	-1.2979046	0.503660886	0.685852082
170	0.0472222	20.65	-0.8823892	0.480732177	0.732444968
180	0.05	19.86	-1.0567426	0.462427746	0.77126496
190	0.0527778	18.91	-1.2979046	0.44026975	0.820367673
200	0.0555556	18.03	-1.2680517	0.419845857	0.867867641
210	0.0583333	17.30	-0.9877497	0.402890173	0.909091277
220	0.0611111	16.52	-1.1308505	0.384585742	0.955588519
230	0.0638889	15.67	-1.1055327	0.364739884	1.008570825
240	0.0666667	15.05	-1.4622077	0.350481696	1.048446798
250	0.0694444	14.27	-1.4622077	0.332177264	1.102086525
260	0.0722222	13.68	-1.1308505	0.31849711	1.144141878
270	0.075	13.10	-1.2390641	0.305009634	1.187411916
280	0.0777778	12.54	-1.5363156	0.291907514	1.231318258
290	0.0805556	11.94	-1.360425	0.278034682	1.280009417
300	0.0833333	11.44	-1.0567426	0.26628131	1.323201972
310	0.0861111	10.92	-1.2390641	0.25433526	1.369101961
320	0.0888889	10.35	-1.360425	0.241040462	1.422790466
330	0.0916667	9.97	-1.6163584	0.232177264	1.46025413
340	0.0944444	9.43	-1.4985753	0.219653179	1.515705435
350	0.0972222	9.07	-1.658918	0.211175337	1.555066509
500	0.1388889	3.87	-1.5363156	0.09017341	2.40602068
600	0.1666667	1.95	-2.3095055	0.045472062	3.090657171
700	0.1944444	0.95	-1.6163584	0.022157996	3.809556848
800	0.2222222	0.55	-1.658918	0.012909441	4.349796357
900	0.25	0.45	-1.9611988	0.010404624	4.56550493
1000	0.2777778	0.35	-2.2294628	0.008092486	4.816819358
1100	0.3055556	0.29	-1.5363156	0.006743738	4.999140915
1200	0.3333333	0.22	-1.658918	0.005009634	5.296392438
1300	0.3611111	0.32	-2.3095055	0.007514451	4.89092733

Table B.4-7

250 ppm Pyrene Contaminated Moist Soil: (Dessicator #2)

(Experiment #2)

	Slope	y-intercept
	0.004418754	-0.009186324
S.E.E.	1.605E-05	0.003266348
r^(2)	0.999551632	0.010003924
	75796.64811	34
	Co=	44.44

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	44.44	3.794171002	1	0
10	0.0027778	42.62	3.752339808	0.959031657	0.041831194
20	0.0055556	40.89	3.710910833	0.920111732	0.083260169
30	0.0083333	39.05	3.664940006	0.87877095	0.129230996
40	0.0111111	37.52	3.624947645	0.844320298	0.169223356
50	0.0138889	35.98	3.583059063	0.809683426	0.211111939
60	0.0166667	34.34	3.536210435	0.772625698	0.257960567
70	0.0194444	32.83	3.491353235	0.738733706	0.302817767
80	0.0222222	31.32	3.44438898	0.704841713	0.349782022
90	0.025	29.98	3.400369453	0.674487896	0.393801549
100	0.0277778	28.66	3.355478359	0.644878957	0.438692643
110	0.0305556	27.43	3.311499012	0.617132216	0.48267199
120	0.0333333	26.33	3.270853023	0.59255121	0.523317979
130	0.0361111	25.18	3.225858287	0.566480447	0.568312715
140	0.0388889	24.11	3.182526571	0.542458101	0.611644431
150	0.0416667	23.15	3.141890508	0.520856611	0.652280494
160	0.0444444	22.23	3.101396191	0.50018622	0.69277481
170	0.0472222	21.36	3.061520014	0.480633147	0.732650988
180	0.05	20.50	3.020391244	0.461266294	0.773779758
190	0.0527778	19.68	2.979602892	0.44283054	0.81456811
200	0.0555556	18.76	2.931800465	0.422160149	0.862370537
210	0.0583333	18.03	2.892209149	0.405772812	0.901961853
220	0.0611111	17.25	2.847632217	0.388081937	0.946538785
230	0.0638889	16.44	2.799969057	0.370018622	0.994201945
240	0.0666667	15.78	2.75887442	0.355121043	1.035296582
250	0.0694444	15.03	2.709979374	0.338175047	1.084191628
260	0.0722222	14.33	2.66204237	0.322346369	1.132128632
270	0.075	13.66	2.614118381	0.30726257	1.180052621
280	0.0777778	13.02	2.566327717	0.29292365	1.227843284
290	0.0805556	12.46	2.522800223	0.280446927	1.271370779
300	0.0833333	11.82	2.469617957	0.265921788	1.324553045
310	0.0861111	11.31	2.425961651	0.254562384	1.368209351
320	0.0888889	10.76	2.375707358	0.242085661	1.418463644
330	0.0916667	10.30	2.331675088	0.231657356	1.462495914
340	0.0944444	9.83	2.285614314	0.22122905	1.508556688
350	0.0972222	9.34	2.234675379	0.210242086	1.559495623
500	0.1388889	3.99	1.383531928	0.089757914	2.410639073
600	0.1666667	1.94	0.66090893	0.043575419	3.133262072
700	0.1944444	0.98	-0.023727561	0.021973929	3.817898563
800	0.2222222	0.68	-0.387692938	0.015270019	4.18186394
900	0.25	0.46	-0.787079	0.010242086	4.581250002
1000	0.2777778	0.36	-1.03321207	0.008007449	4.827383072
1100	0.3055556	0.33	-1.105532732	0.00744879	4.899703733
1200	0.3333333	0.29	-1.239064124	0.006517691	5.033235126
1300	0.3611111	0.28	-1.268051661	0.006331471	5.062222663
1400	0.3888889	0.20	-1.616358355	0.004469274	5.410529357
1500	0.4166667	0.27	-1.297904624	0.006145251	5.092075626
1600	0.4444444	0.26	-1.360424981	0.005772812	5.154595983
1700	0.4722222	0.22	-1.536315648	0.004841713	5.330486649
1800	0.5	0.22	-1.536315648	0.004841713	5.330486649
1900	0.5277778	0.26	-1.360424981	0.005772812	5.154595983

Table B.4-8

250 ppm Pyrene Contaminated Moist Soil: (Dessicator #2)

(Experiment #3)

	Slope	y-intercept
	0.0045234	-0.021955195
S.E.E.	1.607E-05	0.003271122
r^(2)	0.9995709	0.010018545
	79196.16	34
	Co=	43.38

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	43.38	-0.3755716	1	0
10	0.0027778	41.65	-0.8054281	0.960129721	0.040686877
20	0.0055556	39.91	-0.9232112	0.919877909	0.083514325
30	0.0083333	38.18	-0.6200249	0.880198398	0.127607945
40	0.0111111	36.80	-0.8823892	0.848340328	0.164473393
50	0.0138889	35.17	-0.9232112	0.810759252	0.209784122
60	0.0166667	33.82	-0.9877497	0.779473483	0.249136609
70	0.0194444	32.36	-0.7000676	0.745898512	0.293165731
80	0.0222222	31.03	-0.5749045	0.715185044	0.335213967
90	0.025	29.72	-1.0332121	0.685043876	0.37827239
100	0.0277778	28.38	-0.6835383	0.654139641	0.424434431
110	0.0305556	27.19	-1.1308505	0.626859977	0.467032085
120	0.0333333	26.06	-0.8823892	0.600724914	0.509618163
130	0.0361111	24.89	-0.9025919	0.573636017	0.555760201
140	0.0388889	23.74	-0.8823892	0.547310187	0.602739568
150	0.0416667	22.68	-0.787079	0.522701259	0.648745185
160	0.0444444	21.72	-0.8054281	0.500763068	0.691622209
170	0.0472222	20.78	-1.1308505	0.479015643	0.736022025
180	0.05	19.80	-0.9877497	0.456505151	0.784155296
190	0.0527778	18.98	-1.0332121	0.437619229	0.826406086
200	0.0555556	18.13	-1.1055327	0.41797024	0.872345044
210	0.0583333	17.31	-1.0332121	0.399084319	0.918582559
220	0.0611111	16.53	-1.1055327	0.380961465	0.96505705
230	0.0638889	15.73	-1.0332121	0.362647844	1.014323041
240	0.0666667	15.03	-1.0567426	0.346432659	1.060066825
250	0.0694444	14.36	-1.2979046	0.330980542	1.105695692
260	0.0722222	13.74	-1.2680517	0.316673026	1.149885503
270	0.075	13.04	-1.1055327	0.300648607	1.201813113
280	0.0777778	12.55	-1.1308505	0.289202594	1.240627818
290	0.0805556	11.88	-1.1308505	0.273941244	1.294841634
300	0.0833333	11.36	-1.4985753	0.26192293	1.339704978
310	0.0861111	10.82	-1.2680517	0.249332316	1.38896867
320	0.0888889	10.30	-1.2979046	0.237314002	1.438371111
330	0.0916667	9.87	-1.4622077	0.227584891	1.480231962
340	0.0944444	9.38	-1.2680517	0.216138878	1.531834123
350	0.0972222	8.97	-1.658918	0.206791301	1.576045202
500	0.1388889	4.02	-1.658918	0.092712705	2.37824976
600	0.1666667	2.24	-1.6163584	0.051697825	2.962339563
700	0.1944444	1.20	-1.360425	0.027661198	3.587724641
800	0.2222222	0.74	-1.5363156	0.017169019	4.064648714
900	0.25	0.51	-1.6163584	0.011827547	4.437323999
1000	0.2777778	0.46	-1.4985753	0.010682945	4.539106693
1100	0.3055556	0.40	-1.658918	0.00915681	4.693257373
1200	0.3333333	0.37	-1.3286763	0.00858451	4.757795894
1300	0.3611111	0.35	-1.2390641	0.008012209	4.826788766
1400	0.3888889	0.29	-1.5363156	0.006676841	5.009110322
1500	0.4166667	0.29	-1.2680517	0.006676841	5.009110322
1600	0.4444444	0.29	-1.4985753	0.006676841	5.009110322
1700	0.4722222	0.35	-1.5363156	0.008012209	4.826788766
1800	0.5	0.31	-1.658918	0.007249142	4.926872224
1900	0.5277778	0.28	-1.7986799	0.006486074	5.038097859

Table B.4-9

100 ppm Pyrene Contaminated Moist Soil: (Dessicator #2)

(Experiment #4)

	Slope	y-intercept
	0.0043784	-0.015939866
S.E.E.	1.766E-05	0.003594741
r^(2)	0.999447	0.011009701
	61443.993	34
	Co=	39.46

time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	39.46	0.6393098	1	0
10	0.0027778	37.80	0.5946595	0.958053691	0.042851457
20	0.0055556	36.28	0.8077066	0.919463087	0.08396538
30	0.0083333	34.78	0.6037505	0.881291946	0.126366327
40	0.0111111	33.24	0.2931841	0.842491611	0.171391574
50	0.0138889	31.91	0.1034276	0.808724832	0.212296553
60	0.0166667	30.62	0.468278	0.776006711	0.25359411
70	0.0194444	29.42	-0.0939318	0.745595638	0.293571867
80	0.0222222	28.23	0.1400617	0.715394295	0.334921426
90	0.025	27.19	0.0959369	0.688968121	0.372560278
100	0.0277778	25.95	0.1400617	0.657718121	0.418978827
110	0.0305556	24.89	0.1034276	0.630662752	0.460984026
120	0.0333333	23.93	-0.2618127	0.606333893	0.500324467
130	0.0361111	22.85	-0.2726236	0.579068792	0.546333997
140	0.0388889	22.01	-0.1500213	0.557676174	0.583976818
150	0.0416667	21.10	-0.5897196	0.534605705	0.626225804
160	0.0444444	20.18	-0.2094447	0.511325503	0.670748899
170	0.0472222	19.33	-0.4903471	0.489932886	0.713486865
180	0.05	18.53	-0.2946025	0.469588926	0.755897592
190	0.0527778	17.71	-0.3057758	0.448825503	0.801121101
200	0.0555556	16.92	-0.4636788	0.428901007	0.84652914
210	0.0583333	16.19	-0.5897196	0.410234899	0.891025358
220	0.0611111	15.42	-0.5897196	0.390729866	0.939738838
230	0.0638889	14.74	-0.9025919	0.373531879	0.984751925
240	0.0666667	14.05	-0.8054281	0.356124161	1.032475842
250	0.0694444	13.45	-0.9657708	0.340813758	1.076419114
260	0.0722222	12.90	-0.787079	0.326971477	1.11788234
270	0.075	12.30	-0.9232112	0.311661074	1.165838983
280	0.0777778	11.76	-1.156826	0.298028523	1.210566081
290	0.0805556	11.23	-0.8823892	0.284605705	1.256650549
300	0.0833333	10.68	-0.9657708	0.270553691	1.307284711
310	0.0861111	10.25	-1.7986799	0.259647651	1.348429756
320	0.0888889	9.80	-1.2979046	0.248322148	1.393028393
330	0.0916667	9.33	-1.2390641	0.23636745	1.442367695
340	0.0944444	8.89	-1.6163584	0.225251678	1.490536934
350	0.0972222	8.48	-1.4622077	0.214974832	1.537234317
500	0.1388889	3.72	-2.4918271	0.094169463	2.362659321
700	0.1944444	1.98	-4.7944122	0.050125839	2.993218657
900	0.25	0.98	-3.4081178	0.024748322	3.698997584
1100	0.3055556	0.61	-4.101265	0.015520134	4.165617116
1300	0.3611111	0.43	-3.0026527	0.01090604	4.51843849
1500	0.4166667	0.37	-----	0.009437919	4.663019719
1700	0.4722222	0.28	-----	0.007130872	4.943321684
1900	0.5277778	0.23	-----	0.005872483	5.137477699
2100	0.5833333	0.26	-----	0.006501678	5.035695004
2300	0.6388889	0.19	-----	0.004823826	5.334187993

Table B.4-10

100 ppm Pyrene Contaminated Moist Soil: (Dessicator #2)

(Experiment #5)

	Slope	y-intercept
	0.004665956	-0.0253649
S.E.E.	2.11664E-05	0.004307598
r^(2)	0.99930082	0.013192985
	48594.3967	34
	Co=	38.09

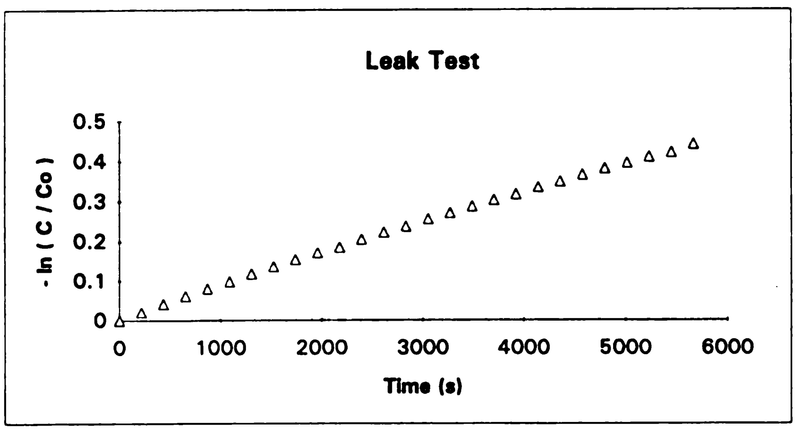
time (s)	time (hrs)	C (mg/L)	ln C	C / Co	- ln C / Co
0	0	38.09	3.640051358	1	0
10	0.0027778	36.56	3.599030198	0.95980882	0.04102116
20	0.0055556	35.06	3.557198565	0.920486639	0.082852793
30	0.0083333	33.58	3.514033335	0.881598957	0.126018023
40	0.0111111	32.14	3.469951144	0.843580274	0.170100214
50	0.0138889	30.73	3.425183269	0.806647838	0.21486809
60	0.0166667	29.38	3.380290697	0.77123615	0.259760661
70	0.0194444	28.09	3.33535226	0.73734521	0.304699098
80	0.0222222	26.95	3.29414962	0.707582012	0.345901739
90	0.025	25.73	3.247644224	0.675429068	0.392407134
100	0.0277778	24.64	3.204259175	0.646752118	0.435792183
110	0.0305556	23.59	3.160662088	0.619161416	0.479389271
120	0.0333333	22.57	3.116545197	0.592439713	0.523506161
130	0.0361111	21.55	3.070391818	0.56571801	0.56965954
140	0.0388889	20.56	3.023213257	0.539648056	0.616838101
150	0.0416667	19.68	2.979602892	0.516619596	0.660448467
160	0.0444444	18.69	2.927822559	0.490549642	0.712228799
170	0.0472222	17.93	2.886686816	0.470779926	0.753364542
180	0.05	17.11	2.83992505	0.449272214	0.800126308
190	0.0527778	16.29	2.790360892	0.427547252	0.849690466
200	0.0555556	15.60	2.747270914	0.409515533	0.892780444
210	0.0583333	14.85	2.697790857	0.389745818	0.942260501
220	0.0611111	14.15	2.649836464	0.37149685	0.990214894
230	0.0638889	13.55	2.606208392	0.355637628	1.033842966
240	0.0666667	12.89	2.556746041	0.338474908	1.083305317
250	0.0694444	12.31	2.51077603	0.323267434	1.129275328
260	0.0722222	11.71	2.460472624	0.307408212	1.179578734
270	0.075	11.08	2.40526616	0.290897241	1.234785198
280	0.0777778	10.63	2.363323299	0.278948512	1.27672806
290	0.0805556	10.09	2.311373944	0.264827287	1.328677414
300	0.0833333	9.48	2.249620712	0.248968064	1.390430647
310	0.0861111	9.08	2.205922275	0.238322833	1.434129084
320	0.0888889	8.69	2.162133258	0.228112101	1.477918101
330	0.0916667	8.18	2.102282146	0.214859874	1.537769212
340	0.0944444	7.82	2.056772742	0.205300891	1.583278616
350	0.0972222	7.47	2.011310368	0.196176407	1.62874099
500	0.1388889	3.08	1.124481669	0.080816859	2.51556969
600	0.1666667	1.56	0.447334829	0.041060178	3.192716529
700	0.1944444	0.83	-0.189242	0.021724962	3.829293358
800	0.2222222	0.55	-0.589719566	0.014555725	4.229770924
900	0.25	0.40	-0.923211175	0.010427982	4.563262533
1000	0.2777778	0.26	-1.328676283	0.006951988	4.968727641
1100	0.3055556	0.27	-1.297904624	0.007169237	4.937955982
1200	0.3333333	0.27	-1.297904624	0.007169237	4.937955982
1300	0.3611111	0.23	-1.462207675	0.006082989	5.102259034
1400	0.3888889	0.26	-1.328676283	0.006951988	4.968727641
1460	0.4055556	0.22	-1.49857532	0.00586574	5.138626678

Table B.5

Leak Test Data: (Following Moist Soil Experiments 4 & 5 from Dessicator #1)

Time (s)	Absorbance	Concentration (mg/L)	Mass of Ozone (mg)	del[M]/dt	- ln C / Co
0	.8582	71.02	21.69		0
218	0.8402	69.53	21.23	0.002086364	0.02119721
436	0.8229	68.10	20.79	0.002005228	0.04200249
654	0.807	66.79	20.39	0.001842955	0.0615135
872	0.7922	65.56	20.02	0.001715455	0.08002329
1090	0.7778	64.37	19.65	0.001669091	0.09836775
1308	0.7628	63.13	19.27	0.001738637	0.1178413
1526	0.7491	61.99	18.93	0.001587955	0.13596469
1744	0.7356	60.88	18.59	0.001564773	0.15415068
1962	0.7229	59.83	18.27	0.001472046	0.17156627
2180	0.7131	59.02	18.02	0.001135909	0.18521551
2398	0.6993	57.87	17.67	0.001599546	0.20475734
2616	0.6866	56.82	17.35	0.001472046	0.22308529
2834	0.6766	55.99	17.10	0.001159091	0.23775692
3052	0.6643	54.98	16.79	0.001425682	0.25610332
3270	0.6543	54.15	16.53	0.001159091	0.27127121
3488	0.644	53.30	16.27	0.001193864	0.28713845
3706	0.6339	52.46	16.02	0.001170682	0.30294596
3924	0.6249	51.72	15.79	0.001043182	0.31724554
4142	0.614	50.81	15.51	0.001263409	0.33484224
4360	0.6055	50.11	15.30	0.000985227	0.34878261
4578	0.5953	49.27	15.04	0.001182273	0.36577169
4796	0.5861	48.50	14.81	0.001066364	0.38134675
5014	0.5778	47.82	14.60	0.000962046	0.39560938
5232	0.5688	47.07	14.37	0.001043182	0.41130829
5450	0.5625	46.55	14.21	0.000730227	0.42244604
5668	0.5515	45.64	13.94	0.001275	0.44219533
5886	0.545	45.10	13.77	0.000753409	0.45405138
6104	0.5354	44.31	13.53	0.001112727	0.47182304
6322	0.528	43.70	13.34	0.000857727	0.48574089

	Slope	y-intercept
	7.57692E-05	0.016562519
S.E.E.	6.5288E-07	0.002403474
r^(2)	0.997925381	0.006747454
	13468.45218	28

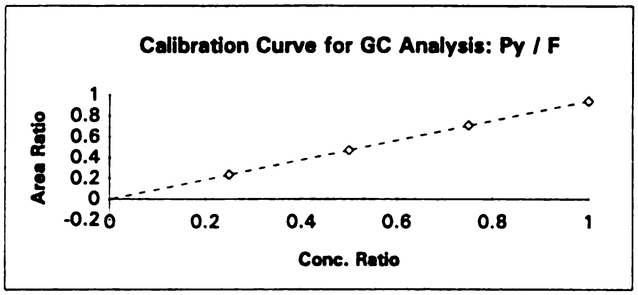


APPENDIX C: Extraction Data

Table C.1

Glass Bead Extraction Data:

Standard #	Ratio Area	Ratio Conc.		Slope	y-inter
1	0.94302	1		0.94857	-0.0026666
2	0.71311	0.75	S.E.E.	0.00684	0.0046843
3	0.4716	0.5	r^(2)	0.9999	0.0038247
4	0.23304	0.25		19222	2



Experiment #1: 6/28/93:

	TREATED				UNTREATED			
	Sample 1	Sample 2	Sample 3		Sample 4	Sample 5	Sample 6	
	70.01	75.74	73.93		72.95	84.80	99.06	
	68.90	72.98	73.99		74.98	86.66	102.72	
	67.87	74.18	73.96		76.36	90.26	106.41	
AVG:	68.93	74.30	73.96	72.40	74.76	87.24	102.73	88.24
ST DEV	1.07	1.39	0.03	3.01	1.71	2.77	3.68	14.01
RSTD:	1.55	1.87	0.04	4.16	2.29	3.18	3.58	15.88
		Removal Efficiency:			17.96	%		

Experiment #2: 7/7/93:

	TREATED				UNTREATED		
	Sample 1	Sample 2	Sample 3		Sample 4	Sample 5	
	71.00	76.86	88.27		98.37	114.05	
	71.98	74.81	87.75		100.21	113.52	
	-----	78.65	94.00		98.02	109.43	
AVG:	71.49	76.77	90.01	79.42	98.87	112.33	105.60
ST DEV	0.70	1.92	3.47	9.54	1.17	2.53	9.52
RSD:	0.97	2.50	3.85	12.01	1.19	2.25	9.02
		Removal Efficiency:			24.79	%	

Experiment #3: 7/8/93:

	TREATED				UNTREATED		
	Sample 1	Sample 2	Sample 3		Sample 4	Sample 5	
	84.83	96.98	81.26		93.22	74.07	
	84.82	93.77	83.12		90.19	70.50	
	83.00	94.15	82.13		91.31	71.48	
AVG:	84.21	94.97	89.59	89.59	91.57	72.02	81.80
STD:	1.06	1.75	7.60	5.38	1.53	1.85	20.16
RSD:	1.25	1.84	8.49	6.00	1.67	2.57	21.92
		Removal Efficiency:			-9.53	%	

Experiment #4: 7/12/93:

	TREATED				UNTREATED			
	Sample 1	Sample 2	Sample 3		Sample 4	Sample 5	Sample 6	
	79.19	65.71	67.98		90.51	63.05	97.32	
	80.10	66.66	68.61		90.90	64.94	97.44	
	80.08	67.14	68.40		90.08	60.44	98.27	
AVG:	79.79	66.50	73.15	73.15	90.50	62.81	97.68	83.66
STD:	0.52	0.72	9.39	6.64	0.41	2.26	0.52	18.41
RSD:	0.65	1.09	12.84	9.08	0.45	3.59	0.53	22.01
		Removal Efficiency:			12.57	%		

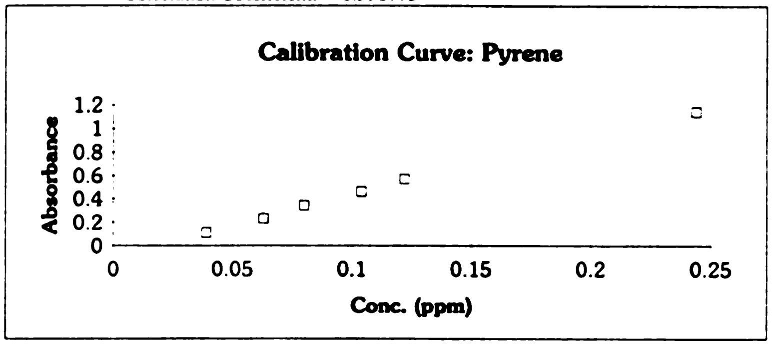
Table C.2-1a

Ottawa Sand Extraction Data: (Experiment #1)

Spectrophotometer Analysis: Shimadzu UV/VIS

Conc. (ppm)	Absorbance		slope	y-inter.
0.11	0.039		0.199	0.01422
0.23	0.063	S.E.	0.005	0.00286
0.34	0.08	r^(2)	0.998	0.00401
0.46	0.104		1627	4
0.57	0.122			
1.14	0.244			

Correlation Coefficient: 0.998773



Final Concentration of Pyrene:

Sample #	Absorbance			Average					
08031a	0.066	0.066	0.066	0.066					
08031b	0.071	0.07	0.07	0.070333					
08031c	0.072	0.072	0.072	0.072					
			AVG:	0.069444	[PY] =	65.0845	ppm		
			SD:	0.003097					
			RSD:	4.459955					
08032a	0.067	0.066	0.067	0.066667					
08032b	0.064	0.064	0.065	0.064333					
08032c	0.063	0.063	0.063	0.063					
			AVG:	0.064667	[PY] =	59.4539	ppm	**AVG:**	61.8109
			SD:	0.001856				**SD:**	2.9251
			RSD:	2.869982				**RSD:**	4.73234
08033a	0.066	0.066	0.066	0.066					
08033b	0.066	0.066	0.066	0.066					
08033c	0.065	0.066	0.066	0.065667					
			AVG:	0.065889	[PY] =	60.8943	ppm		
			SD:	0.000192					
			RSD:	0.292083					

Original Concentration of Pyrene:

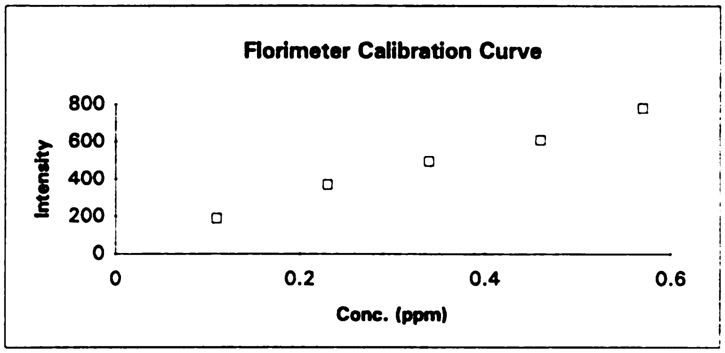
08034a	0.125	0.125	0.125	0.125					
08034b	0.119	0.119	0.119	0.119					
08034c	0.117	0.117	0.117	0.117					
			AVG:	0.120333	[PY] =	187.32	ppm		
			SD:	0.004163					
			RSD:	3.459833					
08035a	0.125	0.125	0.125	0.125					
08035b	0.11	0.11	0.11	0.11					
08035c	0.116	0.116	0.116	0.116					
			AVG:	0.117	[PY] =	181.435	ppm	**AVG:**	190.915
			SD:	0.00755				**SD:**	11.7
			RSD:	6.45285				**RSD:**	6.12839
08036a	0.128	0.128	0.128	0.128					
08036b	0.131	0.132	0.131	0.131333				**Removal**	
08036c	0.13	0.13	0.13	0.13				**Efficiency:**	67.62395
			AVG:	0.129778	[PY] =	203.991	ppm		
			SD:	0.001678					
			RSD:	1.29278					

Table C.2-1b

Ottawa Sand Extraction Data: (Experiment #1)

Florimeter Analysis: Hewlett Packard

Conc. (ppm)	Intensity		slope	y-intercept
0.11	189.2036		1233.7	66.190777
0.23	369.1099	S.E.	58.235	22.054121
0.34	494.7644		0.9934	21.180294
0.46	608.377		448.77	3
0.57	779.0576			
	Correlation Coefficient:		0.9967	



Final Concentration of Pyrene:

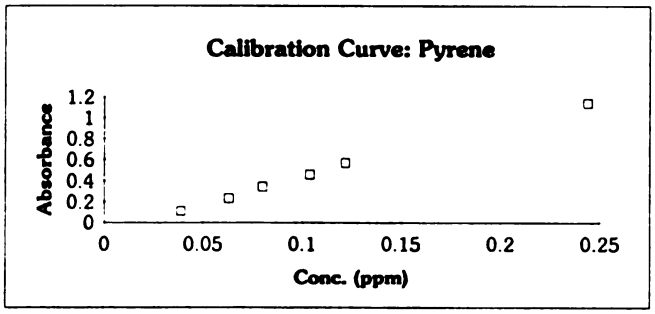
Sample #	Florescence					
08091a	463.3508					
08091b	460.733					
08091c	473.822					
AVG:	465.9686	[PY] =	75.938	ppm		
SD:	6.926047782					
RSD:	1.486376503					
08092a	447.644					
08092b	486.911					
08092c	492.1466					
AVG:	475.5672	[PY] =	77.761	ppm	AVG:	73.83817138
SD:	24.32348044				SD:	5.294498502
RSD:	5.114625322				RSD:	7.17040848
08093a	416.2304					
08093b	424.0838					
08093c	429.3194					
AVG:	423.2112	[PY] =	67.816	ppm		
SD:	6.587985528					
RSD:	1.556666158					
Original Concentration of Pyrene:						
08094a	737.1728					
08094b	735.5497					
08094c	712.0419					
AVG:	728.2548	[PY] =	188.37	ppm		
SD:	14.0642173					
RSD:	1.931222053					
08095a	678.534					
08095b	686.911					
08095c	712.0419					
AVG:	692.4956333	[PY] =	178.2	ppm	AVG:	182.9112824
SD:	17.43806003				SD:	5.127636256
RSD:	2.518147291				RSD:	2.803346075
08096a	703.6649					
08096b	695.288				Removal	
08096c	720.4188				Efficiency:	59.6317021
AVG:	706.4572333	[PY] =	182.17	ppm		
SD:	12.79598067					
RSD:	1.811288789					

Table C.2-2

Ottawa Sand Extraction Data: (Experiment #2)

Spectrophotometer Analysis: Shimadzu UV/VIS

Conc. (ppm)	Absorbance		slope	y-inter
0.11	0.039		0.1988385	0.014
0.23	0.063	S.E.	0.0049295	0.003
0.34	0.08	r^(2)	0.9975475	0.004
0.46	0.104		1627.0206	4
0.57	0.122			
1.14	0.244			
	Correlation Coefficie		0.998773	



Final Concentration of Pyrene:

Sample #	Absorbance			Average					
08041a	0.067	0.067	0.067	6.70E-02					
08041b	0.066	0.066	0.066	6.60E-02					
08041c	0.069	0.068	0.069	6.87E-02					
			AVG:	6.72E-02	[PY] =	62.47	ppm		
			SD:	1.35E-03					
			RSD:	2.00					
08042a	0.065	0.065	0.065	6.50E-02					
08042b	0.069	0.069	0.069	6.90E-02					
08042c	0.071	0.071	0.071	7.10E-02					
			AVG:	6.83E-02	[PY] =	63.78	ppm	**AVG:**	**63.60**
			SD:	3.06E-03				**SD:**	**1.06**
			RSD:	4.47				**RSD:**	**1.66**
08043a	0.067	0.067	0.067	6.70E-02					
08043b	0.07	0.07	0.07	7.00E-02					
08043c	0.07	0.07	0.07	7.00E-02					
			AVG:	6.90E-02	[PY] =	64.56	ppm		
			SD:	1.73E-03					
			RSD:	2.51					

Original Concentration of Pyrene:

08044a	0.164	0.163	0.163	0.16					
08044b	0.163	0.163	0.163	0.16					
08044c	0.166	0.166	0.166	0.17					
			AVG:	0.16	[PY] =	176.65	ppm		
			SD:	1.64E-03					
			RSD:	1.00					
08045a	0.164	0.164	0.164	0.16					
08045b	0.167	0.168	0.167	0.17					
08045c	0.164	0.164	0.164	0.16					
			AVG:	0.17	[PY] =	177.83	ppm	**AVG:**	**178.18**
			SD:	1.92E-03				**SD:**	**1.73**
			RSD:	1.17				**RSD:**	**0.97**
08046a	0.165	0.165	0.165	0.17					
08046b	0.167	0.167	0.167	0.17					
08046c	0.169	0.169	0.169	0.17				**Removal**	
			AVG:	0.17	[PY] =	180.05	ppm	**Efficiency:**	64.31
			SD:	2.00E-03					
			RSD:	1.20					

Table C.2-3

Ottawa Sand Extraction Data: (Experiment #3)

Final Concentration of Pyrene:

Sample #	Absorbance			Average					
08111a	0.062	0.062	0.062	0.062					
08111b	0.063	0.063	0.063	0.063					
08111c	0.065	0.065	0.065	0.065					
			AVG:	6.33E-02	[PY] =	57.8825	ppm		
			STD:	1.53E-03					
			RSD:	2.41					
08112a	0.062	0.062	0.062	0.062					
08112b	0.062	0.062	0.062	0.062					
08112c	0.063	0.063	0.063	0.063					
			AVG:	6.23E-02	[PY] =	56.704	ppm	AVG:	57.23
			STD:	5.77E-04				STD:	0.60
			RSD:	0.93				RSD:	1.05
08113a	0.062	0.062	0.062	0.062					
08113b	0.062	0.062	0.062	0.062					
08113c	0.064	0.064	0.064	0.064					
			AVG:	6.27E-02	[PY] =	57.0968	ppm		
			STD:	1.15E-03					
			RSD:	1.84					

Oringinal Concentration of Pyrene

08114a	0.176	0.176	0.176	0.176					
08114b	0.176	0.176	0.176	0.176					
08114c	0.177	0.177	0.177	0.177					
			AVG:	0.18	[PY] =	191.054	ppm		
			STD:	5.77E-04					
			RSD:	0.33					
08115a	0.18	0.18	0.18	0.18					
08115b	0.177	0.177	0.177	0.177					
08115c	0.179	0.178	0.179	0.18					
			AVG:	0.18	[PY] =	193.673	ppm	AVG:	190.66
			STD:	1.50E-03				STD:	3.23
			RSD:	0.84				RSD:	1.69
08116a	0.172	0.172	0.172	0.172					
08116b	0.174	0.174	0.175	0.17					
08116c	0.173	0.173	0.173	0.173					
			AVG:	0.17	[PY] =	187.257	ppm		
			STD:	1.17E-03					
			RSD:	0.68					

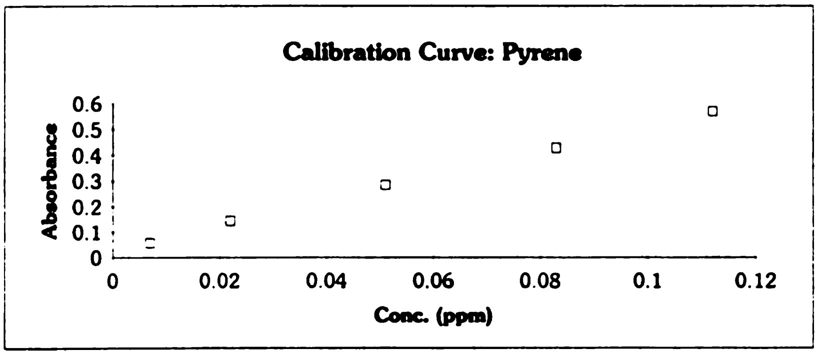
Removal Efficiency:	69.9846

Table C.2-4a

Ottawa Sand Extraction Data: (Experiment #4) 100 ppm Pyrene

Spectrophotometer Analysis: Shimadzu UV/VIS

Conc. (ppm)	Absorbance		slope	y-inter
0.57	0.112		0.20721	-0.0065
0.428	0.083	S.E.	0.00376	0.0013
0.285	0.051		0.99901	0.0016
0.143	0.022		3032.03	3
0.057	0.007			
	Correlation Coefficient:		0.99951	



Original Concentration of Pyrene:

Sample #	Absorbance			Average					
09281a	0.041	0.041	0.041	4.10E-02					
09281b	0.039	0.04	0.04	3.97E-02					
09281c	0.041	0.04	0.041	4.07E-02					
			AVG:	4.04E-02	[PY] =	79.45	ppm		
			SD:	6.94E-04					
			RSD:	1.72					
09282a	0.041	0.041	0.041	4.10E-02					
09282b	0.041	0.041	0.041	4.10E-02					
09282c	0.043	0.043	0.043	4.30E-02					
			AVG:	4.17E-02	[PY] =	81.52	ppm	**AVG:**	79.64
			SD:	1.15E-03				**SD:**	1.80
			RSD:	2.77				**RSD:**	2.25
09283a	0.041	0.041	0.041	4.10E-02					
09283b	0.039	0.04	0.04	3.97E-02					
09283c	0.038	0.038	0.038	3.80E-02					
			AVG:	3.96E-02	[PY] =	77.95	ppm		
			SD:	1.50E-03					
			RSD:	3.80					

Final Concentration of Pyrene:

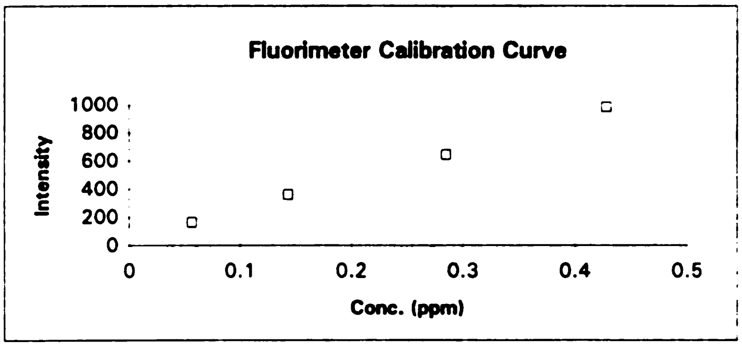
09284a	0.014	0.014	0.014	1.40E-02					
09284b	0.014	0.014	0.014	1.40E-02					
09284c	0.014	0.014	0.014	1.40E-02					
			AVG:	1.40E-02	[PY] =	7.78	ppm		
			SD:	0.00					
			RSD:	0.00					
09285a	0.014	0.014	0.014	1.40E-02					
09285b	0.015	0.015	0.015	1.50E-02					
09285c	0.016	0.016	0.016	1.60E-02					
			AVG:	1.50E-02	[PY] =	8.16	ppm	**AVG:**	8.07
			SD:	1.00E-03				**SD:**	0.26
			RSD:	6.67				**RSD:**	3.27
09286a	0.015	0.015	0.015	1.50E-02					
09286b	0.015	0.015	0.015	1.50E-02					
09286c	0.016	0.016	0.016	1.60E-02				**Removal**	
			AVG:	1.53E-02	[PY] =	8.29	ppm	**Efficiency:**	89.86
			SD:	5.77E-04					
			RSD:	3.77					

Table C.2-4b

Ottawa Sand Extraction Data: (Experiment #4) 100 ppm Pyrene

Florimeter Analysis: Hewlett Packard

Conc. (pp	ntensity		slope	y-inter
0.428	985.8		2186.6301	41.13
0.285	646.2	S.E.	56.439987	15.15
0.143	363.9		0.9986693	15.94
0.057	165		1500.9867	2
Correlation Coefficie			0.9993344	



Original Concentration of Pyrene:

Sample #	Florescence							
09281a	479.1	480	481.9	480.33				
09281b	467	472.2	471.9	470.37				
09281c	467.3	461.8	463.2	464.10				
			AVG:	471.60	[PY] =	69.10 ppm		
			SD:	8.19				
			RSD:	1.74				
09282a	480.5	480.8	485.4	482.23				
09282b	505.9	516.1	515.2	512.40				
09282c	494	492.2	501.2	495.80				
			AVG:	496.81	[PY] =	73.15 ppm	AVG:	69.69
			SD:	15.11			SD:	3.21
			RSD:	3.04			RSD:	4.60
09283a	453.8	455.4	453.2	454.13				
09283b	455.7	457	460.7	457.80				
09283c	458.3	458.2	463.8	460.10				
			AVG:	457.34	[PY] =	66.81 ppm		
			SD:	3.01				
			RSD:	0.66				

Final Concentration of Pyrene:

09284a	173.8	172.3	172	172.70				
09284b	183.4	183.7	180.3	182.47				
09284c	176.9	174.3	177.8	176.33				
			AVG:	177.17	[PY] =	4.90 ppm		
			SD:	4.94				
			RSD:	2.79				
09285a	182.4	181.4	183.2	182.33				
09285b	187.7	184.9	182.6	185.07				
09285c	185.5	182.7	184.1	184.10				
			AVG:	183.83	[PY] =	5.14 ppm	AVG:	4.97
			SD:	1.39			SD:	0.15
			RSD:	0.75			RSD:	2.95
09286a	179.6	183.5	181.7	181.60				
09286b	165.8	166.8	168.5	167.03				
09286c	181.7	180.9	179.4	180.67				
			AVG:	176.43	[PY] =	4.87 ppm		
			SD:	8.15				
			RSD:	4.62				

Removal Efficiency:	92.86

Table C.3-1

Pyrene Contaminated Dry Metea Soil

Original Concentration of Contaminant in Soil: (Experiment # 1)

	CONC. (mg/L)	AREA				
SAMPLE	Pyrene	Fluorene	Pyrene			
Std. 1	104.7	56907	58053			
0102a	130.3	63312	80351	**Average =**	132.1	
0102b	131.5	85444	109401	**Standard Deviation =**	2.16	
0102c	134.3	64040	83785	**Rel. St. Deviation =**	1.64	%
0101a	115.1	61476	68916	**Average =**	114.7	
0101b	114.1	78314	87001	**Standard Deviation =**	0.53	
0101c	114.9	68116	76230	**Rel. St. Deviation =**	0.46	%
0103a	108.3	58050	61239	**Average =**	109.4	
0103b	107.7	58821	61713	**Standard Deviation =**	2.39	
0303c	112.1	70611	77061	**Rel. St. Deviation =**	2.18	%
Std. 2	103.6	56560	57047			
0101a	11308	59105	65493	**Average =**	114.4	
0101b	111.6	57542	62552	**Standard Deviation =**	3.20	
0101c	117.9	57323	65819	**Rel. St. Deviation =**	2.80	%
0102a	135.5	59127	78040	**Average =**	136.4	
0102b	139.8	58692	79928	**Standard Deviation =**	3.01	
0102c	134	56047	73159	**Rel. St. Deviation =**	2.21	%
0103a	113.5	59509	65796	**Average =**	113.8	
0103b	114.1	64112	71212	**Standard Deviation =**	0.30	
0103c	113.7	55028	60956	**Rel. St. Deviation =**	0.25	%
Std. 3	110.5	50290	54131			
0103a	113.7	55605	61546	**Average =**	114.3	
0103b	114.9	60452	67759	**Standard Deviation =**	0.60	
0103c	113.7	55028	60956	**Rel. St. Deviation =**	0.52	%
0101a	115.7	116.4	119.8	**Average =**	117.3	
0101b	116.4	57631	65311	**Standard Deviation =**	2.19	
0101c	119.8	63941	74589	**Rel. St. Deviation =**	1.79	%
0102a	138.5	63524	85707	**Average =**	137.7	
0102b	140.1	62399	85142	**Standard Deviation =**	2.77	
0102c	134.7	57212	75044	**Rel. St. Deviation =**	2.01	%

Final Concentration of Contaminant in Soil: (Experiment #1)

	CONC. (mg/L)	AREA	
SAMPLE	Pyrene	Fluorene	Pyrene
Std.4	109.9	56693	60697

0105a	42.8	67630	28190	**Average =**	42.7	
0105b	42.3	61798	25460	**Standard Deviation =**	0.45	
0105c	43.2	52889	22242	**Rel. St. Deviation =**	1.05	%
0106a	63.3	63187	38939	**Average =**	62.4	
0106b	62.1	57127	30902	**Standard Deviation =**	0.76	
0106c	61.6	52560	31688	**Rel. St. Deviation =**	1.22	%
0104a	30.6	60819	18114	**Average =**	62.4	
0104b	30.6	57191	17049	**Standard Deviation =**	0.76	
0104c	30.2	69698	20484	**Rel. St. Deviation =**	1.22	%
Std. 5	107.8	55427	58190			
0104a	29.2	57759	16423	**Average =**	62.4	
0104b	29.3	57356	16389	**Standard Deviation =**	0.76	
0104c	30.5	66072	19652	**Rel. St. Deviation =**	1.22	%
0105a	41.9	54511	22258	**Average =**	62.4	
0105b	42.8	63408	26414	**Standard Deviation =**	0.76	
0105c	42.2	56461	23221	**Rel. St. Deviation =**	1.22	%
0106a	60.8	56654	33540	**Average =**	62.4	
0106b	62.7	52244	31889	**Standard Deviation =**	0.76	
0106c	63.1	65360	40158	**Rel. St. Deviation =**	1.22	%
Std. 6	111.1	77565	83936			
0106a	62.9	54951	33682	**Average =**	62	
0106b	61.2	72060	42928	**Standard Deviation =**	0.85	
0106c	62	59907	36170	**Rel. St. Deviation =**	1.37	%
0105a	42.8	53870	22477	**Average =**	43.1	
0105b	43.5	59551	25231	**Standard Deviation =**	0.35	
0105c	43.1	53749	22589	**Rel. St. Deviation =**	0.81	%
0104a	30.2	54469	16031	**Average =**	29.9	
0104b	29.5	55427	15920	**Standard Deviation =**	0.49	
0104c	-----	-----	-----	**Rel. St. Deviation =**	1.64	%

Extract	**Avg. Conc.**	**S.D.**	**R.S.D.**			
1	115.5	1.59	1.38	**Average =**	121.1	
2	135.4	2.93	2.16	**Standard Deviation =**	12.4	
3	112.5	2.7	2.4	**Rel. St. Deviation =**	10.2	%
4	30	0.42	1.4	**Average =**	44.5	
5	42.7	0.4	0.94	**Standard Deviation =**	16.2	
6	62.2	0.2	0.32	**Rel. St. Deviation =**	36.4	%
Extraction Efficiency =		96.90%		Treatment Efficiency =	63.2	%

Table C.3-2

Final Concentration of Contaminant in Soil: (Experiment # 2)

	CONC. (mg/L)	AREA				
SAMPLE	Pyrene	Pyrene	Fluorene			
Std. 1	108.1	72533	68914			
0202a	109.2	69484	65348	**Average =**	108.9	
0202b	111	102555	94841	**Standard Deviation =**	2.26	
0202c	106.5	72807	70184	**Rel. St. Deviation =**	2.08	%
Std. 2	110.6	76828	71318			
0201a	61.9	43142	71592	**Average =**	61	
0201b	59	44241	76968	**Standard Deviation =**	1.7	
0201c	62	45080	74661	**Rel. St. Deviation =**	2.79	%
Std. 3	108.3	75640	71685			
0203a	26.3	15887	62003	**Average =**	109.4	
0203b	26.7	15936	61183	**Standard Deviation =**	2.39	
0203c	26.8	16636	63744	**Rel. St. Deviation =**	2.18	%
				Average =	43.8	
				Standard Deviation =	24.3	
				Rel. St. Deviation =	55	%

Original Concentration of Contaminant in Soil: (Experiment #2)

Std. 4	107.2	80754	77344			
0206a	86.6	50326	59674	**Average =**	87.6	
0206b	89.1	53523	61669	**Standard Deviation =**	1.3	
0206c	87.2	57508	60630	**Rel. St. Deviation =**	1.48	%
Std. 5	105.4	61818	60237			
0205a	113.8	77851	70222	**Average =**	114.7	
0205b	113.9	66441	59881	**Standard Deviation =**	1.42	
0205c	116.3	83032	73308	**Rel. St. Deviation =**	1.24	%
Std. 6	109.4	65163	61190			
0204a	120.5	68046	57976	**Average =**	119.5	
0204b	119.8	68738	58919	**Standard Deviation =**	1.12	
0204c	118.3	84261	73119	**Rel. St. Deviation =**	0.94	%
				Average =	107.3	
				Standard Deviation =	17.2	
				Rel. St. Deviation =	16	%

Extraction Efficiency = 85.8 %   Treatment Efficiency = 59.2 %

Table C.3-3

Final Concentration of Contaminant in Soil: (Experiment # 3)

	CONC. (mg/L)	AREA				
SAMPLE	Pyrene	Pyrene	Fluorene			
Std. 1	112.7	68203	62162			
0303a	28.2	15046	54736	**Average =**	29.1	
0303b	29.1	15503	54740	**Standard Deviation =**	0.85	
0303c	29.9	15667	53783	**Rel. St. Deviation =**	2.92	%
Std. 2	110.2	64372	60006			
0302a	36	19204	54826	**Average =**	35	
0302b	33.9	18222	55737	**Standard Deviation =**	1.05	
0302c	35.1	20293	59388	**Rel. St. Deviation =**	3	%
Std. 3	111.7	64619	59390			
0301a	45.2	24736	56222	**Average =**	46	
0301b	46.8	26161	57369	**Standard Deviation =**	0.8	
0301c	46.1	24981	55586	**Rel. St. Deviation =**	1.74	%
				Average =	36.7	
				Standard Deviation =	8.58	
				Rel. St. Deviation =	23.4	%

Original Concentration of Contaminant in Soil: (Experiment #3)

Std. 4	110.6	67297	62505			
0306a	127.4	96836	78031	**Average =**	127.3	
0306b	126.5	85586	69485	**Standard Deviation =**	0.8	
0306c	128.1	69892	56038	**Rel. St. Deviation =**	0.63	%
Std. 5	114.8	97790	87484			
0305a	119.5	64840	55725	**Average =**	120.6	
0305b	120.3	65299	55737	**Standard Deviation =**	1.33	
0305c	122.1	73621	61893	**Rel. St. Deviation =**	1.1	%
Std. 6	111	62259	57620			
0304a	91.5	50215	56379	**Average =**	92.3	
0304b	92.6	51386	57007	**Standard Deviation =**	0.7	
0304c	92.8	51939	57439	**Rel. St. Deviation =**	0.76	%
				Average =	11.34	
				Standard Deviation =	18.6	
				Rel. St. Deviation =	16.4	%

Extraction Efficiency = 90.7 %

Treatment Efficiency = 67.6 %

Table C.3-4

Final Concentration of Contaminant in Soil: (Experiment # 4)

	CONC. (mg/L)	AREA				
SAMPLE	Pyrene	Pyrene	Fluorene			
Std. 1	116.2	71987	63613			
0402a	27	14494	55020	**Average =**	27.4	
0402b	26.5	13715	53133	**Standard Deviation =**	1.15	
0402c	28.7	15292	54697	**Rel. St. Deviation =**	4.2	%
Std. 2	108.6	78554	74272			
0401a	40	22653	58148	**Average =**	40	
0401b	40.3	23014	58683	**Standard Deviation =**	0.35	
0401c	39.6	21868	56684	**Rel. St. Deviation =**	0.88	%
Std. 3	116.6	82345	72491			
0403a	74	37398	51873	**Average =**	74	
0403b	75	41888	57339	**Standard Deviation =**	0.95	
0403c	73.1	41229	57886	**Rel. St. Deviation =**	1.28	%
				Average =	47.1	
				Standard Deviation =	24.3	
				Rel. St. Deviation =	55	%

Original Concentration of Contaminant in Soil: (Experiment # 4)

Std. 4	113.7	71213	64305			
0406a	108.1	56521	53682	**Average =**	108.7	
0406b	108.8	57597	54376	**Standard Deviation =**	0.51	
0406c	109.1	56935	53594	**Rel. St. Deviation =**	0.47	%
Std. 5	114.9	70130	62672			
0405a	140.6	74154	54147	**Average =**	142.1	
0405b	141.8	74243	53756	**Standard Deviation =**	1.62	
0405c	143.8	74408	53127	**Rel. St. Deviation =**	1.14	%
Std. 6	115.6	83221	73922			
0404a	104.8	59085	57883	**Average =**	105.9	
0404b	105.8	56228	54560	**Standard Deviation =**	1.15	
0404c	107.1	55279	52999	**Rel. St. Deviation =**	1.09	%
				Average =	118.9	
				Standard Deviation =	17.2	
				Rel. St. Deviation =	16	%

Extraction Efficiency = 95.1 %

Treatment Efficiency = 60.4 %

Table C.3-5

Original Concentration of Contaminant in Soil: (Experiment # 5)

	CONC. (mg/L)	AREA				
SAMPLE	Pyrene	Pyrene	Fluorene			
Std. 1	111.7	71384	65627			
0503a	108.2	66015	62635	Average =	109.1	
0503b	110.2	59821	55726	Standard Deviation =	1.01	
0503c	108.9	57568	54304	Rel. St. Deviation =	0.92	%
Std. 2	114	75175	67700			
0502a	105.9	57276	55559	Average =	106.97	
0502b	108	63536	60429	Standard Deviation =	1.05	
0502c	107	58124	55762	Rel. St. Deviation =	0.98	%
Std. 3	115.8	90830	80573			
0501a	98.3	55632	58128	Average =	98.8	
0501b	99	54881	56924	Standard Deviation =	0.47	
0501c	99.2	54296	56217	Rel. St. Deviation =	0.48	%
				Average =	105	
				Standard Deviation =	5.42	
				Rel. St. Deviation =	5.2	%

Final Concentration of Contaminant in Soil: (Experiment # 5)

Std. 4	115.2	75750	67494			
0306a	43.5	23796	56177	Average =	43.8	
0306b	44.3	23482	54468	Standard Deviation =	0.46	
0306c	43.5	25881	61111	Rel. St. Deviation =	1.05	%
Std. 5	114.6	72647	65082			
0305a	22.2	11962	55347	Average =	20.9	
0305b	20.2	10464	53267	Standard Deviation =	1.15	
0305c	20.2	10464	53267	Rel. St. Deviation =	5.51	%
Std. 6	119.2	85730	73836			
0304a	42.1	23867	58269	Average =	42.7	
0304b	41.4	22332	55413	Standard Deviation =	1.74	
0304c	44.7	23826	54780	Rel. St. Deviation =	4.07	%
				Average =	35.8	
				Standard Deviation =	12.9	
				Rel. St. Deviation =	36.1	%

Extraction Efficiency = 84 %   Treatment Efficiency = 65.9 %

Table C.3-6

Original Concentration of Contaminant in Soil: (Experiment # 6)

	CONC. (mg/L)	AREA				
SAMPLE	Pyrene	Pyrene	Fluorene			
Std. 1	N.A.	N.A.	N.A.			
0602a	77.7	59138	44777	**Average =**	77.6	
0602b	78.2	60406	46011	**Standard Deviation =**	0.71	
0602c	76.8	57322	42890	**Rel. St. Deviation =**	0.92	%
Std. 2	114.9	68893	61548			
0601a	84.4	55992	46001	**Average =**	83.2	
0601b	83.2	59617	48307	**Standard Deviation =**	1.2	
0601c	82	56042	44728	**Rel. St. Deviation =**	1.44	%
Std. 3	112.2	79919	73146			
0603a	81.2	56581	44764	**Average =**	81.2	
0603b	81.6	56629	45020	**Standard Deviation =**	0.4	
0603c	80.8	56667	44585	**Rel. St. Deviation =**	0.49	%
				Average =	80.67	
				Standard Deviation =	2.84	
				Rel. St. Deviation =	3.52	%

Final Concentration of Contaminant in Soil: (Experiment # 6)

Std. 4	110.4	74469	69237			
0606a	14.8	54967	7929	**Average =**	13	
0606b	12.4	58105	7013	**Standard Deviation =**	1.55	
0606c	11.9	57744	6719	**Rel. St. Deviation =**	11.9	%
Std. 5	108.4	91084	86305			
0605a	18.1	54963	9671	**Average =**	20.2	
0605b	21.9	78186	16697	**Standard Deviation =**	1.93	
0605c	20.6	60139	12038	**Rel. St. Deviation =**	9.55	%
Std. 6	108.2	83878	79614			
0604a	11.6	58369	6589	**Average =**	11.3	
0604b	12.4	58105	7013	**Standard Deviation =**	0.3	
0604c	11.3	68516	7511	**Rel. St. Deviation =**	2.65	%
				Average =	14.83	
				Standard Deviation =	4.72	
				Rel. St. Deviation =	31.85	%

Extraction Efficiency = 96.8 % Treatment Efficiency = 81.6 %

Table C.4-1

Moist Soil Experimental Data: (Dessicator #1)

Final Concentration of Contaminant in Soil: (Experiment # 1)

	CONC. (mg/L)	AREA				
SAMPLE	Pyrene	Pyrene	Fluorene			*Adjusted
Std. 1	96.6	58616	62290			
0103a	94.4	57558	62625	Average =	94.3	93.2
0103b	94.1	55922	61044	Standard Deviation =	0.14	
0103c	95.1	56599	61109	Rel. St. Deviation =	0.15	%
0102a	82.4	50248	62610	Average =	83.1	82.1
0102b	83	50750	62784	Standard Deviation =	0.81	
0102c	84	52321	63930	Rel. St. Deviation =	0.97	%
Std. 2	99.7	60638	62472			
0101a	98.9	59513	61759	Average =	99.3	99.7
0101b	99.4	60046	62030	Standard Deviation =	0.36	
0101c	99.6	60456	62353	Rel. St. Deviation =	0.36	%
				Average =	97.9	91.7
				Standard Deviation =	4.24	8.90
				Rel. St. Deviation =	4.33	9.71 %

Original Concentration of Contaminant in Soil: (Experiment # 1)

						*Adjusted
0106a	102	61789	62230	Average =	102.4	101
0106b	102.6	62088	62138	Standard Deviation =	0.35	
0106c	102.6	61183	61235	Rel. St. Deviation =	0.34	%
Std. 3	97.9	59360	62249			
0105a	92.9	59746	66030	Average =	94	92.9
0105b	95.2	76210	82174	Standard Deviation =	1.15	
0105c	93.9	56633	61958	Rel. St. Deviation =	1.22	%
0104a	96.6	57982	61662	Average =	97.2	94.7
0104b	97.6	60973	64166	Standard Deviation =	0.53	
0104c	97.4	58011	61176	Rel. St. Deviation =	0.55	%
				Average =	97.9	96.2
				Standard Deviation =	4.24	4.3
				Rel. St. Deviation =	4.33	4.47 %

Extraction Efficiency = 76.96 % Treatment Efficiency = 4.68 %

* Calculations have been adjusted for slight variations in the mass of dry soil

Table C.4-2

Moist Soil Experimental Data

Final Concentration of Contaminant in Soil: (Experiment # 2)

	CONC. (mg/L)	AREA					
SAMPLE	Pyrene	Pyrene	Fluorene				*Adjusted
0202a	81	48050	57821				
0202b	81.8	46814	58785	**Average =**	81.3		79.7
0202c	81.2	46529	58862	**Standard Deviation =**	0.42		
Std. 1	99.1	59570	61712	**Rel. St. Deviation =**	0.52	%	
0201a	86.4	49205	58495	**Average =**	86.2		85.5
0201b	85.7	50598	60635	**Standard Deviation =**	0.44		
0201c	86.5	50441	59856	**Rel. St. Deviation =**	1.44	%	
0203a	86.9	48955	57821	**Average =**	87		85.5
0203b	87.2	50332	59254	**Standard Deviation =**	0.15		
0203c	87	48103	56754	**Rel. St. Deviation =**	0.17	%	
				Average =	84.83		83.4
				Standard Deviation =	3.09		3.20
				Rel. St. Deviation =	3.64		3.84 %

Original Concentration of Contaminant in Soil: (Experiment # 2)

SAMPLE	Pyrene	Pyrene	Fluorene				*Adjusted
Std. 2	98.7	61869	64360				
0206a	119.6	70269	60321	**Average =**	120.1		116.4
0206b	122.5	70337	58945	**Standard Deviation =**	1.59		
0206c	119.9	92307	79056	**Rel. St. Deviation =**	1.32	%	
0205a	115.1	62422	55697	**Average =**	114.9		110.7
0205b	112.7	66142	60266	**Standard Deviation =**	2.15		
0205c	117	65504	57475	**Rel. St. Deviation =**	1.87	%	
Std. 3	99.2	62906	65122				
0204a	95.8	56629	60710	**Average =**	97.3		94.6
0204b	95.9	56929	60978	**Standard Deviation =**	2.51		
0204c	100.2	56245	57653	**Rel. St. Deviation =**	2.58	%	
				Average =	110.77		107.2
				Standard Deviation =	11.95		11.3
				Rel. St. Deviation =	10.79		10.54 %

Extraction Efficiency = 85.76 % Treatment Efficiency = 22.2 %

Table C.4-3

Moist Soil Experimental Data

Original Concentration of Contaminant in Soil: (Experiment # 3)

SAMPLE	CONC. (mg/L) Pyrene	AREA Pyrene	AREA Fluorene			*Adjusted	
Std. 1	99.2	83312	86270				
0303a	109	58705	55318	Average =	109.3	113.5	
0303b	109.6	59063	55338	Standard Deviation =	0.31		
0303c	109.4	59886	51225	Rel. St. Deviation =	0.28	%	
0302a	98.9	53427	55471	Average =	98.7	102.4	
0302b	99.5	54446	56161	Standard Deviation =	0.92		
0302c	97.7	54252	56994	Rel. St. Deviation =	0.93	%	
Std. 2	101.7	65671	66286				
0301a	107.2	59047	56555	Average =	107.1	111.1	
0301b	106.5	56040	54038	Standard Deviation =	0.51		
0301c	107.5	58928	56265	Rel. St. Deviation =	0.48	%	
				Average =	105	111.1	
				Standard Deviation =	5.59	5.84	
				Rel. St. Deviation =	5.32	5.26	%

Final Concentration of Contaminant in Soil: (Experiment # 3)

SAMPLE	CONC. (mg/L) Pyrene	AREA Pyrene	AREA Fluorene			*Adjusted	
0306a	66	39995	62219	Average =	66.2	69	
0306b	66.4	41805	64662	Standard Deviation =	0.21		
0306c	66.1	39706	61639	Rel. St. Deviation =	0.32	%	
Std. 3	99.2	62906	65122				
0305a	77.9	45298	59671	Average =	76.3	79.8	
0305b	73.5	46428	64855	Standard Deviation =	2.43		
0305c	77.5	60363	79995	Rel. St. Deviation =	3.18	%	
0304a	76.4	48301	64877	Average =	77	80.4	
0304b	77	46955	62579	Standard Deviation =	0.55		
0304c	77.5	59826	79279	Rel. St. Deviation =	0.71	%	
				Average =	73.2	76.4	
				Standard Deviation =	6.04	6.4	
				Rel. St. Deviation =	8.25	8.38	%

Extraction Efficiency = 84 % Treatment Efficiency = 29.9 %

* Calculations have been adjusted for slight variations in the mass of dry soil

Table C.4-4

Moist Soil Experimental Data

Final Concentration of Contaminant in Soil: (Experiment # 4)

	CONC. (mg/L)	AREA					
SAMPLE	Pyrene	Pyrene	Fluorene			*Adjusted	
0402a	86.8	48081	56861				
0402b	87.1	48666	57342	**Average =**	87	89.5	
0402c	87	47546	56103	**Standard Deviation =**	0.15		
Std. 1	102.7	63146	63137	**Rel. St. Deviation =**	0.17	%	
0401a	80.2	45726	58557	**Average =**	88.3	84	
0401b	81.9	53046	66499	**Standard Deviation =**	0.55		
0401c	79.5	45572	58832	**Rel. St. Deviation =**	1.44	%	
0403a	88.9	65307	75472	**Average =**	80.5	84	
0403b	88	48859	57019	**Standard Deviation =**	1.23		
0403c	87.9	48828	57014	**Rel. St. Deviation =**	1.53	%	
				Average =	85.30	88.1	
				Standard Deviation =	4.18	3.18	
				Rel. St. Deviation =	4.90	3.60	%

Original Concentration of Contaminant in Soil: (Experiment # 4)

Std. 2	99.1	65348	67683			*Adjusted	
0406a	112.3	63462	58003	**Average =**	112.6	115.6	
0406b	112.4	64496	58937	**Standard Deviation =**	0.38		
0406c	113	61610	55979	**Rel. St. Deviation =**	0.34	%	
0405a	118.9	62754	54177	**Average =**	119.4	122.6	
0405b	119.7	64543	55376	**Standard Deviation =**	0.46		
0405c	119.7	64064	54941	**Rel. St. Deviation =**	0.39	%	
Std. 3	101.8	61415	61950				
0404a	101	66848	67959	**Average =**	104.6	107.4	
0404b	106.3	58831	56818	**Standard Deviation =**	3.15		
0404c	106.6	56591	54528	**Rel. St. Deviation =**	3.01	%	
				Average =	112.20	115.2	
				Standard Deviation =	7.41	7.61	
				Rel. St. Deviation =	6.60	6.60	%

Extraction Efficiency = 92.2 %   Treatment Efficiency = 23.5 %

Table C.4-5

Moist Soil Experimental Data

Final Concentration of Contaminant in Soil: (Experiment # 5)

SAMPLE	CONC. (mg/L) Pyrene	AREA Pyrene	AREA Fluorene			*Adjusted	
Std. 1	95.1	66378	71644				
0503a	91.6	54354	60946	Average =	93	95	
0503b	93.4	53809	59129	Standard Deviation =	1.25		
0503c	94	53160	58078	Rel. St. Deviation =	1.34	%	
0502a	81.1	46237	58571	Average =	81.9	84.6	
0502b	82.3	45432	56691	Standard Deviation =	0.67		
0502c	82.2	46817	58465	Rel. St. Deviation =	0.82	%	
Std. 2	98.3	84109	87881				
0501a	84.2	49803	60740	Average =	85.1	86.7	
0501b	85.3	48593	58475	Standard Deviation =	0.86		
0501c	85.9	47696	56998	Rel. St. Deviation =	1.01	%	
				Average =	86.7	88.8	
				Standard Deviation =	5.71	5.50	
				Rel. St. Deviation =	6.59	6.19	%

Original Concentration of Contaminant in Soil: (Experiment # 5)

						*Adjusted	
0506a	97.4	53870	56795	Average =	96.8	100	
0506b	96.1	65624	70104	Standard Deviation =	0.67		
0506c	97	53217	56309	Rel. St. Deviation =	0.69	%	
Std. 3	98.1	64572	67584				
0505a	110.8	61314	56846	Average =	111.2	113.2	
0505b	111.8	62575	57448	Standard Deviation =	0.51		
0505c	111.1	61124	56477	Rel. St. Deviation =	0.46	%	
0504a	107.5	62494	59683	Average =	107.6	109.8	
0504b	107.7	61013	58158	Standard Deviation =	0.12		
0504c	107.5	60386	59682	Rel. St. Deviation =	0.11	%	
				Average =	105.2	107.7	
				Standard Deviation =	6.04	6.4	
				Rel. St. Deviation =	5.74	5.94	%

Extraction Efficiency = 86.16 % Treatment Efficiency = 17.5 %

* Calculations have been adjusted for slight variations in the mass of dry soil

Table C.4-6

Moist Soil Experimental Data: (Dessicator #2)

Final Concentration of Contaminant in Soil: (Experiment # 1)

	CONC. (mg/L)	AREA				*Adjusted	
SAMPLE	Pyrene	Pyrene	Fluorene				
0102a	67.5	35978	54752				
0102b	68.5	35009	52465	**Average =**	68	67.1	
0102c	68.1	33684	50754	**Standard Deviation =**	0.5		
Std. 1	100	50920	52291	**Rel. St. Deviation =**	0.74	%	
0101a	68.5	36169	54232	**Average =**	69.4	68.6	
0101b	69.9	36159	53098	**Standard Deviation =**	0.76		
0101c	69.7	34954	51482	**Rel. St. Deviation =**	1.44	%	
0103a	71.5	36157	51906	**Average =**	71.3	70.2	
0103b	70.8	36640	53128	**Standard Deviation =**	0.47		
0103c	71.7	35539	50927	**Rel. St. Deviation =**	0.66	%	
				Average =	69.60	68.6	
				Standard Deviation =	1.66	1.55	
				Rel. St. Deviation =	2.38	2.26	%

Original Concentration of Contaminant in Soil: (Experiment # 1)

						*Adjusted	
Std. 2	101.8	55372	55864				
0106a	106	52954	51314	**Average =**	106.3	105.7	
0106b	106	55659	53908	**Standard Deviation =**	0.58		
0106c	107	54488	52291	**Rel. St. Deviation =**	0.55	%	
0105a	110.1	53885	50276	**Average =**	110.9	110.2	
0105b	111.1	57391	53065	**Standard Deviation =**	0.76		
0105c	111.6	57983	53365	**Rel. St. Deviation =**	0.69	%	
Std. 3	104	52094	51458				
0104a	101.4	51810	52446	**Average =**	102.5	102.9	
0104b	103.2	50640	50408	**Standard Deviation =**	0.94		
0104c	102.8	51042	50988	**Rel. St. Deviation =**	0.92	%	
				Average =	106.60	106.3	
				Standard Deviation =	4.21	3.68	
				Rel. St. Deviation =	3.95	3.46	%

Extraction Efficiency = 85.04 %   Treatment Efficiency = 35.5 %

Table C.4-7

Moist Soil Experimental Data

Final Concentration of Contaminant in Soil: (Experiment # 2)

	CONC. (mg/L)	AREA				
SAMPLE	Pyrene	Pyrene	Fluorene			*Adjusted
Std. 1	92.7	61127	65994			
0203a	65.3	37730	57859	**Average =**	65	65.5
0203b	64.7	39434	60954	**Standard Deviation =**	0.31	
0203c	65.1	36952	56817	**Rel. St. Deviation =**	0.48	%
0202a	62	37100	59913	**Average =**	61.2	61.9
0202b	60.9	36932	60691	**Standard Deviation =**	0.74	
0202c	60.6	35920	59362	**Rel. St. Deviation =**	1.21	%
Std. 2	93.4	72808	77984			
0201a	59.3	33001	55676	**Average =**	59.7	61.3
0201b	59.9	32796	54780	**Standard Deviation =**	0.38	
0201c	60.1	36609	60964	**Rel. St. Deviation =**	0.64	%
				Average =	62	62.9
				Standard Deviation =	2.73	2.27
				Rel. St. Deviation =	4.41	3.61 %

Original Concentration of Contaminant in Soil: (Experiment # 2)

						*Adjusted
0206a	98.5	58876	59807	**Average =**	99.4	100.2
0206b	99.5	58132	58441	**Standard Deviation =**	0.81	
0206c	100.1	60287	60269	**Rel. St. Deviation =**	0.81	%
Std. 3	91.6	57855	63193			
0205a	100.2	56313	56238	**Average =**	100.7	102.8
0205b	100.7	58885	58514	**Standard Deviation =**	0.55	
0205c	101.3	60435	59710	**Rel. St. Deviation =**	0.55	%
0204a	92.7	52205	56366	**Average =**	92.6	94.9
0204b	92	53078	57753	**Standard Deviation =**	0.6	
0204c	93.2	53376	57311	**Rel. St. Deviation =**	0.65	%
				Average =	97.6	99.3
				Standard Deviation =	4.35	4.03
				Rel. St. Deviation =	4.46	4.05 %

Extraction Efficiency = 79.44 % Treatment Efficiency = 36.5 %

* Calculations have been adjusted for slight variations in the mass of dry soil

Table C.4-8

Moist Soil Experimental Data: (Dessicator #2)

Original Concentration of Contaminant in Soil: (Experiment # 3)

	CONC. (mg/L)	AREA					
SAMPLE	Pyrene	Pyrene	Fluorene			*Adjusted	
0302a	56.6	31902	55250	Average =	56.8	59.3	
0302b	57.1	32725	57362	Standard Deviation =	0.35		
0302c	-----	-----	-----	Rel. St. Deviation =	0.62	%	
Std. 1	93.2	56699	60866				
0301a	70.1	37628	53756	Average =	70.9	73.4	
0301b	71.1	39387	55401	Standard Deviation =	0.72		
0301c	71.5	40435	56594	Rel. St. Deviation =	1.44	%	
0303a	61.4	33913	55250	Average =	61	63.9	
0303b	61.1	46581	76300	Standard Deviation =	0.46		
0303c	60.5	42881	70951	Rel. St. Deviation =	0.75	%	
				Average =	62.90	65.5	
				Standard Deviation =	7.24	7.19	
				Rel. St. Deviation =	11.51	10.98	%

Final Concentration of Contaminant in Soil: (Experiment # 3)

Std. 2	93.5	55197	59078			*Adjusted	
0306a	112.8	65641	58225	Average =	112.7	114.8	
0306b	112.2	61535	54884	Standard Deviation =	0.5		
0306c	113.2	59944	52977	Rel. St. Deviation =	0.44	%	
0305a	89.6	51132	57103	Average =	89.8	93	
0305b	89.6	49975	55790	Standard Deviation =	0.29		
0305c	90.1	48883	54303	Rel. St. Deviation =	0.32	%	
Std. 3	93.2	58859	63216				
0304a	100.5	58615	58341	Average =	100.9	105.5	
0304b	100.8	57180	56773	Standard Deviation =	0.46		
0304c	101.4	55555	54813	Rel. St. Deviation =	0.46	%	
				Average =	101.10	104.4	
				Standard Deviation =	11.45	10.94	
				Rel. St. Deviation =	11.33	10.48	%

Extraction Efficiency = 83.52 % Treatment Efficiency = 37.3 %

Table C.4-9

Moist Soil Experimental Data

Final Concentration of Contaminant in Soil: (Experiment # 4)

	CONC. (mg/L)	AREA				*Adjusted	
SAMPLE	Pyrene	Pyrene	Fluorene				
Std. 1	91.4	60471	66217				
0403a	29.1	16186	55567	Average =	29.4	29.8	
0403b	29.7	22965	77415	Standard Deviation =	0.31		
0403c	29.3	15216	51896	Rel. St. Deviation =	1.05	%	
0402a	27.5	15503	56460	Average =	28.1	29.8	
0402b	28.9	15341	53173	Standard Deviation =	0.74		
0402c	27.8	19558	70290	Rel. St. Deviation =	2.63	%	
Std. 2	92.6	58995	63733				
0401a	28.8	16209	56288	Average =	28.1	29	
0401b	28	16074	57518	Standard Deviation =	0.61		
0401c	27.6	15064	54684	Rel. St. Deviation =	2.17	%	
				Average =	28.5	29.5	
				Standard Deviation =	0.75	0.46	
				Rel. St. Deviation =	2.63	1.57	%

Original Concentration of Contaminant in Soil: (Experiment # 4)

						*Adjusted	
0406a	69.6	37876	54462	Average =	70.3	70.5	
0406b	69.6	37876	54462	Standard Deviation =	1.21		
0406c	71.7	38842	54219	Rel. St. Deviation =	1.72	%	
Std. 3	91.6	57855	63193				
0405a	68.8	37337	54330	Average =	70.5	71.6	
0405b	69.8	38243	54800	Standard Deviation =	2.08		
0405c	72.8	39153	53823	Rel. St. Deviation =	2.95	%	
0404a	67.4	35807	53142	Average =	67.9	68.1	
0404b	67.7	35414	52334	Standard Deviation =	0.57		
0404c	68.5	50724	74060	Rel. St. Deviation =	0.84	%	
				Average =	69.4	70.5	
				Standard Deviation =	1.45	1.79	
				Rel. St. Deviation =	2.08	2.54	%

Extraction Efficiency = 84.603 %   Treatment Efficiency = 58.2 %

* Calculations have been adjusted for slight variations in the mass of dry soil

Table C.4-10

Moist Soil Experimental Data: (Dessicator #2)

Final Concentration of Contaminant in Soil: (Experiment # 5)

SAMPLE	CONC. (mg/L) Pyrene	AREA Pyrene	AREA Fluorene				*Adjusted	
0502a	32	16562	51741	**Average =**	32.1		33	
0502b	31.7	17681	55798	**Standard Deviation =**	0.46			
0502c	17389	17389	53423	**Rel. St. Deviation =**	1.43	%		
Std. 1	95.3	70104	73638					
0501a	28.7	15651	54613	**Average =**	28.6		29.5	
0501b	27.4	10304	55891	**Standard Deviation =**	1.11			
0501c	29.6	21461	72488	**Rel. St. Deviation =**	1.44	%		
0503a	27.4	14665	53601	**Average =**	27.3		28.1	
0503b	27	14995	55491	**Standard Deviation =**	0.23			
0503c	27.4	14077	51493	**Rel. St. Deviation =**	0.84	%		
				Average =	29.33		30.2	
				Standard Deviation =	2.48		2.52	
				Rel. St. Deviation =	8.46		8.36	%

Original Concentration of Contaminant in Soil: (Experiment # 5)

SAMPLE	CONC. (mg/L) Pyrene	AREA Pyrene	AREA Fluorene				*Adjusted	
Std. 2	93.4	59781	64070					
0506a	70.8	37981	53703	**Average =**	71.1		73.3	
0506b	71.2	37914	53318	**Standard Deviation =**	1.03			
0506c	71.3	37594	52772	**Rel. St. Deviation =**	1.45	%		
0505a	60.5	33076	54751	**Average =**	60.5		61.6	
0505b	60.6	31608	52225	**Standard Deviation =**	0.1			
0505c	60.4	33143	54896	**Rel. St. Deviation =**	0.17	%		
Std. 3	95.9	55066	57483					
0504a	73	36446	49966	**Average =**	71.9		74.9	
0504b	71	39039	55039	**Standard Deviation =**	1.03			
0504c	71.6	38666	54020	**Rel. St. Deviation =**	1.43	%		
				Average =	67.83		104.4	
				Standard Deviation =	6.36		7.26	
				Rel. St. Deviation =	9.38		6.96	%

Extraction Efficiency = 84.03 % Treatment Efficiency = 56.8 %

Control Experiment Extraction Data

Final Concentration of Contaminant in Soil:

SAMPLE	CONC. (mg/L) Pyrene	AREA Pyrene	AREA Fluorene			
Std. 1	94.3	58643	62220			
C03a	133.2	77326	58097	**Average =**	133.67	
C03b	133.9	70157	52414	**Standard Deviation =**	0.4	
C03c	133.9	70853	52963	**Rel. St. Deviation =**	0.30	%
C02a	109.2	84401	77347	**Average =**	109.5	
C02b	109.3	58047	53149	**Standard Deviation =**	0.38	
C02c	109.9	61403	55910	**Rel. St. Deviation =**	0.35	%
Std. 2	97.9	89537	91486			
C01a	121.4	63066	52008	**Average =**	122.1	
C01b	122.1	84556	69282	**Standard Deviation =**	0.7	
C01c	122.8	64338	52446	**Rel. St. Deviation =**	0.57	%
				Average =	121.8	
				Standard Deviation =	12.09	
				Rel. St. Deviation =	9.93	%

APPENDIX D: Example Calculations

D.1: Surface Area Calculations

1. **Glass Beads:**

$d = 6 \text{ mm} = 0.6 \text{ cm}$

$M_1 = 110 \text{ g}$

$\rho = 2.65 \text{ g/cm}^3$

$$S_1 = \frac{6 M_1}{\rho d} = \frac{6 \times (110)}{(2.65)\times(0.6)} = 415.1 \text{ cm}^2$$

2. **Ottawa Sand:**

$d = 0.6 \text{ mm} = 0.06 \text{ cm}$

$d' = 0.425 \text{ mm} = 0.0425 \text{ cm}$

$M_1 = 20 \text{ g}$

$\rho = 2.65 \text{ g/cm3}$

$$S_2 = \frac{6 M_1}{\rho d} = \frac{6 \times (20)}{(2.65)\times(0.06)} = 754.7 \text{ cm}^2$$

$$S_{2'} = \frac{6 M_1}{\rho d} = \frac{6 \times (20)}{(2.65)\times(0.0425)} = 1066 \text{ cm}^2$$

Surface Area Ratios:

$$\frac{S_2}{S_1} = \frac{754.7}{415.1} = 1.8 \qquad \frac{S_{2'}}{S_1} = \frac{1066}{415.1} = 2.6$$

D.2: <u>2700 BET Surface Area Analysis</u>

Date: 11/4/93 Sample: Metea Soil

Weight of Sample and Holder...............9.0584 g

Weight of Holder................................9.0347 g

Weight of Sample................................0.0237 g

Atmospheric Pressure (mmHg)...............740

Absolute Temperature (K).....................293.6

Table D.2-1: Run Temperature

Desired N_2 Mole %	5	10	20	30
Ratio Setting	0.53	1.11	2.50	4.29
N_2 Flow Rate (ml/min)	1.2	2.4	5.2	8.7
Total Flow Rate (ml/min)	21.3	22.5	25.3	28.8
Calibration Gas Vol. (ml)	0.5	0.5	0.5	0.5
Calibration Gas Area	1.56	1.54	1.26	1.02
Adsorbed Gas Area	0.60	0.58	0.55	0.54
Attenuation (× 1 or × 10)	× 1	× 1	× 1	× 1
Recorder Range (mV)	20	20	20	20
Chart Speed (cm/min)	1	1	1	1
Adsorbed Gas Vol. (ml)	0.192	0.188	0.218	0.265

1. $P_n = \frac{(1.2)(740)}{(21.3)} = 41.69$ mmHg

2. $P_n = \frac{(2.4)(740)}{(22.5)} = 78.93$ mmHg

3. $P_n = \frac{(5.2)(740)}{(25.3)} = 152.1$ mmHg

4. $P_n = \frac{(8.7)(740)}{(28.8)} = 223.5$ mmHg

Table D.2-2: Calculated Values

Run	$\frac{P_n}{V_{ads}(P_{no}-P_n)}$	$\frac{P_n}{P_o}$
1	0.302	0.055
2	0.616	0.104
3	1.15	0.200
4	1.57	0.294

y-intercept = 0.03 **slope** = $\frac{1.05 - 1.0}{0.19 - 0.18} = 5$

$$V_m = \frac{1}{(0.04 + 5)} = 0.198$$

Total Surface Area:

$$TSA = \frac{(0.198)(4.35)}{(0.0237)} = 36.34\ m^2/g$$

D.3: Calculations of Energy Consumption

Using the Ideal Gas Law; $pV = nRT$

where,
$R = 0.0821$ L atm/mol K
$T = 293$ K
$p = 1$ atm

$$\frac{n}{V} = \frac{P}{RT}$$

$$\frac{n}{V} = \frac{1\ atm}{(293\ K)(0.0821\ \frac{L\ atm}{mol\ K})}$$

$$\frac{n}{V} = 4.157\ x\ 10^{-2}\ \frac{mol}{L}$$

Therefore, the air mass flux through the system;

$$Air = (130\ \frac{ft^3}{\min})(60\ \frac{\min}{hr})(24\ \frac{hr}{day})(7.48\ x\ 10^{-2}\ \frac{lb}{ft^3}) = 14{,}000\ \frac{lb}{day}$$

For 1% ozone in air;

$$Ozone = (0.01)(140{,}000\ \frac{lb}{day}) = 140\ \frac{lb}{day}$$

Therefore, a 150 lb/day ozone generator is sufficient.

Calculation of Cost per tonne of Metea soil:

$$(76\frac{mmol}{kg\ soil})(\frac{1\times10^3\ kg soil}{tonne soil})(\frac{mol}{1000 mmol})(\frac{48g}{mol})(\frac{1\ lb}{454\ g})(\frac{\$0.06}{kWh})(\frac{1800\ kWh}{day})(\frac{day}{140\ lbO_3}) = \frac{\$6.20}{tonne\ soil}$$