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Evaluation of Volatilization of Hazardous Constituents at Hazardous Waste Land Treatment Sites

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EVALUATION OF VOLATILIZATION OF HAZARDOUS CONSTITUENTS AT HAZARDOUS WASTE LAND TREATMENT SITES

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FOREWORD

EPA is charged by Congress to protect the Nation's land, air and water systems, under a mandate of national environmental laws focused on air and water quality, solid waste management and the control of toxic substances, pesticides, noise and radiation, the Agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life.

The Robert S. Kerr Environmental Research Laboratory is the Agency's center of expertise for investigation of the soil and subsurface environment. Personnel at the Laboratory are responsible for management of research programs to: a) determine the fate, transport and transformation rates of pollutants in the soil, the unsaturated zone and the saturated zone of the subsurface environment; b) define the processes to be used in characterizing the soil and subsurface environment as a recptor of pollutants; c) develop techniques for predicting the effect of pollutants on groundwater, soil and indigenous organisms; and d) define and demonstrate the applicability and limitations of using natural processes, indigenous to the soil and subsurface environments, for the protection of this resource.

The evaluation of the impact of land disposal of hazardous materials on human health and the environment has become a prominent issue of concern to the public, industry, regulators and environmental groups alike. Land treatment is an engineered process in which the soil environment is used as a treatment medium and provides final disposal of hazardous constituents in the applied waste. The key to land treatment is the engineering control which optimizes treatment efficiency and minimizes contaminant transport to receiver populations.

Determination of the volatilization component of contaminant transport from land treatment facilities is required to perform a complete mass balance so that it is assured that the tenets of land treatment, i.e., degradation, transformation , **immobilization**, are satisfied. This project was undertaken to evaluate the nature and extent of the volatilization from land treatment systems of a subset of hazardous organics identified in a number of petroleum refining wastes, and to assess the applicability of a simple diffusion based model (the Thibodeaux-Hwang Air Emission Release Rate Model) for predicting measured pure constituent mass emission rates. The study was conducted with a limited number of soils and a limited number of wastes, yet both the laboratory and field results suggest the general applicability of the modeling and measurement approaches evaluated in this report to a wide range of surface waste application emission scenarios.

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ABSTRACT

The magnitude and extent of volatile organic emissions from hazardous waste land treatment systems were evaluated in laboratory and field studies using complex petroleum refining hazardous wastes. Laboratory experiments were conducted using two soils and a inert construction sand to investigate the emission flux rates of seven volatile constituents, i.e., benzene, toluene, ethylbenzene, p-, m-, o-xylene, and naphthalene, from API Separatory Sludge and Slop Oil Emulsion Solids wastes in column and flask laboratory units as a function of waste application rate, application method (surface versus subsurface), soil type and soil physical characteristics. Field experiments were conducted at an active petroleum refinery hazardous waste land treatment site to which a combined API Separator Sludge/DAF bottom sludge was surface applied. The emission rates of the seven pure volatile constituents evaluated in the laboratory studies were quantified in the field study.

Pure constituent collection and quantification in both laboratory and field studies were carried out using a surface isolation emission flux chamber and a split stream Tenax™ sorbent tube concentration system. Laboratory and field sampling train evaluation indicated that the system is best suited for high emission rate measurements, i.e., just following waste application, and requires diligent QA/QC procedures to minimize background contamination and to assure representativeness of measured data. Suggested operating procedures in terms of purge flow rates, split stream sampling rates, sample collection volumes for minimal contaminant sorbent tube breakthrough, etc., are presented.

Measured laboratory and field data were compared to the Thibodeaux-Hwang Air Emission Release Rate (AERR) model in an effort to validate this state-of-the-art land treatment air emission model. Data generally confirm the validity of the diffusion based modeling approach for land treatment air emissions, especially for emission rates immediately following surface waste application. Both field and laboratory surface application measured data correlated with Thibodeaux-Hwang AERR model predictions within a factor of two to ten. Laboratory subsurface application experiments were within one to two orders of magnitude of predicted values. The dynamics of the geometry of the subsurface contaminated zone following subsurface application, along with the hypothesis of concentration gradient development in the soil zone above the application plane, indicate that the simple diffusion based model does not adequately describe the unsteady-state diffusion process occurring following subsurface application events.

The variability observed in point waste loading, and soil physical and temperature conditions observed during the field study suggest that detailed waste loading data (using a pan method described in the report) and site and time specific soil data are required for accurate correlations between measured and predicted waste constituent emission flux rates. Once specific data are collected which describe the physical environment of the land treatment system, the accurate prediction of pure constituent air emissions from surface application and tilling can be provided by the Thibodeaux-Hwang AERR model even for complex hazardous wastes applied to complex soil systems.

This report was submitted in partial fulfillment of Cooperative Agreement CR-810999-01-0 by the Utah Water Research Laboratory, Utah State University under the partial sponsorship of the U. S. Environmental Protection Agency. This report covers a period from August 1983 to January 1986, and the work was completed as of July 1986.

CONTENTS

FIGURES

FIGURES (continued)

TABLES

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

AERR	-- air emission release rate	UWRL	-- Utah Water Research Laboratory
ALC	-- application limiting constituent	VOC	-- volatile organic constituent
CLC	-- capacity limiting constituent	BBT	-- background before tilling
RLC	-- rate limiting constituent	BAT	-- background after tilling
RSKERL	-- Robert S. Kerr Environmental Research Laboratory	WAT	-- waste after first tilling
		WBT	-- waste before tilling
TSDFs	-- treatment, storage and disposal facilities	WST	-- waste after second tilling

SYMBOLS

A	-- area	$H_{C'}$	-- Henry's Law constant (cm^3 oil/cm^3 air)
a_s	-- interfacial area per unit volume of soil	h_p	-- depth of penetration or plow slice depth
C_A	-- average compound concentration in the pore spaces	h_s	-- surface injection depth
		K_{ow}	-- octanol:water partitioning coefficient
C_A^*	-- equilibrium concentration in pore spaces at the evaporating plane	K_{sw}	-- solvent:water partitioning coefficient
		L	-- loading
C_{Ai}	-- compound concentration at the air/soil interface	M_A	-- mass of component applied to soil
		M_{Ar}	-- compound mass remaining after time t
C_{ao}	-- initial compound concentration	M_{At}	-- compound mass loss during period prior to tilling
C_{io}	-- initial compound concentration in the oil		
C_L	-- compound concentration on the oil side of the air/oil interface	MW	-- molecular weight
		P_A	-- compound vapor pressure
d	-- soil particle diameter	S_a	-- soil air filled porosity
D_A	-- compound soil air diffusion coefficient	S_t	-- total soil porosity
D_{Ai}	-- compound air diffusion coefficient	t	-- time
D_o	-- compound diffusion coefficient in oil phase	T	-- temperature
f	-- fraction of oil in the film form = fraction of air filled pore space in the soil	Tb	-- compound boiling temperature
		V_B	-- compound molar volume
F_A	-- compound vapor flux rate	X	-- compound mole fraction in soil water
h	-- initial depth of soil contamination	y	-- variable thickness of soil contamination
H_C	-- Henry's Law constant	Zo	-- oil-layer diffusion length

ΔHvb	-- compound heat of vaporization	ρ_p	-- soil particle density
η_s	-- solvent/waste viscosity	ϕs	-- solvent association parameter
ρ_o	-- oil/waste density		

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SECTION 1

INTRODUCTION

Land treatment may be defined as the engineered usage of the upper soil zone for the treatment and ultimate disposal of waste materials at a rate and to an extent that the land used for disposal will not be irretrievably removed from beneficial use sometime in the future (Overcash and Pal 1979). The characteristics of waste constituents and their interactions within the land treatment system lead to a classification of loading limitations based on: (1) application limiting, (2) rate limiting, or (3) capacity limiting constituents (ALC, RLC, CLC) (K. W. Brown and Associates 1980). These classifications relate to: (1) the loss of waste components due to volatility or leachability as affected by soil and micrometerological site conditions, (2) movement of components from the land treatment area due to their limited degradation, transformation, and/or immobilization, or (3) accumulation of non-assimilable components to levels that limit the future beneficial use of the land treatment area.

The primary emphasis in the monitoring and evaluation of land treatment facilities to date has been related to rates of degradation of biodegradable waste constituents and to the impact of land disposal activities on surface and groundwater systems. This concern for potential releases of hazardous and toxic materials to surface and groundwater supplies has been manifested in the form of requirements for (40 CFR Part 264 Subparts F and M, Part 265 Subparts F and M, and Part 267 Subparts E and F): 1) run-on and run-off controls, 2) leachate prevention and containment, 3) unsaturated zone monitoring systems, and 4) leak detection systems (Solid and Hazardous Waste Amendments of 1984, Section 202).

The loss of volatile waste constituents from land treatment sites during or after waste application has received little attention until recently, yet information gathered at a number of landfills and dump sites in the Love Canal and Hudson River basin areas has indicated that land generated air emissions of toxic materials from these sources is often of greater magnitude than emissions via water transport (Shen and Tofflemire 1980). The 1984 RCRA Amendments acknowledge the potential for air emissions from hazardous waste Treatment, Storage and Disposal Facilities (TSDFs) in Section 201 through the requirement that EPA promulgate regulations for the monitoring and control of air emissions at hazardous waste TSDFs within 30 months of the enactment of the amendments.

This research project was initiated for the evaluation of a sampling system and collection of data relating to the potential magnitude and extent of the volatilization component of hazardous constituent transport at hazardous waste land treatment facilities. Laboratory and field scale validation of the Thibodeaux-Hwang Air Emission Release Rate (AERR) model (Thibodeaux and Hwang 1982) has been conducted to identify the applicability of this modeling approach for describing chemical volatilization relationships in flask, microcosm and full-scale land treatment systems, and for predicting the effectiveness of management tools for the control of air emissions from land treatment activities.

The specific objectives of the project were to:

1. Evaluate an air sampling/quantification method suitable for field use at hazardous waste land treatment facilities in conjunction with emission source testing, compliance monitoring and model validation activities,

2. Evaluate the Thibodeaux-Hwang AERR model, a state-of-the-art land treatment emission model, in both laboratory and field studies using actual hazardous wastes to determine its applicability and limitations relative to the prediction of full-scale hazardous air emissions from land treatment facilities, and

3. Compare emissions from one-dimensional laboratory flasks with two-dimensional laboratory columns in an effort to develop an inexpensive yet representative screening protocol for estimating the volatile organic emission release potential for particular soil/waste mixtures.

SECTION 2

CONCLUSIONS

Based on an extensive laboratory and field scale evaluation of an air sampling/concentration protocol for use in field and laboratory hazardous volatile air emission release rate monitoring and modeling from the land treatment of refinery wastes, the following conclusions were reached:

General

1. The emphasis of this study was a laboratory and field evaluation of the Thibodeaux-Hwang AERR model. The field evaluation was conducted at an operating land treatment system treating petroleum refinery sludges including, but not limited to, hazardous wastes. Therefore, waste organics of particular interest were those contained in U.S. EPA's 40 CFR 261 regulations. Among the volatiles listed there as either spent, non-halogenated solvents (F003 and F005) or Appendix VIII constituents, only benzene, toluene, ethylbenzene, p-, m-, and o-xylene, and naphthalene were identified as major volatile components of a waste considered typical of what would be applied during the field study. The fact that these components were again identified and quantified as major constituents in two additional refinery wastes from a different refinery leads to the conclusion that this RCRA volatile organic profile can be expected when waste streams from API separators, DAF units, and slop oil tanks are analyzed. (reference Table 6).

2. From experience in utilizing the isolation chamber/split stream sampling system, with Tenax™ sorbent collection/concentration, in flask studies, in microcosm studies, and for full scale field sampling, it can be concluded that the system is simple and straightforward, and can provide continuity in sampling protocol over a wide range of sampling and collection activities with little modification between source configurations.

Flux Chamber/Sorbent Collection System

1. The mean recovery efficiencies for the seven compounds of interest from the flux chamber/ Tenax™ solid sorbent collection systems used in this study can be expected to range from 61 to 94%. (reference page 56; Figures 9 and 10).

2. Due to the composition of volatile organics emitted from the refinery wastes evaluated in this study, it was concluded that Tenax™ will out-perform charcoal due to the lack of quantitative recovery of naphthalene from the charcoal. (reference page 56; Tables 9, 10 and 11).

3. When using Tenax™ for source emission measurements, it was concluded that Tenax™ breakthrough volumes are a strong function of collected mass as well as temperature. (reference pages 56 to 60).

4. To limit excessive pressure build-up and potential emission suppression within the enclosures evaluated in this study, it was concluded that they must be operated at low purge flow rates (≤ 1 l/min) if no purge flow pump is utilized. (reference page 61; Figure 12).

5. Operation at these low flow rates will provide complete mix conditions within the flux chamber, allowing for representative grab sampling of a uniform chamber air space. (reference pages 61 to 63; Table 14; Figure 13).

6. A constant flow purge pump downstream of the flux chamber, used in conjunction with a constant volume split stream Tenax™ sampling manifold provides optimal collection/concentration efficiency, air phase mixing, and minimal disturbance to soil surface flux activity during sampling.

7. Results of field breakthrough, blank and manifold variability data indicate that the flux chamber/ solid sorbent system is well suited for high emission rate sampling, i.e., immediately following waste application, but requires diligent QA/QC procedures to minimize background contamination to ensure representativeness during low emission rate sampling. (reference pages 72 to 75; Tables 16 to 19).

Laboratory Thibodeaux-Hwang AERR Model Validation

1. Measured data followed the predicted linear relationship of flux rate versus $1/t^{1/2}$ for the majority of experimental runs conducted, indicating the validity of the modeling approach assuming primarily diffusion controlled vapor movement in simulated land treatment systems. (reference pages 63 to 66; Figures 16 and 17; Appendix G).

2. Owing to the unsteady-state nature of contaminant soil vapor phase concentration gradients during the initial period following subsurface application of the complex wastes, and to the variable boundary conditions observed with time, these flux data did not follow the theoretical linear relationship of flux rate versus $1/t^{1/2}$. It was concluded that the Thibodeaux-Hwang AERR model cannot be used to predict volatile compound flux rates for subsurface application conditions until a pseudo-equilibrium soil concentration profile has been established. (reference page 66; Figure 18; Appendix G).

3. The temporal variation of hp and hs with time was of such a magnitude that it was concluded that incorporation of this time dependent behavior of both hp and hs should be accounted for in laboratory Thibodeaux-Hwang model calculations. (reference page 63; Table 15; Figures 14 and 15).

4. The results of subsurface versus surface waste application studies indicated that a one to four order of magnitude decrease in emission rates can be expected when wastes are subsurface applied. Vapor flux rate suppression was more significant for the soils than the sand used in microcosm studies, leading to the conclusion that soil organic matter interaction is of some importance in soil vapor emission suppression. (reference page 70).

5. Based on studies using a small volatilization screening flask system under controlled laboratory conditions, it can be concluded that this apparatus holds promise for use as an inexpensive method for the determination of soil/waste volatilization potential. (reference page 70).

Field Thibodeaux-Hwang AERR Model Validation

1. It can be concluded that with strict adherence to QC procedures, two independent laboratories can duplicate results precisely for soil oil and grease analyses and for the quantification of the seven volatile organic constituents evaluated in this study in highly complex oily wastes and waste/soil mixtures. (reference page 72; Tables 6 and 16).

2. From the results of field emission rate data, which follow the linear relationship of flux versus $1/\text{time}^{1/2}$, it can be concluded that the Thibodeaux-Hwang AERR model assumption of soil diffusion controlled flux is valid. (reference page 75; Appendix G).

3. Variability inherent in field testing was apparent from site specific waste loading, and soil physical and temperature conditions that were monitored during the field study. It was concluded that site specific information for waste application rates (using the pan method described in the report), and site specific and time specific data for soil bulk density, air filled porosity, temperature, etc., are required for accurate correlations between measured and predicted waste constituent emission flux rates. (reference pages 75 to 77; Tables 11 and 20; Appendix H).

4. The results of model predicted and measured volatile emission data collected during the field study showed the measured data to be two to ten times the predicted results. The validity of the modeling approach and the accuracy of its predictions, especially immediately following waste application and initial tilling operations, is clear from field data collected at the particular field site and with the particular refinery waste used in this study. From these results it can be concluded that a simple diffusion based modeling approach, such as described in the Thibodeaux-Hwang AERR model, is valid for describing hazardous air emission rates from complex hazardous waste land treatment systems. (reference pages 75 to 77; Figures 22 and 24; Appendix J).

SECTION 3

RECOMMENDATIONS

Results of investigations of contaminant soil emission sampling and concentration equipment and its use in field and laboratory model validation activities has led to a number of recommendations regarding needs for future air emission modeling and sampling studies.

1. Based on field breakthrough results it is recommended that further investigations be conducted to assess chromatographic effects of a complex matrix on select compound retention. Alternative sample collection methods, such as whole air sampling via evacuated canisters, should also be considered for use in conjunction with the surface isolation flux chamber sampling system.

2. Initial studies with the small-scale volatilization flasks for emission rate estimates were encouraging, and it is recommended that continued emphasis be placed on refinement of such a technique to provide rapid screening of hazardous waste air emission release potentials. Modifications to the procedures should be made to simulate subsurface injection to determine if air emission management techniques can be assessed rapidly on a flask scale.

3. Efforts should be pursued to reduce the thermal impact, both positive and negative, on the land treatment area during sampling since contaminant vapor pressure is a controlling parameter of vapor mobility in the environment.

4. It is recommended that waste application point sampling, e.g., small metal collection pans on either side of the sampler location as used in this study, be conducted as a matter of routine in all future field measurement studies.

5. Based on results of subsurface application experiments in laboratory studies, it is recommended that incorporation of the time dependent behavior of h_p and h_s be considered in further refinement of the Thibodeaux-Hwang AERR model to aid in the evaluation of emission rates during early emission periods. The time dependent development of contaminant soil vapor density gradients following subsurface waste application events should also be evaluated, as this process is not described by the Thibodeaux-Hwang AERR model.

6. Finally, it is recommended that further development of the isolation chamber/split stream collection system be conducted to extend its applicability to a wider range of experimental and field scale sampling/analysis situations.

SECTION 4

LAND TREATMENT MODEL DEVELOPMENT AND DESCRIPTION

REVIEW OF SOIL VOLATILIZATION FUNDAMENTALS

Although a paucity of information exists relating to the modeling of organic contaminant emissions from land treatment sites, much information exists concerning the volatilization of organics, i.e., pesticides, from soil surfaces. General definitions of volatilization include the loss of chemicals from surfaces in the vapor phase, indicating that volatilization requires the vaporization and movement of chemicals from a surface into the atmosphere above the surface. The rate of contaminant volatilization is a complex function of the properties of the contaminant and its surrounding environment. For organics in soil systems Spencer and Cliath (1977) indicate that the factors affecting volatilization include:

1. Contaminant vapor pressure
2. Contaminant concentration
3. Soil/chemical adsorption reactions
4. Contaminant solubility in soil water
5. Contaminant solubility in soil organic matter
6. Soil temperature, water content, organic content, porosity, and bulk density

The major contaminant property affecting volatilization is its vapor pressure, while the major environmental factors affecting contaminant mobility are the various soil/air, soil/water, and air/water partition coefficients that exist for the various soil/water/air environments existing within the soil system. Additional complexity results if the contaminant is added in a carrier fluid such as oil in refinery wastes, where partitioning of the contaminant between the oil/soil, oil/water, and oil/air phases would also be expected to affect the volatilization of hazardous compounds in the waste.

Volatilization From a Nonadsorbing Surface

When a contaminant evaporates from a nonadsorbing surface into the air, its evaporation rate or volatilization rate has been shown to be determined solely by its vapor pressure and its rate of diffusion through air (Hartley 1969). The molecular theory of gases indicates that the mean velocity of molecules are related to the inverse of the square root of their molecular weights. Since the diffusion coefficient of molecules is also related to their mean free path and mean molecular velocity, their molecular diffusion coefficients can be shown to be inversely proportional to the square root of their molecular weight. The rate of mass transfer by molecular diffusion is proportional to the diffusion coefficient and the molecule vapor density, while the vapor density is proportional to the vapor pressure times the molecular weight (Hartley 1969). These results yield a relationship between the mass transfer of a compound, on the basis of its vapor pressure, with respect to the vapor pressure and volatilization rate for a model compound under a given set of conditions:

$$F_b = \frac{P_b (MW_b)^{1/2}}{P_a (MW_a)^{1/2}} \cdot F_a \qquad (1)$$

where: F = vapor flux rate, (mass/length^2/time),
P = vapor pressure, (mass/length^2),
MW = molecular weight, (mass), and
a, b = model compound and volatilizing compound, respectively.

Volatilization From an Adsorbing Surface

Adsorption of a compound onto an adsorbing surface reduces its chemical activity, or fugacity, resulting in a reduction in its vapor pressure (Spencer and Cliath 1977). This reduction in vapor pressure significantly decreases the vaporization rate of the compound, thus invalidating Equation 1 unless the effective vapor pressure of the compound in the soil is determined by some means such as presented by Spencer and Cliath (1969).

Further complications result when the compound is incorporated into the soil as is common in land treatment practices. Under such conditions, volatilization of the compound involves: 1) the desorption of the compound from liquid layers that coat the soil particles, 2) diffusion through the air filled pore spaces within the soil column to the air/soil interface, and followed finally by 3) diffusion from the soil surface to the overlying atmosphere (Thibodeaux 1979). Vaporization under soil incorporation conditions occurs at a much slower rate as compared to surface spreading due to reductions in the vapor pressure of the compound and the slow rate of diffusion within the soil column to the air/soil interface. As volatilization occurs, a concentration gradient develops between equilibrium and actual concentration levels in all phases, resulting in a driving force for continued diffusion. The rate of diffusion declines with time, however, as this concentration gradient is reduced due to an ever increasing diffusion path length to the air/soil surface (Hamaker 1972). Simplification of this complex problem by assuming a compound concentration at the soil surface equal to zero and a soil column of infinite depth has resulted in relationships for mass flux rate with time based on Fick's second law of diffusion in the general form as presented by Mayer et al. (1974):

$$F_A = \frac{D_A \cdot C_{Ao}}{(\pi \cdot D_A \cdot t)^{1/2}} \qquad (2)$$

where: F_A = component mass flux rate, (mass/length^2/time),
D_A = component soil air diffusion coefficient, (length^2/time),
C_{Ao} = initial component concentration, (mass/length^3), and
t = time.

Contaminant Advection

An additional source of contaminant volatilization from soil systems is an advection process, labeled the "wick effect" by Hartley (1969), that describes the net contaminant transport via a large upward diffusion of water toward the soil surface due to evaporation. The impact of this advection term will vary from compound to compound and is a function of the compound's soil adsorption characteristics, water solubility, and partition coefficients in the air, soil and water phases. A simple relationship for this flux term, F, was presented by Spencer and Cliath (1973):

$$F = F_W \cdot X \qquad (3)$$

where: F_W = water mass flux rate, (mass/length^2/time), and
X = component mole fraction in soil water.

A complete accounting for the mass flux of a volatile component from a soil system can then be written using the summation of Equations 2 and 3 to account for flux due to diffusion and due to mass transport via advection with evaporated soil moisture.

VAPOR TRANSPORT IN LAND TREATMENT SYSTEMS

The models described above are limited in that they lack the ability to include soil incorporation terms for describing land treatment operations, these models only consider air pore diffusion, and soil properties are included only as they relate to their effect upon the apparent soil diffusion coefficient, D_s. To accurately model volatile organic emissions from land treatment sites, both the soil pore diffusion and soil surface diffusion phenomenon must be considered, and means must be provided to predict diffusion as a function of soil characteristics and diffusion length characteristics for surface application or subsurface injection.

Thibodeaux Model

Thibodeaux (1979) began the development of land treatment diffusion models by describing the evaporation and diffusion of chemicals within the pore spaces of soil systems using the concept of a "dried-out" zone (Figure 1). In his model, soil contamination to a soil depth of h was assumed, with compound evaporation from soil surfaces, vapor diffusion into soil air spaces, and movement of the vapor up and out of the air/soil interface. A "dried-out" zone develops at the air/soil surface which is relatively free of adsorbed contaminant but through which vapors from the lower level must travel. With time, this "dried-out" zone increases in depth, correspondingly reducing the contaminated zone to an ever decreasing thickness, y. The soil column is assumed to be isothermal and capillary action, soil adsorption of vapor through the "dried-out" zone, and biodegradation are all considered negligible. Vapor diffusion through soil pores in the "dried-out" zone is considered limiting, resulting in the following expression for compound mass flux rate from the contaminated zone through the dry surface zone:

$$F_A = \frac{D_A}{(h-y)} \cdot (C_A^* - C_{Ai}) \qquad (4)$$

where
- h = initial depth of soil contamination, (length),
- y = variable thickness of soil contamination after onset of diffusion, (length),
- C_A^* = equilibrium concentration of component in pore spaces at the evaporating plane, (mass/length^3), and
- C_{Ai} = concentration of the compound at the air/soil interface, (mass/length^3).

The time for all of the liquid to vaporize from the contaminated zone, t_e, is given as:

$$t_e = \frac{h \cdot M_A}{2D_A \cdot (C_A^* - C_{Ai})} \qquad (5)$$

where:
- A = surface area of contaminated region, (length^2), and
- M_A = mass of component applied to the contaminated zone.

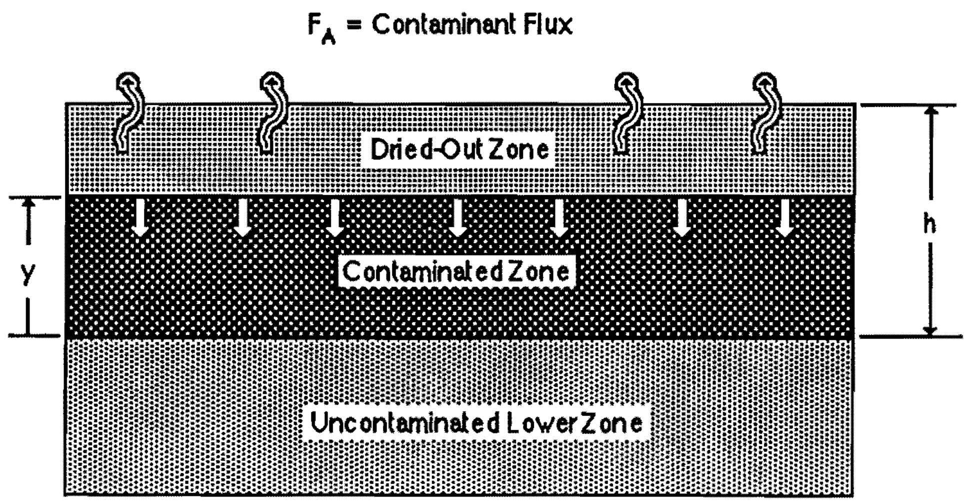

Figure 1. Thibodeaux model description of surface soil emissions. Adapted from Thibodeaux (1979).

Upon complete vaporization within the contaminated zone, diffusion can be modeled as the diffusion of a chemical from vapor filled pores that are saturated to a depth of h. Analysis of the multicomponent continuity equation with appropriate boundary conditions (Thibodeaux 1979) results in an expression for the average concentration in the contaminated zone at time t of:

$$C_A = C_{Ai} + (C_A^* - C_{Ai}) \cdot \frac{8}{\pi^2} \cdot \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \cdot \exp\left[-\frac{D_A \cdot t \cdot (2n+1)^2 \cdot \pi^2}{4h^2}\right] \qquad (6)$$

where C_A = average compound concentration in the pore spaces at time t, (mass/length^3).

Thibodeaux (1979) presented a graphical representation of the fraction of chemical remaining, $F_A = C_A/C_A^*$, versus dimensionless time, $\log(D_A t/h^2)$, allowing the determination of compound lifetime for pore diffusion. Total decontamination time is thus the sum of results from Equation 5 for vaporization time and Equation 6 for vapor diffusion time.

Thibodeaux-Hwang AERR Model

Refinement of the "dried-out" zone approach to air emissions from land treatment of petroleum wastes has been carried out by Thibodeaux and Hwang (1982) and represents the state-of-the-art description for the volatilization of organics from land treatment operations. This model assumes an isothermal soil column, no capillary action through the soil layer, no adsorption in the soil pore space, and no biodegradation of applied organics within the soil column. The description of vapor movement through the soil/waste matrix is valid for surface or subsurface waste applications through the use of surface injection depth, h_s, and depth of penetration or plow slice depth, h_p (Figure 2).

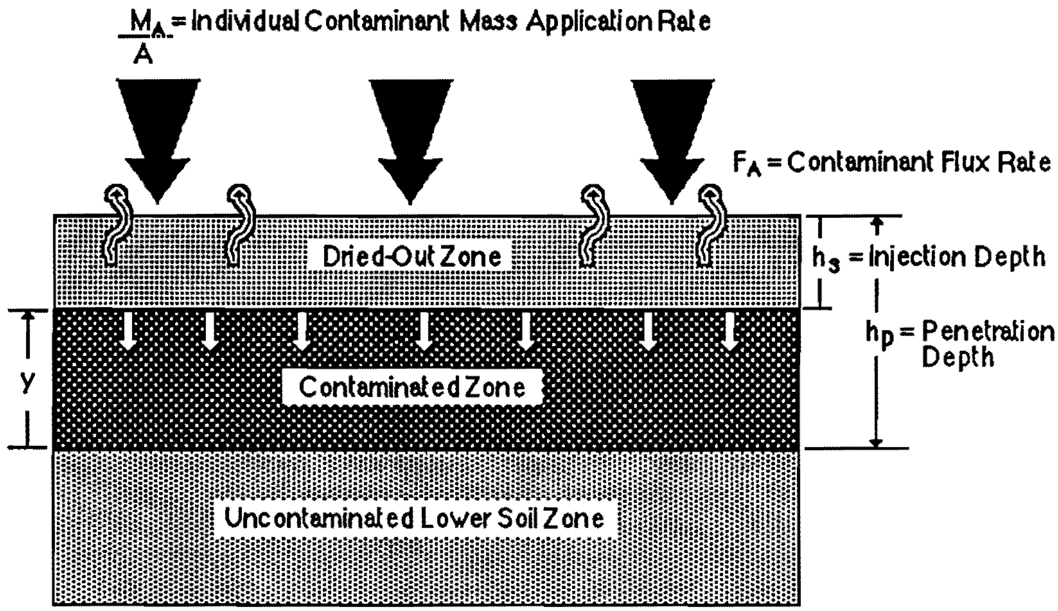

Figure 2. Theoretical contaminant behavior described by the Thibodeaux-Hwang AERR model. Adapted from Thibodeaux and Hwang (1982).

Under steady-state conditions, the time for the initial mass applied to the soil to completely volatilize into the soil pore space, t_e, and the mass flux rate of each component, F_A, are determined through a mass balance of the component assuming Fickian diffusion through the soil column. Assuming a component vapor concentration at the air/soil interface equal to 0, the following relationship for evaporation time can be developed:

$$t_e = \frac{M_A \cdot (h_p + h_s)}{2A \cdot D_A \cdot C_A^*} \tag{7}$$

while mass flux rate is given as:

$$F_A = \frac{D_A \cdot C_A^*}{\left(h_s^2 + \frac{2D_A \cdot t \cdot A \cdot (h_p - h_s) \cdot C_A^*}{M_A}\right)^{1/2}} \tag{8}$$

where: t = time after component application.

The component pore-space concentration, C_A^*, is related to the component concentration within the applied oil by equating the rate of movement through the oil phase to that through the dry soil column. The transfer rate equality takes the form of:

$$a_s \cdot A \cdot y \frac{Do}{Zo} \cdot (C_{io} - C_L) = \frac{D_A \cdot A}{(h_p - y)} \cdot (C_A^* - 0) \quad (9)$$

where: a_s = interfacial area per unit volume of soil, (length),
Do = component diffusion coefficient in the oil phase, (length^2/time),
Zo = oil-layer diffusion length, (length),
C_{io} = initial component concentration in the oil, (mass/length^3),
C_L = component concentration on the oil side of the air/oil interface, (mass/length^3),
y = average thickness of the wet zone, (length).

The concentration of the component in the air and oil phases within the soil pore space is related by a modified Henry's Law constant to yield:

$$C_A^* = H_{C'} \cdot C_L \quad (10)$$

where: $H_{C'}$ = Henry's Law constant with units of cm^3 oil/cm^3 air.

Substitution of Equation 9 into Equation 10 allows for the expression of the concentration of the component in the soil vapor phase in terms of its initial concentration within the oil as:

$$C_A^* = \left[\frac{H_{C'}}{1 + H_{C'} \cdot \dfrac{D_A \cdot Zo}{Do \cdot a_s \cdot y \cdot (h_p - y)}} \right] \cdot C_{io} \quad (11)$$

Estimating an average value for the lengthening dry zone diffusion path, $y \cdot (h_p - y)$, by the integral of $y \cdot (h_p - y)$ from 0 to $h_p - h_s$ divided by $h_p - h_s$ yields:

$$y \cdot (h_p - y) = \frac{h_p^2 + h_p \cdot h_s - 2h_s^2}{6} \quad (12)$$

Substitution of Equation 12 into Equation 11 results in Equation 13:

$$C_A^* = \left[\frac{H_{C'}}{1 + H_{C'} \cdot \dfrac{6 \cdot D_A \cdot Zo}{Do \cdot a_s \cdot (h_p^2 + h_p \cdot h_s - 2h_s^2)}} \right] \cdot C_{io} \quad (13)$$

The relative importance of the oil layer diffusion rate is highly dependent upon the oil-layer diffusion length, Zo, and the interfacial area, a_s, which are intimately tied to the waste application rate and the nature of the soil in the land treatment system. Thibodeaux and Hwang (1982) present equations for Zo and a_s for oil/soil interactions that result in either "film" forms or "lump" forms within the soil column. Oil interactions resulting in a thin coating around hypothetical particles result in film forms, while soil aggregation and clumping results in the entrapment of oil lumps within the soil matrix. Based on simple geometry and an assumed orthogonal arrangement of soil particles, a description of these physical parameters take the following form:

Film Form: Lump Form:

$$Zo = \frac{d \cdot \rho_p \cdot f}{6 \cdot \rho_o} \quad (14) \qquad Zo = \frac{d}{2} \quad (15)$$

$$a_s = 6/d \quad (16) \qquad a_s = 2.7/d \quad (17)$$

where: d = particle diameter, i.e., effective size, (length),
ρ_p = soil particle density, (mass/length^3),
ρ_o = oil density, (mass/length^3), and
f = fraction of oil in the film form = fraction of air filled pore space in soil.

The fraction of pore spaces that are air filled is assumed to be 50 percent, yielding an estimated f value of 0.5

If a thin oil diffusion length, on the order of soil particle diameter, can be assumed, Equation 13 can be simplified to Equation 18:

$$C_A^* = H_{C'} \cdot C_{io} \quad (18)$$

Under most land treatment applications expected, this Zo value would normally not be small, requiring the general use of the complete expression as given in Equation 13.

If the land treatment unit is tilled at time t less than the volatilization life-time of the hazardous constituents of interest, the equations above must be modified for the new geometry which results. The mass of contaminant lost during the period prior to tilling, M_{At}, is determined from the integration of Equation 8 from t = 0 to t = time of tilling, resulting in Equation 19:

$$M_{At} = \frac{M_A}{(h_p - h_s)} \cdot \left[\left(h_s^2 + \frac{2\, D_A \cdot A \cdot t \cdot (h_p - h_s) \cdot C_A^*}{M_A}\right)^{1/2} - h_s\right] \quad (19)$$

The mass remaining after time t, $M_{Ar} = M_A - M_{At}$, is then used in Equations 7 and 8 above to determine the evaporation time and mass flux rate for the residual mass from the tilled soil, assuming uniform mass distribution within soil column of dimensions h_p = tilling depth and $h_s = 0$.

With the use of Equations 7 through 19, the rate of organic emissions from land treatment sites before and after tilling can be determined once the following three sets of parameters are measured: 1) soil parameters including bulk density, particle diameter and particle density; 2) compound parameters including air and oil molecular diffusivity and modified Henry's Law constant; and 3) operational parameters including surface injection and penetration or plow splice depth, tilling depth, surface area of application, mass application, and time.

SECTION 5

MATERIALS AND METHODS

LABORATORY MATERIALS AND METHODS

Sampling train and Thibodeaux/Hwang AERR model evaluations were conducted on a laboratory scale. Sampling train evaluation consisted of a quantitative investigation of each of the system components, i.e., flux chamber, purge/sampling flow system, and sorbent collection/concentration tubes, along with a qualitative description of the applicability of system use for field applications in terms of ease of use, reliability, durability, etc. Flux chamber design and operation were evaluated based on chamber positive pressure development and potential flux rate suppression studies, and on tracer studies used to describe mixing conditions within the chamber during emission measurements as a function of purge gas flow rate through the chamber. Solid sorbent evaluation included the analysis of collection and recovery of pure compounds identified as major volatile components of petroleum refinery wastes, i.e., benzene, toluene, ethylbenzene, o-, m-, p-xylene, and naphthalene, and their mixtures using Tenax™ and charcoal sorbent tubes. Spike recovery and breakthrough analyses provided data for this evaluation. The effects of sampling stream moisture content on the collection and recovery efficiency of the charcoal tubes were also investigated. Finally, the combined flux chamber/sorbent tube sampling train was evaluated in terms of sampling train collection and recovery efficiency using mixtures of the pure compounds listed above.

Model evaluation was carried out using modular, beaded glass process pipe microcosm systems, and ground-glass erhlenmeyer flask screening apparatus used in conjunction with solid sorbent sampling/ concentration systems. Measured versus predicted pure compound emission rates were compared for several petroleum refining hazardous wastes under a range of soil, waste loading, and waste application conditions.

Solid Sorbent Evaluation

Although established solid sorbent collection and concentration procedures for a wide range of volatile hazardous constituents are available from the U.S. EPA (1984) and the U.S. Public Health Service (1978), limited work has been reported on their use in hazardous waste land treatment emission measurements. Criticism has been leveled against solid sorbent concentration methods by a number of authors (Walling 1984, Jarke 1985). This criticism pertains to sampling procedures with respect to quantification of sorbent collection, concentration, recovery and breakthrough efficiency. When applying solid sorbent collection methods to air emission measurements from land treatment facilities, concern over compound retention, breakthrough volume and recovery efficiency become even more critical than in ambient air sampling. Such concern is due to the elevated levels of constituents released from the soil surface, especially immediately following waste application. During this study, detailed compound collection and recovery data were collected for Tenax™ and charcoal sorbent tubes because of the importance of quantifying trapping efficiency on a compound specific basis.

Tenax™ Sorbent Tube Manufacture/Preparation--

All Tenax™ sorbent traps used in compound collection/recovery studies were prepared according to U. S. EPA EMSL/RTP (U. S. EPA 1981a) and Research Triangle Institute (RTI 1983) standard operating procedures for the cleanup and preparation of Tenax™ cartridges for use in volatile organic air contaminant sampling. Tenax™ sorbent traps consisted of 5 mm i.d., 10 cm long stainless steel tubing loosely packed in the interior 8 cm with 0.27 to 0.28 g of prepared Alltech Associates, Inc., 60/80 mesh Tenax™ GC solid sorbent material. Once packed, the traps were thermally desorbed for a minimum of two hours at 290°C to ensure the conditioning of packing material and to minimize background organic levels in the cartridges. A single trap from a lot of 20 was checked for background contamination via thermal desorption/GC-FID analysis. A cartridge was rejected and the lot was reconditioned if background contamination was evident. Once the cartridge tested as clean, cartridges in the lot were placed in muffled Teflon® lined screw capped culture tubes containing a clean glass wool plug to immobilize the cartridge. The culture tubes were then placed in air tight metal containers and stored at 2 to 4°C until needed. Tubes used in the study were prepared no earlier than three weeks prior to their use to accommodate the recommended maximum tube storage time of four weeks.

Charcoal Tube Preparation--

Charcoal sorbent tubes used in the study were NIOSH approved SKC standard 50/100 mg charcoal tubes (SKC#226-01). Standard NIOSH methods (U. S. Public Health Service 1978) were used in all blank and sample preparation procedures.

Laboratory Microcosm Units

Modular, 7.62 cm I.D., beaded glass process pipe microcosm systems were used in conjunction with Tenax™ solid sorbent traps for sample collection and concentration in laboratory AERR model validation studies. Figure 3 shows a typical microcosm unit which consisted of two 15.25 cm long body sections and removable bottom and top caps for ease of unit assembly and disassembly for cleaning. Sections of each unit are connected via Teflon™ lined pipe clamps to provide air and water tight seals at all joints. The top cap section had four glass inlet tubes to provide inlet and outlet ports for purge gas, a port for connection to a Magnehelic or manometer for pressure determinations, and a port for head space temperature and gas composition determinations. Brass Swagelok™ fittings with Teflon™ ferrules were used at all connections, with Teflon™ tubing used for all transfer lines to the point of split stream sorbent tube sampling. Tygon™ tubing was used downstream of the sampling point for purge gas venting to an enclosed hood for discharge from the experimental area.

Organic-free high purity breathing air was utilized as purge gas to eliminate the possibility of oxygen limitations to microbial reactions carried out during the volatilization experiments. A series of four microcosms were connected to a single purge gas source via balanced glass Y's, with flow balance checked by Magnehelic or manometer readings to ensure equal flow to each microcosm unit. Microcosm units were placed in a constant temperature room to eliminate temperature variation during a given run. Glass T's were provided in the effluent lines to allow the measurement of hazardous components in the microcosm purge gas via split stream sampling through Tenax™ packed solid sorbent tubes.

Volatilization Screening Flasks

A small scale laboratory unit for the screening of the volatilization potential of various soil/waste mixtures was evaluated in the laboratory phase of this study. The experimental apparatus used for these air emission measurements is shown in Figure 4. The system consisted of four 500 ml, ground glass neck, erhlenmeyer flasks with fitted glass aeration caps connected to a single high quality breathing air purge gas source via balanced glass Y's. The purge air flowed over the surface of the soil-waste mixture contained within each flask and exitted the aeration cap through an effluent tube close to the top of the flask. The flow path and configuration of the flasks encouraged effective mixing over the surface of the soil. Effluent purge gas containing volatile constituents from the soil-waste mixture left the flasks through Teflon™ tubing, passed glass T's used for split stream sampling, and was conducted via Tygon™ tubing

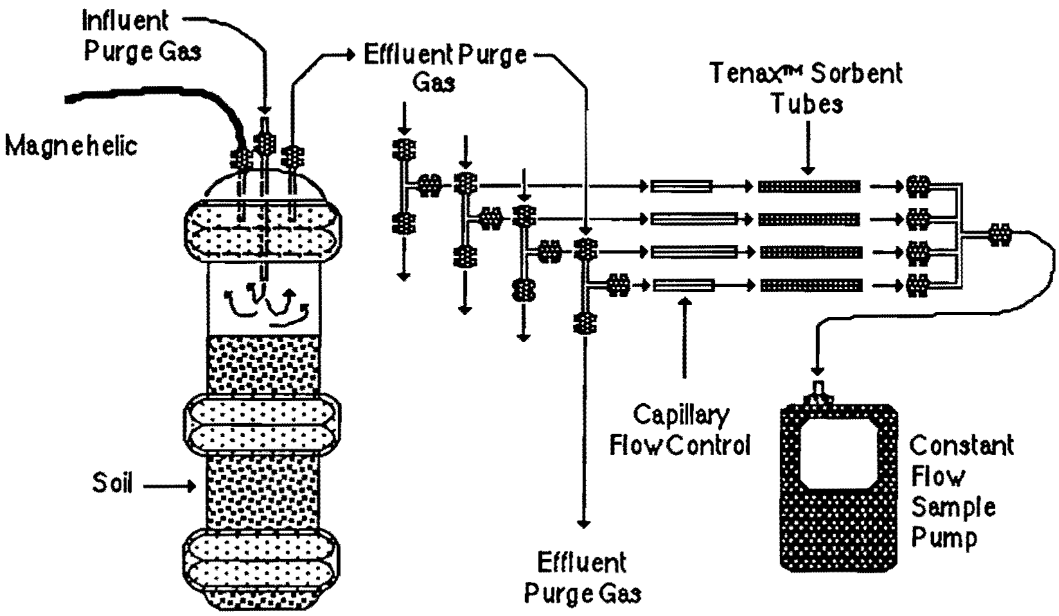

Figure 3. Laboratory microcosm apparatus used in laboratory AERR model validation studies.

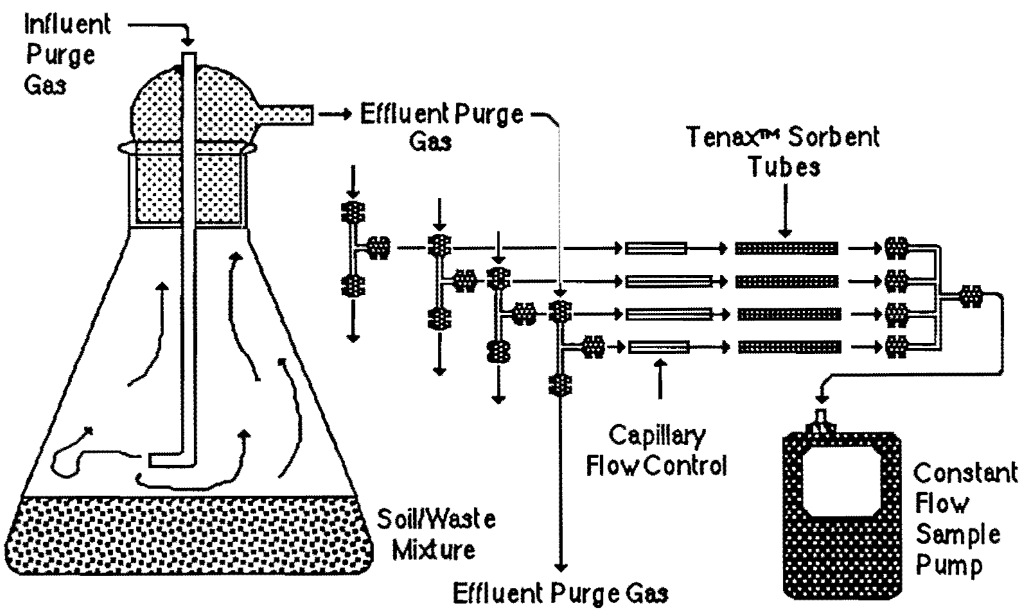

Figure 4. Screening flask apparatus used in laboratory AERR model validation studies.

to a vent for discharge away from the experimental area. Split stream sampling was conducted using a constant volume sample pump connected to a balanced, capillary flow controlled glass and Teflon™ sampling manifold.

Waste/Soil Characterization Methods

Two listed hazardous wastes from the petroleum refining industry were utilized in laboratory experiments, an API Separator Sludge and Slop Oil Emulsion Solids collected at a refinery in the Salt Lake City, Utah, area. Constituent analyses were conducted on methanol extracts of samples of the waste used in each laboratory experiment. The extract procedure used was a modification of Method 5030 "Purge-and-Trap Method" (U. S. EPA 1982a), in which 3 to 5 g of waste are extracted with 40 ml distilled in glass methanol, the mixture is centrifuged, and the centrate is stored without headspace at 4°C prior to analysis via purge and trap/GC-FID detection. Pure constituents of interest, i.e., benzene, toluene, ethylbenzene, p-, m-, o-xylene, and naphthalene, were quantified via standard spike recovery analysis procedures. Waste oil and grease content was determined utilizing a modified freon soxhlet extraction/gravimetric procedure (SOP-21) employed by the U. S. EPA , Robert S. Kerr Environmental Research Laboratory (RSKERL), Ada, Oklahoma. Water content was determined using ANSI/ASTM Method D95-70, "Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation."

Waste physical parameters were determined according to standard methods including: 1) density using the Pycnometer Method-Method 29 (American Society of Agronomy 1965), and 2) viscosity using ANSI/ASTM Method D445-74, "Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)," (ASTM 1977).

Soil parameters evaluated during the study included: 1) media particle size distribution via Dry Sieve Analysis-Method 43-4.3 (American Society of Agronomy 1965), 2) particle density using Pycnometer Method-Method 29-3 (American Society of Agronomy 1965), and 3) bulk density via gravimetric measurement of a known volume of media in flask and microcosm units. All other physical soil parameters used in the study were calculated from these measured parameters. Boundary condition measurements, i.e., h_p and h_s, were determined in the laboratory experiments by visual identification of the wetting front. Penetration depth and subsurface application depth values are reported as length measurements with respect to the soil surface using a flexible, graduated ruler attached to the outside surface of the laboratory units.

Soil chemical parameters evaluated included: 1) soil organic carbon using Method 505-Organic Carbon (Total) Combustion-Infrared Method (AWWA 1981), 2) oil and grease using RSKERL SOP-21, and 3) specific organic constituents by methanol extraction/purge and trap analysis using a modified Method 5030 (U. S. EPA 1982a).

FIELD MATERIALS AND METHODS

The ultimate objective of this research project was to provide field evaluation of the Thibodeaux-Hwang AERR model for the prediction of volatile organic emissions from land treatment facilities. Field studies involved the use of a sampling chamber, termed an "emission isolation flux chamber", for the collection and concentration of volatile organics emitted from a soil surface following waste application. The use of an enclosed chamber for the measurement of gases released from soil and plant surfaces has been widely practiced in the soil and biological sciences (Hill et al. 1978, Adams et al. 1978, Jury and Collins 1982, Johensson et al. 1983), however, the method has been only recently applied to the investigation of volatile hazardous emissions from land treatment facilities. Flux chambers used in this study were evaluated on a laboratory scale for the quantification of pure compound collection efficiency, and chamber mixing and pressure development relationships prior to being used in field sampling activities.

Flux Chamber Design

An "emission isolation flux chamber" encloses a defined head space above a defined soil surface area. An organic-free purge gas is introduced into the chamber at a known controlled rate to sweep volatile contaminants out of the chamber for collection/concentration by any means appropriate for the contaminants of interest. The flux chamber investigated in this study was a modification of a design developed for the U. S. EPA Environmental Monitoring Laboratory, Las Vegas, Nevada, by Radian Corporation (Schmidt and Balfour 1983, Balfour et al. 1983, Eklund 1985). It consisted of a 68.7 x 68.7 cm square exterior dimension (effective emission surface area=4560 cm^2), clear acrylic double-domed skylight modified for isolation flux sampling as shown in Figure 5. The acrylic double-dome interior was lined with opaque, adhesive Teflon™ tape to provide a non-adsorbing, non-reactive interior surface, and to prevent contamination of the sampling system via out-gassing from the chamber interior. Double-dome construction, as well as the opaque lining, were incorporated into the design as it was felt these characteristics would serve to reduce the effects of incident radiation on heating within the chamber when used for emission sampling in field monitoring studies. Teflon™ was used for all bulk head fittings and purge gas inflow and outflow lines to provide an inert surface in all areas of the chamber. Bulk head openings were provided for influent and effluent lines as well as for temperature and chamber interior pressure determinations.

Sampling System Design

A high-purity breathing air purge gas was passed through the flux chamber via a constant volume sampling pump operated at rates of 2 to 6 liters/minute during sampling events. The sampling pump provided energy to overcome interior chamber pressure development so high purge rates and short chamber residence times were possible without the occurrence of large differential pressures between chamber interior and ambient exterior conditions. Purge gas flow adjustment was made via a glass and Teflon™ Gilmont micro-valve flow controller. Flow calibration was carried out using a 1 liter bubble tube flow meter, and interior pressure measurements were determined by means of a Dwyer Magnehelic gauge reading 0.5 inches water full-scale.

Solid sorbent traps were sampled through a glass T similar to those described above for the laboratory experimental units. The traps were connected to the chamber effluent line via a Teflon™ and glass three-place, constant flow, capillary manifold, with all connections made via brass or stainless steel, Teflon™-lined Swagelok® connectors. The effluent of the sorbent traps was connected to a second glass manifold, to which an additional constant rate sampling pump, operated at 200 to 300 ml/minute/trap, was connected. The second sampling pump was used to overcome the large pressure drop developed through the manifold/sorbent tube system, thus preventing additional pressure build-up and potential vapor suppression within the sampling chamber.

Effluent sampling pump flow rate calibration was conducted on-site using a bubble tube flow meter. An effort was made to adjust purge gas flow rates by monitoring interior chamber pressure with Dwyer Magnehelics, however, the soil at the field site was too porous to provide an air tight seal between the chamber and soil surface. Purge gas flow rates were subsequently adjusted to purge pump flow values based on bubble tube flow meter calibrations carried out in the field before each major sampling event, or at least two times daily, to ensure minimal pressure development during sampling.

Temperature measurement of the chamber air space, 0.64 cm soil depth and 5.1 cm soil depth under the sampling chambers were made using a thermocouple/electronic readout system accurate to $\pm$ 0.1°C.

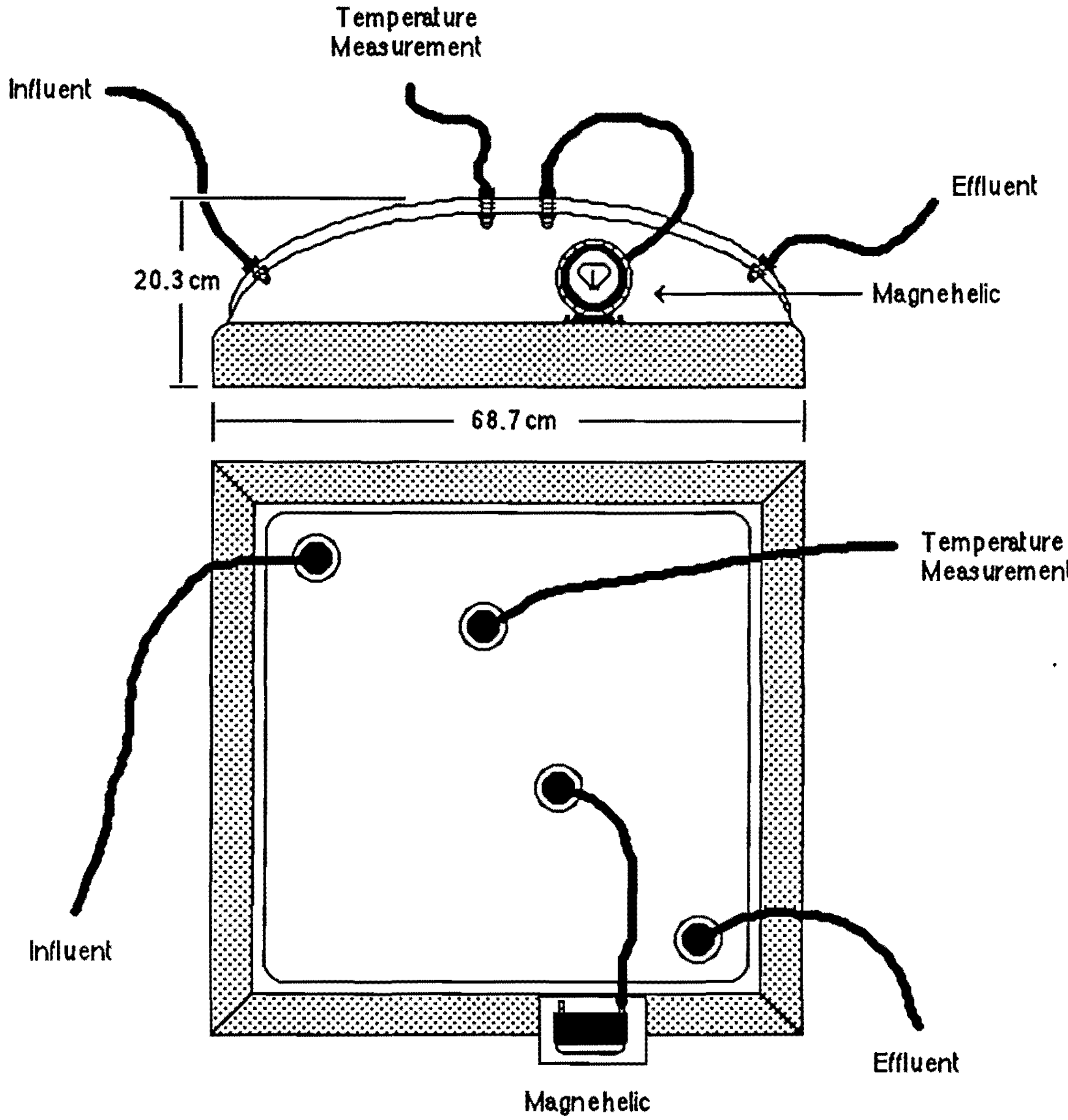

Figure 5. Schematic of isolation flux chamber evaluated in study.

Temperature readings were taken manually prior to, during and following each sampling period during each sampling event.

Waste/Soil Characterization Methods

Waste samples at flux chamber locations were collected in 6 inch x 27 inch x 4 inch sheet metal pans placed on either side of the flux chamber sampling locations, perpendicular to the long axis of the land treatment application area. These sample collection pans were used for mass application rate measurements, and for sample collection for physical/chemical property and specific constituent concentration determinations. The collection pans were removed from the application area following passage of the waste application vehicle, and were immediately analyzed on-site gravimetrically using a top loading balance for application rate determinations. The total sample volume of the two pans at each sampling site were composited. Aliquot waste samples were subsequently collected for density, viscosity and specific constituent measurements as being characteristic of the waste applied at specific sampling locations within the land application site. Duplicate samples were collected in 500 ml VOA bottles with Teflon™ lined screw caps, making sure no head space was present following collection. All samples were stored at 2 to 4°C prior to transport to UWRL facilities for final analysis. Specific VOC analysis samples were analyzed via purge and trap Method 5030 (U. S. EPA 1982a) following methanol extraction no later than 12 hours after collection. In addition to 12 waste samples analyzed on-site via GC analysis, six samples were shipped at low temperature via overnight express to the UWRL for preparation via methanol extraction prior to GC/MS analysis at UWRL facilities. One composite waste sample also was prepared and shipped to the RSKERL for GC/MS analysis at that facility. Waste oil and grease content and physical parameters were determined as described for laboratory scale experiments.

Composite soil samples for particle size distribution, particle density, oil and grease, and specific constituent analyses were manually collected with a trowel from the surface to a 15 cm depth. Samples were composited and stored at 2 to 4°C in air-tight, zip-lock freezer bags for transportation to the UWRL and the RSKERL (oil and grease samples) for final analysis. Bulk density and moisture content samples were collected according to Core Method-Method 30-2 (American Society of Agronomy 1965) using a core sampler from the upper three inches of the soil surface. These samples were transferred to air-tight, zip-lock freezer bags and stored at 2 to 4°C prior to analysis on site at the refinery facility. All soil analyses in the field study were conducted using standard procedures as described for laboratory studies. The magnitude of h_p prior to tilling was determined by visual identification of the bottom of the wetting front during field excavation activities during which composite soil samples were collected. The plow splice depth, h_p, following tilling was estimated by visual observation of subsurface soil conditions at each sampler location following each tilling event. All penetration depths are reported as length measurements with respect to the soil surface as determined using a graduated ruler.

ANALYTICAL METHODS

Analyses of the Tenax™ sorbent tubes were carried out using a Tekmar LSC-1 Liquid Sample Concentrator equipped with a modified trap oven to accommodate the 2 mm x 10 cm, thin walled, stainless steel sorbent tubes using desorbe and trap bake temperatures of 250°C and a desorb time of 4 minutes. Samples were desorbed into an HP 5880 Gas Chromatograph equipped with an FID detector. A 2 m long, 2 mm i.d. small bore glass column packed with SP-1200/1.75% Bentone® 34 on 100/120 Supelcoport was used for compound separation and quantification. The following GC conditions were used throughout the study period:

Injector Temperature = 250°C Detector Temperature = 250°C Carrier Flow = 35 ml/min
Oven Temperature Program:
- Initial Temperature = 35°C Initial Time = 4 minutes
- Program Rate 1 = 2°C/min to 60 °C, no hold time
- Program Rate 2 = 10°C/minute to 165°C, 20 minute hold time.

Analyses of charcoal sorbent tube carbon disulfide extracts were carried out via direct injection into an HP 5880 gas chromatograph using column, injector, oven and temperature programming conditions as described above.

Analyses of methanol extracts of waste samples and field and laboratory soil/waste mixtures were carried out according to standard GC and GC/MS protocol, "Volatile Aromatics-Method 8020" utilizing "Purge and Trap-Method 5030" procedures (U. S. EPA 1982a) for sample concentration and injection. The best analytical results were obtained in the purge and trap procedures using a waste methanol extract:distilled water ratio of 0.5 ml:100 ml. This ratio was used for all liquid purge and trap samples analyzed during the study. An HP 5880 gas chromatograph was used for all methanol extract analyses, and all GC conditions were identical to those listed above.

GC/MS analyses were conducted for: 1) direct injection standards, 2) thermally desorbed spike, blank and field sample sorbent tubes, and 3) purge and trap/thermally desorbed methanol extracts of wastes. An HP 5985B GC/MS/Data System was used. All analyses were conducted in a manner similar to that described previously for the HP 5880 GC. The mass spectrometer was tuned prior to analyses using perfluorotributylamine (PFTBA) and the HP "Autotune" program which optimizes ion source, mass filter, and electron multiplier parameters for optimum sensitivity, peak resolution and mass axis calibration. A DFTPP abundance normalization program was also run to meet EPA specifications for spectral reproducibility. All samples were analyzed using the glass packed SP-1200/1.75% Bentone® 34 on 100/120 Supelcoport column because of the separation it provides for the three xylene isomers of interest in the study. Table 1 provides a summary of the GC/MS analysis conditions used.

QA/QC PROCEDURES

The Quality Assurance Plan submitted for Cooperative Agreement CR-810999-01-0 served as the basis for QA/QC procedures for the laboratory and field studies conducted during this research project.

A minimum of ten percent of the sampling/analysis effort in both laboratory and field phases of the project was devoted to quality control in the form of spikes, blanks, replicate analyses, and performance audit samples. Duplicate analyses by the UWRL and the RSKERL for field waste sample specific volatile constituent identification/quantification, and soil and waste oil and grease analysis also provided additional quality control checks for the accuracy and validity of sampling, concentration and analysis methods used for these parameters in the study. A summary of measurement methods and data quality objectives used for maintenance of data quality throughout the project is presented in Table 2.

Field method blank and spiked blank sampling, along with replicate analyses carried out via sampling of three (plus breakthrough) parallel sorbent traps during the background and sample collection periods, provided quality control during field activities. Ten randomly selected sorbent tubes, including blanks and tubes used for actual sample collection and concentration, were spiked with a mixture of a known mass of the volatile compounds of interest prior to their use in field sampling. This sample spiking allowed an evaluation of the impacts of sampling activity on recovery efficiency due to sample collection and transport as well as from unexpected compound breakthrough. Spiked sorbent tubes were prepared at the refinery laboratory facility according to EMSL/RTP (U. S. EPA 1981b) "Standard Operating Procedure for the Preparation of Tenax Cartridges Containing Known Quantities of Organics Using Flash Vaporization." Blank traps (22 randomly sampled during field activities) were removed from their culture tubes, were exposed to the atmosphere for 10 to 15 seconds, were returned to their culture tubes, and were stored, transported, and analyzed as all other traps used in field sampling. These blanks were used to indicate compound background levels occurring during sample collection.

The QA/QC goal of analyzing a minimum of 90 percent of all samples collected in the laboratory and field sampling effort was met through the successful analysis of greater than 98 percent of all samples collected.

TABLE 1. GC/MS ANALYSIS CONDITIONS

Instrument:	
Gas chromatograph:	HP 5840
Mass spectrometer:	HP 5985B
Data system:	HP
Column:	2 m x 2 mm small bore glass packed column SP-1200/1.75% Bentone® 34 on 100/120 Supelcoport
Temperature program:	35°C (4min) to 60°C at 2°C/min, no hold time, then to 165°C at 10°C/min with 20 min final hold time
Injector temperature:	290°C
Transfer line temperature:	300°C
Carrier gas:	Helium at 30 ml/min
Thermal desorption:	LSC-1, Desorption temperature=250°C Desorption time=4 min
Purge parameters:	Purge flow rate=30 ml/min Purge time=12 min
Solvent:	Methanol (distilled-in-glass)
Mass spectrometer operating conditions:	
Ion source temperature:	280°C
Ionization energy:	70 eV
Trap current:	200 μA
Electron multiplier:	-1.75 kV
Scan range:	50 to 450 amu
Scan speed:	1 to 2 sec/scan

TABLE 2. MEASUREMENT METHODS AND DATA QUALITY OBJECTIVES FOR WASTE AND SOIL ANALYSES

Parameters	Method	Measurement Method/ Instrumentation	Precision	Accuracy
A. Wastes:				
Organic Constituents	3500 Series* 5000 Series* 8000 Series*	Extraction or purge and trap; analysis by HPLC, GC, or GC/MS	± 20%	± 20%
Inorganic Constituents (metals)	3500 Series* 7000 Series*	Digestion; analysis by flame AA, flameless, AA, or ICP	± 10%	± 10%
Residue	Section 160.1, 160.2† Method 209#	Suspended solids; volatile suspended solids; total solids; total dissolved solids	± 10%	Not applicable
Total Organic Carbon	Method 505#	Infrared with persulfate and heat digestion; carbon analyzer	± 10%	± 15%
Oil and Grease	Section 413.1+ Method 503#	Partition-gravimetric method	± 15%	± 18%
Viscosity	Method D445-74 ‡	Flow time through capillary viscometer	± 10%	±5 %
Density	Chapter 29 **	Pycnometer method	± 10%	±5 %
Particle Size Distribution	Chapter 43 **	Hydrometer method	± 10%	Not applicable
Total Porosity	Chapter 21 **	Density method	± 20%	Not applicable
Air-Filled Porosity	Chapter 21 **	Difference method	± 20%	Not applicable
Bulk Density	Chapter 30 **	Core method	± 20%	Not applicable

TABLE 2 (continued)

Parameters	Method	Measurement Method/ Instrumentation	Precision	Accuracy
Particle Density	Chapter 29 **	Pycnometer method	± 10%	Not applicable
Moisture Content	Chapter 7 **	Gravimetric	± 20%	Not applicable
Total Organic Carbon	Chapter 29 †† Method 505#	Combustion; carbon analyzer	± 10%	± 15%
Oil and Grease	Section 413.1+ Method 503#	Extraction method for sludge samples	± 15%	± 18%
Organic Constituents	Chapter 6 †† 3500 Series* 8000 Series*	Extraction; analysis by HPLC, GC, or GC/MS	± 20%	± 20%
hp and hs		Direct observation of wetting front, ruler measurement	± 10 %	Not applicable
C. Pure Volatile Constituents:				
	Volumes 1 through 4 ##, Adsorption Collection Techniques	Solid sorbent collection; Desorption/extraction; analysis by HPLC, GC, or GC/MS	± 5%	± 10 %

* U. S. EPA (1982a).
† U. S. EPA (1979).
\# APHA (1980).
‡ American Society for Testing and Materials (1977).
** American Society of Agronomy (1965).
†† American Society of Agronomy (1982).
\## U. S. PHS (1978).

Representativeness of soil samples used in laboratory experimental studies was ensured through the use of standard sieving and sampling procedures for two soils (Durant Clay Loam and Kidman Sandy Loam) and a clean construction sand. A single supply of each soil medium was used throughout the laboratory phase of the project to ensure relative uniformity of soil material and comparability between laboratory runs conducted during the course of the project. Waste sample (API Separator Sludge K051 and Slop Oil Emulsion Solids K049) representativeness during laboratory studies was ensured through the use of a single supply for each waste type along with standard mixing and sampling procedures for waste aliquot collection. A methanol extract/purge and trap waste characterization was also carried out for each waste aliquot collected.

Field data representativeness and comparability was ensured through the use of standard sampling techniques for all soil, waste, sorbent tube and temperature samples collected. Sampling pans and waste compositing for waste application rate measurements at each sampling location were used to provide an accurate point determination of waste and constituent loading. Soil samples for residual waste component measurements and physical soil parameters were composited from the surface to 15 cm to provide representative values over the active soil incorporation zone.

Method calibration procedures were checked on a daily basis. Corrective action was taken if analyzed known standards deviated more than 10 percent from the standard calibration curves used as a basis for sorbent tube constituent quantification. Performance audits were conducted prior to the initiation and at the conclusion of the field sample activities and were passed without modifications to sampling and/or analysis procedures. Both field and laboratory sorbent tube chromatograms were identified according to the labeling system utilized in field sample collection, were analyzed for specific compounds of interest, and were retained for future reference.

Sample custody forms were generated for each field sample and blank collected (Figure 6) and were used to ensure proper handling, treatment and data evaluation for all samples analyzed. Standardized data forms for collection and computer calculation of data using electronic spreadsheet software ensured and facilitated the generation of accurate, complete, and comparable data throughout the study.

Sample Custody Form

Sample Type________ Sample Number ________

Flow Rate _____ ml/min Sampling Start Time _____

Sampling Duration ________ min

Analyses to be Conducted ____________

VOC ____________

GC GC/MS ____________

____

Sampled by __________ Analyzed by ____________

Date Sampled __________ Date Analyzed ____________

Blank YES NO Spiked Blank YES NO

Figure 6. Sample custody/analysis form used for field samples.

SECTION 6

EXPERIMENTAL PROCEDURES

LABORATORY PROCEDURES

Sampling is a key step in the measurement and detection of contaminants for evaluation and analysis of models for use in predicting the fate of such contaminants in the environment. The flux chamber sampling unit and solid sorbent collection/concentration system used in this study were evaluated in terms of contaminant collection and recovery efficiency, breakthrough volumes as a function of collection mass and temperature, allowable sampling and purge flow rates, sampling configuration, ease of use and system durability.

Solid Sorbent Collection/Concentration System Evaluation

Tenax™ Sorbent Collection/Concentration Evaluation--

Tenax™ recovery data were collected for a number of aromatic compounds identified in hazardous wastes evaluated in laboratory and field emission studies including: benzene, toluene, o-, m-, p-xylene, ethylbenzene and naphthalene. These data were collected utilizing U. S. EPA EMSL/RTP (U. S. EPA 1981b) standard operating procedures for the spiking of Tenax™ cartridges with a known mass of an organic constituent. The procedure involves the use of a flash vaporization technique (Figure 7) in which a microflow valve controlled organic-free nitrogen purge gas passing through a 5 mm i.d., 13 cm long L-shaped glass injector tube, is heated to approximately 300°C. A half-hole septum provides gas-tight access for sample injection into the heated zone, and a Teflon® lined Swagelok® connector is used for attachment of sorbent traps to the effluent end of the injector tube. Spiking procedures were carried out as follows: 1) the heating unit was brought to temperature with a constant purge flow passing through it, 2) two sorbent traps were removed from cold storage and were connected in series to the effluent of the injector tube using Teflon® lined Swagelok® connectors, 3) a 10 µl syringe was inserted into the half-hole septum and from 2 to 5 µl of standard solution (pure compounds dissolved in distilled-in-glass methanol) were slowly injected into the center of the heated section, 4) the syringe was removed from the half-hole septum and the traps were left on the unit to concentrate the desired purge sample volume, and 5) at the completion of the desired sampling time, the traps were removed from the injector tube, were placed in their respective labeled culture tubes and were then placed in cold storage prior to GC/FID analysis. Data were collected for compound mass injection levels ranging from 0.09 to 250 µg. Spikes for recovery/desorption efficiency experiments were prepared using a sample volume of 200 ml (purge flow of 40 ml/min for a sample time of 5 min) which corresponds to the approximate breakthrough volume of methanol solvent.

Data evaluation consisted of quantification of the mass recovery of the seven pure volatile constituents of interest from the Tenax™ sorbent tubes, and was based on calibration data generated from direct on-column injection of the same standard solutions used in sorbent tube spiking procedures. Results were reported as percent of injected constituent recovery as a function of mass injection level.

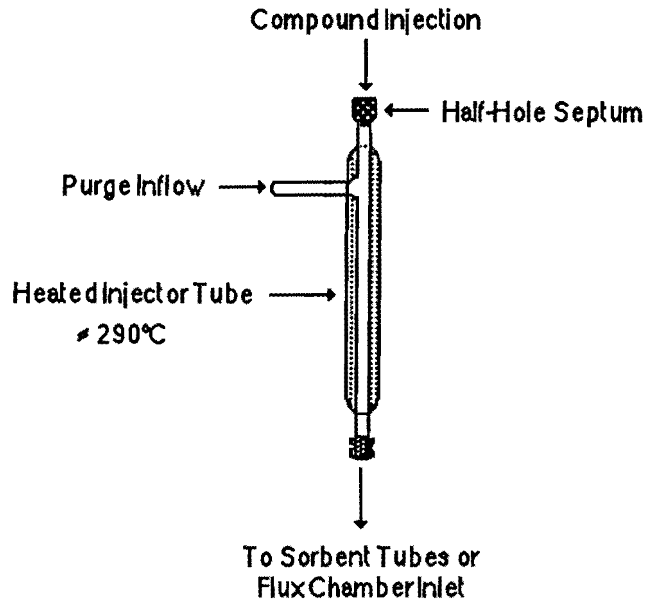

Figure 7. Schematic of flash evaporation unit utilized for Tenax™ sorbent tube spiking, chamber mixing studies and sorbent tube/chamber recovery studies.

Charcoal Sorbent Collection/Recovery Evaluation--

Charcoal sorbent tube recovery data were obtained for the same pure volatile compounds used in the Tenax™ studies according to standard NIOSH (U. S. PHS 1978) methods for all charcoal blank and sample preparation procedures. These methods entail: 1) breaking the ends off the tubes and sealing them with parafilm, 2) injecting a known mass of each compound in 20 to 40 µl of hexane solution directly into the primary charcoal bed with a microliter syringe, 3) allowing the tube to stand at least overnight to ensure complete adsorption, and 4) desorbing each section of the charcoal tube in 1 ml of carbon disulfide for at least 30 minutes on a shaker table prior to GC analysis for constituent quantification. Analyses of constituents in the carbon disulfide were carried out via direct injection into an HP 5880 gas chromatograph using column, injector, oven and temperature programming conditions described in Section 5 of this document.

Experiments pertaining to the effects of moisture on compound recovery efficiency were conducted using the charcoal tubes. Charcoal has a known affinity for water which can potentially interfere with volatile constituent/charcoal sorption interactions. Procedures in these experiments were identical to those described earlier except that an additional 30 µl volume of distilled water was added to charcoal tubes following compound spiking in the hexane solution. The sorbent tubes to which water was applied were allowed to equilibrate for 48 hours before being desorbed and analyzed via GC/FID procedures. This provided adequate time for the complete adsorption of compounds and moisture by the charcoal.

Quantification of the mass recovery of the seven pure volatile constituents of interest from the charcoal sorbent tubes was based on calibration data generated from direct on-column injection of the same standard solutions used in sorbent tube spiking procedures. Results were reported as percent of injected constituent recovery as a function of mass injection level for individual constituents, constituent mixtures, and constituent mixtures with moisture.

Sorbent Tube Breakthrough Evaluation--

Due to difficulties in consistently recovering naphthalene from the charcoal tubes at efficiencies greater than 50 percent, only Tenax™ traps were used for breakthrough volume evaluation studies. Tenax™ breakthrough analyses were conducted using the procedures described earlier for Tenax™ Sorbent Collection/Concentration Evaluation. Injected mass levels of 1.1 to 120 µg were used at collection temperatures of 20-22°C and 32-35°C. A purge flow rate of 200 ml/min, comparable to that used in laboratory and field emission measurements, was used in these experiments for time periods of 5 minutes to 2 hours. This procedure resulted in sample volumes ranging from 1 to 24 liters. Breakthrough experiments were conducted in a constant temperature environment, with temperature and purge flow rate monitored at 15 minute intervals during breakthrough sampling. Flow rate adjustments were made using a glass microflow valve to provide constant flow rates during the runs.

Quantification of the mass recovery of the seven pure volatile constituents of interest from the primary and secondary (breakthrough) Tenax™ sorbent tubes was based on calibration data generated from direct on-column injection of the same standard solutions used in sorbent tube spiking procedures. Results were reported as percent total constituent recovery on both traps as well as mass recovered and percent of injected constituent recovered on each sorbent tube as a function of mass injection level, temperature, and sorbent tube collection volume.

Flux Chamber Evaluation--

Flux chamber pressure and mixing studies--The flow regime within the flux chamber is of critical importance as component emission rate calculations are based on the assumption that emission measurements from the chamber effluent are representative of a completely-mixed chamber volume (Schmidt and Balfour 1983, Balfour et al. 1983, Eklund 1985). In addition, adequate flow and turbulence must be provided to assure no component mass accumulation within the chamber that may affect the component's flux from the soil surface into the lower atmosphere (Thibodeaux and Hwang 1982, Hwang 1985). Counter to the desire for maximizing flow and turbulence within the flux chamber is the need for minimizing positive pressure development within the chamber due to its potential for emission suppression and possible flux reversal during emission sampling.

The impact of purge flow rate on chamber pressure development was evaluated through monitoring chamber interior pressure (with respect to ambient), indicated by a Dwyer Magnehelic, as a function of purge flow determined at the chamber effluent port. A Teflon™ coated acrylic sheet was used to seal the bottom of the chamber making it air tight. Pressure determinations were made over a range of purge flows from 0.7 to 4 l/min as suggested in Radian protocol (Schmidt and Balfour 1983, Balfour et al. 1983, Eklund 1985). Results were presented as interior pressure in inches of water as a function of purge flow through the flux chamber.

Mixing within the flux chamber as a function of purge flow rate was evaluated using standard tracer techniques. The flash vaporization apparatus described earlier was placed up-stream of the flux chamber and was used to vaporize the liquid acetone used as a tracer. Continuous output of chamber effluent acetone vapor concentrations were obtained using an AID Model 81 portable GC equipped with a photoionization detector. Flow curves were evaluated utilizing standard procedures (Marske and Boyle 1973) to provide a quantitative description of chamber mixing conditions in terms of dimensionless indicator retention time parameters and the Morril dispersion index.

Flux chamber/sorbent tube collection/recovery evaluation--Contaminant collection and recovery efficiency for the combined flux chamber/solid sorbent sampling train was evaluated at 22°C ± 2°C to indicate the effect if any the flux chamber had on observed mass recovery efficiency results for the Tenax™ sorbent collection/concentration tubes. The flux chamber was configured as described earlier for the mixing studies, with a four position Tenax™ sorbent split-stream sampling system placed in the effluent purge gas line. The solid sorbent tubes (sampling and breakthrough traps) were connected to the chamber effluent line via a Teflon™ and glass constant flow, capillary manifold with all connections made via brass or stainless steel, Teflon™ lined Swagelok® connectors. The effluent ends of the sorbent traps were connected to a second glass manifold to which a constant flow personal sampling pump, operated at 800 ml/min (200 ml/tube/min), was connected.

Compound recovery data using the flux chamber/sorbent tube sampling train were collected in a manner identical to that explained earlier for the Tenax™ trap spike recovery experiments except that: 1) data were collected for compound mass levels ranging from 0.5 to 90 µg, 2) chamber purge flow was maintained at 4 l/minute, and 3) sampling continued for three theoretical chamber retention times to ensure representative sampling of the chamber volume. Sorbent traps were analyzed as described previously, and individual trap data were pooled to indicate overall recovery efficiency, contaminant breakthrough, and collection variability between positions on the constant flow sampling manifolds.

Volatilization Screening Flask Experiments--

A specific soil/waste treatment was routinely set-up in triplicate along with a soil blank, or as two treatments run in duplicate, for each volatilization screening experiment. The units were maintained at room temperature (22°C ± 2°C) during the screening studies. All units were simultaneously sampled at various time intervals to evaluate the measured volatilization potential of various soil/waste/application rate combinations using a simple screening apparatus for comparison with model predictions and more elaborate experimental units.

An experimental run was initiated by first placing 200 g of the actual field soil within each test unit. At time t=0, the appropriate amount of waste was added to the soil in the flask, the soil/waste mixture was quickly mixed, and the test unit was quickly capped. Once capped, event timing was begun, the purge gas was initiated at a microflow valve-controlled rate of 200 ml/min. Initial emission measurements were obtained by drawing a split stream sample of flask effluent gas through the sorbent traps via a constant volume sample pump and a balanced, capillary flow controlled, four-place sampling manifold. This procedure allowed the concurrent sampling of all flask units for the same period of time and during the same time period over the volatilization run. Sample pump rate and purge gas flow rates were measured before each sampling event via a bubble tube flow meter, and the duration of the sorbent tube sampling was recorded for accurate emission flux rate calculations. The sorbent traps were sampled at a rate of 200 ml/min/trap for a period not exceeding five minutes to minimize breakthrough of benzene. Breakthrough traps were used in at least the first five sampling events to allow the quantification of breakthrough that occurred during this time. All mass flux values were calculated with the inclusion of this observed breakthrough mass.

Upon completion of the sampling event, the sorbent tubes were placed in muffled culture tubes and were stored at 4°C for a maximum of four weeks prior to specific component identification via GC/FID analysis. Sorbent tube desorption was carried out using a Tekmar™ LSC-1 liquid sample concentrator as described in Section 5, with sample tubes desorbed for four minutes at a temperature of 250°C prior to component separation and identification.

The sampling and analysis procedure was repeated at selected time intervals following waste addition corresponding to the anticipated log decay in emission rates of volatile organics from the soil systems. Although specific sampling times varied between runs, the general sampling schedule followed was: 15 min, 1 hour, 2.5 hour, 10 hour, 24 hours, 50 hours and 100 hours. Blank and spike traps were used throughout the sampling period and during sorbent tube analysis to maintain QA/QC standards during these studies.

For each volatile constituent of interest, the calculation of measured mass collected in the flask effluent gas versus time was made. Measured emission rates (mass/area/time) as a function of time and 1/time$^{1/2}$ were then calculated based on the soil surface area exposed to the purge air, the fraction of purge air actually sampled through the traps, and the cumulative time during effluent sampling.

Microcosm Experiments--

Two soil/waste treatments were routinely set-up in duplicate, with four microcosms sampled as a unit in each microcosm experiment. The microcosms were maintained in a constant temperature room at various temperatures during the studies to evaluate the effect of temperature on observed pure constituent emission rates.

An experimental run was initiated by first placing a given depth of soil media within a microcosm unit, the depth being dependent upon the application method being simulated during the run, i.e., surface or subsurface. A maximum application of depth of approximately 15.24 cm (6 inches) is possible with the two-piece body shown in Figure 3, while deeper application depths are possible with additional body units connected in series. The mass of soil added to each unit was measured for as placed bulk density calculations. Waste was then applied to the soil in the units at time t = 0 in a rapid and as uniform a fashion as possible. The application rates used were based on a weight percent of waste applied with respect to the top 15.24 cm (6 inches) of soil in the microcosms. If subsurface injection was simulated, the appropriate amount of soil was added to the unit immediately following waste application to provide the desired soil depth above the application point. The units were then capped and sealed air tight, event timing was initiated, and purge gas was started and maintained constant at 300 to 500 ml/min/microcosm during the volatilization experiments.

Glass T's were provided in the effluent lines to allow the measurement of components in the microcosm purge gas via split stream sampling through Tenax™ packed solid sorbent tubes. Air sampling consisted of drawing a constant volume sample of microcosm effluent gas through the sorbent traps via a constant volume sample pump and a balanced, capillary flow controlled, two- or four-place sampling manifold. Separate sampling of surface and subsurface microcosms was necessary when they were used within the same microcosm run due to the higher emission rates produced from surface application with respect to lower emission rates when subsurface waste application was utilized. This procedure allowed the concurrent sampling of identical waste application method microcosm units (i.e., surface versus subsurface) for the same period of time and during the same time period over the volatilization run. These methods also allowed the use of sampling rates and sampling durations that minimized compound breakthrough in surface application units, while allowing the collection of a sufficient mass for accurate emission rate measurements from the subsurface application units. The sorbent traps were sampled at a rate of 50 to 200 ml/min/trap for a period not exceeding five minutes to minimize breakthrough of the benzene. Breakthrough traps were used in the first five sampling events to allow the quantification of breakthrough that occurred during this time. All mass flux values were calculated with the inclusion of this observed breakthrough. The sampling and analysis procedure was repeated at selected time intervals following waste addition corresponding to the predicted log decay in emission rates of volatile organics from the soil systems. Although specific sampling times varied between runs, the general sampling schedule followed was: 15 min, 1 hour, 2.5 hour, 10 hour, 24 hours, 50 hours and 100 hours. Blank and spike traps were used throughout the sampling period and during sorbent tube analysis to maintain QA/QC standards during these studies.

Upon completion of each sampling event, the sorbent tubes were placed in muffled culture tubes and stored at 4°C for a maximum of two weeks prior to specific component identification via GC/FID analysis. Sorbent tube desorption was carried out using a Tekmar™ LSC-1 liquid sample concentrator as described in Section 5, with sample tubes desorbed for four minutes at a temperature of 250°C prior to component separation and identification.

Initial soil data collected for each microcosm included the soil depth above the application point, h_s, and total depth and weight of soil in the microcosms. Data relating to the physical conditions of the microcosm systems were collected at each sampling time and included: 1) air and soil temperature, 2) height of the capillary rise observed above the injection point, and 3) depth of the waste wetting front below the soil surface, h_p. The sample rate through each sorbent tube and the purge gas flow rates were measured before each sampling event via a bubble tube flow meter, and the duration of the sorbent tube sampling was recorded for emission flux rate calculations.

For each volatile constituent of interest, the calculation of measured mass collected in the flask effluent gas versus time was made. Measured emission rates (mass/area/time) as a function of time and $1/\text{time}^{1/2}$ were then calculated based on the soil surface area exposed to the purge air, the fraction of purge air actually sampled through the traps, and the cumulative time during effluent sampling. Results of measured data as a function of waste application method, soil media, temperature, and application rate were compared to indicate the effect of these operating parameters on contaminant emission rates. Comparison with predicted model data indicated the validity of the modeling approach for emission prediction in a controlled laboratory setting.

FIELD PROCEDURES

Field validation of the Thibodeaux-Hwang AERR model was carried out at a mid-Western oil refinery. Volatile organic compound emission rates from a typical land treatment area at the facility prior to and following application of a typical API separator/DAF sludge to the site were monitored utilizing the emission flux chamber sampling/concentration system as previously described.

Field Experimental Design

Waste Application/Tilling Methods--

The application plot used in field experiments is identified by the refinery as Plot 2 Row 11. The test plot was divided lengthwise in half with three emission measurement locations per each half (Figure 8), to conform with waste application methods normally utilized by the refinery. Individual waste application events, spaced two hours apart, were made independently to each side of the field plot. Loading near the center of the test plot was heavier than to either side because applications to each overlapped in the center. Waste application was carried out via gravity feed from a tank truck equipped with a slotted application pipe approximately 3 m in length and 8 cm diameter. Each side of the application area received a full truck load of waste corresponding to approximately 880 gallons as reported by the tank truck operator.

Tilling was carried out on one half of the application plot at a time using a rototiller. Tilling was conducted approximately 24 hours after waste application. The test plot was retilled approximately 155 hours after waste application due to rainfall that had occurred following the first tilling event. Tiller depth was variable, ranging from approximately 17 cm at Sampler Location F to approximately 23 cm at Sampler Location E (Figure 8). From visual observation, tilling resulted in a uniform, expanded soil except in the wetter areas of the test plot (West end) where 1 cm and smaller soil/waste clumps were still evident after tilling. The West end of the test plot was lower in elevation than the rest of the site and tended to collect and pond rain water.

Flux Chamber Field Sampling/Storage Procedures--

Sampling was conducted at the field plot using six sampling flux chambers. Four distinct sampling phases were conducted: 1) background sampling of the test site prior to tillage, 2) background sampling

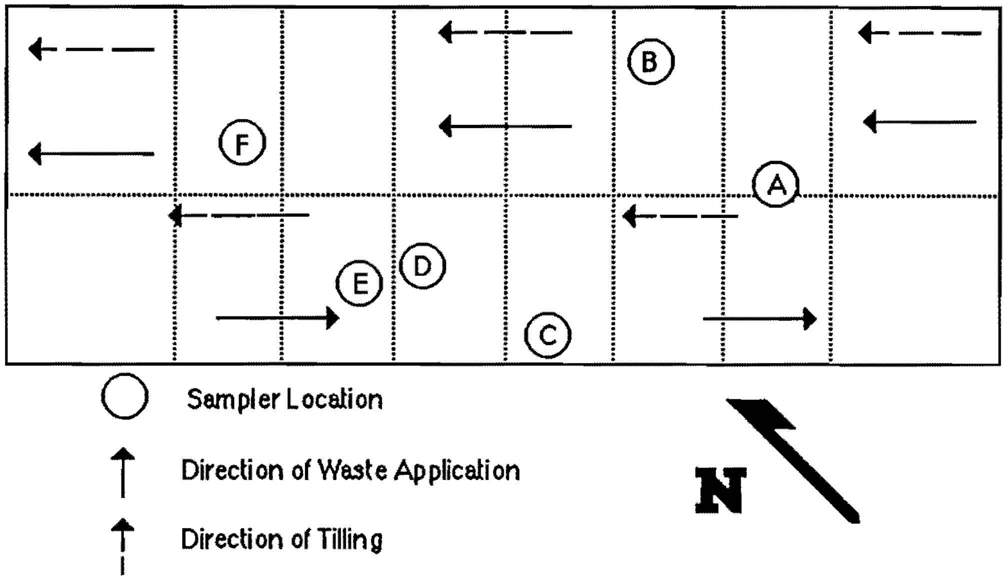

Figure 8. Refinery land treatment field site indicating sampler locations during field sampling activities.

of the test site following tillage and prior to waste application, 3) specific constituent emission sampling following waste addition, and 4) specific constituent emission sampling following two tilling operations.

Sampling chambers were systematically placed to provide a representative estimate of emissions from the entire application site both during background and specific constituent emission sampling. A systematic random sampling of the application area, entailing a plot grid and a random numbers table, was used to select sampling locations. The approximate 6 m by 182 m application area was subdivided into six subsections, with each subsection further subdivided into 396 grid locations of 0.69 m by 0.69 m. Each sampling chamber was placed within a subsection at a location based on the internal grid system and random number assignment. The final placement of flux chambers at the refinery land treatment site is shown in Figure 8. Once placed at a sampling location, sampling was conducted at that same location during background and specific constituent sampling to preserve spatial continuity of the data collected. Sample collection frequency was based on a logarithmic time scale in anticipation of results following the trends predicted by the Thibodeaux-Hwang AERR model. The actual sampling schedule used during the field study for the sampling phases described earlier is shown in Table 3.

The sampling flux chambers were cleaned and pressure checked for leakage prior to use in the field. Themocouple temperature probes were placed at appropriate locations (i.e., 0.6 cm (1/4 inch) and 5 cm (2 inch) soil depth plus chamber air) under the areas of flux chambers sampling. Temperature readings were collected for soil and ambient temperatures prior to chamber placement in the land application area. The chambers were then placed in the appropriate locations within the application area at each sampling event. The chambers were forced into the soil such that the bottom of the Teflon™ lined acrylic dome rested on, and the aluminum dome rim made a tight seal with the soil surface. Purge gas was applied to the flux chambers, and the balanced effluent pumps were operated for four retention volumes (≈15 minutes) prior to sample collection with the sorbent traps. The sorbent trap manifold/sample pump system was connected to the chamber effluent line via a glass and Teflon™ valve, and was isolated from the effluent line prior to actual sampling through the closing of this valve. Temperature measurements were read for soil, chamber air and ambient air throughout the sampling event, and sorbent tubes were placed

TABLE 3. SCHEDULE OF SAMPLING AND TILLING EVENTS DURING FIELD EMISSION MEASUREMENT TESTING

Day	Absolute Time	Sampling Event	Location	Elapsed Time (hrs)	Comments
6/25	1:12 p	BBT	A	-27.43	Background before tilling
	1:48 p		B	-26.58	
	2:17 p		C	-23.93	
	2.32 p		D	-23.68	
	3.07 p		E	-23.52	
	3.03 p		F	-23.17	
6/25	8:11 p	BAT 1	A	-20.43	Background after tilling Event 1
	5:40 p		B	-22.66	
	5:53 p		C	-20.18	
	7:03 p		D	-19.18	
	7:32 p		E	-19.27	
	7:08 p		F	-19.09	
6/26	10:43 a	BAT 2	A	-5.51	Background after tilling Event 2
	10:32 a		B	-5.83	
	11:42 a		C	-2.43	
	10:05 a		D	-4.18	
	11:17 a		E	-3.27	
	9:51 a		F	-4.32	
6/26	4:26 p	WBT 1	A	0.17	Waste application before tilling Event 1
	4:20 p		B	0.02	
	2:11 p		C	0.02	
	2:11 p		D	0.02	
	2:24 p		E	0.02	
	4:12 p		F	0.02	
6/26	4:32 p	WBT 2	A	0.42	Waste application before tilling Event 2
	4:36 p		B	0.26	
	2:26 p		C	0.25	
	2:29 p		D	0.30	
	2:29 p		E	0.12	
	4:27 p		F	2.25	
6/26	5:40 p	WBT 3	A	1.60	Waste application before tilling Event 3
	5:36 p		B	1.27	
	3:24 p		C	1.22	
	3:15 p		D	1.15	
	3:34 p		E	1.05	
	5.17 p		F	3.12	

TABLE 3 (continued)

Day	Absolute Time	Sampling Event	Location	Elapsed Time (hrs)	Comments
6/26	8:30 p	WBT 4	A	4.03	Waste application before tilling
	8:21 p		B	3.93	Event 4
	7:39 p		C	5.55	
	7:57 p		D	5.77	
	8:05 p		E	5.57	
	8:41 p		F	6.52	
6/26	9:45 p	WBT 5	A	5.32	Waste application before tilling
	9:32 p		B	5.17	Event 5
	9:02 p		C	6.82	
	9:13 p		D	7.03	
	9:22 p		E	6.15	
	10:05 p		F	7.96	
6/27	1:51 p	WBT 6	A	21.49	Waste application before tilling
	2:04 p		B	21.73	Event 6
	4:09 p		C	26.00	
	4:35 p		D	26.23	
	4:12 p		E	25.68	
	2:14 p		F	24.07	
6/27	2:51 p	WAT 1	A	0.01	Waste application after first
	2:52 p		B	0.01	tilling Event 1
	5:00 p		C	0.01	
	5:01 p		D	0.01	
	4:59 p		E	0.01	
	2:58 p		F	0.01	
6/27	3:07 p	WAT 2	A	0.18	Waste application after first
	3:07 p		B	0.24	tilling Event 2
	5:12 p		C	0.18	
	5:08 p		D	0.13	
	5:08 p		E	0.07	
	3:08 p		F	0.18	
6/27	8:52 p	WAT 3	A	6.02	Waste application after first
	8:49 p		B	5.94	tilling Event 3
	9:38 p		C	4.61	
	10:18 p		D	5.35	
	10:01 p		E	5.04	
	9:15 p		F	6.35	

TABLE 3 (continued)

Day	Absolute Time	Sampling Event	Location	Elapsed Time (hrs)	Comments
6/28	12:10 p	WAT 4	A	21.33	Waste application after fir
	12:11 p		B	21.34	tilling Event 4
	1:55 p		C	20.90	
	1:15 p		D	20.35	
	1:08 p		E	20.12	
	12:20 p		F	21.43	
6/28	12:26 p	WAT 5	A	21.58	Waste application after first
	12:26 p		B	21.57	tilling Event 5
	2:05 p		C	21.06	
	1:30 p		D	20.55	
	1:25 p		E	20.37	
	12:35 p		F	21.71	
6/29	11:17 a	WAT 6	A	44.43	Waste application after first
	11:30 a		B	44.62	tilling Event 6
	11:38 a		C	42.61	
	11:52 a		D	44.88	
	11:54 a		E	42.92	
	12:13 p		F	45.32	
7/2	11:57 a	WAT 7	A	105.10	Waste application after first
	12:24 p		B	105.52	tilling Event 7
	12:56 p		C	103.91	
	1:23 p		D	104.43	
	1:48 p		E	104.79	
	2:08 p		F	107.23	
7/3	12:00 N	WAT 8	A	129.15	Waste application after first
	11:44 a		B	128.85	tilling Event 8
	11:27 a		C	126.43	
	11:17 a		D	126.33	
	10:58 a		E	125.95	
	10:49 a		F	127.92	
7/3	2:55 p	WST 1	A	1.92	Waste application after second
	1:15 p		B	0.40	tilling Event 1
	1:21 p		C	0.38	
	1:38 p		D	0.68	
	1:45 p		E	0.80	
	2:06 p		F	1.22	

TABLE 3 (continued)

Day	Absolute Time	Sampling Event	Location	Elapsed Time (hrs)	Comments
7/5	12:31 p	WST 2	A	45.62	Waste application after second tilling Event 2
	12:13 p		B	46.97	
	11:47 a		C	46.37	
	11:24 a		D	45.81	
	11:09 a		E	45.33	
	10:43 a		F	44.63	

within the sampling manifold system just prior to the completion of the pre-sampling purge events. The manifold pumps were operated initially at a rate of 0.6 to 0.9 liters/min, and the valve to the effluent purge line was opened, initiating the sampling event. Sample collection via Tenax™ sorbent traps was carried out for a 5 to 15 minute sampling period during the sampling event to ensure adequate contaminant mass collection, while minimizing contaminant breakthrough during the sample collection period. Cold packs were also placed on the Tenax™ sorbent tubes during sampling in a further effort to reduce breakthrough during field sample collection.

Sample sorbent tubes were randomly selected for use at the various sampling locations from tubes prepared as described in Section 5. Labels were placed on the culture tubes containing the sorbent traps to document their placement within the sample manifold with respect to sample position, sample time, and any observed conditions pertinent to sample collection. Upon completion of the sampling sequence for a given tube, the duration of the sampling event and miscellaneous conditions pertinent to sample collection occurring during sampling were recorded. Following the sampling event, the valve to the sorbent trap manifold/sampling pump system was closed and the sampling pump was stopped. The sorbent traps were placed in their respective glass culture tubes, and then placed in air-tight metal containers. The samples were stored at 2 to 4°C at the refinery facility prior to analysis on-site, via thermal desorption and GC analysis for volatile constituents of interest, or were transported back to the UWRL for final analysis. Isolation flux chambers were then removed from their sampling locations, were rinsed with methanol and acetone, and were inspected for damage, leaks, etc., prior to being used for emission sampling at the next designated sampling time.

Transportation of sorbent tubes and soil and waste samples to and from the UWRL facility was carried out using land transportation, with low temperature conditions maintained using a AC/DC/propane refrigerator designed for portable use. Once at the UWRL facility, samples were maintained at 2 to 4°C prior to processing via thermal desorption and GC and/or GC/MS analysis for volatile constituents of interest. All sorbent tube samples were analyzed within six weeks of collection. A total of seven sorbent tubes from throughout the study were retained for GC/MS analysis to allow confirmation of specific volatile constituents quantified via GC analysis.

The following information is a summary outline of the procedures utilized during field sampling for the collection and analysis of soil, waste, and air emission samples and blanks necessary for adequate Thibodeaux-Hwang AERR model validation:

A. Sampling Preparation
  1. Instrument Calibration
    a. Calibrate pump via bubble tube flow meter
    b. Calibrate laboratory GC via analysis of duplicates and calibration standards
    c. Calibrate manifold flow via bubble tube flow meter
    d. Calibrate thermocouple thermometer
  2. Flux Chamber Check
    a. Check visual damage and general condition
    b. Pressure check
  3. Sampler Location Placement
    a. Randomize sampler placement in six subplots of application area
    b. Stake location of sampler on grass travel lanes for spatial continuity between sampling times

B. Background Sampling Events
  1. Background Sampling Before Tilling
    a. Soil Sampling
      i. Collect particle size, bulk density and moisture content, and particle density samples at three points around the sampler
      ii. Place soil thermocouples under and within flux chamber sampler
    b. Air Emission Sampling
      i. Place sampling chambers at designated locations in subplots using soil surface to seal chamber
      ii. Place inclined shade over sampler to reduce temperature build-up within chambers
      iii. Initiate calibrated purge pump
      iv. Purge with high purity breathing air for three retention volumes at 2 to 6 l/min purge flow
      v. Record soil temperature, chamber air temperature, weather conditions, ambient air temperature and sampling time
      vi. Connect sampling manifold to split-stream T, connect sampling traps to manifold, connect pump manifold to sampling traps, open manifold valve and initiate calibrated sampling pump
      vii. Sample the chamber purge gas for 5 to 15 minutes
      viii. At the end of the sampling period, close manifold valve, remove sampling manifold from split stream, record duration of sampling time and pertinent sampling conditions, i.e., soil temperature, chamber and ambient air temperature, etc., disconnect traps from the manifolds, place traps in culture tubes, and store tubes under low temperature conditions prior to analysis or shipping
      ix. Remove shading and sampling chambers from soil surface, rinse with methanol and acetone, swab dry, check condition of interior and transport lines, and store in low hydrocarbon vapor area until next sampling event
  2. Background Sampling After Tilling
    a. Remove soil thermocouples from sampler locations
    b. Till land application site as per normal operations
    c. Repeat steps B.1.a. i. through B.1.b. ix. shortly after tilling
    d. Repeat steps B.1.b. i. through B.1.b. ix. approximately 18 hours after tilling

C. Waste Application Sampling Events
  1. Waste Application Sampling
    a. Place sheet metal collection pans on either side of flux chamber locations
    b. Waste Sampling
      i. Bulk samples of applied waste are obtained at sampler locations from grab sampling of application pan samples
      ii. Waste collection pans are weighed for mass application rate calculations

c. Aliquots of bulk sample are placed into VOA bottles for density, viscosity, and specific VOC determinations
d. Repeat steps B.1.a. ii. through B.1.b. iii. and B.1.b. v. through B.1.b.viii. as soon as possible after the waste application event
e. Repeat steps B.1.a. ii. through B.1.b. ix. approximately 1 to 2 hours and 3 to 5 hours after the waste application event
f. Repeat steps B.1.a. i. through B.1.b. ix. approximately 6 to 8 hours after the waste application event
g. Repeat steps B.1.a. ii. through B.1.b. ix. approximately 21 to 26 hours after the waste application event

2. Waste Application Sampling After Tilling
   a. Remove soil thermocouples from sampler locations
   b. Till land application site as per normal operations
   c. Repeat steps B.1.a. i. through B.1.b. ix. shortly after tilling
   d. Repeat steps B.1.b. i. through B.1.b. ix. approximately 5 and 10 hours after tilling
   e. Repeat steps B.1.a. i. through B.1.b. ix. approximately 24 hours after tilling
   f. Repeat steps B.1.b. i. through B.1.b. ix. approximately 48, 100 and 124 hours after tilling
3. Waste Application Sampling After Second Tilling
   a. Remove soil thermocouples from sampler locations
   b. Till land application site as per normal operations
   c. Repeat steps B.1.a. i. through B.1.b. ix. shortly after tilling
   d. Repeat steps B.1.b. i. through B.1.b. ix. approximately 45 hours after tilling
   e. Remove soil thermocouples from sampler locations and complete field sampling

Flux Shading Procedures--

Large temperature differentials were observed between the flux chamber interior air space and ambient air temperature that reached a maximum of 49.5°C during initial background sampling and 33.7°C during sampling following waste application. Flux chamber shading was utilized in all sampling events following soil tilling after waste application, (WAT), in order to evaluate the effect shading had on chamber air and soil temperatures. Flux chamber shading was accomplished utilizing wooden 2x2s supporting a 2 ft x 4 ft sheet of plywood angled to shade the entire flux chamber. Several sampling events were conducted without and without shading to evaluate the effect of soil and chamber air temperature on measured emission rates.

Field QA/QC Procedures--

Field blank and spike traps were used in conjunction with breakthrough traps as described in Section 5 to provide quality control information for field sorbent tube samples. Field blanks were obtained by the random selection of sorbent tubes at various time intervals during field activities. These blanks were removed from their culture tubes, were exposed to ambient conditions for approximately 15 seconds (the approximate time required for sorbent tube placement in the sampling manifolds) and were placed back into their respective culture tubes prior to documenting sampling period, sampling location and blank identification on sample custody forms. These blanks were then transported, stored, and processed in a manner identical to the sorbent tubes used for actual sample collection.

Additionally, soil and waste samples were split with the RSKERL in Ada, Oklahoma, for oil and grease, and specific constituent quantification using identical sample processing and analytical procedures for comparison purposes to ensure quality control for these parameter measurements. All other measurements were conducted in at least duplicate to provide statistical information regarding measurement precision for comparison with original QA/QC goals established for the study. Results of field QA/QC samples are located in Section 8.

Field Data Evaluation--

For each volatile constituent of interest, the calculation of measured mass collected in the flux chamber effluent gas versus time was made. Measured emission rates (mass/area/time) as a function of time and $1/\text{time}^{1/2}$ were then calculated based on the soil surface area exposed to the purge air, the fraction of purge air actually sampled through the traps, the cumulative time during effluent sampling, the recovery efficiency of the contaminant observed in the flux chamber/sorbent tube laboratory recovery efficiency experiments, and the correction due to blank contaminant mass levels observed from field blank tubes. Results of measured data as a function of soil media characteristics, temperature, and application rate were compared to indicate the effect of these operating parameters on contaminant emission rates. Comparison with predicted model data indicated the validity of the modeling approach for emission prediction under actual field sampling and environmental conditions.

SECTION 7

PARAMETER CALCULATION/ESTIMATION METHODS

PARAMETERS REQUIRED FOR THIBODEAUX-HWANG AERR MODEL

A number of critical model parameters must be calculated or estimated for the soil and waste system under consideration. However, only a limited theoretical base exists for the determination of the majority of these soil/waste/component characteristics. The approach taken in this research was to utilize correlation equations for estimation of parameters that could not be directly determined experimentally.

Soil Diffusion Coefficient

The major compound property affecting vapor diffusion within a soil system is the effective soil diffusion coefficient, D_A. This parameter has been correlated with physical properties of the soil, namely soil total porosity, air filled porosity, and tortuosity. A convenient form of the expression has been presented by Farmer et al. (1973):

$$D_A = D_{Ai} \cdot (S_a^{10/3})/S_t^2 \qquad (20)$$

where D_{Ai} = component air diffusion coefficient, (length^2/time),
S_a = soil air filled porosity = S_t - decimal soil moisture content, and
S_t = total soil porosity = 1 - soil bulk density/particle density.

Modified Henry's Law Constant

Component partitioning within the complex soil/water/air/oil environment in a contaminated soil system will also significantly affect its movement. The partition parameter of concern in the Thibodeaux-Hwang model is the modified Henry's Law constant which describes the equilibrium partitioning of a component between a soil oil film and the soil vapor phase. No direct calculation method is available for such a parameter; therefore, its estimation was based on a combination of partition coefficients and component and waste properties.

Correlation equations are available (Lyman et al. 1982) for the estimation of a solvent:water partition coefficient for a number of organic solutes and solvents. These correlation equations take the form of:

$$\log K_{sw} = a \cdot \log K_{ow} + b \qquad (21)$$

where K_{sw} = the component solvent:water partition coefficient,
K_{ow} = the octanol:water partition coefficient, and
a,b = the slope and intercept, respectively, of the solvent regression equation.

These equations can be adapted for use in land treatment facility emission modeling by the appropriate choice of a representative solvent in the complex waste of concern. Hexane was found to be a major component of the wastes used in this study based on GC/MS analyses and was chosen as a model solvent for partition parameter estimation. With hexane used to as the solvent system, a = 0.541 and b = 1.203 (Lyman et al. 1982).

Component K_{ow} values can be estimated using correlation equations based on aqueous solubility. Hansch et al. (1968) presented the following relationship for aromatic compounds which were of primary concern in this study:

$$\log 1/S = 0.996 \cdot \log K_{ow} - 0.339 \qquad (22)$$

where S = component water solubility, (moles/liter).

An estimate of the effective Henry's Law constant for a particular waste component may then be made using its actual Henry's Law constant, cm^3 water/cm^3 air, and the calculated K_{sw} from Equations 21 and 22 above. The effective Henry's constant describes the equilibrium partitioning predicted between the soil vapor space and the oil matrix on the soil particles, and has units of cm^3 oil/cm^3 air:

$$H_C' = H_C/K_{sw} \qquad (23)$$

Oil Diffusion Coefficient

The final parameter required for model application is the diffusivity of waste components in the oil film. Diffusion coefficient estimates for compounds in multi-solute systems are also not fully developed, and the estimation of this parameter was based on a modification of the Wilke-Chang equation for the liquid waste solution as follows (Lyman et al. 1982):

$$D_o = \frac{7.4 \times 10^{-8} \cdot (\phi s \cdot MW)^{1/2} \cdot T}{\eta s \cdot V_B^{0.6}} \qquad (24)$$

where ϕs = solvent association parameter = 1.0 for non-dissociating solvents,
MW = component gram molecular weight, (g/g-mole),
T = absolute temperature, (°K),
ηs = solvent/waste viscosity, (centipoises), and
V_B = molar volume, (cm^3/g-mole).

TEMPERATURE CORRECTION OF LABORATORY AND FIELD MODELING PARAMETERS

Due to the temperature sensitivity of many of the physical and chemical parameters of the waste and individual constituents in the waste, various temperature correction procedures were utilized for waste viscosity, contaminant vapor pressure and contaminant vapor diffusivity estimations. Although laboratory temperature conditions were uniform within a given experiment, temperature variation between experiments required temperature adjustment of model parameters for comparison purposes with model predictions. In addition, field soil temperature variability was quite large throughout the day and demanded temperature correction, again for proper model parameter input into the Thibodeaux-Hwang AERR model.

Waste Viscosity Temperature Corrections

Waste viscosity is critical in the prediction of a contaminant oil diffusion coefficient as indicated in Equation 24. Temperature correction for this parameter was carried out using a modification of a method presented by Gambill (1959), and recently reviewed by Wooley (1986). The method entails the use of actual viscosity data to derive an Antoine-type curve of the form: $\log \eta s = -2.32417 + 758.56/(T + 53.698 + D)$, where T is temperature in °C. The coefficient D is calculated from this expression using measured viscosity data in centipoises at a given temperature. The equation is then used for the prediction of viscosity values at any temperature desired.

Data collected for the field waste (Table 4) were used to calculate the value of D for the waste applied in the field experiments. From these data it was determined that the best fit to the measured data could be obtained using a variable D with temperature, resulting in the following expression:

$$\log \eta s = -2.32417 + 758.56/(T - 0.4148 \cdot T + 196.8806) \qquad (25)$$

Equation 25 was used for all field data to estimate a waste viscosity value in centipoises. This viscosity value was then input into Equation 24 for the estimation of contaminant oil diffusion coefficients as soil and waste temperatures changed during field sampling.

Contaminant Vapor Pressure Temperature Adjustments

Contaminant vapor pressure temperature corrections were made using a method described by Lyman et al. (1982) which uses the Antoine equation for compounds which are liquids or gases at the given temperature. The method involves the use of the contaminant normal boiling point, Tb, a parameter Kf (derived from consideration of dipole moments of the compounds of interest) used for the calculation of the heat of vaporization at the normal boiling point, ΔHvb, and the contaminant vapor pressure at an absolute temperature, T. Values of Kf of 1.0 for benzene and naphthalene, and 0.99 for all other compounds (Lyman et al. 1982) was used along with their reported boiling points to calculate ΔHvb/Tb according to the following equation:

$$\Delta Hvb/Tb = Kf \cdot (8.75 + R \cdot \ln Tb) \qquad (26)$$

where R = 1.987 cal/(mol • °K).

The natural log of the contaminant vapor pressure in atmospheres was then calculated using the following expression given in Lyman et al. (1982):

$$\ln P = \frac{\Delta Hvb \cdot (Tb - C_2)^2}{\Delta Zb \cdot R \cdot Tb^2}\left[\frac{1}{(Tb - C_2)} - \frac{1}{(T - C_2)}\right] \qquad (27)$$

where ΔZb = 0.97,
C_2 = $-18 + 0.19 \cdot Tb$, and
T = temperature at which vapor is to be predicted, (°K).

Results of Equation 27 were used in all model calculations for field data to account for the wide variability in soil temperature observed during the study.

Contaminant Air Diffusivity Temperature Corrections

Reported literature values for contaminant air diffusion coefficients required correction to the observed laboratory and field temperatures. Temperature correction for gas phase diffusivity values was based on the Chapman-Enskog formula as presented by Thibodeaux (1979) which indicates that the diffusivity of a contaminant in the air phase is related to the 3/2 power of the absolute temperature, i.e.:

$$D_{T2} = D_{T1} \cdot \frac{(T2)^{3/2}}{(T1)^{3/2}} \qquad (28)$$

Equation 28 was used to correct reported contaminant air diffusion coefficients for changes in temperature that occurred during laboratory and field studies.

TABLE 4. KINEMATIC AND DYNAMIC VISCOSITY MEASUREMENTS FOR SUN OIL WASTE COMPOSITE*
DETERMINED 8/28/85

Temp (°C)	Time (sec)	C† (m^2/sec)	Kinematic Viscosity (cst)	Average	Dynamic Viscosity# (cp)	Mean	S. D.	C. V. (%)
16.5	72.72	3.03E-07	22.03		22.34			
16.5	74.00	3.03E-07	22.42		22.74			
16.5	72.53	3.03E-07	21.98	22.14	22.29	22.14	0.25	1.1
18.3	68.93	3.03E-07	20.89		21.18			
18.3	69.03	3.03E-07	20.92		21.21			
18.3	69.86	3.03E-07	20.89	20.90	21.19	20.90	0.02	0.1
20.1	67.95	3.03E-07	20.59		20.88			
20.1	68.18	3.03E-07	20.66		20.95			
20.1	67.64	3.03E-07	20.49	20.58	20.79	20.58	0.08	0.4
22.2	63.67	3.00E-07	19.10		19.37			
22.2	64.00	3.00E-07	19.20		19.47			
22.2	63.52	3.00E-07	19.06	19.12	19.33	19.12	0.07	0.4
24.6	60.35	2.97E-07	17.92		18.18			
24.6	60.38	2.97E-07	17.93		18.19			
24.6	60.42	2.97E-07	17.94	17.93	18.20	17.93	0.01	0.1
26.5	58.12	2.97E-07	17.26		17.51			
26.5	58.02	2.97E-07	17.23		17.47			
26.5	58.11	2.97E-07	17.26	17.25	17.50	17.25	0.02	0.1
29.9	54.79	2.97E-07	16.27		16.50			
29.9	55.04	2.97E-07	16.35		16.58			
29.9	55.85	2.97E-07	16.59	16.40	16.82	16.40	0.17	1.0

* Sample represents waste composite centrifuged at 3000 rpm for 5 minutes. Three layers were observed after centrifugation: a dark oily upper layer, a clear middle layer, and a thick solid layer. The clear middle layer was the largest fraction and was used for viscosity measurements presented in the table.

†From Dr. Gordon Flammer, Utah State University for #100 viscometer.

#Density measured using a circulating density meter.

SECTION 8

RESULTS AND DISCUSSION

WASTE/SOIL ANALYSES

Two hazardous petroleum refinery wastes: 1) API Separator Sludge K051 and 2) Slop Oil Emulsion Solids K049, were selected for testing in the laboratory studies due to their large quantity production in the United States, the current extent of their disposal in land treatment systems, and the broad range of physical, chemical and toxicological characteristics represented by the compounds they contain. Two soils (Kidman sandy loam and Durant clay loam) were chosen for use in laboratory volatilization studies to represent a range of soil types that might potentially receive applications of hazardous wastes. In addition to the soils, washed construction sand was evaluated as an inert medium within which volatilization of hazardous waste constituents could be studied. Samples of wastes, API Separator Sludge and DAF Bottoms, and soils were obtained from the refinery at which the field studies were conducted. This refinery has been operating an apparently successful hazardous waste land treatment facility since 1975.

Waste Analyses

API Separator Sludge Solids are generated from primary settling of wastewaters that enter the oily water sewer. This waste sludge typically consists of approximately 73 percent water, 8 percent oil and 19 percent solids (ERT 1984). The solids are largely sand and coarse silt, but also often contain significant quantities of heavy metals such as chromium and lead. The heavy oils that settle in an API separator become part of the bottom sludge and are largely composed of heavy tars, large multiple branched aliphatic compounds, polyaromatic hydrocarbons, and coke fines. The composition of the oily material in the separator sludge depends to a large extent on the source of crude being refined and the refining process employed at the refinery in question, while the amount of coke fines is dependent on the amount of thermal cracking used in the refining process.

Slop Oil Emulsion Solids are the residual solids remaining after the treatment of the emulsion layer produced from the recovery of oil from slop oil. These emulsion solids are typically 40 percent water, 43 percent oil and 12 percent solids. Chromium and lead are often present in significant concentrations in the solid phase of this waste (ERT 1984).

Gross chemical and physical parameters of the hazardous wastes used in the laboratory study are shown in Table 5, along with waste viscosity and density determinations required as input in model validation procedures. These data indicate that the laboratory API Separator Sludge with a measured oil and grease content of 35 percent, was much higher in oil and grease than typical separator sludge waste. The Slop Oil Emulsion Solids waste was found to be high in solids content (26 percent versus typically 12 percent) and extremely low in measured water content (0.1 percent versus typically 40 percent water content).

Methanol extracts of the separator sludge, slop oil, and field wastes showed the presence of the seven volatile compounds of interest at mean concentration levels (M_A in Equations 7, 8 and 19) shown in Table 6. Laboratory specific volatile constituent data show relatively large coefficients of variation typical for complex wastes. Based on results of field data, it appears that this variation was largely due to

TABLE 5. GROSS PHYSICAL/CHEMICAL PROPERTIES OF HAZARDOUS WASTES USED IN THE STUDY

Waste	Oil and Grease (μg/g)*			Solids (μg/g)		
	Mean	St. Dev.	C. V. (%)	Mean	St. Dev.	C. V. (%)
API Separator Sludge	350000	25000	7.0	257000	32000	12.4
Slop Oil	460000	49000	11.0	227000	27000	11.9
Field Waste						
	Water Content (%)**			**Dynamic Viscosity (cp)#**		
	Mean	St. Dev.	C. V. (%)	Mean	St. Dev.	C. V. (%)
API Separator Sludge	47†	2.8	7.0	22.32 @ 17°C	0.03	0.1
				18.14 @ 25.4°C	0.01	0.0
Slop Oil	0.1§	--	--	48.12 @ 16°C	0.25	0.5
				39.54 @ 25.5°C	0.28	0.7
Field Waste				22.46 @ 16.5°C	0.25	1.1
				17.49 @ 26.5°C	0.02	0.1

* Modified from RSKERL SOP-21.

** Standard Method of Test for Water in Petroleum Products and Bituminous Materials by Distillation. ASTM D95-70.

Sample density @ 21°C = 0.8185 g/cc for Slop Oil, 0.9806 g/cc for Separator Sludge, and 1.014 g/cc @ 16.5°C for field waste. Separator Sludge viscosity determination for oil layer separated following centrifugation.

† Utah Water Research Laboratory Apparatus.

§ USEPA Robert S. Kerr Environmental Research Laboratory Apparatus.

TABLE 6. SPECIFIC ORGANIC CONSTITUENTS OF HAZARDOUS WASTES USED IN THE STUDY

	Compound	Mass (µg/g Waste) Mean	St. Dev.	C. V. (%)	n
SLOP OIL					
	Benzene	5421	2403	44	16
	Toluene	7696	1953	25	18
	Ethylbenzene	1639	657	40	18
	p-Xylene	3399	928	27	18
	m-Xylene	8500	1910	22	18
	o-Xylene	3365	1108	33	18
	Naphthalene	1621	687	42	16
SEPARATOR SLUDGE					
	Benzene	2350	648	28	6
	Toluene	2487	899	36	8
	Ethylbenzene	605	212	35	9
	p-Xylene	1686	467	28	8
	m-Xylene	3641	607	17	8
	o-Xylene	2194	654	30	9
	Naphthalene	2306	692	30	9
FIELD WASTE					
UWRL Analyses (GC)					
	Benzene	249.2	29.7	12.0	10
	Toluene	631.7	50.0	8.0	10
	Ethylbenzene	22.0	1.2	6.0	10
	p-Xylene	33.2	4.6	14.0	10
	m-Xylene	181.2	14.9	8.0	10
	o-Xylene	56.0	3.0	5.0	10
	Naphthalene	124.6	8.8	7.0	10
RSKERL Analyses (GC/MS)					
	Benzene	278			
	Toluene	687			
	Ethylbenzene	36			
	p-Xylene & m-Xylene	238			
	o-Xylene	81			
	Naphthalene	108			

changing characteristics of the wastes used in laboratory studies which took place over the ten month period, as well as to routine waste sampling, extraction, and analysis errors. The data generated in laboratory tests suggest that an evaluation of specific volatile constituents is necessary in each aliquot of raw waste prior to its use in volatilization runs. Table 6 data also indicate that the hazardous wastes used in laboratory studies were significantly higher in all constituents than the waste applied during the field study. This once again indicates the importance of accurate waste characterization as the waste generating and handling processes have a significant impact on the concentration of volatile constituents actually applied to the land treatment system. Comparison of GC analyses conducted at the UWRL with those conducted at the RSKERL via GC/MS procedures indicate very good correlation between results. This finding substantiates the accuracy of measured data and the analytical procedures used in the field study.

Prominent aliphatic and aromatic compounds, along with their substituted analogs identified in GC/MS analyses of the volatile and base/neutral fractions of the wastes used in laboratory studies, are presented in Tables 7 to 9.

Soil Analyses

Soil physical, chemical and biological properties of the Kidman sandy loam, the Durant clay loam, the washed construction sand, and the field soil are indicated in Table 10. The laboratory media were used during the study to provide a range of soil particle sizes and particle size distributions, textures, organic contents, exchange capacities and water holding capacities to investigate the sensitivity of the Thibodeaux-Hwang AERR model to these critical soil parameters. The effective size listed in Table 10 is defined as the diameter of particles representing 10 percent of the mass of the sample analyzed by dry sieve analysis and was taken as the representative diameter for Zo and a_s estimations in Equations 14 through 17. Other critical soil physical parameters, including total porosity, air filled porosity, and bulk density were determined on an individual basis for each laboratory unit (microcosm or flask) for each experiment conducted. These data are presented in Appendices F and G along with measured and theoretical emission data.

Physical soil parameters necessary for field validation were collected at various time intervals throughout the field sample excursion as describe in Section 6. Table 11 presents a summary of physical properties measured for the field soil for each time period and at each sampler location. Data obtained during background sampling, both before and after tilling, indicated that the soil within the experimental field plot was quite uniform and well mixed. Due to non-uniform waste application within the field plot, however, waste before tilling (WBT) samples indicated generally a greater bulk density and lower total porosity for sample locations C, D, E, and F than at locations A and B. Due to the variable nature of measured moisture content during the period throughout the field plot, variable air filled porosity values were also observed. After the first tilling following waste application (WAT), bulk density and total porosity results approached initial background levels and were once again relatively uniform throughout the field plot. Following the second tilling after waste application (WST), field site soil physical characteristics were very uniform. Soil moisture content variability became apparent during this period, however, due to a rainfall event which allowed moisture to pond in the low lying areas of the field site, especially at sample locations C, E and F. Both the spatial and temporal variability of these soil parameters were incorporated into calculations for theoretical emission rates by their substitution into model equations described in Section 4 at time increments corresponding to actual field sampling times.

TABLE 7. ORGANIC COMPOUNDS TENTATIVELY IDENTIFIED IN API SEPARATOR SLUDGE AND SLOP OIL WASTE SAMPLES (VOLATILE FRACTION) BY GC/MS

Compound	Molecular Weight	Retention Time (min)
Cyclohexane	84	5.93
2,2,4-trimethylpentane	114	6.53
Methyl-cyclohexane	98	7.45
Toluene	92	8.55
1,3-dimethyl-trans-cyclohexane	112	8.82
Octane	114	9.28
Ethyl-cyclohexane	112	10.15
p-xylene	106	10.95
o-xylene	106	11.5
1-ethyl-3-methylbenzene	120	12.9
trimethylbenzene	120	13.57
1-methyl-4-propyl-benzene	134	14.6
1-methyl-2 or 4/1-methylethyl-benzene	134	14.8
1-methyl-3(1-methylethyl)benzene, or 1-ethyl-2,4-dimethylbenzene	134	15.17
(1,1-dimethylbutyl)benzene	162	15.3
Undecane	156	15.35
1-ethyl-3,5- or 2,4- or 1,2-dimethylbenzene	134	15.85
1-ethyl-3,5-dimethyl or 1,2,3/4,5-tetramethylbenzene	134	15.93
Octacosane	394	17.05
Naphthalene	128	17.2
1-ethyl-1-methyl-cyclopentane	112	17.83
2,3-dihydro-1,6-dimethyl-1H-indene	146	18.4
Octadecane	254	18.6
Methyl-naphthalene	142	18.98
2-methyl-naphthalene	142	19.27
Pentacosane	352	20.07
1,1'-biphenyl	154	20.2
Ethylnaphthalene	156	20.47
Dimethyl-naphthalene	156	20.62
Ethyl-naphthalene	156	21.4
2-(1-methylethyl--naphthalene	170	22.02
Trimethyl-naphthalene	170	22.3
1,6,7-trimethylnaphthalene	170	22.83
1-methyl-9HFluorene	180	24.75
Phenanthrene	178	25.73
4-methylphenanthrene	192	27.02
Dimethyl-phenanthrene	206	28.48

TABLE 8. ORGANIC COMPOUNDS TENTATIVELY IDENTIFIED IN API SEPARATOR SLUDGE WASTE (BASE NEUTRAL FRACTION) BY GC/MS

Compound	Formula	Molecular Weight	Retention Time (minutes)
Heptane	C6H16	100	0.8
Hexane, 2, 5-Dimethyl, Heptane, 2-Methyl	C8H18	114	1.0
Cyclopentane, ethyl-methyl, or alkane	C8H16	112	1.1
Cyclohexpane, dimethyl?	C8H16	112	1.8
Benzene, methyl	C7H8	92	2.1
Nonane	C9H20	128	3.0
Cyclohexane, 1-ethyl-4-methyl?	C9H18	126?	3.1
Benzene, dimethyl	C8H10	106	4.4
Nonane, 4-methyl, actane, dimethyl	C10H22	142	4.6
Benzene, dimethyl	C8H10	106	5.4
Decane	C10H22	142	6.1
Decane, 4-methyl	C11H24	156	6.6
Benzene, propyl	C9H12	120	7.2
Benzene, ethyl methyl; Benzene, trimethyl	C9H12	120	7.5
Benzene, alkyl substituted	C9H12	120	7.7
Benzene, trimethyl; Benzene, ethyl methyl	C9H12	120	8.1
Benzene, trimethyl; Benzene, ethyl methyl	C9H12	120	8.4
Undecane	C11H24	156	9.1
Benzene, trimethyl; Benzene, ethyl methyl	C9H12	120	9.4
Benzene, diethyl; Benzene, methyl propyl	C10H14	134	9.8
Benzene, diethyl; Benzene, methyl propyl	C10H14	134	10.0
Benzene, diethyl; Benzene, methyl propyl	C10H14	134	10.2
Benzene, ethyl dimethyl; Benzene, tetramethyl; etc.,	C10H14	134	10.5
Benzene, ethyl dimethyl; Benzene, tetramethyl; etc.,	C10H14	134	10.8
Dodecane	C12H26	170	11.4
Benzene, ethyl dimethyl; Benzene, tetramethyl, etc.,	C10H14	134	11.7
Benzene, Dimethylethyl methyl?	C11H16	148	11.9
Tridecane, methyl?	C14H30	198	12.6
Tridecane	C13H28	184	13.4
Naphthalene, Azulene	C10H8	128	14.1
Tetradecane	C14H30	198	15.2

TABLE 8 (continued)

Compound	Formula	Molecular Weight	Retention Time (minutes)
Naphthalene, methyl	C11H10	142	15.9
Naphthalene, methyl	C11H10	142	16.5
Pentadecane	C15H32	212	16.9
Tetradecane, trimethyl	C17H36	240	17.5
1,1'-Biphenyl	C12H10	154	17.7
Naphthalene, Dimethyl	C12H12	156	17.9
Naphthalene, Dimethyl	C12H12	156	18.3
Hexadecane	C16H34	226	18.4
Naphthalene, Dimethyl	C12H12	156	18.7
Hexadecane, Dimethyl	C18H38?	254?	19.0
1,1'-Biphenyl, methyl	C13H12	168	19.4
Heptadecande	C17H36	240	20.0
Naphthalene, trimethyl	C13H14	170	20.2
Naphthalene, trimethyl	C13H14	170	20.6
Octadecane	C18H38	254	21.4
Naphthalene, alkyl substituted?	C14H16	184	22.0
Nonadecane	C19H40	268	22.7
Eicosane	C20H42	282	24.0
Phenanthrene, anthracene	C14H10	178	24.6
Heneicosane	C21H44	296	25.2
Dibenzothiophene, methyl; 9H-thioxanthene	C13H10S	198	25.4
Dibenzothiophene, methyl; 9H-thioxanthene	C13H10S	198	25.7
Anthracene/Phenanthrene methyl substituted	C15H12	192	26.0
Docosane	C22H46	310	26.2
Anthracene/phenanthrene methyl substituted	C15H12	192	26.4
Dibenzothiophene, dimethyl	C14H12S	212	26.9
Tricosane	C23H48	324	27.4
Phenanthrene/anthracene, dimethyl	C16H14	206	27.6
Phenanthrene/anthracene, dimethyl	C16H14	206	27.9
Tetracosane	C24H50	338	28.5
Phenanthrene/anthracene, Trimethyl	C17H16	220	28.9
Phenanthrene/anthracene,	C17H16	220	29.2
TrimethylPentacosane	C25H52	352	29.5
Hexacosane	C26H54	366	30.6
Heptacosane	C27H56	380	31.5
Octacosane	C28H58	394	32.5
Nonacosane	C29H60	408	33.7
	C30H62	422	35.0

TABLE 9. ORGANIC COMPOUNDS TENTATIVELY IDENTIFIED IN SLOP OIL EMULSION SOLIDS WASTE (BASE/NEUTRAL FRACTION) BY GC/MS

Compound	Formula	Molecular Weight	Retention Time (minutes)
Dichloromethane	CH2Cl2	85	
Hexane, 2,2-dimethyl; or Butane, 2,2,3,3 tetra-methyl	C8H18	114	0.8
Heptane	C6H16	100	1.0
Methyl benzene	C7H8	92	2.3
Nonane	C9H20	128	3.5
Benzene, dimethyl	C8H10	106	5.1
Benzene, dimethyl	C8H10	106	5.9
Decane	C10H22	142	6.8
Benzene, propyl	C9H12	120	7.5
Benzene, ethyl methyl substituted	C9H12	120	7.9
Cyclohexane, butyl, or thiophthene	C10H20 C6H4S2	140 140	8.1
Benzene, ethyl methyl; or benzene, trimethyl	C9H12	120	8.4
Benzene, trimethyl; or benzene, ethyl methyl	C9H12	120	8.8
Benzene, methyl propyl; benzene, ethyl dimethyl, or benzene, tetramethyl	C10H14	134	9.3
Undecane	C11H24	156	9.5
Benzene, 1,2,3-trimethyl	C9H12	120	9.7
Benzene, diethyl	C10H14	134	10.1
Benzene, methylpropyl; or benzene, tetramethyl; or benzene, ethyldimethyl	C10H14	134	10.3
Benzene, tetramethyl; benzene, ethyldimethyl; or benzene, methylpropyl	C10H14	134	10.7
Benzene, ethyl-dimethyl substituted; benzene, 1- methyl-4-(1-methylethyl)-; or benzene, diethyl; acenaphthylene	C10H14 C12H8	134 152	10.9
Alkyl-substituted benzene	C11H16	148	11.1
Dodecane	C12H26	170	11.7
Benzene, ethyl dimethyl substituted; or benzene, methyl-dipropyl	C10H14	134	11.8
Benzene, diethylmethyl	C11H16	148	12.1
Benzene, diethylmethyl; or benzene, ethyltrimethyl	C11H16	148	12.5
Indane, dimethyl; naphthalene, or tetrahydromethyl; benzene	C11H14 C11H16	146 148	13.3

TABLE 9 (continued)

Compound	Formula	Molecular Weight	Retention Time (minutes)
Tridecane	C13H28	184	14.2
Naphthalene	C10H8	128	14.4
Tetradecane	C14H30	198	15.4
Naphthalene, -methyl	C11H10	142	16.2
Naphthalene, -methyl	C11H10	142	16.6
Pentadecane	C15H32	212	17.1
Naphthalene, dimethyl substituted	C12H12	156	18.5
Hexadecane	C16H34	226	18.7
Naphthalene, dimethyl substituted	C12H12	156	18.8
Naphthalene, methyl ethyl	C13H14	170	19.0
Naphthalene, trimethyl, or naphthalene, methyl ethyl	C13H14	170	19.5
Naphthalene, alkyl substituted	C13H14	170	
Naphthalene, alkyl substituted	C13H14	170	20.1
Heptadecane	C17H36	240	20.2
Naphthalene, trimethyl substituted	C13H14	170	20.4
Naphthalene, trimethyl substituted	C13H14	170	20.7
Naphthalene, tetramethyl; or naphthalene, alkyl substituted	C14H16	184	20.9
Biphenyl, dimethyl; or biphenyl ethyl	C14H14	182	
Octadecane	C18H38	254	21.6
Naphthalene, methyl, isopropyl	C14H16	184	22.2
Naphthalene, dimethyl, isopropyl	C15H18	198	22.5
naphthalene, alkyl substituted	C14H16	184	
Nonadecane	C19H40	268	23.0
Eicosane	C20H42	282	24.2
Phenanthrene/anthracene	C14H10	178	24.7
Heneicosane	C21H44	296	25.3
Anthracene; phenanthrene, methyl substituted	C15H12	192	26.1
Anthracene; phenanthrene, methyl substituted	C15H12	192	26.2
Docosane	C22H46	310	26.4
Anthracene; phenanthrene, methyl substituted	C15H12	192	26.6
Dibenzothiophene, dimethyl	C14H12S	212	26.9
Dibenzothiophene, dimethyl	C14H12S	212	27.1
Phenanthracene, anthracene, dimethyl substituted	C16H14	206	27.4
Penanthrene, dimethyl substituted; anthrazene	C16H14	206	27.8
Benzo[ghi]fluoranthene	C18H10	226	28.0
Tetracosane	C24H50	338	28.4

TABLE 9 (continued)

Compound	Formula	Molecular Weight	Retention Time (minutes)
Phenanthrene, trimethyl; anthrene, trimethyl	C17H16	220	28.9
Fluoranthene; pyrene	C16H10	202	29.2
Pentacosane	C25H52	352	29.5
Hexacosane	C26H54	366	30.5
Heptacosane	C27H56	380	31.5
Octacosane	C28H58	394	32.5
Nonacosane	C29H60	408	33.6

TABLE 10. PHYSICAL/CHEMICAL/BIOLOGICAL CHARACTERISTICS OF MEDIA UTILIZED IN LABORATORY AND FIELD MODEL VALIDATION STUDIES

Parameter	Kidman Sandy Loam	Durant Clay Loam	Sieved Fine Sand	Field Soil
Packed Bulk Density (g/cc)	1.44	1.59	1.48	0.93 to 1.20
Texture	Loam	Silt Loam	Sand	Clay Loam
Moisture (%) at:				
1/3 atmosphere	20	41.6		
1 atmosphere				14.34 to 30.33
15 atmospheres	7	12		
Saturation	24	55		
Effective Size (mm)	0.29	0.111	0.284	0.23(1.29 Site F)
Uniformity Coefficient	12.8	7.41	1.65	19.7 (11.1 Site F)
pH	7.9	6.6		
CEC (meq/100g)	10.1	20.5		
Organic Carbon (%)	0.5	2.88	Negligible	
Soil Plate Counts:				
Bacteria	$6.7x10^6/g$	$5.1x10^7/g$		
Fungi	$1.9x10^4/g$	$2.6x10^5/g$		

*Range encountered during field investigation.

TABLE 11 . FIELD SOIL PARAMETER DATA SUMMARY

Sampling Event	Location		% Moisture Content	Bulk Density (g/cc)	TotalPorosity (%)	Air Filled Porosity (%)
BBT	A-F	Mean	19.1	1.03	61.1	42.0
		S.D.	2.9	0.07	2.6	3.4
		C.V.	15.4	6.8	4.3	8.1
BAT 1	A-F	Mean	19.0	0.95	64.1	45.1
		S.D.	2.6	0.07	2.8	3.6
		C.V.	13.5	7.6	4.3	8.1
WBT 2	A&B	Mean	23.0	1.04	60.8	37.8
		S.D.	5.2	0.09	3.3	4.7
		C.V.	22.5	8.4	5.5	12.4
	C-F	Mean	27.3	1.2	54.7	27.4
		S.D.	3.0	0.1	3.6	3.9
		C.V.	10.9	11.3	6.8	14.9
WBT 6	A&B	Mean	28.9	1.04	60.8	31.9
		S.D.	2.7	0.18	6.7	2.7
		C.V.	9.2	17.2	11.1	10.0
	C-F	Mean	28.0	1.10	58.5	30.5
		S.D.	2.0	0.09	3.2	2.8
		C.V.	7.1	7.8	5.6	8.9
WAT 1	A-F	Mean	30.3	0.95	64.1	33.9
		S.D.	6.8	0.13	4.8	8.4
		C.V.	22.6	13.3	7.4	24.9
WAT 7	A &C-F	Mean	17.0	1.05	60.4	43.4
		S.D.	1.9	0.10	3.6	4.0
		C.V.	11.0	9.0	6.0	9.4
	B	Mean	23.0	1.05	60.4	37.4
		S.D.	0.35	0.10	3.6	4.0
		C.V.	1.5	9.0	6.0	9.4
WST 1	A-F	Mean	A 14.8	0.93	64.8	46.9
		S.D.	B 17.6	0.09	3.5	4.5
		C.V.	C 19.2	9.9	5.4	9.6
			D 16.3			
			E 18.0			
			F 21.8			
WST 2	A-F	Mean	A 14.6	1.02	61.4	45.5
		S.D.	B 17.5	0.07	2.7	3.6
		C.V.	C 15.7	7.0	4.4	7.9
			D 14.3			
			E 15.4			
			F 18.2			

SAMPLING/COLLECTION SYSTEM EVALUATION

Tenax™ Recovery/Desorption Efficiency Results

Constituent mass recovery data from the Tenax™ and Tenax™/chamber recovery studies for the seven aromatic compounds of interest are presented in Figures 9 and 10, along with the mass injection levels utilized and the mean and 95% Confidence Intervals resulting for each compound. Mass injection levels were chosen based on expected sorbent tube mass collection levels from Thibodeaux-Hwang model emission estimates (Thibodeaux and Hwang 1982) and GC and GC/MS analyses of Slop Oil and API Separator Sludge waste samples that were used in subsequent laboratory and field emission measurement studies. Data represent 30 to 44 analyses, with a minimum of four tubes used at each of six to eight mass levels applied over the range of masses investigated for each compound. As indicated in Figure 9, Tenax™ mean recovery efficiencies ranged from 78 to 97 percent for all compounds of interest, with coefficients of variation under 10 percent for all compounds except naphthalene which produced a C.V. = 14.4 percent. Corresponding 95% Confidence Intervals for compound recovery efficiencies ranged from ± 0.9 percent for m-xylene to ± 3.8 percent for naphthalene over mass injection levels ranging from 0.09 to 250 µg/tube. These results are approximately 10 percent lower than those presented in the literature (Pellizzari 1977, Pellizzari and Little 1980) for benzene and toluene, 30 percent lower for naphthalene (Timmons et al. 1985), and 30 percent higher for ethylbenzene, yet are felt to be representative of recovery efficiencies that can be expected for the wide range of mass levels collected in land treatment air emission measurement activities.

Tenax™/chamber recovery efficiencies shown in Figure 10 ranged from 60.5 percent ± 12.9 percent for naphthalene, to 94.0 percent ± 12.5 percent for toluene, indicating a much wider range of variability than with the sorbent tubes used alone. This variability is attributed to component losses within the sampling unit, sampling manifold between-tube variability, and purge flow/sorbent tube/sampling flow variability during the sampling event in addition to analytical errors inherent in tube desorption and GC analysis. With the wide confidence interval about the means of Tenax™/chamber recovery data, no significant difference existed between recovery results of the Tenax™ alone versus the Tenax™/chamber sampling system except for p- and m-xylene and naphthalene. These results suggest that recovery data should be collected which allow the quantification of collection and recovery efficiency values for the combined sampling/collection system. All Tenax™ sorbent tube collection data are located in Appendix B along with statistical information related to recovery performance.

Charcoal Recovery/Desorption Efficiency Results

Mean charcoal tube recovery data are shown in Figure 11 along with 95% Confidence Intervals and compound mass injection levels used. No significant difference at the 95% confidence level was observed for recovery data for benzene, toluene, and the three xylenes when analyzed as individual compounds, when in mixtures, or when moisture was added to charcoal tubes. Recovery data were comparable with those collected using Tenax™ for benzene, toluene, and the xylenes; however, consistent quantitative recovery of naphthalene at levels greater than 50 percent were not possible from over 100 samples analyzed during the study. Similar difficulties have been reported for the recovery of aromatics from charcoal using pentane as a solvent (Timmons et al. 1985). Because of the interest in monitoring naphthalene in subsequent laboratory and field studies, charcoal was not used in further sampling system analyses. All charcoal sorbent tube collection data are located in Appendix A along with statistical information related to recovery performance.

Tenax™ Breakthrough Results

Because of the efficiency of collection and recovery of all seven compounds of interest using Tenax™, this sorbent material was further investigated with respect to operating limitations in terms of

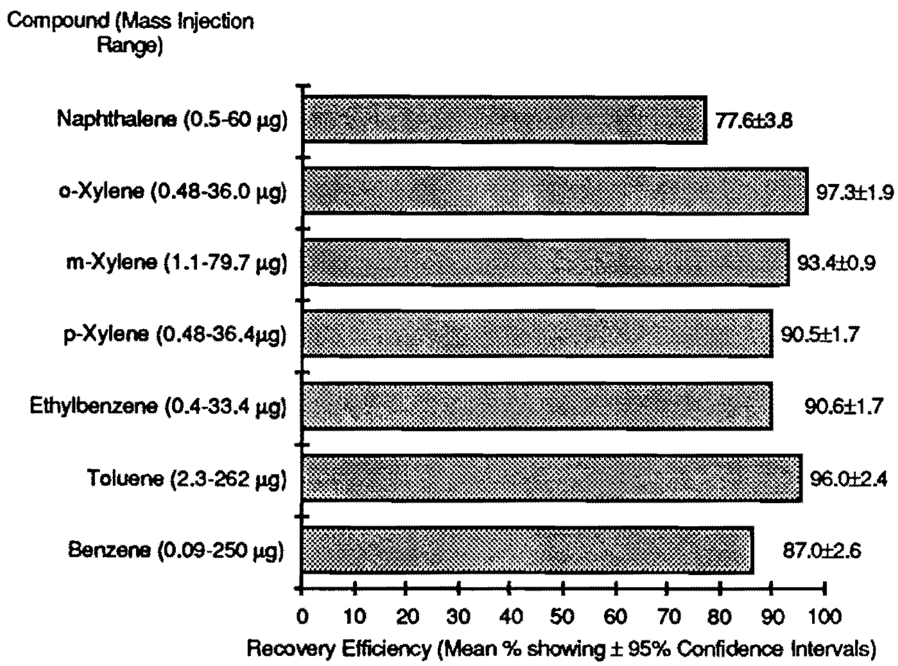

Figure 9. Tenax™ recovery efficiency data

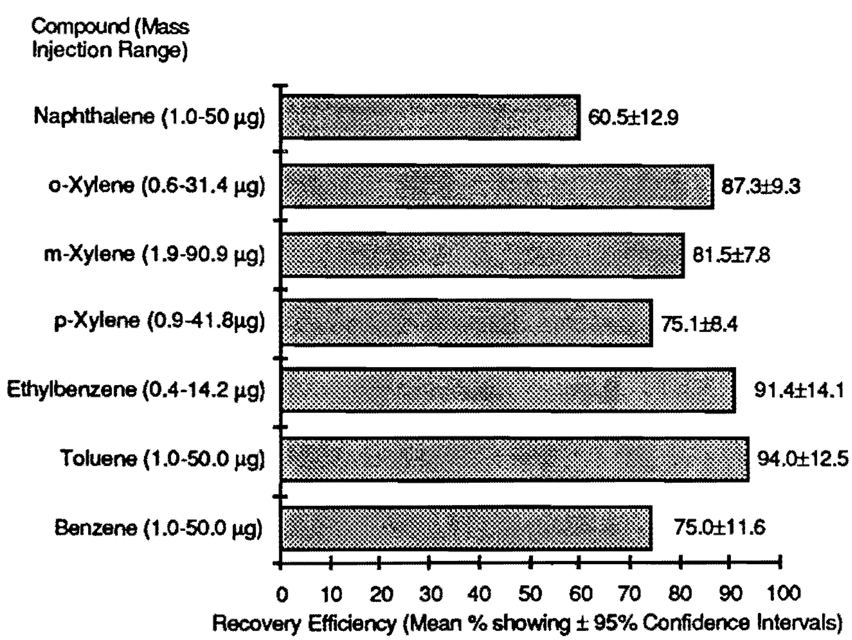

Figure 10. Tenax™/flux chamber recovery efficiency data

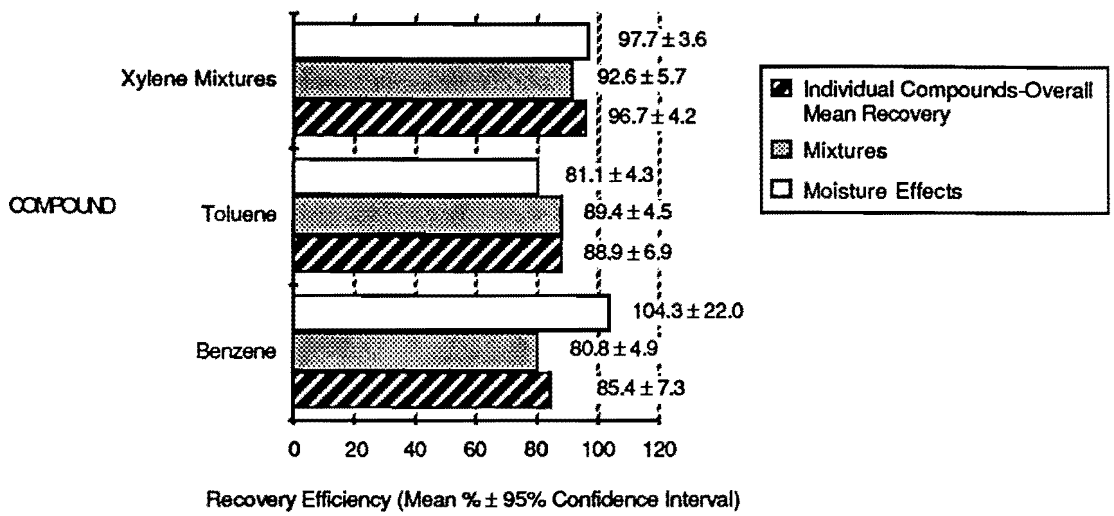

Figure 11. Charcoal recovery efficiency data, individual compounds, mixtures and moisture effects

breakthrough volume during sampling. A range of mass levels from 1.1 to 120 μg were used to spike individual Tenax™ traps connected in series at 19 to 23°C and 28 to 32°C working temperatures used in laboratory and field emission measurement experiments. Results of these breakthrough studies are summarized in Table 12. Results are expressed as collected sample volume in liters/0.28 g sorbent tube at a given compound mass level which provided a 50 percent and 90 percent retention of the injected mass on the first trap of the two trap series. These values were generated from the following expressions representing least-squares regression of all collected breakthrough data for benzene and toluene:

Benzene (28-32°C) 1.1 to 120 μg/Trap

$$\ln[90\%\text{Breakthrough Volume(l)}] = 1.36 - 0.04 \cdot [\text{Mass}(\mu g)] + \frac{[\text{Mass}(\mu g)]^2}{5734}, \quad r^2 = 0.8824 \qquad (29)$$

$$\ln[50\%\text{Breakthrough Volume(l)}] = 2.90 - 0.06 \cdot [\text{Mass}(\mu g)] + \frac{[\text{Mass}(\mu g)]^2}{3731}, \quad r^2 = 0.8668 \qquad (30)$$

Toluene (28-32°C) 2 to 120 μg/Trap

$$\ln[90\%\text{Breakthrough Volume(l)}] = 3.73 - 0.12 \cdot [\text{Mass}(\mu g)] + \frac{[\text{Mass}(\mu g)]^2}{1000}, \quad r^2 = 0.9507 \qquad (31)$$

$$\ln[50\%\text{Breakthrough Volume(l)}] = 3.69 - 0.025 \cdot [\text{Mass}(\mu g)], \quad r^2 = 0.9536 \qquad (32)$$

Benzene (19-23°C) 1.8 to 120 μg/Trap

$$\ln[90\%\text{Breakthrough Volume(l)}] = 2.28 - 0.032 \cdot [\text{Mass}(\mu g)], \quad r^2 = 0.9136 \qquad (33)$$

$$\ln[50\%\text{Breakthrough Volume(l)}] = 2.54 - 0.023 \cdot [\text{Mass}(\mu g)] + \frac{[\text{Mass}(\mu g)]^2}{10747}, \quad r^2 = 0.9599 \qquad (34)$$

All other compounds did not breakthrough in sufficient levels, even with 120 μg injections and 24 liter collection volumes, to allow development of regression equations for breakthrough volume predictions.

TABLE 12. TENAX SORBENT TUBE BREAKTHROUGH VOLUMES AS A FUNCTION OF TEMPERATURE AND MASS INJECTION LEVEL

Mass Level	Benzene	Toluene	Ethylbenzene	p-Xylene	m-Xylene	o-Xylene	Naphthalene
19-23°C Tenax Breakthrough Volumes (l) for a Given Percent Recovery on First Trap of Two Trap Series							
120.0 µg							
90% Recovery	0.20	5.08	25.01	32.55	25.84	21.03	*
50% Recovery	3.15	14.68	110.6	150.0	115.1	91.78	*
60.0 µg							
90% Recovery	1.87	*	*	*	*	*	*
50% Recovery	4.90	*	*	*	*	*	*
Mass Range:	8.5-15.0 µg	10-15.3 µg	9.7 µg	13.4 µg	29.8 µg	11.2 µg	18.0 µg
90% Recovery	3.02	25.41	*	*	*	*	*
50% Recovery	7.79	49.52	*	*	*	*	*
Mass Range:	1.8-2.0 µg	2.2 µg	1.1 µg	1.8 µg	4.2 µg	1.9 µg	2.4 µg
90% Recovery	5.27	*	*	*	*	*	*
50% Recovery	28.10	*	*	*	*	*	*
28-32°C Tenax Breakthrough Volumes (l) for a Given Percent Recovery on First Trap of Two Trap Series							
120.0 µg							
90% Recovery	0.28	0.20	11.31	12.08	10.97	12.77	*
50% Recovery	0.60	2.50	22.22	22.48	24.09	25.44	*
60.0 µg							
90% Recovery	0.71	0.22	14.28	14.87	15.24	14.90	*
50% Recovery	1.79	5.96	24.88	25.43	27.05	28.54	*
15.0 µg							
90% Recovery	1.21	17.35	*	*	*	*	*
50% Recovery	3.54	33.20	*	*	*	*	*
1.1-4.2 µg							
90% Recovery	4.50	19.22	*	*	*	*	*
50% Recovery	13.67	40.35	*	*	*	*	*

* = >>24 liters

The benzene breakthrough data collected in this study were used to generate a series of regression equations for the prediction of the percent recovery of benzene as a function of mass injected and sample volume collected on the 0.28 g sorbent tubes. These regression equations were developed for specific temperature and benzene mass injection levels as indicated below:

Benzene (19-23°C) 1.8 to 60 μg/Trap

$$\% \text{ Recovery} = (-3.99 - 0.154 \cdot (\text{Mass, } \mu g)) \cdot \text{Vol. Collected (l)} + 111.9 \quad , r^2 = 0.7876 \qquad (35)$$

Benzene (19-23°C) 120 μg/Trap

$$\% \text{ Recovery} = (-12.9) \cdot \text{Vol. Collected (l)} + 91.5 \quad , r^2 = 0.9716 \qquad (36)$$

Benzene (28-32°C) 1.8 to 120 μg/Trap

$$\% \text{ Recovery} = (2.706 - 0.973 \cdot (\text{Mass, } \mu g)) \cdot \text{Vol. Collected (l)} + 117.2 \quad , r^2 = 0.8244 \qquad (37)$$

A number of references report data for breakthrough volume for volatile aromatics utilizing Tenax™ sorbent tubes (Pellizzari 1980, U. S. EPA 1982b). These values are summarized in Table 13 for water, benzene, toluene and ethylbenzene for which data have been reported. These data indicate a major discrepancy in the suggested breakthrough volumes appropriate for Tenax™ sorbent tube sampling. Comparison of Table 13 values with those collected in this study also indicate that reported data do not adequately address the effect mass has on breakthrough volume. Under conditions of high volatile constituent mass loadings to the sorbent tubes, as is likely in source emission sampling, breakthrough volumes may be greatly overestimated based on current EPA sampling protocol (U. S. SEPA 1982b). For source emission measurement sampling for which 1 to 20 μg are collected during sampling, a maximum 200 to 500 ml sample volume is recommended when using Tenax™ sorbent tubes to ensure minimum (≤10 percent) breakthrough of compounds with volatilities similar to that of benzene.

TABLE 13. LITERATURE TENAX TRAP BREAKTHROUGH VOLUME RESULTS*

		Breakthrough Volume at Stated Temperature (liter/0.28 g Tenax)				
Compound	B.P. (°C)	10°C	21°C	27°C	32°C	38°C
Benzene	80	13.7	6.9	4.8	3.4	2.4/5.3†
Toluene	110.6	62.9	31.2	22.0	15.5	10.9/27.2†
Ethylbenzene	136	177.2	88.2	62.0	43.8	30.8/56.0†
Water	100	0.0	0.0	0.0	0.0	0.0

*Breakthrough volumes shown are those reported by Pellizzari (1980) representing a 50% mass breakthrough, except those indicated by a † which are reported by U. E. EPA (1982b) for an unspecified mass breakthrough.

Isolation Flux Pressure Development Results

The development of pressure under the flux chamber during purging was found to be significant at purge flow rates as low as 1 liter/min as indicated in Figure 12. Pressure increased rapidly at purge flows greater than 1 liter/min, reaching nearly 2 inches of water with respect to the outside of the chamber at a purge rate of 6 liters/min. Because Radian protocol recommends purge rates between 1 and 10 liters/min (Schmidt and Balfour 1983, Balfour et al. 1983, Eklund 1985), concern over interior pressure effects on emission measurements are warranted. Pressure increases should be quantified as a function of flow rate for the particular chamber being used in emission sampling. If a sealed sampling chamber is utilized in field measurements, purge flows on the order of 1 to 1.5 liters/min should be an upper limit unless a constant volume sampling pump downstream of the sampling chamber is used to balance pressure between the chamber interior and the ambient atmosphere.

Isolation Flux Chamber Mixing Results

Because of the low flow rate necessary to minimize pressure build-up under the flux chamber, concern was raised regarding the mixing characteristics of the chamber at low purge rates. Complete-mix conditions are assumed within the sampling chamber when using chamber effluent concentrations for the estimate of surface flux rates. Flux chamber mixing results were used to test this assumption. Table 14 provides a summary of indicator retention time parameters and index data from mixing studies at purge flow rates ranging from 0.73 to 3.73 liters/min. These data were calculated based on flow curves generated from acetone tracer concentration profiles in the flux chamber effluent measured over time without internal mechanical mixing. A typical flow curve is shown in Figure 13, and indicates the complete-mix nature of the flow regime once the tracer is uniformly dispersed within the chamber. The decay portion of all flow curves did not vary more than 15 percent from corresponding theoretical complete-mix curves, meeting suggested Radian protocol for the use of flux chambers for soil surface emission measurements (Balfour et al. 1983).

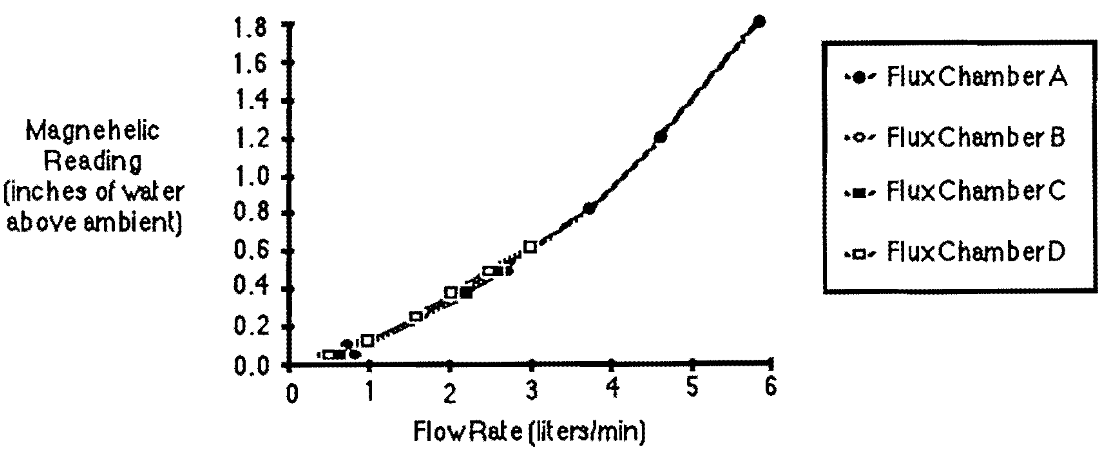

Figure 12. Pressure above ambient developed under flux chamber as a function of purge flow rate.

TABLE 14. FLUX CHAMBER MIXING DATA INDICATOR RETENTION TIME PARAMETERS/INDICES†

Flow Rate (ml/min)	Theoretical Retention Time T (min)	Ti (min)	Tm (min)	Ta (min)	Ti/T	Tm/T	Ta/T	T10 (min)	T90 (min)	Morril Index
732	30.4	1.28	6.67	30.44	0.04	0.22	1.00	7.51	83.89	11.17
732	30.4	0.55	5.65	14.91	0.02	0.19	0.49	3.82	30.65	8.02
1650	13.5	0.40	4.16	8.97	0.03	0.31	0.67	2.62	17.87	6.82
1650	13.5	0.24	2.00	8.35	0.02	0.15	0.62	2.16	17.07	7.90
2727	8.2	0.18	0.44	4.73	0.02	0.05	0.58	0.88	10.39	11.81
2727	8.2	0.10	0.19	4.61	0.01	0.02	0.56	0.60	10.69	17.82
2727	8.2	0.40	0.92	8.78	0.05	0.11	1.08	1.10	20.50	18.64
2727	8.2	0.14	0.49	4.68	0.02	0.06	0.57	0.54	10.92	20.22
3726	6.0	0.30	0.46	3.78	0.05	0.08	0.63	0.66	8.42	12.76
3726	6.0	0.10	0.19	3.04	0.02	0.03	0.51	0.52	6.82	13.12
3726	6.0	0.40	0.68	4.12	0.07	0.11	0.69	0.76	9.35	12.30
3726	6.0	0.45	0.86	7.30	0.08	0.14	1.22	1.06	16.98	16.02

† Ti = Time to initial tracer detection
† Tm = Time to peak concentration of tracer
† Ta = Time to centroid of area ≈ average retention time
† T10 = Time to 10% area under tracer curve
† T90 = Time to 90% area under tracer curve
† Morril Dispersion Index = T90/T10

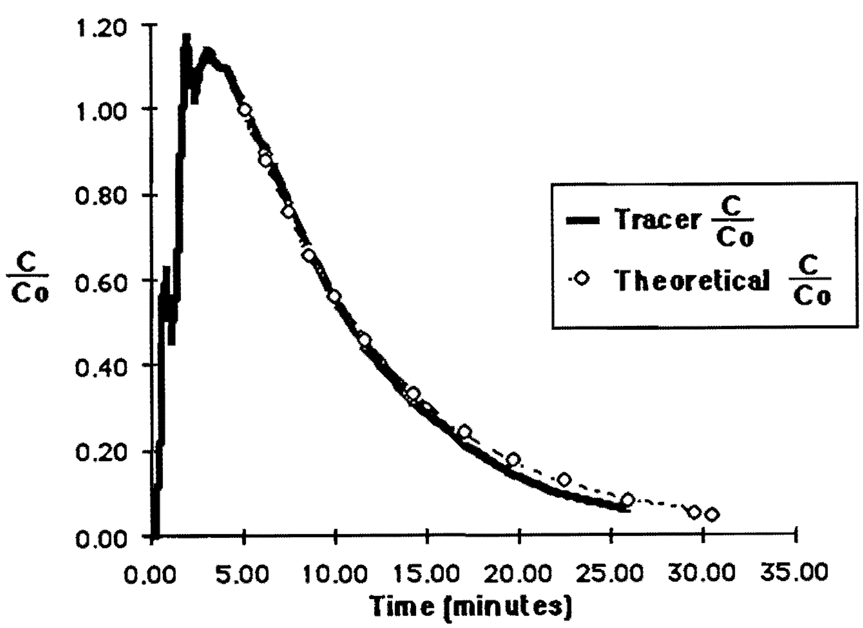

Figure 13. Typical flux chamber flow curve, Run #4.

Inspection of the data in Table 14 indicates that mixing conditions within the sampling chamber were relatively insensitive to purge flow rate based on calculated retention time parameters and Morril Index values. The Morril Index is a relative measure of dispersion within a reactor, indicating the spread of the flow curve based on the ratio of the time to 90 percent curve area to the time to 10 percent curve area. As this ratio increases, the degree of mixing or dispersion within the reactor increases, and the reactor is classified as being more completely-mixed. Morril Index values ranged from 6.82 to 20.22, with an average index value ±95% Confidence Interval of 13.18 ± 2.86. No trend in dispersion with purge flow rate was evident. The additional retention time index parameters used, i.e., Ti/T, Tm/T, and Ta/T, also confirmed flow regime similarity among all flow rates investigated. These results are encouraging as the complete-mix assumption for flux chamber contents appears to be valid, even at flow rates as low as 0.73 l/min . This expands the applicability of the flux chamber approach as it allows the use of such a chamber for representative soil surface emission measurements without a downstream purge pump.

LABORATORY MODEL EVALUATION

Temporal Variation of hp and hs

Both capillary rise and penetration depth were observed to follow a linear relationship with log time in both the sand and soil media for both wastes studied. A linear depth versus log time plot of the wetting front data resulted in relationships as shown in Figures 14 and 15. The rate of hs increase with time was shown to be a function of both the waste type and the media properties and ranged from 0.33 cm/log(hour) for Separator Sludge application to sand to 2.31 cm/log(hour) for Slop Oil application to the Kidman sandy loam. An increase in hp with time occurred in all units, with the rate being much more rapid in the sand than the soil as expected from particle size and organic carbon content considerations. The slope of hp versus log(hour) was shown to be a function of both the media type and waste characteristics, and for the soil microcosms ranged from 0.71 to 2.96 cm/log(hour) for the Slop Oil applied to the Kidman and Durant soils, respectively. The same waste application to the sand resulted in slope values greater than 4.8 cm/log(hour). The Separator Sludge was evaluated using only the Kidman soil and the sand, and the mean slope values were approximately 1.5 units lower for both as indicated in Table 15. Relationships for the Kidman soil appeared independent of waste loading rate, however, the Durant soil showed an increase in the change in hp with 1/log(time) with an increase in loading rate as shown in Table 15. These variable relationships with time indicate that the dynamic nature of the boundary conditions occurring within the treatment zone can be significant in low organic matter soils when it is loaded with a low viscosity waste, or even in high organic content soils at high waste loading rates. The variable hp and hs values are not accounted for in the Thibodeaux-Hwang model as presented in Section 4. An effort was made to incorporate variable boundary conditions into model results, however, through the solution of the Thibodeaux-Hwang model over discrete time periods ranging from 0 to 1, 0 to 10, and 0 to 100 hours using mean values of hs and hp during these time increments based on data as plotted in Figures 15 and 16. Raw hp and hs data from the microcosm runs are provided in Appendix E along with linear regression data for all depth versus log time relationships investigated.

Measured Versus Theoretical Emission Rates in Microcosm Units

Emission Rate Temporal Relationships--

The first test of model validity is related to the ability of the model to describe, in general terms, the nature of emission rates from soil systems. If the model as written in Equation 8 describes vapor emissions from soils, a plot of emission rate as a function of $1/\text{time}^{1/2}$ should follow a straight line, the slope and intercept of which would be related to the input parameters given in the equation. Data plotted in this fashion is expected to have a positive slope decreasing in magnitude from the most volatile benzene, to the least volatile naphthalene.

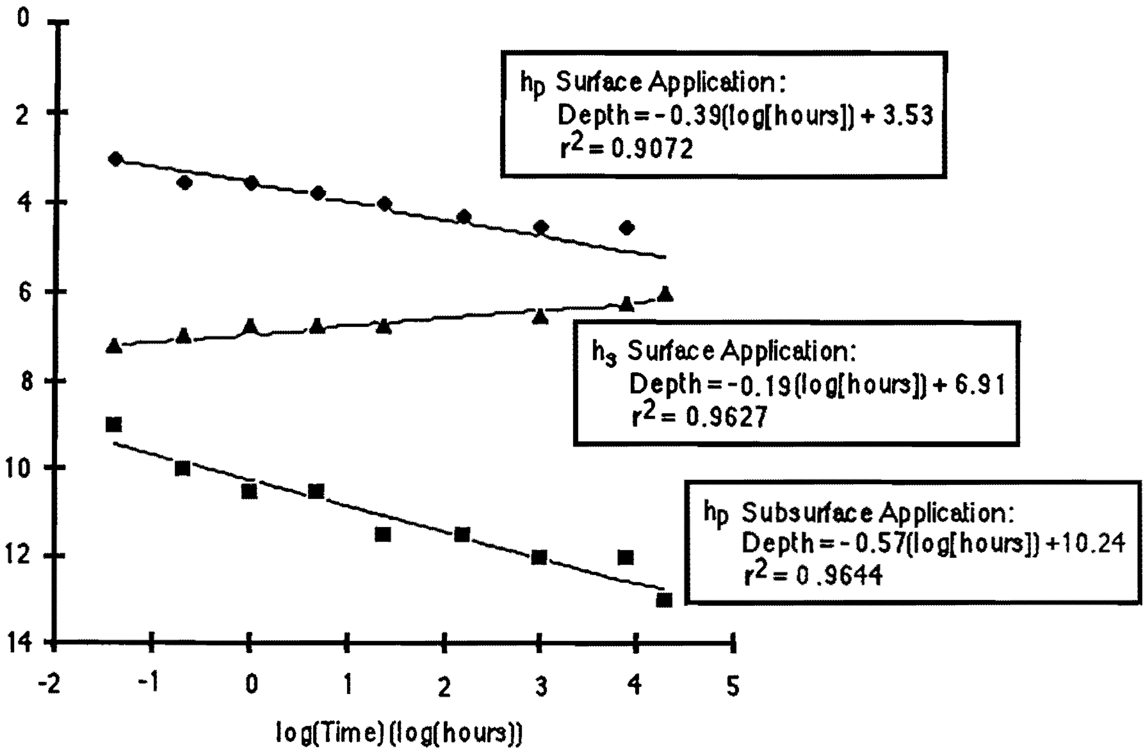

Figure 14. Temporal variation of hp and hs following Separator Sludge surface and subsurface application to Kidman sandy loam.

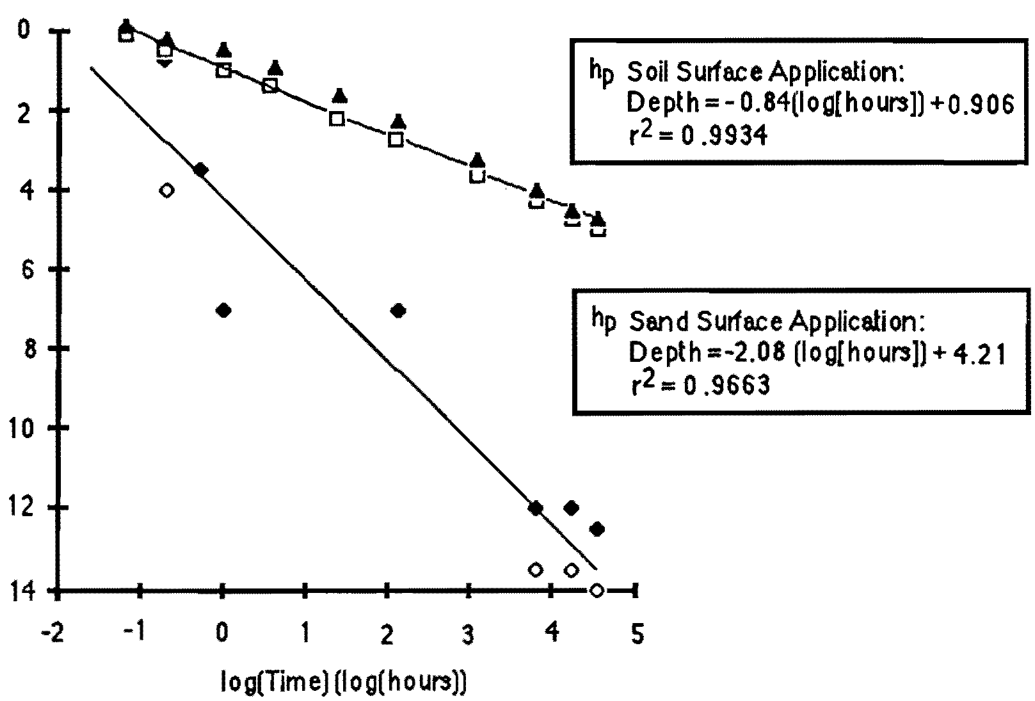

Figure 15. Temporal variation of hp following Slop Oil surface application to sand and Kidman sandy loam.

TABLE 15. MEAN HP AND HS TEMPORAL CHARACTERISTICS AS A FUNCTION OF WASTE AND MEDIA TYPE

Waste	Media	Application Method†	Waste Loading (g/microcosm)		Regression Slope (cm/log(hours)) h_p	h_s
Slop Oil	Kidman	SS	49.3		-2.96	2.31
	Kidman	SS	54.2		-2.72	1.45
	Kidman	SS	31.9		-2.09	
	Kidman	SS	31.3		-1.92	
	Kidman	SS	79.0		-2.26	
	Kidman	SS	79.0		-2.61	1.88
	Kidman	S	38.1		-2.09	
	Kidman	S	37.7		-1.91	
				Mean =	-2.32	1.88
				S.D. =	-0.40	0.43
				C.V. =	17.1	22.7
Slop Oil	Durant	SS	30.6		-1.03	0.34
	Durant	SS	30.9		-1.08	0.33
	Durant	S	30.3		-0.762	
	Durant	S	30.8		-0.708	
				Mean =	-0.895	0.34
				S.D. =	-0.19	
				C.V. =	20.9	
	Durant	SS	57		-1.85	
	Durant	SS	57		-1.54	
				Mean =	-1.70	
Slop Oil	Sand	S	37.7		-4.84	
		S	37.9		-5.09	
				Mean =	-4.96	
Separator Sludge	Kidman	SS	38.0		-1.35	0.42
	Kidman	S	37.1		-0.90	
	Kidman	SS	36.5		-0.61	0.33
	Kidman	S	34.4		-0.999	
				Mean =	-0.96	0.37
				S.D. =	-0.30	
				C.V. =	31.6	
Separator Sludge	Sand	SS			-4.29	
	Sand	S			-2.64	
				Mean =	-3.46	

† SS = Subsurface, S = Surface Application Methods

Figures 16 and 17 show typical results of Separator Sludge and Slop Oil data collected in the study that fit the diffusion based assumption for emission flux predictions very well. Appendix G contains a comparison of measured versus theoretical values for all constituent flux rate versus $1/\text{time}^{1/2}$ data collected. Results for the majority of regressions of surface waste applied microcosm experiments indicated the validity of the Thibodeaux-Hwang modeling approach for describing volatile emissions from laboratory soil systems. The majority of these experiments yielded highly correlated (r^2>0.85) flux rate versus $1/\text{time}^{1/2}$ relationships indicating the Fickian nature of constituent emission from the microcosm units. The notable exception was the surface applied Separator Sludge/sand experiment (Run#3, Position #6) which yielded correlation coefficients for the regression of measured flux rates of less than 0.2 to 0.6 for all compounds of interest.

The subsurface application experiments in virtually all media did not exhibit ideal behavior, however. These experiments produced increasing flux rates (negative slope of flux rate versus $1/\text{time}^{1/2}$) with time to a point, until such time as apparent diffusion type behavior occurred as indicated by decreasing linear flux versus $1/\text{time}^{1/2}$ relationships. Data presented in Appendix G clearly show the duality of vapor emission rates in these units. These increasing flux rates with time suggest a decreasing diffusion path length that could occur in subsurface applications due to capillary rise within the soil microcosm. Those media possessing the greatest opportunity for soil capillarity development, i.e., the Kidman sandy loam, would be expected to produce the greatest amount of non-ideal behavior in subsurface applications. However, all media used in the laboratory experiments were observed to produce this phenomenon. Regression of this early period flux data against the natural log of time was investigated to determine whether the flux increase could be correlated in a manner similar to the boundary condition variability described earlier. These results vary, with some data regressing well against log(time) (Run#1 Position #2, Slop Oil subsurface Kidman sandy loam; Run #1 Position #4, subsurface sand), while others (Run #3 Position #5, Separator Sludge subsurface sand) showed no significant correlation with log(time). Following the flux increase during the early portion of the subsurface runs (variable from four to ten hours), contaminant behavior for all constituents and in all media reverted to diffusion based control as indicated by significant regression coefficients for flux versus $1/t^{1/2}$ for the later portions of the runs. Regression of the second portion of the flux curves from the subsurface experiments are presented in Appendix G, and typical data from which these diffusion based relationships were generated are shown in Figure 18.

The reason for the anomalous behavior in the subsurface experiments is not fully understood, but can be attributed to unsteady-state diffusion behavior during the initial emission period. This behavior is likely due to the variable boundary geometry which changes with time following waste application, along with the development of contaminant concentration profiles within the soil column during this time (Thibodeaux, personal communication, 1986.). Immediately following subsurface waste application, no contaminant exists within the soil vapor pore space above the point of application. As the contaminant vapor moves from the application plane toward the soil surface, a concentration gradient profile develops. This concentration profile provides the driving force for steady-state diffusion as described by the Thibodeaux-Hwang AERR model, however, while the profile is developing, contaminant flux rates would be expected to increase from very low levels to some maximum value before finally decreasing logarithmically, as was observed in laboratory subsurface application experiments. The Thibodeaux-Hwang AERR model describes emission flux during the period following development of this steady-state concentration gradient profile, and Equation 8 should not be applied to subsurface application events until that point in time when a "pseudo-equilibrium" soil concentration profile has been established, and steady-state diffusion assumptions hold true.

Actual Versus Predicted Flux Data--

A second indicator of model validity is the relationship of the magnitude of the estimated parameter to that actually measured. Appendix G indicates all calculated model emission rates and measured component flux values for the sampling periods used in the laboratory microcosm studies. All measured

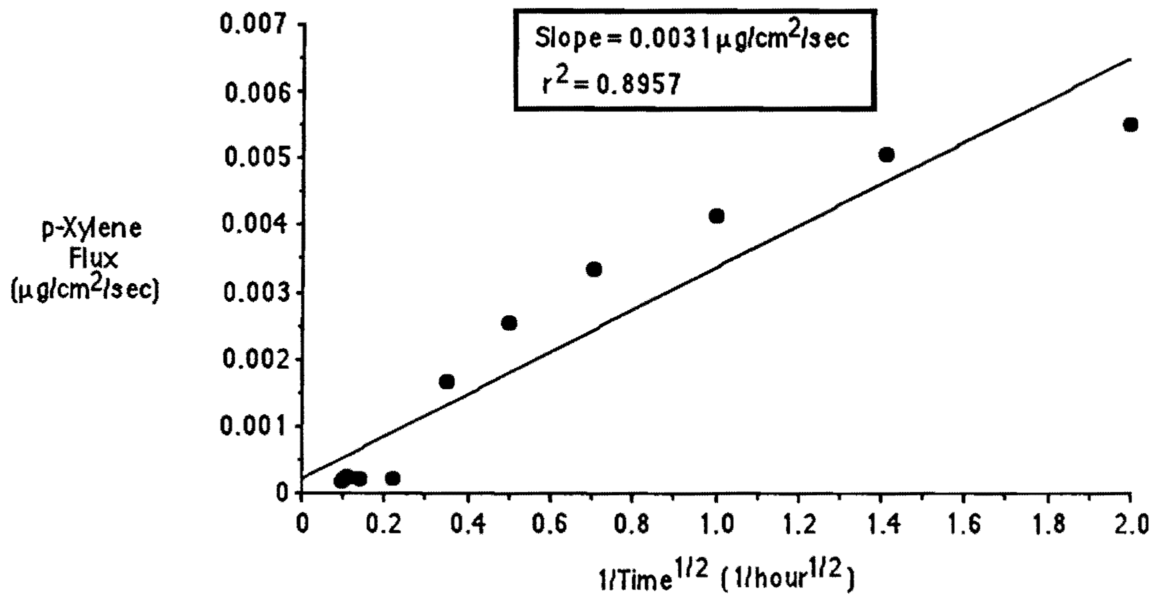

Figure. 16. Separator Sludge surface application to Kidman sandy loam, Run#4, Position#8.

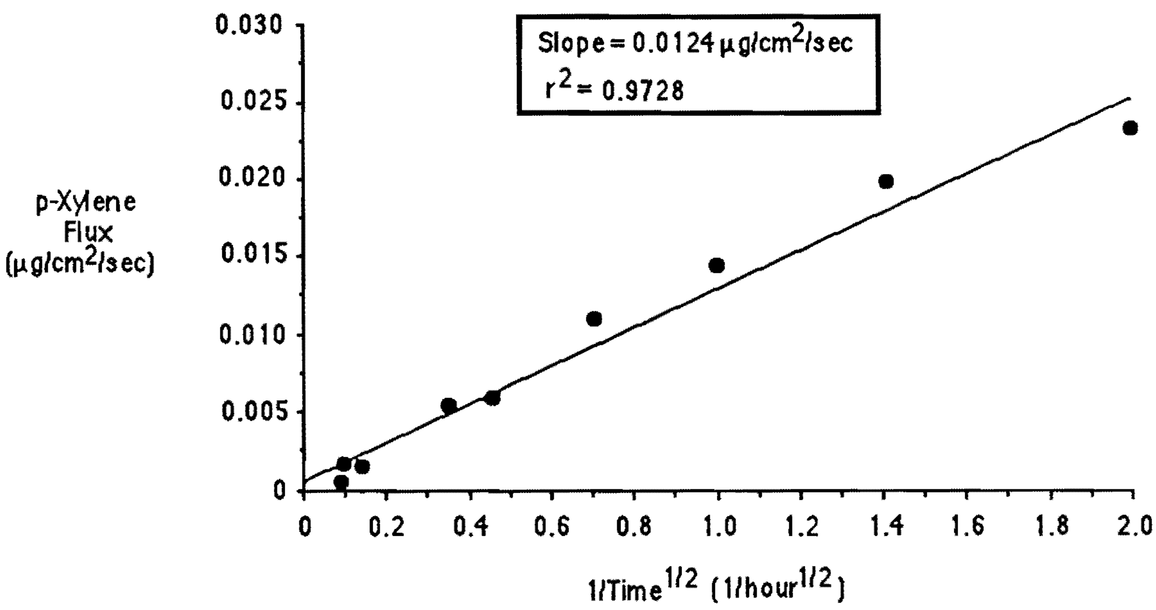

Figure 17. Slop Oil surface application to Durant clay loam, Run#8, Position#5.

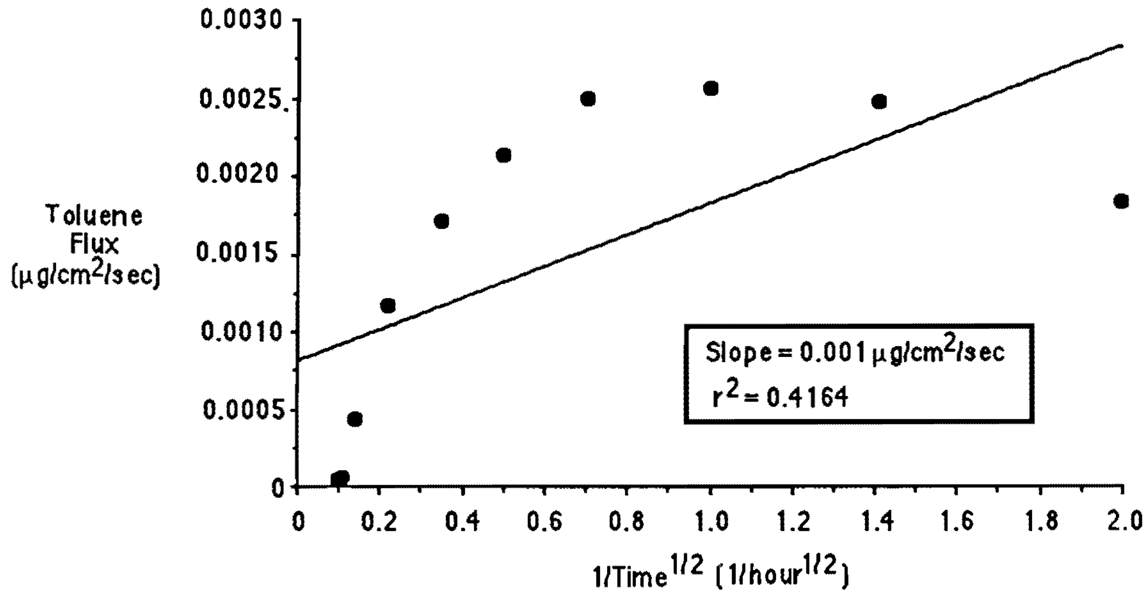

Figure 18. Separator Sludge subsurface application to 30 mesh sand, Run#4, Position#5.

data reported in Appendix G represent recovery efficiency corrected values based on laboratory Tenax™ recovery efficiency data presented in Figure 9 and Appendix B. The Thibodeaux-Hwang model predicted values were calculated using time averaged hp and hs values based on observed boundary condition movement during the experiments as described earlier. Refer to Appendix L for example procedures used to calculate Thibodeaux-Hwang AERR model emission rate predictions.

Model estimates based on equations and methodology presented above consistently overestimated the flux rates for pure constituents by a factor of two to ten in all experiments except a subset of the subsurface application runs which showed variances between measured and predicted flux rates of two orders of magnitude or greater. The runs showing poor model fit included: Run #3 Position #7 Separator Sludge subsurface application to Kidman Sandy Loam, Run #4 Position #7 Separator Sludge subsurface application to Kidman Sandy Loam, and Run #7 Position #1 Slop Oil subsurface application to Durant Clay Loam. These runs produced some flux estimates two to three orders of magnitude higher that those predicted from Equation 8. Problems associated with unsteady-state diffusion, which is not described by the Thibodeaux-Hwang AERR model, as well as the lack of sufficient mass collected for reliable emission rate quantitation are thought to be the cause of these divergent results for subsurface application runs. Figures 19 and 20 indicate the relationship between measured and model predicted emission rates for all data collected in microcosm surface and subsurface application experiments, respectively.

Laboratory emission study data, especially those from surface application runs, produced highly correlated relationships between measured and predicted flux rates and flux rate changes with $1/t^{1/2}$. These results clearly indicate the validity of the Thibodeaux-Hwang modeling approach for vapor emission estimates once steady-state diffusion assumptions are satisfied.

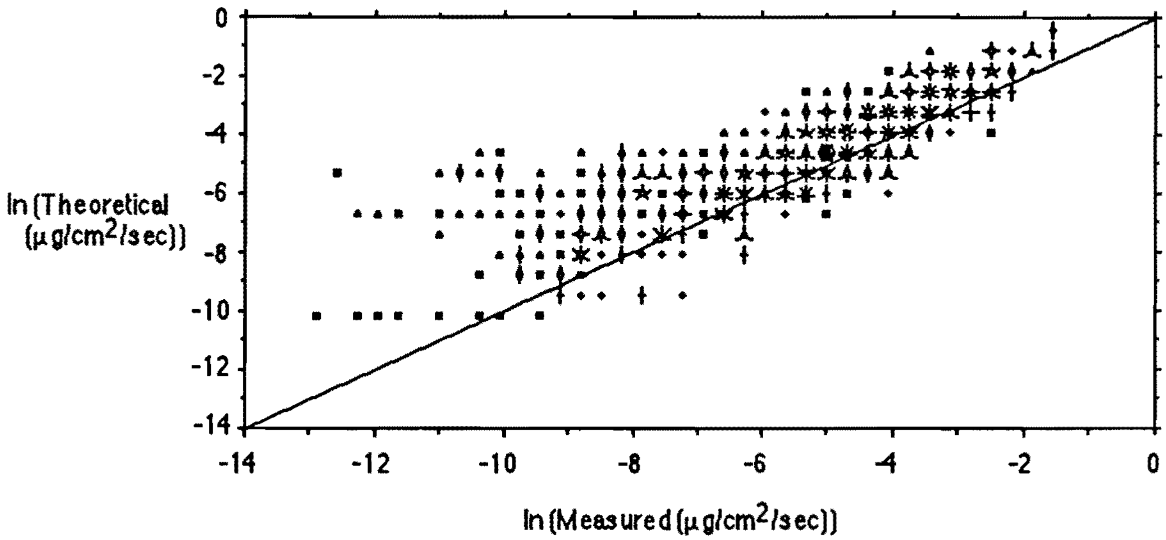

Figure 19. Parity plot of surface application microcosm data.

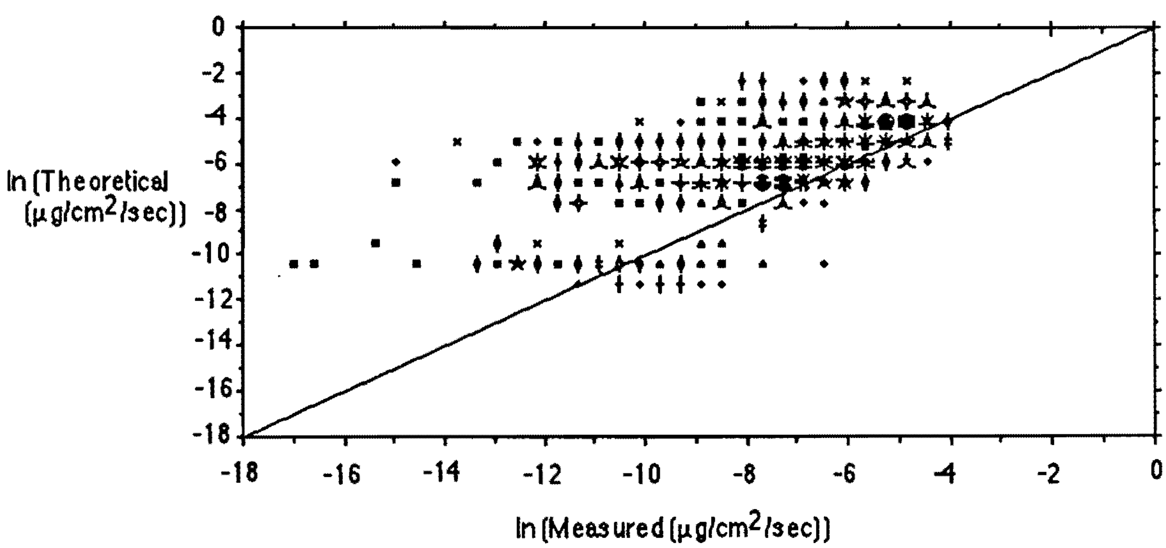

Figure 20. Parity plot of subsurface application microcosm data.

Surface Versus Subsurface Application--

A potential air emission control procedure that has been proposed for land treatment facilities is the use of subsurface waste application methods in place of current spreading and tilling practices. An analysis of the effects of application methods on contaminant emission rates confirmed the anticipated benefits of subsurface application for both waste types and both soils used. Results from the sand runs were mixed, with from 0 to 2 orders of magnitude reduction in emission rates observed during the study. Measured contaminant flux rates through soils used in the study were reduced by a factor of 10 to 10,000 when waste subsurface application was carried out. Emission reduction factors of only 10 to 100 were predicted from the Thibodeaux-Hwang AERR model for subsurface versus surface waste application, indicating that interactions not accounted for in the model, such as soil adsorption, may have significantly affected emission flux rates in these laboratory columns.

Soil Characteristics Affecting Soil Vapor Emissions--

The physical structure and water holding capacity of the medium is considered to some degree in the Thibodeaux-Hwang model through the use of media particle characteristics for estimating the configuration of the soil oil (Equations 14 through 17) and through the use of total and air filled porosity for effective contaminant soil diffusion coefficient estimations. The model, however, does not take into account adsorption of the contaminant vapor within the soil column. The soil media used in the laboratory studies were chosen to investigate the effects of physical soil characteristics as well as adsorption and partitioning on soil vapor emissions. As indicated earlier in discussions of h_p and h_s variabilty, media type had a major impact on waste movement and subsequent vapor emissions measured during the laboratory studies. As would be expected with the Durant clay loam, which has an effective size more than three times larger than the Kidman soil, capillary rise in this soil was very small. Downward boundary movement was also greatly attenuated in the Durant soil, which is likely due to its relatively high organic matter content. Although this high organic matter content did not provide additional flux attenuation over the Kidman soil, both soils provided significant reductions (factor of 2 to 200) in flux rates following subsurface application as compared to the sand units during Run #4 sampling. These results indicate the apparent importance of soil organic matter on attenuation of vapor movement in soil.

Microcosm Versus Screening Flask Results

Comparison was made between two-dimensional microcosm units and the smaller, simpler, less expensive screening flask apparatus to determine whether such a simplified system could be used for initial volatile emission estimate screening. Flask systems were operated as surface microcosm units with constant h_p values and $h_s=0$.

Appendix F contains all data collected using the screening flask apparatus. An inspection of these data indicates a good correlation with theoretical Fickian diffusion assumptions in terms of high regression coefficients for flux versus $1/t^{1/2}$ relationships. The absolute magnitude of slope values for this relationship varied within a factor of two to ten between the microcosm and screening flask units for all compounds except naphthalene, which often varied by a factor of fifteen or more.

Appendix F data indicate that the absolute magnitude of flux rates observed for all compounds in the Separator Sludge when applied to the sand and the Kidman soil, and Slop Oil applied to the sand flask runs were equivalent to those observed in the microcosm runs. However, flux rates from the flask units were consistently an order of magnitude higher than microcosm results in the Slop Oil applied to the Kidman and Durant soil experiments. This screening flask method seems to hold promise for the easy determination of waste/soil volatilization potentials and appears accurate for some waste/soil combinations. More work is required, however, to identify operating and/or sampling characteristics that result in the low observed flask system emission rates as compared to both microcosm and theoretical estimation methods for real soil/waste systems such as investigated in this study.

FIELD MODEL EVALUATION

Refinery/Waste/Land Treatment Facility Description

The hazardous waste used for field sampling activities was generated from a mid-Western refinery which has a crude oil processing capacity of approximately 90,000 barrels per day. Operations conducted at the facility include atmospheric distillation, vacuum distillation, delayed coking, fluid catalytic cracking, catalytic reforming, aromatic isomerization, lube oil processing, and asphalt processing.

The field study utilized a test plot which has been used routinely in the past for land treatment of oily sludges. Figure 21 indicates oil application and soil concentration data for the field test plot as provided by refinery personnel. These data correspond well with those reported from UWRL and RSKERL analyses (Table 16), and indicate a pseudo-equilibrium soil oil content of approximately 9 to 12 percent on a dry soil weight basis.

Most of the sludge applied to the site in the last three years has been an oily wastewater treatment sludge composed of API separator and DAF bottom sludges with an average composition of 71 percent water, 22 percent oil, and 7 percent solids. The field test plot also receives biological sludge from the facility activated sludge plant two to three time a year. Single monthly sludge applications of 20 to 25 bbls oil per plot or approximately 100 bbls oil/ac (equivalent to 75 bbls sludge per plot) are normal during warm periods. Loading at half these rates are routinely applied during cold weather operation. Plots are generally tilled within a few days of surface waste application. A second tilling is usually carried out two to three weeks later. A four week treatment period from the first tilling event is generally used before waste is reapplied in a given location.

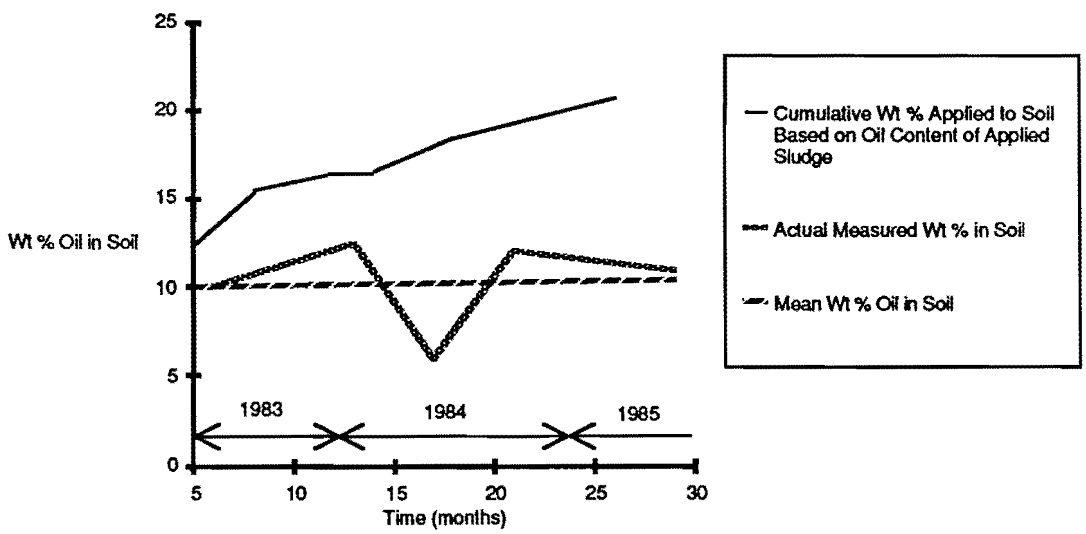

Figure 21. Biodegradation relationships at refinery field site, Plot 2.

Waste application to Plot 2 prior to the field study (6/25 to 7/5/85) included: 1) biosludge application during the period 2/6 to 2/11/85 at a rate of 72 bbls sludge per plot, with tilling occurring from 2/11 to 2/18/85, and 2) two oil wastewater treatment sludge applications with the following characteristics:

Waste Application	Application Rate	Tilling Date
3/27/85	76 bbls sludge, 19 bbls oil	4/1/85
5/31/85	38 bbls sludge, 10 bbls oil	6/4/85

Waste was applied to Plot 2 one week earlier than the normal four week treatment period, but was added at a typical rate of approximately 76 bbls sludge per plot based on estimates from the tank truck operator.

Field QA/QC Program Results

Data collected in the field QA/QC program were used to evaluate sampling, transport, storage and analyses activities to indicate the reliability and accuracy of results obtained. QC procedures used during field activities included: 1) analyses of waste/soil oil and grease samples split between the UWRL and RSKERL, 2) analyses of waste samples for specific constituent identification, 3) analyses of field blanks, spiked blanks and spiked samples for Tenax™ recovery and breakthrough evaluation, and 4) determination of sampler manifold tube recovery variability to indicate the acceptability of sampler field operation for comparison with similar laboratory generated values.

Oil and Grease Analyses--

Data for oil and grease analyses conducted on waste/soil mixtures obtained at sampler locations within the field land treatment plot are located in Table 16. These data include results for laboratory analyses of standard oil and grease samples and indicate the validity of in-house analytical methods. The data indicate the reliability of sampling and analysis methods for oil and grease samples collected during the field study, with parameter variability less than 20 percent between laboratories for all but sample WAT1C. These results add confidence to general field operating procedures in terms of accuracy and precision of collected data.

Field Blank and Spike Tenax™ Data--

Blank sorbent tube data collected throughout the field study are presented in Table 17. These data are divided into blanks collected before waste application and those collected following waste application. As other investigators have reported (Eklund 1985, Jarke 1985, Timmons et al. 1985), a number of very high mass levels of benzene and toluene were detected on several blanks collected during field sampling. A number of these high blank values were attributed to the GC analysis technique employed at the UWRL which resulted in high mass carry over from waste before tilling samples into blank sorbent tube analyses. The problem was subsequently corrected through post analysis temperature programming designed to rid the column of high residual contaminant masses between samples. These high benzene mass levels, i.e., 41.55 µg in WBT2F, 41.3 µg in WBT5E, and 16.3 µg in WBT3C samples, were not found in any other blanks used throughout the study and were traced back to high level WBT samples run just prior to analysis of these blank tubes. These high erroneous values were not included in blank corrections for mass collection data. The mean values presented in Table17 exclude these high mass tubes contaminated during GC analysis. These adjusted mean blank values were used for all blank corrections within their respective sampling time periods, i.e., BBT and BAT, WBT, WAT, and WST. Blank correction values generally decreased as compound vapor pressure increased. Blank background levels increased during the waste application period before slowly falling to pre-waste application levels by the WAT sampling event.

TABLE 16. OIL AND GREASE ANALYSES RESULTS

SAMPLE: LABORATORY QA/QC SAMPLES

	Measured Oil & Grease (mg/kg)	Actual Oil & Grease (mg/kg)
#2 Fuel Oil	940000±10000	>880000
EPA Reference Oil (Prudhoe Bay Crude)	860000 ± 10000	>880000

SAMPLE: FIELD SAMPLE OIL AND GREASE COMPARISON DATA, UWRL AND RSKERL

		UWRL Oil & Grease† % dry wt	RSKERL Oil & Grease % dry wt	RSKERL Oil & Grease % wet wt			UWRL Oil & Grease† % dry wt	RSKERL Oil & Grease % dry wt	RSKERL Oil & Grease % wet wt
BBT1					**WBT2**				
	A	11.26/10.48	10.0	8.0		A	25.6	21.0	16.0
	B	8.9	9.0	7.4		B	19.37/16.39	24.0	16.0
	C	7.7	10.0	8.2		C	15.5	25.0	18.0
	D	7.0	9.2	7.6		D	17.6	25.0	18.0
	E	7.3	9.0	7.7		E	18.1	23.0	16.0
	F	9.31/8.99	11.0	8.9		F	22.3	28.0	19.0
WBT6					**WAT1**				
	A	16.1	21.0	14.0		A	9.4*/8.4*	9.5	7.1
	B	17.8*	21.0	16.0		B	14.4	13.0	8.4
	C	13.8	12.0	7.1		C	11.3	4.8	3.1
	D	27.1	24.0	18.0		D	16.6/16.1	17.0	12.0
	E	14.3	17.0	11.0		E	14.6	12.0	9.1
	F	20.1	15.0	11.0		F	9.4*	11.0	8.1
WST2									
	A		11.0	9.4					
	B		9.1	7.5					
	C		9.9	8.1					
	D		11.0	9.8					
	E		8.8	7.1					
	F		12.0	9.4					

* Designates percent oil on a wet weight basis for UWRL samples.
† Multiple values indicate results of duplicate analyses.

TABLE 17. SUMMARY OF FIELD BLANK DATA

Background	Benzene	Toluene	Ethylbenzene	p-Xylene	m-Xylene	o-Xylene	Naphthalene	COMMENTS
	MASS RECOVEREY (µg)							
BBT1B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
BBT1B-SB	0.30	0.00	0.04	0.00	0.04	0.03	0.15	
BAT1E	3.70	0.90	0.00	0.00	0.00	0.00	0.00	
BAT2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MEAN	1.00	0.23	0.01	0.00	0.01	0.01	0.04	
ST. DEV	1.81	0.45	0.02	0.00	0.02	0.02	0.08	
C.V.	180.55	200.00	200.00		200.00	200.00	200.00	
n	4.00	4.00	4.00	4.00	4.00	4.00	4.00	
t0.5|n-1	3.18	3.18	3.18	3.18	3.18	3.18	3.18	
C. I.*	2.87	0.72	0.03	0.00	0.03	0.02	0.12	
Waste Before Tilling								
WBT2A	0.28	0.04	0.00	0.00	0.00	0.00	0.00	
WBT3E-SB	0.49	0.22	0.14	0.00	0.00	0.00	0.00	
WBT4B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
WBT4C	0.16	0.02	0.00	0.00	0.00	0.00	0.00	
WBT2F	41.55	9.11	0.04	0.06	0.10	0.00	0.00	**High Mass**
WBT3C	16.37	7.41	0.26	0.05	0.33	0.06	0.00	**Sorbent Tube**
WBT5E	41.30	15.96	0.05	0.06	0.27	0.06	0.00	**Preceeding**
WBT6B	3.40	0.99	0.01	0.10	0.12	0.04	0.02	**These GC Runs**
Not IncludingProblem Traps MEAN	0.23	0.07	0.04	0.00	0.00	0.00	0.00	
ST. DEV	0.21	0.10	0.07	0.00	0.00	0.00	0.00	
C.V.	88.80	144.75	200.00	--	--	--	--	
n	4.00	4.00	4.00	4.00	4.00	4.00	4.00	
t0.5|n-1	3.182	3.162	3.182	3.182	3.182	3.182	3.182	
C. I.*	0.33	0.16	0.11	0.00	0.00	0.00	0.00	
IncludingProblem Traps MEAN	12.94	4.22	0.06	0.03	0.10	0.02	0.00	
ST. DEV	18.41	5.99	0.09	0.04	0.13	0.03	0.01	
C.V.	142.21	142.02	148.32	115.23	128.88	141.42	282.84	
n	8.00	8.00	8.00	8.00	8.00	8.00	8.00	
t0.5|n-1	2.365	2.365	2.365	2.365	2.365	2.365	2.365	
C. I.*	15.39	5.01	0.08	0.03	0.11	0.02	0.01	
Waste After Tilling								
WAT2E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
WAT5B	0.01	0.00	0.00	0.00	0.00	0.00	0.02	
WAT6B	2.59	0.81	0.04	0.01	0.03	0.02	0.00	
WAT6E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
WAT7F	0.63	1.14	0.00	0.01	0.04	0.01	0.01	
WAT8B	5.77	2.16	0.15	0.00	0.10	0.07	0.00	
WAT8F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
MEAN	1.29	0.59	0.03	0.00	0.02	0.01	0.00	
ST. DEV	2.19	0.84	0.06	0.00	0.04	0.03	0.01	
C.V.	170.48	142.63	207.01	170.78	153.81	180.09	183.59	
n	7.00	7.00	7.00	7.00	7.00	7.00	7.00	
t0.5|n-1	2.45	2.45	2.45	2.45	2.45	2.45	2.45	
C. I.*	2.03	0.77	0.05	0.00	0.03	0.02	0.01	
Waste After Second Tilling								
WST1A	0.00	0.00	0.06	0.00	0.23	0.04	0.00	
WST1D	0.45	0.12	0.00	0.00	0.01	0.01	0.01	
WST2A	0.14	0.00	0.00	0.00	0.01	0.00	0.09	
MEAN	0.20	0.04	0.02	0.00	0.08	0.02	0.03	
ST. DEV	0.23	0.07	0.03	0.00	0.13	0.02	0.05	
C.V.	117.10	173.21	173.21	--	152.42	124.90	147.99	
n	3.00	3.00	3.00	3.00	3.00	3.00	3.00	
t0.5|n-1	4.30	4.30	4.30	4.30	4.30	4.30	4.30	
C. I.*	0.57	0.17	0.09	0.00	0.32	0.05	0.12	

* C. I. = 95% Confidence Intervals

Spiked Tenax™ field trap data are presented in Table 18. Several traps were not considered in recovery results due to known problems with their transport from the field site to the UWRL facility, namely culture tube breakage and tube warping that required the use of shop facilities to retool the tube to fit the Tekmar trap oven. These activities would be expected to have an unknown effect on contaminant retention and recovery and results are presented for reference only. The wide variability in recovery efficiency results is particularly obvious for benzene and naphthalene, with field recovery values including the range of recovery efficiencies observed in laboratory recovery studies (Table B-2). Recovery data presented in Table B-2 were used for field recovery efficiency mass calculations for comparisons of measured flux rates with Thibodeaux-Hwang AERR model predictions.

Laboratory and Field Manifold Data--

Table 19 contains laboratory and field data regarding variability of measured mass between the three sorbent tubes used on each sampling manifold. Field data were grouped according to field sampling events, while laboratory data were pooled from all flux chamber/Tenax™ mass recovery data collected. Field data were much more variable than laboratory data and appear to be significantly affected by mass collection level. During sampling events when the highest mass of contaminants were being emitted, i.e., just following waste application, background contamination and sorbent tube variability became less significant, and between trap variability approached those values observed in a controlled laboratory setting. Prior to waste application, and further in time after the application event, sorbent tube characteristics and background contamination become more significant, requiring a strict QA/QC program to ensure adequately prepared and stored sorbent tubes.

Measured Versus Theoretical Emission Rates in Field Studies

Emission Rate Temporal Relationships--

As with laboratory microcosm and flask units, the relationship of flux versus $1/t^{1/2}$ can be used to investigate the nature of the observed emission event with respect to simple Fickian diffusion assumptions. All flux data collected during the field study are summarized in Appendix J, along with the slope and regression coefficients for the relationship of emission flux rate versus $1/t^{1/2}$. Inspection of these data indicates the general validity of the diffusion assumption. Most measured data follow the relationship quite well with regression coefficients generally 0.7 and above. There are notably exceptions with the bulk of the naphthalene data and a number of WBT ethylbenzene samples, however. Data become nearly perfect for all compounds of interest following waste/soil tilling. This suggests that waste ponding on the soil following waste application may be the cause of some variability in the observed results.

Actual Versus Predicted Flux Data--

The second test of model validity is the absolute match of measured and predicted data. Due to the great variability in point waste application, temperature, soil condition, etc., values at a given sampling site, a large amount of site specific data was collected for use as input to the Thibodeaux-Hwang AERR model.

The first major piece of data necessary is the waste mass application rate at each sampler location, as this parameter is a major input to model calculations. Sampler-specific mass application data were collected as described earlier using metal pan collectors, and resulted in the following:

SITE	WASTE APPLICATION RATE (g/cm^2)
A	1.35
B	1.09
C	1.92
D	1.30
E	1.44
F	1.56

TABLE 18. FIELD SPIKE DATA SUMMARY

		RECOVERY EFFICIENCY (%)							COMMENTS
		Benzene	Toluene	Ethylbenzene	p-Xylene	m-Xylene	o-Xylene	Naphthalene	
	Lab Spike	124.50	108.50	101.50	99.50	106.00	104.50	68.00	
	BBT1B-SB	160.00	94.00	108.00	90.00	108.00	106.00	130.00	
	BBT1D1	212.00	166.00	114.00	106.00	114.00	106.00	36.00	
	BAT2A3	145.00	100.00	86.00	80.00	102.00	78.00	24.00	
	WBT3E-SP	124.50	111.00	107.00	94.50	98.00	98.50	28.50	
	WAT7D2	54.00	180.00	53.00	65.90	72.00	94.00	57.00	
	BAT1B2	70.00		196.00	186.00	186.00	114.00		Tube Broke
	WAT7B1	14.00	64.00	122.50	105.00	117.50	98.00	84.25	Tube Refitted
Not IncludingProblem Traps	MEAN	136.67	126.58	94.92	89.32	100.00	97.83	57.25	
	ST. DEV	51.81	36.73	22.63	14.45	14.75	10.83	39.48	
	C.V.	37.91	29.02	23.84	16.18	14.75	11.07	68.95	
	n	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
	t0.5|n-1	2.571	2.571	2.571	2.571	2.571	2.571	2.571	
	C. I.*	54.37	38.55	23.76	15.17	15.48	11.37	41.43	
IncludingProblem Traps	MEAN	113.00	117.64	111.00	103.36	112.94	99.88	61.11	
	ST. DEV	63.73	41.03	40.48	35.98	32.63	10.79	37.45	
	C.V.	56.40	34.88	36.47	34.81	28.89	10.80	61.29	
	n	8.00	7.00	8.00	8.00	8.00	8.00	7.00	
	t0.5|n-1	2.365	2.447	2.365	2.365	2.365	2.365	2.447	
	C. I.*	53.29	37.95	33.85	30.08	27.28	9.02	34.64	

* C. I. = 95% Confidence Interval

TABLE 19 LABORATORY AND FIELD MANIFOLD TUBE VARIABILITY

		COMPOUND RELATIVE STANDARD DEVIATION WITHIN MANIFOLD GROUP						
		Benzene	Toluene	Ethylbenzene	p-Xylene	m-Xylene	o-Xylene	Naphthalene
LABORATORY								
	Mean	13.9	16.3	14.1	14.4	14.2	14.4	19.9
	S.D.	9.5	9.2	9.7	10.4	7.8	6.6	12.2
	C.V.	68.3	56.4	68.8	72.2	54.9	45.8	61.3
	n=	80	85	90	90	90	85	85
	FIELD							
BBT	Mean	121.5	120.8	135.2	140.0	119.1	83.4	173.0
	S.D.	29.0	56.2	64.0	42.2	63.5	68.6	–
	C.V.	23.8	46.5	47.4	30.1	53.3	82.3	–
	n=	17	16	10	7	13	13	1
WBT	Mean	31.0	23.4	30.3	43.9	22.0	23.7	104.4
	S.D.	34.8	33.6	34.8	41.5	23.2	25.4	47.4
	C.V.	112.3	143.7	114.9	94.4	105.5	107.1	45.5
	n=	36	36	36	22	36	36	35
WAT	Mean	50.5	64.6	65.6	87.2	28.8	36.3	76.3
	S.D.	42.8	48.9	61.4	63.0	38.3	32.1	49.8
	C.V.	84.7	75.8	93.6	72.3	132.8	88.6	65.3
	n=	48	48	48	38	48	48	48
WST	Mean	59.2	72.3	126.3	72.8	29.5	31.8	72.1
	S.D.	45.4	49.6	65.4	65.1	36.3	26.5	79.1
	C.V.	76.8	68.6	51.8	89.4	123.1	83.4	109.7
	n=	12	12	12	12	12	12	10

Next, individual constituent data are required to convert this mass loading rate to M_A in Equation 8. These data were presented earlier in Table 6. Results presented in Table 6 for UWRL analysis of the field waste were used for theoretical mass emission levels based on the approach outlined in Sections 6 and 7.

Finally, site and time specific information regarding soil and temperature conditions throughout the study are required for adequate model calculations. A detailed summary of all temperature data collected during the field study is presented in Appendix H. All field soil data for the field experiments are located in Table 11, while Table 20 contains sampler location specific plow splice depths. The 2 inch soil temperature at the completion of the sampling time, given in Appendix H, was used as input to model parameters requiring temperature adjustment as it provided the best correlation between measured and predicted field flux rates. Refer to Appendix L for example procedures used to calculate Thibodeaux-Hwang AERR model emission rate predictions for the field emission study.

The results of these calculations and comparisons with actual measured data are presented in Appendix J, and Figure 22 for the sampling events following waste application. Appendix K contains all background flux data collected prior to waste application. The theoretical calculations were based on updated temperature and soil property data to ensure an accurate description of the land treatment system using the model.

Inspection of data in Appendix J indicates the validity of the Thibodeaux-Hwang approach for air emission modeling from land treatment facilities for waste before tilling and initial waste after tilling events. Most measured data, with the exception of naphthalene, were well within an order of magnitude of the predicted values, with many being within a factor of two or less during these sampling periods. Naphthalene emissions measured at all sites, and during all sampling events generally were within one to two orders of magnitude of theoretical estimates. Results for all compounds deviated from model predictions by a factor of ten or greater some 70 hours following initial tilling after waste application. These deviations from model predictions are apparent from Figure 23 which shows a gradual movement of measured field flux data away from theoretical predictions during the latter (WAT and WST) field sampling events. This increased deviation from the model with time may be related to component biodegradation/adsorption within the soil column that is not accounted for in the Thibodeaux-Hwang model.

Figure 23 indicates the variability in emission rates measured for benzene flux at field Site D during field sampling that was typical for all data collected. Emission spikes were produced during waste application and tilling events for all compounds quantified during the study at all sampler locations. Figure 23 also indicates the variability of soil percent oil and grease content measured at Site D, also clearly identifying waste application and tilling events which occurred through time at the site. Theoretical and measured flux data for benzene emissions at sampling Site D are shown in Figure 24. The validity of the modeling approach and the accuracy of its prediction is evident from these curves, especially during emission events immediately following waste application and initial tilling. Results give encouraging evidence that a simple modeling approach, such as that of the Thibodeaux-Hwang AERR model, may be adequate and highly effective for the description of a highly complex hazardous waste land treatment system.

TABLE 20. MEASURED TILLER PLOW SPLICE DEPTH
(MEASURED 7/3/85 FOLLOWING TILLING)

Chamber Location	Plow Splice Depth (cm)	Mean Plow Splice Depth (cm)
A	19.3	
	18.0	
	19.3	18.9
B	22.0	
	23.7	
	20.5	22.1
C	21.0	
	23.3	
	22.7	22.3
D	21.5	
	20.5	
	21.5	21.2
E	24.0	
	22.2	
	21.8	22.7
F*	--	
	--	
	--	16.8

* Sample site too wet for direct observation. Tiller stated he used minimum plow splice depth (16.8 cm) at this location.

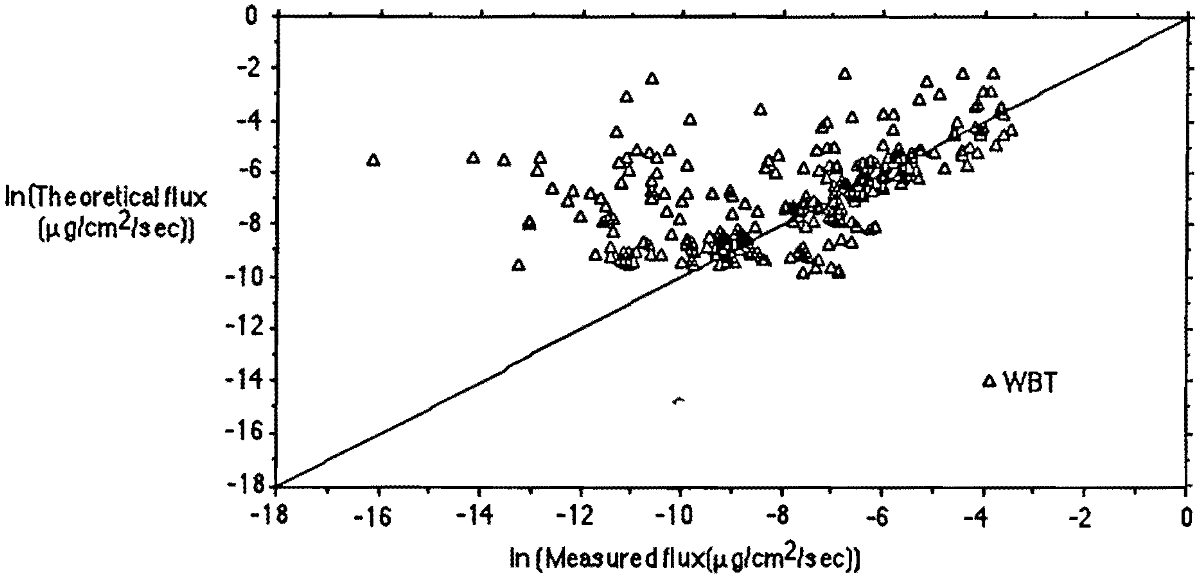

Figure 22a. Parity plot of data collected during WBT field sampling events.

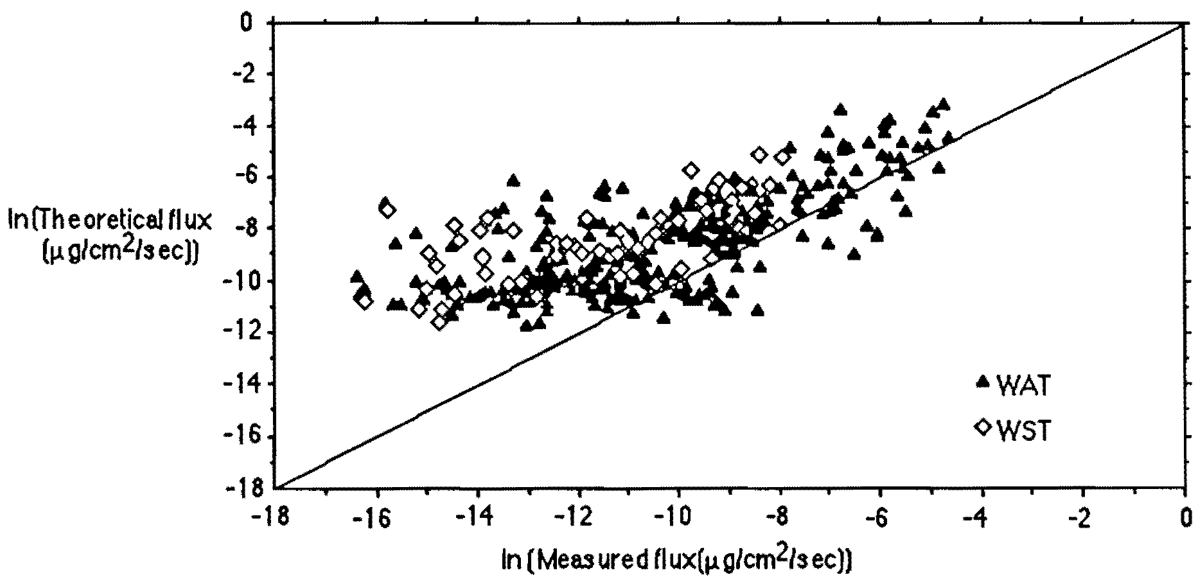

Figure 22b. Parity plot of data collected during WAT and WST field sampling events.

Figure 22. Parity plots of theoretical versus measured field flux data.

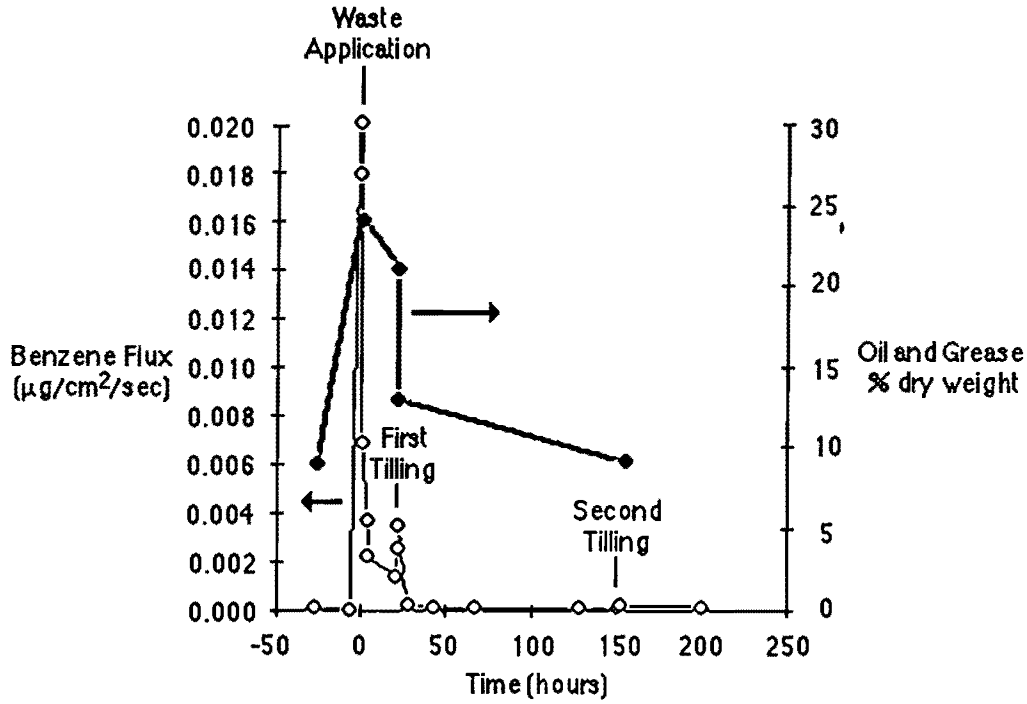

Figure 23. Measured benzene flux and oil and grease variability with time, Field Site B

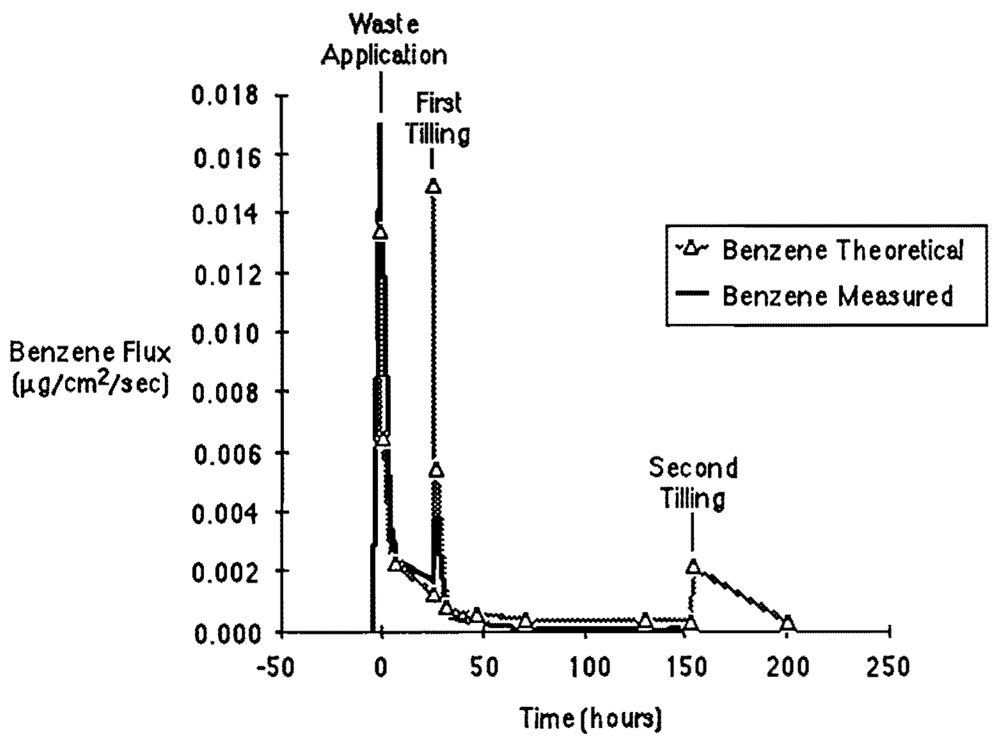

Figure 24. Benzene theoretical and measured flux, Field Site D

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APPENDIX A CHARCOAL SOLID SORBENT RECOVERY DATA

TABLE A-1 CHARCOAL RECOVERY DATA FOR PURE COMPOUNDS

Mass (µg)	% Benzene Recovery	Mass (µg)	% Toluene Recovery	Mass (µg)	% Xylenes Recovery	Mass (µg)	% p-Xylene Recovery	Mass (µg)	% m-Xylene Recovery	Mass (µg)	% o-Xylene Recovery	Mass (µg)	% Acetone Recovery
17.57	130.90	17.34	32.18	17.37	80.91	30.00	106.66	30.00	104.47	30.00	101.37	15.71	99.84
17.57	120.17	17.34	12.38	17.37	95.20	30.00	106.48	30.00	104.24	30.00	101.80	15.71	102.71
17.57	163.12	17.34	22.28	17.37	80.91	30.00	107.98	30.00	105.68	30.00	103.17	15.71	108.53
17.57	141.64	17.34	71.78	17.37	88.05	30.00	107.28	30.00	104.96	30.00	102.53	23.56	109.48
26.36	108.73	17.34	61.88	17.37	88.05	30.00	106.25	30.00	104.81	30.00	101.33	23.56	84.43
26.36	123.04	26.01	80.85	26.06	92.04	30.00	106.91	30.00	104.38	30.00	101.70	23.56	28.51
26.36	130.20	26.01	80.85	26.06	87.27	30.00	99.59	30.00	97.55	30.00	95.58	23.56	86.78
26.36	108.73	26.01	80.85	26.06	101.57	30.00	101.41	30.00	99.83	30.00	98.22	23.56	107.02
26.36	101.57	26.01	80.85	26.06	101.57	36.42	91.57	50.00	97.80	36.03	99.97	31.42	66.71
30	61.47	26.01	74.25	26.06	101.57	36.42	94.82	50.00	97.38	36.03	99.60	31.42	108.24
30	62.29	30.00	97.87	34.74	97.63	50.00	98.84	50.00	100.68	50.00	96.24	31.42	102.99
30	58.77	30.00	97.90	34.74	94.06	50.00	98.26	50.00	100.77	50.00	96.34	31.42	103.66
30	62.69	30.00	104.77	34.74	94.06	50.00	101.22	50.00	99.82	50.00	99.49	31.42	84.72
30	61.01	30.00	104.63	34.74	90.48	50.00	101.35	50.00	100.59	50.00	99.85	60.00	82.64
30	62.82	30.00	99.19	500.00	89.68	50.00	100.60	50.00	103.23	50.00	99.21	60.00	80.24
30	61.19	30.00	99.89	500.00	114.87	50.00	101.53	50.00	102.42	50.00	99.92	60.00	71.84
30	60.76	30.00	97.78	500.00	89.68	50.00	104.42	50.00	105.14	50.00	102.16	60.00	77.82
30	59.86	30.00	98.61	500.00	105.98	50.00	103.56	50.00	104.96	50.00	104.37	250.00	78.30
30	61.53	30.00	98.50	500.00	119.31	50.00	106.31	79.72	94.33	50.00	102.89	250.00	71.18
35.14	97.67	30.00	98.37	500.00	119.31	50.00	106.34	79.72	93.92	50.00	101.61	250.00	92.54
35.14	92.30	34.68	75.49	1000.00	96.69							250.00	92.54
35.14	113.78	34.68	70.54	1000.00	81.88							250.00	85.42
35.14	92.30	34.68	70.54	1000.00	107.80							250.00	99.66
35.14	92.30	34.68	80.44	1000.00	105.95							500.00	103.22
65	57.68	65.00	96.47	1000.00	92.99							500.00	106.77
65	57.80	65.00	97.36	1000.00	72.99							500.00	113.89
65	57.90	65.00	96.78	1500.00	116.81							500.00	96.10
65	57.75	65.00	97.58	1500.00	106.44							500.00	99.66
65	57.73	65.00	91.58	1500.00	91.87							500.00	106.77
65	57.05	65.00	91.54	1500.00	103.97							1000.00	124.57
65	57.09	65.00	98.37	1500.00	84.21							1000.00	121.01
65	57.67	65.00	98.58	1500.00	100.51							1000.00	119.23
65	55.50	65.00	98.40									1000.00	122.79
65	51.58	65.00	98.17									1000.00	112.11
439	75.00	281.80	106.64									1000.00	122.79
439	95.83	281.80	125.22										
439	66.67	281.80	125.22										
439	91.67	281.80	106.84										
439	100.00	281.80	106.84										
439	100.00	563.60	62.61										
878	91.67	563.60	62.61										
878	79.17	563.60	53.42										
878	93.75	563.60	71.80										
878	95.83	563.60	71.80										
878	79.17	563.60	80.99										
878	79.17	1127.20	118.62										
1317	102.78	1127.20	123.21										
1317	94.44	1127.20	109.43										
1317	102.78	1127.20	132.40										
1317	95.83	1127.20	104.83										
1317	100.00	1127.20	114.02										
1317	102.78												
Mean	85.44	Mean	88.90	Mean	96.70	Mean	102.57	Mean	101.35	Mean	100.37	Mean	96.42
St. Dev.	26.24	St. Dev.	24.48	St. Dev.	11.60	St. Dev.	4.48	St. Dev.	3.67	St. Dev.	2.40	St. Dev.	19.74
C. V.	30.71	C. V.	27.53	C. V.	12.00	C. V.	4.36	C. V.	3.62	C. V.	2.39	C. V.	20.47
n=	52	n=	51	n=	32	n=	20	n=	20	n=	20	n=	35
t 0.5|n-1=	2.0094	t 0.5|n-1=	2.0105	t 0.5|n-1=	2.04	t 0.5|n-1=	2.093	t 0.5|n-1=	2.093	t 0.5|n-1=	2.093	t 0.5|n-1=	2.034
C. L.	92.76	C. L.	95.79	C. L.	100.88	C. L.	104.66	C. L.	103.07	C. L.	101.49	C. L.	103.21
	78.13		82.01		92.51		100.47		99.63		99.24		89.63

TABLE A-2 CHARCOAL RECOVERY DATA FOR PURE COMPOUNDS IN MIXTURES

Mass (μg)	% Benzene Recovery	Mass (μg)	% Toluene Recovery	Mass (μg)	% Xylenes Recovery	Mass (μg)	% Acetone Recovery
17.57	97.88	17.32	88.39	17.36	100.73	31.44	47.32
17.57	101.81	17.32	99.69	17.36	109.45	31.44	54.46
17.57	93.96	17.32	95.92	17.36	109.45	31.44	47.32
17.57	78.24	17.32	92.15	17.36	109.45	47.16	50.6
17.57	113.59	17.32	110.99	17.36	118.17	47.16	60.13
17.57	86.1	17.32	107.22	17.36	109.45	47.16	60.13
17.57	82.17	17.32	103.46	17.36	100.73	62.88	37.95
17.57	82.17	17.32	99.69	17.36	100.73	62.88	73.69
26.36	62.62	25.98	76.51	26.04	78.78	62.88	52.25
26.36	67.86	25.98	89.06	26.04	84.6		
26.36	73.1	25.98	99.11	26.04	107.85		
26.36	83.57	25.98	86.55	26.04	96.22		
26.36	78.33	25.98	81.53	26.04	94.6		
26.36	75.72	25.98	81.53	26.04	94.6		
26.36	73.1	25.98	81.53	26.04	78.78		
26.36	73.1	25.98	73.99	26.04	72.97		
35.14	68.58	34.64	95.05	34.72	89.61		
35.14	78.4	34.64	95.05	34.72	89.61		
35.14	82.33	34.64	85.63	34.72	76.53		
35.14	72.51	34.64	74.33	34.72	76.53		
35.14	72.51	34.64	76.22	34.72	76.53		
35.14	74.47	34.64	76.22	34.72	76.53		
35.14	84.29	34.64	89.4	34.72	85.25		
35.14	82.33	34.64	87.52	34.72	85.25		
Mean	80.78	Mean	89.45	Mean	92.60	Mean	53.76
St. Dev.	11.58	St. Dev.	10.62	St. Dev.	13.56	St. Dev.	10.15
C. V.	14.34	C. V.	11.87	C. V.	14.65	C. V.	18.88
n=	24	n=	24	n=	24	n=	9
t 0.5|n-1=	2.069	t 0.5|n-1=	2.069	t 0.5|n-1=	2.069	t 0.5|n-1=	2.306
C. L.	85.67	C. L.	93.93	C. L.	98.33	C. L.	61.56
	75.89		84.96		86.87		45.96

TABLE A-3 CHARCOAL RECOVERY DATA FOR PURE COMPOUNDS WITH MOISTURE

Mass (μg)	% Benzene Recovery	Mass (μg)	% Toluene Recovery	Mass (μg)	% Xylenes Recovery	Mass (μg)	% Acetone Recovery
17.57	184.6	17.34	71.78	17.37	88.05	15.71	36.4
17.57	152.38	17.34	81.68	17.37	88.05	15.71	80.16
17.57	141.64	17.34	61.88	17.37	95.2	15.71	37.67
17.57	120.17	17.34	71.78	17.37	95.2	15.71	35.1
17.57	109.43	17.34	81.68	17.37	95.2	15.71	82.78
26.36	80.1	26.01	80.85	26.06	96.8	23.56	72.76
26.36	130.2	26.01	80.85	26.06	96.8	23.56	45.37
26.36	108.73	26.01	80.85	26.06	96.8	23.56	60.54
26.36	94.41	26.01	80.85	26.06	96.8	23.56	67.57
35.14	65.45	26.01	87.45	26.06	106.33	23.56	62.57
35.14	81.56	34.68	85.39	34.74	104.78	31.42	91.6
35.14	65.45	34.68	85.39	34.74	94.06	31.42	91.28
35.14	60.08	34.68	90.34	34.74	108.35	31.42	111.11
35.14	65.45	34.68	90.34	34.74	104.78	31.42	92.31
		34.68	85.39			31.42	84.56
Mean	104.26	Mean	81.10	Mean	97.66	Mean	70.12
St. Dev.	38.03	St. Dev.	7.61	St. Dev.	6.26	St. Dev.	23.52
C. V.	36.48	C. V.	9.38	C. V.	6.41	C. V.	33.54
n=	14	n=	15	n=	14	n=	15
t 0.5|n-1=	2.16	t 0.5|n-1=	2.145	t 0.5|n-1=	2.16	t 0.5|n-1=	2.145
C. L.	126.22	C. L.	85.31	C. L.	101.27	C. L.	83.14
	82.30		76.89		94.04		57.09

APPENDIX B TENAX™ SOLID SORBENT RECOVERY DATA

TABLE B-1 TENAX RECOVERY DATA FOR PURE COMPOUND MIXTURES

Mass (µg)	% Benzene Recovery	Mass (µg)	% Toluene Recovery	Mass (µg)	% Ethylbenzene Recovery	Mass (µg)	% p-Xylene Recovery	Mass (µg)	% m-Xylene Recovery	Mass (µg)	% o-Xylene Recovery	Mass (µg)	% Naphthalene Recovery
0.09	86.50	2.27	109.79	0.42	89.23	0.48	90.64	1.10	93.75	0.48	92.48	0.50	69.48
0.09	92.67	2.27	110.43	0.42	90.93	0.48	92.25	1.10	93.03	0.48	93.07	0.50	93.34
0.09	109.04	2.27	108.90	0.42	90.74	0.48	92.30	1.10	93.42	0.48	95.28	0.50	90.39
0.09	92.73	2.27	108.49	0.42	86.01	0.48	86.80	1.10	95.07	0.48	100.99	0.50	86.50
1.5	102.70	2.27	106.56	0.65	75.99	0.48	88.40	1.10	89.02	0.48	87.37	0.50	72.16
1.5	89.75	5.00	94.42	0.65	89.31	0.73	74.42	1.64	92.15	0.72	112.40	1.50	49.57
1.5	89.23	5.00	92.27	0.65	77.09	0.73	88.01	1.64	93.23	0.72	96.16	1.50	56.44
1.5	103.54	5.00	94.38	0.65	64.88	0.73	76.68	1.64	93.64	0.72	113.02	1.50	70.62
1.5	90.44	5.00	93.92	0.65	91.13	0.73	84.13	1.84	95.00	0.72	102.42	1.50	72.72
2.5	92.14	5.00	92.13	1.96	89.37	0.73	91.48	1.64	93.74	0.72	95.21	1.50	61.14
2.5	97.93	29.50	93.64	1.96	89.22	2.16	89.04	4.73	91.07	2.14	93.00	2.50	61.47
2.5	92.90	29.50	94.78	1.96	88.77	2.16	89.39	4.73	90.89	2.14	93.42	2.50	81.91
2.5	91.96	29.50	93.32	1.96	90.71	2.16	89.09	4.73	91.00	2.14	91.98	2.50	87.84
2.5	103.29	29.50	93.43	1.96	86.09	2.16	90.82	4.73	93.15	2.14	95.57	2.50	85.85
10	82.80	29.50	92.48	5.43	92.70	2.18	85.93	4.73	93.62	2.14	102.70	2.50	64.61
10	84.97	41.56	94.44	5.43	95.16	5.92	92.95	12.87	93.70	5.88	95.91	10.00	70.17
10	87.64	41.56	97.48	5.43	95.13	5.92	95.12	12.87	95.87	5.88	98.54	10.00	75.13
10	87.20	41.56	95.74	5.43	94.50	5.92	95.29	12.87	95.97	5.88	98.21	10.00	81.27
10	85.48	41.56	94.85	5.43	93.00	5.92	94.32	12.87	95.47	5.88	97.75	10.00	70.99
25	85.07	41.56	94.88	8.93	96.91	5.92	93.28	12.87	94.49	5.88	97.18	10.00	81.99
25	84.78	112.58	89.75	8.93	93.84	9.77	96.44	21.08	97.66	9.66	99.41	20.00	85.03
25	81.83	112.58	87.70	8.93	96.75	9.77	93.42	21.08	95.11	9.66	97.47	20.00	91.48
25	81.03	112.58	89.52	8.93	97.02	9.77	95.94	21.08	99.56	9.66	103.16	20.00	97.69
25	81.35	112.58	92.91	16.97	89.56	9.77	96.76	21.08	97.72	9.66	99.63	20.00	96.85
50	74.14	112.58	87.73	16.97	86.29	18.45	89.41	39.88	90.26	18.30	92.17	20.00	90.35
50	75.71	262.33	96.64	16.97	90.09	18.45	85.99	39.88	87.89	18.30	90.50	45.00	83.61
50	74.60	262.33	95.94	16.97	91.33	18.45	90.15	39.88	90.83	18.30	92.71	45.00	76.77
50	73.49	262.33	95.60	16.97	91.62	18.45	91.35	39.88	92.23	18.30	95.11	45.00	75.06
50	76.34	262.33	93.24	33.39	89.29	18.45	91.57	39.88	92.30	18.30	94.22	45.00	71.96
100	100.98	262.33	94.63	33.39	95.81	36.42	89.58	79.72	89.07	36.03	93.72	45.00	75.06
100	76.45			33.39	94.29	36.42	95.95	79.72	95.01	36.03	98.39	60.00	74.82
100	75.08			33.39	91.78	36.42	94.48	79.72	93.66	36.03	98.47	60.00	82.64
100	79.27			33.39	93.95	36.42	91.57	79.72	94.33	36.03	99.97	60.00	80.24
100	79.99					36.42	94.82	79.72	93.92	36.03	99.60	60.00	71.84
100	85.59											60.00	77.82
100	89.68												
100	79.67												
100	81.79												
100	80.51												
250	93.88												
250	93.65												
250	87.08												
250	87.45												
250	87.44												
Mean	87.04	Mean	96.00	Mean	90.56	Mean	90.52	Mean	93.44	Mean	97.27	Mean	77.57
St. Dev.	8.65	St. Dev.	8.30	St. Dev.	4.85	St. Dev.	4.99	St. Dev.	2.53	St. Dev.	5.35	St. Dev.	11.19
C. V.	9.94	C. V.	6.56	C. V.	5.36	C. V.	5.52	C. V.	2.71	C. V.	5.50	C. V.	14.43
n=	44	n=	30	n=	33	n=	34	n=	34	n=	34	n=	35
t 0.5|n-1=	2.018	t 0.5|n-1=	2.045	t 0.5|n-1=	2.038	t 0.5|n-1=	2.036	t 0.5|n-1=	2.036	t 0.5|n-1=	2.036	t 0.5|n-1=	2.034
C. L.	89.67	C. L.	98.35	C. L.	92.28	C. L.	92.27	C. L.	94.32	C. L.	99.14	C. L.	81.41
	84.40		93.65		88.84		88.78		92.55		95.40		73.72

TABLE B-2 TENAX/FLUX CHAMBER RECOVERY DATA FOR PURE COMPOUND MIXTURES

Mass (μg)	% Benzene Recovery	Mass (μg)	% Toluene Recovery	Mass (μg)	% Ethylbenzene Recovery	Mass (μg)	% p-Xylene Recovery	Mass (μg)	% m-Xylene Recovery	Mass (μg)	% o-Xylene Recovery	Mass (μg)	% Naphthalene Recovery
0.5	143.70	0.5	79.10	0.32		0.56		1.06		0.39		0.5	73.80
0.5	135.70	0.5	251.00	0.32		0.56		1.06		0.39		0.5	124.10
0.5	85.60	0.5	102.00	0.32		0.56		1.06		0.39		0.5	101.70
1	71.30	1	97.40	0.36	113.00	0.91	81.60	1.93	89.70	0.65	99.30	1	52.50
1	108.00	1	162.00	0.36	169.00	0.91	111.50	1.93	115.30	0.65	121.90	1	133.20
1	68.40	1	90.70	0.36	79.90	0.91	60.70	1.93	62.90	0.65	64.70	1	82.10
2	74.50	2	82.50	0.72	99.40	1.82	71.70	3.86	76.90	1.30	85.20	2	55.30
2	57.70	2	110.20	0.72	68.90	1.82	58.10	3.86	64.10	1.30	70.00	2	65.80
2	134.10	2	105.10	0.72	97.20	1.82	64.10	3.86	72.10	1.30	64.70	2	69.70
5	69.10	5	77.00	1.79	70.40	4.54	63.20	9.66	70.70	3.26	76.10	5	37.30
5	74.90	5	101.10	1.79	76.70	4.54	67.80	9.66	76.30	3.26	89.30	5	61.80
5	62.40	5	88.80	1.79	75.40	4.54	69.00	9.66	75.20	3.26	85.60	5	56.10
10	63.90	10	97.60	2.84	108.40	8.36	97.70	18.18	104.30	6.28	111.70	10	60.60
10	78.10	10	95.90	2.84	93.50	6.36	95.60	18.18	85.10	6.28	109.00	10	54.00
10	55.50	10	65.50	2.84	75.00	8.38	70.20	18.18	91.40	6.28	78.80	10	47.30
50	68.20	50	64.60	14.20	77.00	41.79	73.20	90.90	82.50	31.36	88.90	50	38.40
50	59.80	50	75.60	14.20	73.80	41.79	71.30	90.90	77.40	31.36	80.90	50	46.00
50	59.60	50	76.30	14.20	73.30	41.79	70.90	90.90	78.90	31.36	84.00	50	46.80
Mean	82.81	Mean	102.36	Mean	91.39	Mean	75.11	Mean	81.52	Mean	67.34	Mean	67.03
St. Dev.	28.22	St. Dev.	42.55	St. Dev.	25.42	St. Dev.	15.16	St. Dev.	14.16	St. Dev.	16.89	St. Dev.	27.41
C. V.	34.08	C. V.	41.57	C. V.	27.81	C. V.	20.19	C. V.	17.37	C. V.	19.33	C. V.	40.89
n=	18	n=	18	n=	15	n=	15	n=	15	n=	15	n=	18
t 0.5|n-1=	2.11	t 0.5|n-1=	2.11	t 0.5|n-1=	2.145	t 0.5|n-1=	2.145	t 0.5|n-1=	2.145	t 0.5|n-1=	2.145	t 0.5|n-1=	2.11
C. L.	96.84	C. L.	123.52	C. L.	105.47	C. L.	83.50	C. L.	89.36	C. L.	96.69	C. L.	80.66
	68.77		81.19		77.32		66.71		73.68		77.99		53.40

APPENDIX C TENAX™ SORBENT BREAKTHROUGH DATA

TABLE C-1 19 TO 23°C BREAKTHROUGH DATA

Benzene				Toluene				Ethylbenzene				p-Xylene		
Mass (μg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (μg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (μg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (μg)	Volume (l)	% 1st Trap
1.8	1	100.0	106.0	2.15	1	100.0	104.5	1.1	1	100.0	111.2	1.8	1	100.0
	3	98.4	104.0		3	99.8	106.0		3	100.0	126.3		3	99.9
	6	100.0	103.0		6	100.0	105.4		6	100.0	112.9		6	100.0
	12	63.0	99.3		12	100.0	106.5		12	100.0	114.2		12	100.0
	12	50.6	101.6		12	100.0	105.5		12	100.0	112.8		12	100.0
	24	3.5	71.5		24	100.0	105.0		24	100.0	111.8		24	100.0
	24	0.0	40.9		24	99.0	89.5		24	100.0	97.0		24	100.0
2.0	1	97.0	115.0	2.0	1	100.0	106.5	2.0	1	100.0	91.0	2.0	1	100.0
	3	91.4	93.5		3	100.0	90.5		3	100.0	79.5		3	100.0
	6	93.2	125.0		6	100.0	113.5		6	100.0	107.0		6	100.0
	6	78.9	104.5		6	100.0	113.5		6	100.0	112.5		6	100.0
	24	8.0	75.0		24	99.6	112.0		24	100.0	111.5		24	100.0
8.44	24	0.0	11.8	10.18	24	85.7	112.7	6.46	24	100.0	115.2	8.94	24	100.0
	26.6	0.7	99.2		26.6	87.2	110.6		26.6	100.0	112.3		26.6	100.0
12.7	1	100.0	95.4	15	1	100.0	98.9	9.7	1	100.0	92.2	13.4	1	100.0
	3	100.0	95.6		3	100.0	97.9		3	100.0	92.4		3	100.0
	6	79.6	92.4		6	100.0	79.9		6	100.0	90.9		6	100.0
	6	90.3	87.2		6	96.9	16.9		6	100.0	86.5		6	100.0
	12	60.2	88.2		12	97.3	77.4		12	100.0	87.7		12	100.0
	24	10.4	77.9		24	98.7	75.1		24	100.0	91.8		24	100.0
15	1	99.4	105.0	15.3	1	100.0	94.3	15	1	100.0	97.5	15	1	100.0
	3	97.8	105.4		3	100.0	94.6		3	100.0	96.3		3	100.0
	6	61.1	70.4		6	99.9	92.8		6	100.0	81.9		6	100.0
	6	68.8	18.6		6	100.0	88.1		6	94.8	17.8		6	100.0
	12	14.1	102.4		12	100.0	89.6		12	100.0	77.1		12	100.0
	24	6.1	43.4		24	99.2	92.3		24	100.0	76.1		24	100.0
60	1	99.9	98.1	60	1	100.0	94.9	60	1	100.0	97.8	60	1	100.0
	1	99.8	94.9		1	100.0	93.8		1	100.0	98.6		1	100.0
	3	90.6	109.4		3	100.0	91.9		3	100.0	98.5		3	100.0
	3	64.8	90.3		3	91.9	108.4		3	99.6	97.3		3	99.8
	6	33.5	138.2		6	96.2	99.8		6	100.0	97.0		6	100.0
120	1	74.2	115.0	120	1	99.3	125.5	120	1	100.0	108.1	120	1	100.0
	3	54.9	113.9		3	100.0	126.4		3	100.0	109.8		3	100.0
	3	58.3	62.6		3	99.6	81.5		3	100.0	81.2		3	100.0
	6	11.3	130.0		6	89.7	124.9		6	100.0	106.4		6	99.2
	6	9.8	126.2		6	89.0	124.3		6	99.9	98.4		6	100.0
	24	3.5	6.9		24	4.4	82.3		24	83.7	81.6		24	87.6
	24	2.0	15.5		24	17.6	81.1		24	96.8	80.8		24	98.0

TABLE C-1 (continued)

m-Xylene					o-Xylene				Naphthalene			
Recovery of Injected	Mass (μg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (μg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (μg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected
103.3	4.2	1	100.0	102.1	1.9	1	100.0	90.5	2.0	1	84.9	73.0
110.2		3	100.0	112.0		3	97.3	100.5		3	93.1	65.0
104.5		6	100.0	103.3		6	100.0	91.0		6		
105.2		12	100.0	104.9		12	100.0	92.6		6	100.0	107.5
104.5		12	100.0	104.1		12	100.0	91.2		24	100.0	107.0
99.8		24	100.0	106.7		24	97.0	96.4	2.4	1	98.9	101.0
66.5		24	100.0	91.0		24	100.0	81.6		3	99.7	99.9
87.0	2.0	1	100.0	91.5	2.0	1	100.0	92.0		6	98.3	101.5
77.5		3	100.0	80.5		3	100.0	80.0		12	98.2	103.3
102.5		6	100.0	114.5		6	99.0	102.0		12	99.8	99.7
112.5		6	100.0	115.0		6	100.0	114.0		24	100.0	95.0
114.5		24	100.0	114.5		24	100.0	114.0		24	99.8	93.4
99.0	19.84	24	100.0	116.8	7.5	24	100.0	135.5	12	24	99.9	116.0
96.5		26.6	100.0	113.9		26.6	100.0	132.3		26.6	99.1	112.1
91.1	15	1	100.0	100.3	11.3	1	100.0	94.3	15	1	99.9	97.4
91.6		3	100.0	102.9		3	100.0	94.4		3	99.0	96.1
90.0		6	100.0	83.7		6	100.0	92.6		6	99.0	72.2
85.6		6	97.4	17.9		6	100.0	88.7		6	100.0	15.5
86.1		12	100.0	79.1		12	100.0	90.4		12	100.0	62.9
91.0		24	100.0	79.0		24	100.0	93.7		24	100.0	17.7
98.0	29.8	1	100.0	93.2	15	1	100.0	95.6	18.0	1	99.8	86.8
101.3		3	100.0	93.4		3	100.0	93.9		3	100.0	88.2
81.3		6	100.0	92.0		6	100.0	84.2		6	99.8	87.6
15.4		6	100.0	87.4		6	99.6	16.0		6	99.6	82.8
76.3		12	100.0	89.5		12	100.0	78.9		12	100.0	71.4
74.7		24	100.0	92.8		24	100.0	77.5		24	99.1	89.7
100.9	60	1	100.0	101.3	60	1	100.0	97.3	60	1	100.0	45.5
97.3		1	100.0	95.7		1	100.0	95.7		1	99.7	30.2
89.9		3	100.0	85.4		3	100.0	95.6		3	85.6	47.1
87.9		3	99.4	84.4		3	98.3	97.8		3	99.0	57.7
100.8		6	100.0	101.5		6	99.9	97.3		6	73.7	3.7
49.6	120	1	100.0	62.3	120	1	99.9	120.2	120	1	79.1	51.5
52.4		3	100.0	65.2		3	100.0	120.3		3	44.0	31.8
91.1		3	100.0	76.4		3	100.0	85.0		3	99.9	14.3
51.4		6	99.7	49.8		6	99.7	119.5		6	100.0	13.7
36.5		6	99.8	43.4		6	99.6	120.4		6	98.2	10.8
85.2		24	84.2	82.5		24	81.9	83.6		24	100.0	13.9
89.5		24	97.0	77.8		24	94.3	85.6		24	99.6	10.7

TABLE C-2 28 TO 32°C BREAKTHROUGH DATA

Benzene				Toluene				Ethylbenzene				p-Xylene			
Mass (µg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (µg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (µg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (µg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected
1.8	3	100	79	2	1	100	89.5	1.1	3	100	90.3	1.8	3	100	84.8
	3	100	91.3		1	100	91		3	100	102.3		3	100	95.8
	6	73.2	104.3		12	100	111		8	100	120		6	100	94.4
	6	100	75.7		12	100	111		6	100	94.5		6	100	84.8
2	1	91.2	102		12	68.2	89.5	2	1	100	78.5	2	1	100	74
	1	96.3	95.5		12	89.7	106.5		1	100	78.5		1	100	72.5
	12	78	104.5		24	0	17.5		12	100	97.5		12	100	94.5
	12	0	79		24	83.8	114.5		12	100	47		12	100	13
	12	39.4	16.5	2.15	3	100	83.9		12	100	92.5		12	100	92.5
	12	20	25		3	100	95.6		12	100	106		12	100	104.5
	24	0	3		6	100	97		24	12.5	11.5		24	10.5	9.5
	24	27.3	16.5		6	100	82.8		24	100	93.5		24	100	88
12.66	3	97.3	82.6	15	1	100	105.7	9.69	3	100	83.1	13.41	3	100	82.3
	6	100	87.8		1	100	92.7		6	100	86.4		6	100	85.2
	12	28.1	93.6		1	99.9	122.3		12	100	88.2		12	100	87.3
15	1	99.5	110		3	100	102.7	15	1	100	74	15	1	100	42.8
	1	99.5	100		3	99.9	111.7		1	100	86		1	100	86.4
	1	74.2	130.8		6	87.7	93.8		1	100	115.2		1	100	106.9
	3	63.6	134.2		6	90.6	112.4		3	100	102.5		3	100	113.4
	3	67.5	121.5		12	97.6	101		3	100	112.3		3	100	110
	6	5.9	78.1		12	99.9	120.7		6	41.7	113.4		6	43	113.2
	6	5	26.6		12	99.9	101.6		6	99.6	93.8		6	99.9	101.2
	12	1.7	92.5		24	89.2	100.6		12	100	100.2		12	100	117.1
	12	100	8.9		24	63.2	112.6		12	99.8	124		12	99.8	123.7
	12	1	101.6	15.27	3	100	84		12	100	105.1		12	99.9	105.1
	24	2.9	23.4		6	100	87.6		24	100	97.7		24	100	110.4
	24	7.8	66		12	100	85		24	100	96.1		24	100	110.4
60	0.2	100	89.6	60	0.2	100	91.3	60	0.2	100	99.8	60	0.2	100	99.8
	0.2	100	86.1		0.2	100	68.3		0.2	100	96.5		0.2	100	101
	1	91.5	85.5		1	100	94.5		1	100	94.5		1	100	95.7
	1	100	133.3		1	50.1	100		1	100	99		1	99.5	100
	1	10.5	100		1	81.6	100		1	93.5	100		1	96	100
	1	71.9	89.5		1	99.9	96.2		1	100	97.1		1	100	98.1
	3	0.5	100		3	24.6	100		3	100	122.7		3	100	124.9
	3	2.2	100		3	78	100		3	100	127.6		3	100	130.3
	6	1.1	67.5		6	32.2	129.6		6	98.4	131.7		6	99.3	132.5
	6	1.9	132		6	88.1	129		6	100	128.8		6	100	130.9
	12	0.8	64.3		12	31.9	131.8		12	98.7	134		12	99.2	137.4
	12	2.1	24.2		12	5.9	129.7		12	91.6	128.9		12	93.4	130.8
	12	1	44.9		12	24.2	133.6		12	97.6	133.4		12	98.6	135.6
	24	26.6	1.1		24	0.8	123.4		24	57.2	133.6		24	59.5	134
	24	28.6	1		24	0.8	107.8		24	51.6	119.3		24	53.5	119.2
120	0.2	100	108.9	120	0.2	100	108.25	120	0.2	100	98.6	120	0.2	100	36.1
	0.2	100	108.1		0.2	100	107.75		0.2	100	98.2		0.2	100	36.6
	1	0	103.9		1	56.6	100		1	99.5	100		1	99.8	100
	1	1.7	100		1	67.4	100		1	98.9	100		1	99.5	100
	3	2	104.5		3	57.2	113.7		3	98	112.6		3	98.9	131
	3	0.8	76.2		3	29.7	115.4		3	96.7	111.8		3	98.1	126.1
	8	0.8	89.4		6	21.9	117.9		6	90.4	113.7		6	93.1	124
	6	1.1	50		6	6.9	143.7		6	85.7	134.3		6	89.9	155.1
	12	0.5	100		12	7.5	100		12	100	96.1		12	100	109.7
	12	0.5	91.6		12	54.9	25.3		12	91.5	110.4		12	91.8	128.4
	24	34.8	0.6		24	0.6	87		24	37.6	115.7		24	39.2	117.3
	24	51.5	0.6		24	1.6	44.2		24	40.7	85.8		24	41.6	87.3

TABLE C-2 (continued)

m-Xylene				o-Xylene				Naphthalene			
Mass (µg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (µg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected	Mass (µg)	Volume (l)	% Recovery 1st Trap	% Recovery of Injected
2	1	100	78	1.9	3	100	75.6	2.0	1	96.4	55
	1	100	76		3	100	84.9		1	98.7	79.5
	12	100	98.5		6	100	85.9		12	98.7	77.5
	12	100	37.5		6	100	74.8		12	95.6	66.5
	12	100	97	2	1	100	79		12	100	91
	12	100	112.5		1	100	79		12	100	95.5
	24	6.7	7.5		12	100	97		24	100	22
	24	100	93.5		12	100	53.5		24	100	85.5
4.2	3	100	85.1		12	100	97.5	2.4	3	100	83.3
	3	100	94.9		12	100	111.5		3	100	90.4
	6	100	98		24	28.6	10.5		6	100	90.2
	6	100	84.5		24	100	93.5		6	100	82.9
15	1	100	63.7	12.81	3	100	74.7	15	1	100	16.5
	1	100	85.7		6	100	76.4		1	99.6	94.2
	1	100	143.8		12	100	77.6		3	99.1	105.6
	3	100	114.4	15	1	100	77.1		6	99.9	94.5
	3	100	119.3		1	100	85.3		12	99.6	104.5
	6	99.8	101.6		1	100	126.7		12	100	113.7
	6	41.9	116.5		3	100	100.3		24	99.9	90.6
	12	100	119.3		3	100	117.2		24	100	101.6
	12	99.8	127.2		6	99	89	18	3	99.8	81.2
	12	100	107.7		6	39	115.6		6	99.6	82.7
	24	100	112.9		12	100	96.5		12	100	91.8
	24	100	112.8		12	99.6	129.8	60	0.2	98.7	45.9
29.76	3	100	84		12	99.9	106.9		0.2	100	89
	6	100	87.6		24	100	95.1		3	90	100
	12	100	88.1		24	99.9	94.1		3	62.7	100
60	0.2	100	101	60	0.2	100	96.6		6	99.5	24.5
	0.2	100	99.2		0.2	100	91.8		6	100	43.4
	1	100	96.1		1	100	96.1		12	100	115.3
	1	100	99.2		1	100	98.7		12	100	112.2
	1	94.2	100		1	89.7	100		12	100	66
	1	99	100		1	97.5	100		24	100	40.7
	3	100	132.2		3	100	122.2		24	100	106.3
	3	100	130.6		3	100	129.5	120	0.2	99.4	55.5
	6	98.6	135.8		6	96.7	137		0.2	100	14.1
	6	100	130.9		6	99.9	128.9		3	100	27.7
	12	98.9	136.6		12	98.1	133.1		3	100	17.9
	12	93	131.4		12	90.2	129.6		6	100	19.6
	12	98	135.5		12	96	136.2		6	100	23.8
	24	65	135.9		24	67.9	130.9		12	100	14
	24	60.5	121.8		24	65.2	119.8		12	100	66.4
120	0.2	100	44.2	120	0.2	100	120.2		24	100	19.8
	0.2	100	42.5		0.2	100	121.3		24	100	19.8
	1	99.5	100		1	98.6	100				
	1	98.9	100		1	97.8	100				
	3	98	101.9		3	96.4	116.1				
	3	96.9	104.2		3	94.8	115.2				
	6	91	109.7		6	87.9	116.4				
	6	87	122		6	85.8	137.5				
	12	100	93.6		12	100	96.2				
	12	87.1	110.9		12	99.4	102.9				
	24	48.3	119.6		24	53.6	118.2				
	24	50.4	92.2		24	56	97.1				

APPENDIX D CHAMBER MIXING DATA

Flow Curve Data for Shroud Mixing Studies

Run #	1	Run #	2	Run #	3	Run #	4	Run #	5	Run #	6
Q (l/min)=	0.732	Q (l/min)=	0.732	Q (l/min)=	1.65	Q (l/min)=	1.65	Q (l/min)=	2.72	Q (l/min)=	2.72
T (min)=	30.4	T (min)=	30.4	T (min)=	13.5	T (min)=	13.5	T (min)=	8.2	T (min)=	8.2
Co (mg/l) =	35.83	Co (mg/l) =	17.92	Co (mg/l) =	35.83	Co (mg/l) =	35.97	Co (mg/l) =	53.91	Co (mg/l) =	35.95
Time (minutes)	[Tracer] (mg/l)	Time (minutes)	[Tracer] (mg/l)	Time (minutes)	[Tracer] ppm	Time (minutes)	[Tracer] ppm	Time (minutes)	[Tracer] ppm	Time (minutes)	[Tracer] ppm
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.20	0.00	0.60	0.00	0.40	0.00	0.30	0.00	0.2	0.00	0.14	0.00
1.35	2.18	0.65	4.02	0.42	2.01	0.32	0.77	0.21	8.05	0.15	1.2
1.79	10.14	0.86	6.42	0.58	4.05	0.56	8.01	0.26	16.04	0.27	20.03
2.05	220.02	1.24	4.95	0.73	10.11	0.59	11.98	0.3	27.99	0.28	40.03
2.49	28.88	1.51	6.28	0.77	14.43	0.68	20.03	0.31	35.99	0.35	60.01
2.88	23.93	1.72	9.91	0.91	15.75	0.84	22.36	0.32	46.03	0.38	79.96
3.45	19.24	1.91	14.47	1.08	14.18	0.97	20.04	0.35	55.99	0.47	101.21
3.80	24.10	2.17	18.46	1.28	12.36	1.19	16.36	0.38	66.03	0.49	120
4.04	30.43	2.46	17.53	1.59	16.44	1.42	20.01	0.44	74.81	0.55	87.89
4.18	36.94	2.92	22.01	1.69	20.41	1.54	23.99	0.5	68.03	0.6	59.97
4.49	44.50	3.25	24.40	1.90	30.30	1.63	27.97	0.59	60	0.68	40.04
4.81	47.35	4.36	26.86	2.21	34.98	1.68	32.04	0.65	51.99	0.77	29.03
5.24	44.77	5.23	27.48	2.47	34.36	1.83	39.99	0.86	35.26	0.96	31.96
5.74	41.39	5.65	27.59	3.27	40.89	2.00	41.98	1.06	40.04	1.28	36.67
6.33	43.77	7.86	25.50	4.16	41.40	2.18	39.93	1.17	47.95	1.73	31.98
6.64	46.86	9.15	23.47	5.20	39.41	2.46	36.54	1.2	51.94	3.02	23.92
7.14	48.71	11.84	19.47	6.74	34.10	2.90	39.98	1.34	59.97	3.96	20
7.88	47.73	14.54	16.21	8.41	28.05	3.08	40.84	1.44	61.74	6.46	11.96
8.85	47.83	19.88	11.17	9.67	24.03	3.45	39.99	1.67	59.99	10.48	5.31
9.59	48.31	25.26	7.62	11.10	20.14	4.04	39.26	1.79	56.07	14.21	2.38
10.83	47.26	30.65	5.05	12.55	16.06	5.10	35.97	1.97	51.98	18.56	1.02
14.05	44.38	35.98	3.34	14.54	12.00	6.19	32.64	2.55	47.92	20.45	0.55
17.98	40.31	41.37	2.27	18.13	7.10	7.44	27.94	3.07	43.96		
22.41	35.83			20.81	4.84	8.61	23.93	3.41	39.98		
26.90	31.55			24.61	2.69	9.93	19.99	4.35	32.06		
31.66	27.21			28.66	1.35	11.61	15.93	5.59	23.95		
37.66	22.8			30.92	0.88	14.30	11.19	6.56	20.01		
43.01	19.34					17.00	7.80	8.08	14.07		
47.03	17.29					19.68	5.19	10.79	7.72		
53.17	14.34					22.41	3.42	13.45	4.22		
59.10	12.32					25.95	1.94	16.15	2.08		
65.14	10.30							18.89	0.77		
70.97	8.85										
77.48	7.32										
83.5	6.06										
90.73	5.19										
96.3	4.48										
101.94	3.91										

(continued)

APPENDIX D (continued)

Flow Curve Data for Shroud Mixing Studies

Run #	7	Run #	8	Run #	9	Run #	10	Run #	11	Run #	12
Q (l/min)=	2.72	Q (l/min)=	2.72	Q (l/min)=	3.73	Q (l/min)=	3.73	Q (l/min)=	3.73	Q (l/min)=	3.73
T (min)=	8.2	T (min)=	8.2	T (min)=	6.0	T (min)=	6.0	T (min)=	6.0	T (min)=	6.0
Co (mg/l) =	35.98	Co (mg/l) =	53.61	Co (mg/l) =	53.87	Co (mg/l) =	35.79	Co (mg/l) =	35.95	Co (mg/l) =	35.89
Time (minutes)	[Tracer] (mg/l)	Time (minutes)	[Tracer] (mg/l)	Time (minutes)	[Tracer] ppm	Time (minutes)	[Tracer] ppm	Time (minutes)	[Tracer] ppm	Time (minutes)	[Tracer] ppm
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.4	0.00	0.1	0.00	0.3	0.00	0.4	0.00	0.1	0.00	0.45	0.00
0.49	8.02	0.10003	21.48	0.31	12.01	0.53	19.95	0.116	4.05	0.5	11.92
0.51	16.02	0.10004	33.42	0.316	20.07	0.54	40.11	0.127	8.06	0.51	32.01
0.54	28.03	0.1005	41.51	0.32	39.99	0.58	60.04	0.139	12.05	0.73	47.97
0.6	43.95	0.101	53.5	0.33	60	0.68	80.1	0.145	16.01	0.78	68.02
0.66	68.01	0.103	65.56	0.34	68.02	0.68	92.48	0.169	20.08	0.83	79.93
0.73	84.03	0.15	77.52	0.35	79.99	0.81	40.03	0.174	28.08	0.86	87.12
0.92	96.21	0.16	89.57	0.36	95.97	0.84	34	0.187	32.04	1.07	60
1.03	79.9	0.17	97.55	0.39	102.5	1.05	34.9	0.187	40.07	1.35	37.72
1.16	67.98	0.18	99.94	0.46	115	1.7	28	0.189	59.98	1.56	38.5
1.26	55.97	0.19	110	0.51	79.98	2.91	19.96	0.19	72	3.07	32.03
1.42	39.95	0.22	89.52	0.53	68.04	4.31	13.76	0.191	80	5.05	23.96
1.53	32.04	0.27	69.48	0.66	59.89	6.33	7.94	0.192	88.41	6.23	19.98
1.79	27.16	0.28	57.5	0.83	64.05	9.68	3.27	0.193	44.05	7.85	15.96
2.25	31.93	0.59	41.91	1.1	59.99	12.35	1.6	0.195	37.84	10.05	11.96
2.53	35.98	0.74	49.46	1.42	56.02	19.29	0.37	0.37	41.34	12.28	8.73
2.85	38.96	1.06	55.22	1.67	52.03			0.81	36.03	12.95	8
3.33	36.01	1.4	49.5	2.3	44.01			1.2	32.01	17.69	4.16
3.97	30.52	1.96	43.44	3.47	32.01			1.62	28.04	28.53	0.62
4.78	29.43	2.62	37.47	4.53	24			2.84	20.03	39.31	0.02
5.76	26.08	3.8	29.44	5.22	20.05			4.18	13.87		
8.17	20.01	4.64	25.51	7.02	12.21			6.12	8.04		
11.22	14.8	6.53	17.51	8.51	8.06			8.43	4.01		
13.15	11.96	8.65	11.24	12.45	2.48			9.58	2		
16.53	8.49	9.4	9.45	15.49	0.98			10.16	0.99		
21.96	5.01	12.11	5.34	16.7	0.38			10.45	0.49		
27.43	2.92	17.1	1.65					10.59	0.24		
32.78	1.72	18.13	1.12								
38.17	1.02	19.17	0.6								
43.49	0.59										

Appendix E Microcosm hp and hs Temporal Variations

Run #	Position #	Waste Type	Amount of waste appl. (g)	Soil Type	Application	Time (hrs)	hp (cm)	hs (cm)	Slope (cm/log[t])	Y-Intercept (cm)	R-squared
1	1	Slop Oil	50.84	30 mesh sand	subsurface	0.00	6.50	6.50			
						0.50	18.5 (bottom)				
	2	Slop Oil	49.27	Kidman	subsurface	0.50	9.00	6.50	-2.963	-9.83	0.995 (hp)
						2.50	11.00		2.306	-5.8	(hs)
						5.00	12.00				
						10.00	12.50	3.50			
						25.00	14.00				
						50.25	15.00				
	3	Slop Oil	54.16	Kidman	subsurface	0.00	8.50	6.50	-2.723	-9.69	0.977 (hp)
						0.50	9.00	5.00	1.454	-4.95	0.960 (hs)
						2.50	11.00	4.25			
						5.00	11.00	4.00			
						10.00	12.50				
						25.00	13.50				
						50.25	14.50				
	4	Slop Oil	52.33	30 mesh sand	subsurface	0.00	6.00	6.00			
						0.50	19.5 (bottom)				
2	1	Slop Oil	37.68	30 mesh sand	surface	0.00	0.00	0.00	-4.837	-3.255	0.98 (hp)
						0.25	0.25				
						0.50	0.70				
						0.75	3.50				
						1.00	7.00				
						8.25	7.00				
						45.25	12.00				
						69.50	12.00				
						93.50	12.50				
	2	Slop Oil	37.87	30 mesh sand	surface	0.00	0.00	0.00	-5.087	-4.415	0.982 (hp)
						0.25	0.30				
						0.50	4.00				
						45.25	13.50				
						69.50	13.50				
						93.50	14.00				
	3	Slop Oil	38.05	Kidman	surface	0.00	0.00	0.00	-2.092	-0.516	0.988 (hp)
						0.25	0.00				
						0.50	0.25				
						1.00	0.50				
						2.00	1.00				
						4.00	1.50				
						8.25	2.25				
						20.25	3.25				
						45.25	4.00				
						69.50	4.50				
						93.50	4.75				

(continued)

Run #	Position #	Waste Type	Amount of waste appl. (g)	Soil Type	Application	Time (hrs)	hp (cm)	hs (cm)	Slope (cm/log[t])	Y-Intercept (cm)	R-squared
2	4	Slop Oil	37.7	Kidman	surface	0.00	0.00	0.00	-1.91	-1.118	0.993 (hp)
						0.25	0.30				
						0.50	0.50				
						1.00	1.00				
						2.00	1.50				
						4.00	2.20				
						8.00	2.75				
						20.25	3.60				
						45.25	4.25				
						69.50	4.75				
						93.50	5.00				
3	5	Sep. Sludge	36.3	30 mesh sand	subsurface	0.00	7.50	7.50	-4.29	-17.523	0.974 (hp)
						0.25	15.00				
						0.50	16.50				
						1.00	17.00				
						4.00	20.3(bottom)				
						72.00		6.25			
	6	Sep. Sludge	36.01	30 mesh sand	surface	0.00	0.00	0.00	-2.643	-9.37	0.951 (hp)
						0.25	8.50				
						0.50	8.50				
						1.00	8.50				
						72.00	14.50				
	7	Sep. Sludge	37.96	Kidman	subsurface	0.00	7.50	7.50	-1.349	-10.241	0.930 (hp)
						0.25	9.00	7.25	0.416	-6.909	0.926 (hs)
						0.50	10.00	7.00			
						1.00	10.50	6.75			
						2.00	10.50	6.75			
						4.00	11.50	6.75			
						9.00	11.50				
						20.00	12.00	6.50			
						49.00	12.00	6.25			
						72.00	13.00	6.00			
	8	Sep. Sludge	37.09	Kidman	surface	0.00	0.00	0.00	-0.902	-3.529	0.822 (hp)
						0.25	3.00				
						0.50	3.50				
						1.00	3.50				
						2.00	3.75				
						4.00	4.00				
						9.00	4.25				
						20.00	4.50				
						49.00	4.50				
						72.00	6.00				

(continued)

Run #	Position #	Waste Type	Amount of waste appl. (g)	Soil Type	Application	Time (hrs)	hp (cm)	hs (cm)	Slope (cm/log[t])	Y-Intercept (cm)	R-squared
4	5	Sep. Sludg	35.94	30 mesh sand	subsurface	0.00	7.50	7.50			
						0.10	8.25				
						0.50	20 (bottom)				
	6	Sep. Sludg	35.85	30 mesh sand	surface	0.00	0.00	0.00			
	7	Sep. Sludg	36.48	Kidman	subsurface	0.00	7.00	7.00	-0.613	-10.311	0.935 (hp)
						0.10	9.50	6.50	0.328	-6.144	0.915 (hs)
						0.25	10.00	6.25			
						0.50	10.25	6.25			
						1.00	10.25	6.00			
						2.00	10.50	6.00			
						4.00	10.75	6.00			
						6.00	11.00	5.80			
						8.00	11.00	5.80			
						18.00	11.00	5.80			
						20.00	11.00	5.80			
						24.00	11.00	5.80			
						50.00		5.50			
	8	Sep. Sludg	34.43	Kidman	surface	0.00	0.00	0.00	-0.999	-2.68	0.952 (hp)
						0.10	2.00				
						0.25	2.25				
						0.50	2.50				
						1.00	2.50				
						2.00	2.75				
						4.00	3.00				
						6.00	3.25				
						8.00	3.50				
						18.00	3.75				
						20.00	3.75				
						24.00	3.75				
						31.00	4.50				
						43.00	4.50				
						50.00	4.50				
						76.50	4.75				
						90.00	4.75				
						96.00	4.75				
5	1	Sep. Sludg	6.74	30 mesh sand	flask	0.00	1.70	0.00			
	2	Sep. Sludg	6.87	30 mesh sand	flask	0.00	1.70	0.00			
	3	Sep. Sludg	6.93	Kidman	flask	0.00	1.50	0.00			
	4	Sep. Sludg	7.08	Kidman	flask	0.00	1.50	0.00			
6	1	Slop Oil	7.94	30 mesh sand	flask	0.00	1.70	0.00			
	2	Slop Oil	7.94	Kidman	flask	0.00	1.50	0.00			
	3	Slop Oil	7.89	Durant	flask	0.00	2.50	0.00			
	4	Slop Oil	7.88	Durant	flask	0.00	2.50	0.00			

(continued)

Run #	Position #	Waste Type	Amount of waste appl. (g)	Soil Type	Application	Time (hrs)	hp (cm)	hs (cm)	Slope (cm/log[t])	Y-Intercept (cm)	R-squared
7	1	Slop Oil	30.61	Durant	subsurface	0.00	7.00	7.00	-1.032	-10.9428	0.960 (hp)
						0.08	10.00	7.00	0.3443	-6.7231	0.960 (hs)
						1.00	10.50	6.75			
						2.00	11.50	6.75			
						5.25	11.50	6.50			
						21.25	12.50	6.25			
						41.25	12.50	6.25			
						68.00	13.00	6.00			
						92.00	13.00	6.00			
						118	13.00	6.00			
	2	Slop Oil	30.9	Durant	subsurface	0.00	7.00	7.00	-1.078	-10.454	0.973 (hp)
						0.08	9.00	7.00	0.326	-6.678	0.967 (hs)
						1.00	10.50	6.75			
						2.00	11.00	6.50			
						5.25	11.50	6.50			
						21.25	12.00	6.25			
						41.25	12.00	6.25			
						68.00	12.50	6.00			
						92.00	12.50	6.00			
	3	Slop Oil	30.33	Durant	surface	0.00	0.00	0.00	-0.7623	-3.4707	0.973(hp)
						0.08	2.50				
						0.50	3.50				
						1.50	3.50				
						4.50	4.00				
						20.50	4.50				
						41.00	4.50				
						67.50	5.00				
						92.50	5.00				
						117.50	5.00				
	4	Slop Oil	30.81	Durant	surface	0.00	0.00	0.00	-0.708	-3.41	0.88 (hp)
						0.08	2.50				
						0.50	3.50				
						1.50	3.50				
						4.50	4.00				
						20.50	4.00				
						41.00	4.00				
						67.50	5.00				
						91.50	5.00				
						117.50	5.00				

(continued)

Run #	Position #	Waste Type	Amount of waste appl. (g)	Soil Type	Application	Time (hrs)	hp (cm)	hs (cm)	Slope (cm/log[t])	Y-Intercept (cm)	R-squared
8	5	Slop Oil	30.82	Kidman (wet)	surface	0.00	0.00	0.00			
						0.50	27 (bottom)				
	6	Slop Oil	31.23	Kidman (wet)	surface	0.00	0.00	0.00			
						0.50	27 (bottom)				
	7	Slop Oil	31.87	Kidman	subsurface	0.00	7.50	7.50	-2.09	-11.283	0.991(hp)
						0.17	10.00	7.50			
						0.67	10.50	7.50			
						0.92	11.50	7.50			
						2.00	11.75	7.50			
						4.50	12.50	7.50			
						23.60	14.00	7.50			
						45.00	14.75	7.50			
						48.00	14.75	7.50			
						67.00	15.00	7.50			
						72.00	15.25	7.50			
						90.00	15.50	7.50			
						100.00	15.50	7.50			
						123.00	15.75	7.50			
	8	Slop Oil	31.26	Kidman	subsurface	0.00	7.50	7.50	-1.918	-11.07	0.985(hp)
						0.17	10.00	7.50			
						0.67	10.50	7.50			
						0.92	11.00	7.50			
						2.00	11.50	7.50			
						4.50	12.25	7.50			
						23.60	13.50	7.50			
						45.00	14.00	7.50			
						48.00	14.00	7.50			
						64.00	14.50	7.50			
						72.00	15.00	7.50			
						90.00	15.00	7.50			
						100.00	15.00	7.50			
						123.00	15.25	7.50			
9	1	Slop Oil	79	Kidman	subsurface	0.00	7.50	7.50	-2.256	-12.612	0.985 (hp)
						0.17	11.00	<4			
						0.25	11.50	<4			
						1.25	12.50	<4			
						11.00	14.50	0.50			
						33.00	16.00	0.00			
						48.50	16.50	0.00			
						60.00	17.00	0.00			

(continued)

Run #	Position #	Waste Type	Amount of waste appl. (g)	Soil Type	Application	Time (hrs)	hp (cm)	hs (cm)	Slope (cm/log[t])	Y-Intercept (cm)	R-squared
9	2	Slop Oil	79	Kidman	subsurface	0.00	7.50	7.50	-2.606	-13.995	0.995 (hp)
						0.17	12.00	5.00	1.876	-3.9511	0.971 (hs)
						0.25	12.50	5.00			
						1.25	14.00	4.50			
						11.00	17.00	2<4.5			
						33.00	>17.00	1.00			
						48.50	>17.00	0.75			
						60.00	18.50	0.50			
	3	Slop Oil	57	Durant	subsurface	0.00	7.50	7.50	-1.846	-12.962	0.840 (hp)
						0.17	12.00	6.00			
						0.25	12.00	6.00			
						1.25	13.00	6.00			
						11.00	13.00	6.00			
						33.00	16.00				
						48.50	16.50				
						60.00	17.00	4.50			
	4	Slop Oil	57	Durant	subsurface	0.00	7.50	7.50	-1.538	-14.817	0.996 (hp)
						0.17	13.50	6.50			
						0.25	14.00	6.50			
						1.25	15.00	6.50			
						11.00	16.50	6.00			
						33.00	17.00				
						48.50	17.50				
						60.00	17.50	5.50			
10	1	Slop Oil	16.5	Kidman	Flask	0.00	1.50	0.00			
	2	Slop Oil	16.5	Kidman	Flask	0.00	1.50	0.00			
	3	Slop Oil	16.2	Durant	Flask	0.00	2.50	0.00			
	4	Slop Oil	16.2	Durant	Flask	0.00	2.50	0.00			

APPENDIX F. VOLATILIZATION SCREENING FLASK FlUX DATA - MEASURED VERSUS THEORETICAL

RUN#: 5
POSITION#: 1
WASTE TYPE: Separator Sludge
LOADING: 3.37%

SOIL TYPE: 30 mesh sand
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.45
% MOISTURE: 0.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.45283
AIR-FILLED POROSITY: 0.45283
APPLICATION AREA (cm^2): 58.3

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	2.10E-02	1.38E-01	1.59E-02	6.44E-02	NI	1.07E-02	3.23E-03	2.28E-03	1.56E-02	5.91E-02	4.01E-03	3.53E-02	5.75E-05	5.38E-03
0.50	1.96E-02	9.74E-02	1.34E-02	4.55E-02	NI	7.56E-03	2.71E-03	1.61E-02	1.47E-02	4.18E-02	3.57E-03	2.50E-02	1.59E-04	3.73E-03
1.00	1.74E-02	6.89E-02	9.94E-03	3.22E-02	NI	5.35E-03	2.71E-03	1.14E-02	1.08E-02	2.95E-02	3.21E-03	1.77E-02	1.30E-04	2.64E-03
2.00	4.29E-03	4.87E-02	5.60E-03	2.28E-02	NI	3.78E-03	2.07E-03	8.07E-03	9.12E-03	2.09E-02	2.53E-03	1.25E-02	1.61E-04	1.87E-03
4.00	3.75E-03	3.44E-02	2.76E-03	1.61E-02	2.58E-04	2.67E-03	7.62E-04	5.71E-03	4.53E-03	1.48E-02	1.54E-03	8.80E-03	1.42E-04	1.32E-03
8.00	1.65E-03	2.44E-02	1.56E-03	1.14E-02	NI	1.89E-03	3.07E-04	4.03E-03	2.82E-03	1.04E-02	8.93E-04	6.20E-03	6.46E-05	9.33E-04
20.00	3.27E-05	1.15E-02	1.74E-04	7.20E-03	NI	1.20E-03	3.72E-04	2.55E-03	2.24E-03	6.60E-03	7.21E-04	4.00E-03	9.40E-05	5.91E-04
50.00	NP	9.74E-03	NP	4.55E-03	BDL	7.60E-04	BDL	1.61E-03	9.63E-05	4.18E-03	3.72E-05	2.50E-03	5.31E-05	3.73E-04
73.00	7.07E-06	8.23E-03	BDL	3.85E-03	BDL	6.40E-04	5.73E-07	1.36E-03	5.69E-05	3.53E-03	3.20E-05	2.10E-03	3.75E-05	3.15E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
slope=	0.0133	0.0695	0.0094	0.0322		0.0053	0.0018	0.0114	0.0090	0.0295	0.0022	0.0177	0.0001	0.0027
r^2=	0.8802	0.9992	0.9600	1.0000		1.0000	0.8537	1.0000	0.9227	1.0000	0.8881	1.0000	0.6392	0.9998
(n=9)	n=8		n=7				n=7							

RUN#: 5
POSITION#: 2
WASTE TYPE: Separator Sludge
LOADING: 3.44%

SOIL TYPE: 30 mesh sand
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.45
% MOISTURE: 0.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.45283
AIR-FILLED POROSITY: 0.45283
APPLICATION AREA (cm^2): 58.3

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	2.58E-02	1.39E-01	1.50E-02	6.45E-02	NI	1.08E-02	3.13E-03	2.30E-02	1.42E-02	5.96E-02	3.51E-03	3.57E-02	9.46E-05	5.33E-03
0.50	1.83E-02	9.84E-02	1.08E-02	4.60E-02	NI	7.63E-03	3.07E-03	1.63E-02	1.27E-02	4.22E-02	3.44E-03	2.52E-02	1.75E-04	3.77E-03
1.00	1.25E-02	6.95E-02	9.45E-03	3.25E-02	NI	5.40E-03	2.75E-03	1.15E-02	1.15E-02	2.98E-02	3.06E-03	1.78E-02	2.30E-04	2.66E-03
2.00	5.33E-03	4.92E-02	5.05E-03	2.30E-02	NI	3.82E-03	1.94E-03	8.15E-03	8.32E-03	2.11E-02	2.47E-03	1.26E-02	2.01E-04	1.88E-03
4.00	3.24E-03	3.48E-02	2.42E-03	1.63E-02	3.21E-04	2.70E-03	3.07E-04	5.76E-03	3.75E-03	1.49E-02	1.33E-03	8.90E-03	1.39E-04	1.33E-03
8.00	7.59E-04	2.46E-02	ND	1.15E-02	NI	1.91E-03	NI	4.07E-03	ND	1.05E-02	4.88E-04	6.30E-03	3.39E-05	9.42E-04
20.00	3.81E-04	1.56E-02	9.21E-05	7.27E-03	3.15E-05	1.21E-03	1.84E-04	2.58E-03	1.41E-03	6.67E-03	5.23E-04	4.00E-03	1.21E-04	5.96E-04
50.00	NP	9.83E-03	NP	4.60E-03	BDL	7.60E-04	NI	1.63E-03	1.05E-04	4.22E-03	5.52E-05	2.50E-03	3.95E-05	3.77E-04
73.00	BDL	8.31E-03	BDL	3.88E-03	1.44E-05	6.50E-04	BDL	1.38E-03	4.42E-06	3.56E-03	BDL	2.10E-03	7.04E-05	3.19E-04
slope=	0.0152	0.0695	0.0085	0.0323	0.0009	0.0054	0.0018	0.0012	0.0083	0.0298	0.0020	0.0178	0.0001	0.0027
r^2=	0.9891	1.0000	0.9613	1.0000	0.9510	1.0000	0.7669	1.0000	0.8964	1.0000	0.8270	1.0000	0.5726	1.0000
(n=9)	n=7		n=6		n=3		n=7		n=8		n=8			

(continued)

RUN#: 5
POSITION#: 3
WASTE TYPE: Separator Sludge
LOADING: 3.47%

SOIL TYPE: Kidman sandy loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.47
% MOISTURE: 1.60%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.445283
AIR-FILLED POROSITY: 0.429283
APPLICATION AREA (cm^2): 60

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	5.27E-03	1.37E-01	3.50E-03	6.38E-02	8.23E-03	1.06E-02	1.92E-03	2.26E-02	8.62E-03	5.85E-02	2.47E-03	3.50E-02	BDL	5.23E-03
0.50	3.91E-03	9.68E-02	2.58E-03	4.51E-02	NI	7.49E-03	NI	1.60E-02	ND	4.14E-02	1.27E-03	2.47E-02	1.01E-05	3.70E-03
1.00	3.08E-03	6.85E-02	2.22E-03	3.19E-02	NI	5.29E-03	1.28E-03	1.13E-02	5.05E-03	2.93E-02	1.81E-03	1.75E-02	2.32E-04	2.61E-03
2.00	1.03E-03	4.84E-02	1.50E-03	2.26E-02	1.54E-04	3.74E-03	7.71E-04	7.99E-03	4.09E-03	2.07E-02	1.36E-03	1.24E-02	1.22E-04	1.85E-03
4.00	2.21E-04	3.42E-02	6.19E-04	1.59E-02	1.71E-07	2.65E-03	3.60E-04	5.65E-03	9.03E-04	1.46E-02	3.44E-04	8.70E-03	1.01E-04	1.31E-03
8.00	BDL	2.42E-02	2.72E-05	1.13E-02	BDL	1.87E-03	2.67E-04	3.99E-03	1.23E-03	1.03E-02	3.96E-04	6.20E-03	3.63E-04	9.24E-04
20.00	NP	1.53E-02	NP	7.13E-03	BDL	1.18E-03	NI	2.53E-03	1.65E-04	6.54E-03	5.15E-05	3.90E-03	3.23E-05	5.84E-04
50.00	2.24E-05	9.68E-03	BDL	4.51E-03	BDL	7.50E-04	NP	1.60E-03	BDL	4.14E-03	BDL	2.50E-03	8.98E-06	3.70E-04
73.00	NP	8.18E-03	NP	3.81E-03	NP	6.30E-04	BDL	1.35E-03	BDL	3.50E-03	BDL	2.10E-03	1.12E-05	3.12E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
slope=	0.0031	0.0069	0.0020	0.0319	0.0058	0.0053	0.0010	0.0113	0.0048	0.0293	0.0012	0.0175	0.0002	0.0026
r^2=	0.9459	1.0000	0.9278	1.0000	0.9876	1.0000	0.9391	1.0000	0.9347	1.0000	0.8016	1.0000	0.9760	1.0000

RUN#: 5
POSITION#: 4
WASTE TYPE: Separator Sludge
LOADING: 3.54%

SOIL TYPE: Kidman sandy loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.47
% MOISTURE: 1.60%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.445283
AIR-FILLED POROSITY: 0.429283
APPLICATION AREA (cm^2): 60

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	2.03E-02	1.38E-01	1.31E-02	6.45E-02	1.26E-02	1.07E-02	3.68E-03	2.28E-02	1.63E-02	5.91E-02	4.28E-03	3.54E-02	2.37E-04	5.28E-03
0.50	1.48E-02	9.79E-02	1.27E-03	4.56E-02	NI	7.57E-03	2.59E-03	1.62E-02	1.22E-02	4.18E-02	2.99E-03	2.50E-02	1.77E-04	3.73E-03
1.00	1.85E-02	6.92E-02	5.96E-03	3.22E-02	NI	5.35E-03	2.02E-03	1.14E-02	7.84E-03	2.96E-02	2.48E-03	1.77E-02	8.30E-05	2.64E-03
2.00	4.30E-03	4.89E-02	4.05E-03	2.28E-02	5.94E-05	3.78E-03	1.36E-03	8.08E-03	6.21E-03	2.09E-02	1.94E-03	1.25E-02	2.00E-04	1.87E-03
4.00	6.85E-04	3.46E-02	1.58E-03	1.61E-02	NI	2.68E-03	5.74E-04	5.71E-03	3.87E-03	1.48E-02	1.16E-03	8.80E-03	4.42E-05	3.12E-03
8.00	3.15E-05	2.45E-02	1.27E-04	1.14E-02	7.69E-06	1.89E-03	1.24E-04	4.04E-03	1.63E-03	1.05E-02	5.66E-04	6.30E-03	6.14E-05	9.34E-04
20.00	2.04E-05	1.55E-02	BDL	7.21E-03	1.80E-05	1.20E-03	2.75E-05	2.55E-03	4.51E-04	6.61E-03	1.99E-04	4.00E-03	6.67E-05	5.91E-04
50.00	2.20E-05	9.79E-03	BDL	4.56E-03	NP	7.60E-04	NP	1.62E-03	3.24E-06	4.18E-03	2.43E-06	2.50E-03	1.17E-05	3.74E-04
73.00	BDL	8.27E-03	BDL	3.85E-03	2.32E-05	6.40E-04	5.24E-05	1.37E-03	3.82E-05	3.53E-03	7.44E-06	2.10E-03	5.05E-05	3.16E-04
slope=	0.0126	6.90E-02	0.0061	0.0322	0.007	0.0053	0.0021	0.0114	0.009	0.0295	0.0023	0.0177	0.0001	0.0025
r^2=	0.8312	1.0000	0.6200	11.0000	0.9182	1.0000	0.9790	1.0000	0.9917	1.0000	0.9744	1.0000	0.7110	0.8819

(continued)

APPENDIX F. (continued)

RUN#: 6
POSITION#: 1
WASTE TYPE: Slop Oil
LOADING: 3.97%

SOIL TYPE: 30 mesh sand
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.45
% MOISTURE: 0.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.4528302
AIR-FILLED POROSITY: 0.4528302
APPLICATION AREA (cm^2): 58.3

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	ND	2.86E-01	ND	1.80E-01	ND	2.62E-02	ND	4.17E-02	ND	1.25E-01	ND	4.91E-02	ND	3.36E-03
0.50	6.30E-02	2.02E-01	4.19E-02	1.27E-01	1.80E-02	1.85E-02	1.06E-02	2.95E-02	2.70E-02	8.83E-02	7.39E-03	3.47E-02	2.04E-04	2.38E-03
1.00	4.59E-02	1.43E-01	3.57E-02	9.01E-02	1.77E-02	1.31E-02	8.73E-03	2.08E-02	2.47E-02	6.24E-02	5.77E-03	2.45E-02	1.10E-04	1.68E-03
2.00	4.83E-02	1.01E-01	3.72E-02	6.37E-02	2.60E-02	9.27E-03	1.00E-02	1.47E-02	3.52E-02	4.42E-02	9.09E-03	1.74E-02	2.39E-04	1.19E-03
4.00	4.50E-02	7.15E-02	3.23E-02	4.51E-02	NI	6.56E-03	1.05E-02	1.04E-02	2.40E-02	3.12E-02	7.93E-03	1.23E-02	2.42E-04	8.40E-04
8.00	1.88E-02	5.06E-02	1.68E-02	3.19E-02	NI	4.64E-03	5.82E-03	7.37E-03	1.40E-02	2.21E-02	4.58E-03	8.70E-03	1.21E-04	5.94E-04
20.00	7.67E-03	3.20E-02	7.24E-03	2.02E-02	NI	2.93E-03	4.46E-03	4.66E-03	1.02E-02	1.40E-02	3.84E-03	5.50E-03	2.91E-04	3.76E-04
40.00	3.65E-04	2.26E-02	1.04E-03	1.43E-02	NI	2.07E-03	1.63E-03	3.29E-03	4.63E-03	9.87E-03	1.57E-03	3.90E-03	1.81E-04	2.66E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
slope=	0.0464	0.1429	0.0307	0.0899	-0.0105	0.0131	0.0058	0.0209	0.0168	0.0625	0.0035	0.0245	0.0000	0.0017
r^2=	0.7970	1.0000	0.7473	1.0000	0.6297	1.0000	0.5673	1.0000	0.5076	1.0000	0.3700	1.0000	0.0465	1.0000

RUN#: 6
POSITION#: 2
WASTE TYPE: Slop Oil
LOADING: 3.97%

SOIL TYPE: Kidman sandy loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.47
% MOISTURE: 1.60%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.445283
AIR-FILLED POROSITY: 0.429283
APPLICATION AREA (cm^2): 60

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	6.20E-02	2.82E-01	3.59E-02	1.76E-01	3.78E-03	2.56E-02	5.29E-03	4.07E-02	1.29E-02	1.22E-01	3.78E-03	4.80E-02	1.55E-05	3.28E-03
0.50	5.27E-02	2.00E-01	3.29E-02	1.25E-01	NI	1.81E-02	5.22E-03	2.88E-02	1.31E-02	8.63E-02	3.67E-03	3.39E-02	3.28E-05	2.31E-03
1.00	4.55E-02	1.41E-01	2.87E-02	8.82E-02	NI	1.28E-02	4.75E-03	2.04E-02	1.19E-02	6.10E-02	3.51E-03	2.40E-02	7.66E-05	1.64E-03
2.00	4.11E-02	9.98E-02	2.73E-02	6.23E-02	ND	9.06E-03	5.31E-03	1.44E-02	1.33E-02	4.31E-02	3.94E-03	1.70E-02	6.76E-05	1.16E-03
4.00	4.66E-02	7.06E-02	2.81E-02	4.41E-02	ND	6.41E-03	6.34E-03	1.02E-02	1.44E-02	3.05E-02	4.81E-03	1.20E-02	8.09E-05	8.21E-04
8.00	1.68E-02	4.99E-02	1.50E-02	3.12E-02	3.31E-03	4.53E-03	4.32E-03	7.20E-03	9.76E-03	2.16E-02	3.38E-03	8.50E-03	9.90E-05	5.80E-04
20.00	6.75E-03	3.16E-02	6.81E-03	1.97E-02	NI	2.87E-03	1.96E-03	4.55E-03	6.95E-03	1.36E-02	1.87E-03	5.40E-03	2.98E-05	3.67E-04
40.00	3.05E-04	2.23E-02	2.04E-03	1.39E-02	5.30E-03	2.03E-03	1.94E-03	3.22E-03	5.34E-03	9.65E-03	1.63E-03	3.80E-03	5.31E-05	2.60E-04
slope=	0.0303	0.1411	0.0162	0.0881	-0.0004	0.0128	0.0014	0.0204	0.0031	0.0610	0.0008	0.0240	0.0000	0.0016
r^2=	0.7313	1.0000	0.6951	1.0000	0.1463	1.0000	0.3028	1.0000	0.3723	1.0000	0.2093	1.0000	0.2824	1.0000

(continued)

APPENDIX F. (continued)

RUN#: 6
POSITION#: 3
WASTE TYPE: Slop Oil
LOADING: 3.95%

SOIL TYPE: Durant clay loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.1
% MOISTURE: 4.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.5849057
AIR-FILLED POROSITY: 0.5449057
APPLICATION AREA (cm^2): 52.8

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	7.11E-02	2.63E-01	4.19E-02	1.64E-01	1.30E-02	2.39E-02	7.06E-03	3.80E-02	1.80E-02	1.14E-01	4.89E-03	4.47E-02	1.94E-04	3.06E-03
0.50	6.07E-02	1.86E-01	3.90E-02	1.16E-01	NI	1.69E-02	6.13E-03	2.68E-02	1.56E-02	8.05E-02	4.53E-03	3.16E-02	1.39E-04	2.16E-03
1.00	5.90E-02	1.31E-01	3.72E-02	8.22E-02	NI	1.20E-02	8.81E-03	1.90E-02	2.11E-02	5.69E-02	6.22E-03	2.24E-02	1.40E-04	1.53E-03
2.00	6.64E-02	9.30E-02	3.90E-02	5.81E-02	2.01E-02	8.45E-03	9.64E-03	1.34E-02	2.22E-02	4.02E-02	6.82E-03	1.58E-02	2.38E-04	1.08E-03
4.00	5.13E-02	6.57E-02	2.99E-02	4.11E-02	5.98E-03	5.97E-03	7.97E-03	9.49E-03	1.89E-02	2.84E-02	8.37E-03	1.12E-02	1.87E-04	7.65E-04
8.00	1.43E-02	4.65E-02	9.90E-03	2.91E-02	NI	4.22E-03	4.77E-03	6.71E-03	1.05E-02	2.01E-02	3.75E-03	7.90E-03	1.20E-04	5.41E-04
20.00	6.93E-03	2.94E-02	6.43E-03	1.84E-02	1.27E-03	2.67E-03	1.88E-03	4.24E-03	5.93E-03	1.27E-02	1.28E-03	5.00E-03	BDL	3.42E-04
40.00	4.07E-04	2.08E-02	2.56E-03	1.30E-02	1.51E-03	1.89E-03	1.98E-03	3.00E-03	5.42E-03	8.99E-03	1.74E-03	3.50E-03	3.77E-06	2.42E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=8)														
slope=	0.0359	0.1315	0.0208	0.0820	0.0016	0.0120	0.0022	0.0190	0.0058	0.0570	0.0014	0.0224	0.0001	0.0015
r^2=	0.6333	1.0000	0.6552	1.0000	0.3173	1.0000	0.2389	1.0000	0.3140	1.0000	0.1812	1.0000	0.2131	1.0000
t<4hrs (n=4)														
slope=	0.0050	0.1315	0.0027	0.0820		0.0120	-0.0022	0.0190	-0.0038	0.0570	-0.0016	0.0224	0.0000	0.0015
r^2=	0.2548	1.0000	0.6277	1.0000		1.0000	0.6044	1.0000	0.5083	1.0000	0.7026	1.0000	0.0473	1.0000
t≥4hrs (n=4)														
slope=	0.1429	0.1315	0.0763	0.0820	0.0142	0.0120	0.0187	0.0190	0.0403	0.0570	0.0148	0.0224	0.0005	0.0015
r^2=	0.9008	1.0000	0.8959	1.0000	0.9495	1.0000	0.9604	1.0000	0.9519	1.0000	0.9302	1.0000	0.9949	1.0000

RUN#: 6
POSITION#: 4
WASTE TYPE: Slop Oil
LOADING: 3.94%

SOIL TYPE: Durant clay loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.1
% MOISTURE: 4.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.5849057
AIR-FILLED POROSITY: 0.5449057
APPLICATION AREA (cm^2): 52.8

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	9.06E-02	2.63E-01	4.60E-02	1.64E-01	2.71E-02	2.39E-02	1.28E-02	3.80E-02	4.33E-02	1.14E-01	1.08E-02	4.47E-02	3.53E-04	3.06E-03
0.50	7.11E-02	1.86E-01	4.09E-02	1.16E-01	3.07E-02	1.69E-02	1.15E-02	2.68E-02	4.11E-02	8.05E-02	1.04E-02	3.16E-02	3.89E-04	2.16E-03
1.00	6.55E-02	1.31E-01	4.35E-02	8.22E-02	3.19E-02	1.20E-02	1.17E-02	1.90E-02	4.18E-02	5.69E-02	1.08E-02	2.24E-02	3.54E-04	1.53E-03
2.00	6.71E-02	9.30E-02	4.08E-02	5.81E-02	3.29E-02	8.45E-03	1.11E-02	1.34E-02	3.96E-02	4.02E-02	1.04E-02	1.58E-02	3.55E-04	1.08E-03
4.00	5.12E-02	6.57E-02	3.54E-02	4.11E-02	ND	5.97E-03	1.17E-02	9.49E-03	2.96E-02	2.84E-02	8.56E-03	1.12E-02	3.63E-04	7.65E-04
8.00	1.74E-02	4.65E-02	1.66E-02	2.91E-02	NI	4.22E-03	6.31E-03	6.71E-03	1.42E-02	2.01E-02	5.06E-03	7.90E-03	2.95E-04	5.41E-04
20.00	6.84E-04	2.94E-02	4.54E-03	1.84E-02	1.39E-02	2.67E-03	7.31E-03	4.24E-03	1.36E-02	1.27E-02	5.66E-03	5.00E-03	4.71E-03	3.42E-04
40.00	1.31E-04	2.08E-02	1.51E-03	1.30E-02	5.91E-03	1.89E-03	2.09E-03	3.00E-03	5.49E-03	8.99E-03	1.51E-03	3.50E-03	2.84E-04	2.42E-04
all (n=8)														
slope=	0.0475	0.1315	0.0224	0.0820	0.0104	0.0120	0.0042	0.0190	0.0195	0.0570	0.0041	0.0224	-0.0008	0.0015
r^2=	0.7736	1.0000	0.6233	1.0000	0.4348	1.0000	0.5355	1.0000	0.6745	1.0000	0.5765	1.0000	0.1188	1.0000
t<4hrs (n=4)														
slope=	0.0190	0.1315	0.0032	0.0820	-0.0044	0.0120	0.0012	0.0190	0.0024	0.0570	0.0002	0.0224	0.0000	0.0015
r^2=	0.8425	1.0000	0.5200	1.0000	9673	1.0000	0.8212	1.0000	0.7551	1.0000	0.2047	1.0000	0.0133	1.0000
t≥4hrs (n=4)														
slope=	0.1531	0.1315	0.1006	0.0820	0.1220	0.0120	0.0231	0.0190	0.0629	0.0570	0.0168	0.0224	-0.0053	0.0015
r^2=	0.9334	1.0000	0.9786	1.0000	1 (n=2)	1.0000	0.7816	1.0000	0.8906	1.0000	0.7718	1.0000	0.1316	1.0000

RUN#: 10
POSITION#: 1
WASTE TYPE: Slop Oil
LOADING: 8.00%

SOIL TYPE: Kidman sandy loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.42
% MOISTURE: 2.36%

TEMPERATURE (°C): 23
TOTAL POROSITY: 0.4641509
AIR-FILLED POROSITY: 0.4405509
APPLICATION AREA (cm^2): 52.8

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	3.39E-02	3.31E-01	4.37E-02	2.07E-01	5.72E-03	3.00E-02	1.63E-02	4.77E-02	4.41E-02	1.43E-01	1.70E-02	5.62E-02	3.97E-04	3.85E-03
1.00	2.08E-02	1.65E-01	3.05E-02	1.03E-01	NI	1.50E-02	1.27E-02	2.39E-02	3.49E-02	7.15E-02	1.38E-02	2.81E-02	3.23E-04	1.92E-03
10.50	7.35E-03	5.23E-02	1.10E-02	3.27E-02	NI	4.75E-03	6.18E-03	7.54E-03	1.74E-02	2.26E-02	6.70E-03	8.90E-03	1.81E-04	6.08E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
slope=	0.0155	0.1649	0.0189	0.1031		0.0149	0.0058	0.0237	0.0153	0.0712	0.0059	0.0280	0.0001	0.0019
r^2=	0.9874	1.0000	0.9542	1.0000		1.0000	0.9288	1.0000	0.9223	1.0000	0.9009	1.0000	0.9211	1.0000
(n=3)														

RUN#: 10
POSITION#: 2
WASTE TYPE: Slop Oil
LOADING: 7.95%

SOIL TYPE: Kidman sandy loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.42
% MOISTURE: 2.36%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.4641509
AIR-FILLED POROSITY: 0.4405509
APPLICATION AREA (cm^2): 52.8

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	6.63E-03	3.30E-01	7.83E-03	2.06E-01	NI	2.99E-02	3.13E-03	4.76E-02	8.48E-03	1.43E-01	3.54E-03	5.60E-02	5.56E-04	3.83E-03
1.00	2.19E-02	1.65E-01	3.17E-03	1.03E-01	NI	1.50E-02	1.34E-02	2.38E-02	3.58E-02	7.13E-02	1.34E-02	2.80E-02	2.08E-04	1.92E-03
10.50	6.88E-03	5.21E-02	1.18E-02	3.26E-02	NI	4.73E-03	4.78E-03	7.52E-03	1.74E-02	2.25E-02	5.79E-03	8.90E-03	5.30E-05	6.06E-04
slope=	-0.0012	0.1644	-0.0018	0.1026		0.0149	-0.0016	0.0237	-0.0068	0.0713	-0.0019	0.0279	0.0003	0.0019
r^2=	0.0142	1.0000	0.1325	1.0000		1.0000	0.0637	1.0000	0.1744	1.0000	0.1016	1.0000	0.9873	1.0000

(continued)

APPENDIX F. (continued)

RUN#: 10
POSITION#: 3
WASTE TYPE: Slop Oil
LOADING: 7.90%

SOIL TYPE: Durant clay loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.09
% MOISTURE: 8.95%

TEMPERATURE (°C): 23
TOTAL POROSITY: 0.5886792
AIR-FILLED POROSITY: 0.4991792
APPLICATION AREA (cm^2): 49.5

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	4.23E-02	3.00E-01	4.23E-02	1.88E-01	7.51E-03	2.73E-02	2.15E-02	4.34E-02	5.74E-02	1.30E-01	2.23E-02	5.11E-02	1.10E-03	3.50E-03
1.00	3.01E-02	1.50E-01	4.05E-02	9.40E-02	NI	1.37E-02	1.61E-02	2.17E-02	4.57E-02	6.51E-02	1.65E-02	2.56E-02	2.87E-04	1.75E-03
10.50	9.78E-03	4.75E-02	1.49E-02	2.97E-02	NI	4.32E-03	8.72E-03	6.86E-03	2.41E-02	2.06E-02	1.03E-02	8.10E-03	2.52E-03	5.53E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
slope=	0.0187	0.1493	0.0152	0.0936		0.0136	0.0074	0.0216	0.0191	0.0647	0.0070	0.0254	-0.0007	0.0017
r^2=	0.9397	1.0000	0.7090	1.0000		1.0000	0.9628	1.0000	0.9263	1.0000	0.9847	1.0000	0.2951	1.0000
(n=3)														

RUN#: 10
POSITION#: 4
WASTE TYPE: Slop Oil
LOADING: 7.90%

SOIL TYPE: Durant clay loam
APPLICATION: flask
BULK DENSITY(g/cm^3): 1.09
% MOISTURE: 8.95%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.5886792
AIR-FILLED POROSITY: 0.4991792
APPLICATION AREA (cm^2): 49.5

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	5.22E-02	3.00E-01	5.62E-02	1.87E-01	5.15E-03	2.72E-02	2.00E-02	4.33E-02	5.02E-02	1.30E-01	1.70E-02	5.10E-02	BDL	3.49E-03
1.00	2.67E-02	1.50E-01	3.92E-02	9.37E-02	NI	1.36E-02	4.32E-03	2.16E-02	4.50E-02	6.49E-02	1.78E-02	2.55E-02	9.87E-04	1.74E-03
10.50	9.05E-03	4.74E-02	1.34E-02	2.96E-02	NI	4.31E-03	5.66E-03	6.84E-03	2.01E-02	2.05E-02	7.31E-03	8.10E-03	3.69E-04	5.52E-04
slope=	0.0255	0.1494	0.0247	0.0931		0.0135	0.0090	0.0216	0.0169	0.0648	0.0053	0.0254	0.0009	0.0017
r^2=	1.0000	1.0000	0.9510	1.0000		1.0000	0.7737	1.0000	0.7979	1.0000	0.5878	1.0000	1.0000	1.0000
(n=3)													(n=2)	

NI= not integrated NP= no peak recognized ND= no data BDL= below detectable limits

APPENDIX G. MICROCOSM FLUX DATA - MEASURED VERSUS THEORETICAL

RUN#: 1 SOIL TYPE 30 mesh sand TEMPERATURE (°C): 15.1
POSITION#: 1 APPLICATION: subsurface TOTAL POROSITY: 0.3962264
WASTE TYPE: Slop Oil BULK DENSITY(g/cm^3): 1.6 AIR-FILLED POROSITY: 0.3962264
LOADING: 4.57% % MOISTURE: 0.00% APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.00	5.25E-03	1.66E-02	5.35E-03	1.51E-02	9.65E-04	1.66E-03	3.29E-04	2.06E-03	1.02E-03	6.28E-03	2.65E-04	2.69E-03	#VALUE!	3.04E-05
0.50	6.82E-03	1.64E-02	5.70E-03	1.50E-02	2.25E-04	1.65E-03	2.59E-04	2.05E-03	7.78E-04	6.26E-03	1.66E-04	2.68E-03	3.30E-06	3.04E-05
1.00	ND	1.61E-02	ND	1.48E-02	ND	1.65E-03	ND	2.05E-03	ND	6.24E-03	ND	2.67E-03	#VALUE!	3.03E-05
2.50	5.74E-03	1.66E-02	5.65E-03	1.56E-02	8.69E-04	1.77E-03	4.00E-04	2.22E-03	1.17E-03	6.74E-03	2.56E-04	2.88E-03	3.21E-06	3.34E-05
5.00	7.35E-03	1.57E-02	6.98E-03	1.50E-02	1.31E-03	1.73E-03	5.78E-04	2.19E-03	1.70E-03	6.63E-03	3.61E-04	2.83E-03	1.88E-06	3.34E-05
10.00	ND	1.39E-02	ND	1.38E-02	ND	1.64E-03	ND	2.12E-03	ND	6.38E-03	ND	2.72E-03	#VALUE!	3.33E-05
25.00	ND	1.03E-02	ND	1.14E-02	ND	1.54E-03	ND	2.16E-03	ND	6.31E-03	ND	2.66E-03	#VALUE!	4.13E-05
50.00	5.84E-03	8.61E-03	6.88E-03	9.42E-03	2.05E-03	1.32E-03	8.65E-04	1.91E-03	2.71E-03	5.51E-03	5.61E-04	2.31E-03	5.38E-08	4.10E-05
101.50	5.55E-03	6.32E-03	7.28E-03	7.03E-03	2.36E-03	1.02E-03	9.09E-04	1.54E-03	3.08E-03	4.37E-03	6.24E-04	1.82E-03	4.04E-07	4.03E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=8)	flux vs 1/t^0.5													
slope=	0.0007	0.0065	-0.0012	0.0047	-0.0015	0.0003	-0.0005	0.0002	-0.0017	0.0007	-0.0003	0.0003	2.40E-06	8.40E-06
r^2=	0.2421	0.5708	0.6526	0.4737	0.8964	0.2963	0.8466	0.1013	0.7966	0.1827	0.8192	0.2088	0.7199	0.6886
t<5hrs (n=3)	flux vs ln(t)													
slope=		0.0001		0.0004		0.0001		0.0001		0.0003	0.0001	0.0001	-5.60E-08	1.90E-06
r^2=		0.2203		0.5985		0.8157		0.8157		0.7875	1 (n=2)	0.7819	1 (n=2)	0.7932
t≥5hrs (n=5)	flux vs 1/t^0.5													
slope=	0.0051	0.0265	-0.0004	0.0218	-0.0028	0.0018	-0.0009	0.0014	-0.0037	0.0053	-0.0007	-0.0003	-5.70E-07	-2.60E-05
r^2=	0.9985	0.9579	0.1462	0.9081	0.9679	0.7808	0.9999	0.5700	0.9775	0.6654	0.9856	0.8494	0.8422	0.7793

RUN#: 1 SOIL TYPE Kidman sandy loam TEMPERATURE (°C): 15.1
POSITION#: 2 APPLICATION: subsurface TOTAL POROSITY: 0.4301887
WASTE TYPE: Slop Oil BULK DENSITY(g/cm^3): 1.51 AIR-FILLED POROSITY: 0.4137887
LOADING: 4.71% % MOISTURE: 1.64% APPLICATION AREA (cm^2): 45.6

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.00	3.57E-03	1.64E-02	8.56E-03	1.49E-02	NI	1.65E-03	NI	2.04E-03	7.04E-03	6.21E-03	5.16E-03	2.67E-03	NP	3.00E-05
0.50	6.53E-03	1.64E-02	4.55E-03	1.49E-02	2.04E-03	1.64E-03	4.97E-04	2.03E-03	1.89E-03	6.21E-03	4.32E-04	2.66E-03	4.71E-05	3.00E-05
1.00	7.51E-03	1.63E-02	5.69E-03	1.49E-02	1.31E-03	1.64E-03	3.95E-04	2.03E-03	1.24E-03	6.20E-03	2.59E-04	2.66E-03	8.95E-05	3.00E-05
2.50	8.03E-03	2.07E-02	5.91E-03	1.94E-02	7.84E-04	2.19E-03	2.91E-04	2.75E-03	8.68E-04	8.36E-03	1.54E-04	3.58E-03	2.50E-05	4.13E-05
5.00	8.52E-03	1.97E-02	6.98E-03	1.87E-02	9.20E-04	2.15E-03	3.62E-04	2.71E-03	1.01E-03	8.24E-03	2.11E-04	3.52E-03	3.30E-06	4.13E-05
10.00	1.08E-02	1.76E-02	1.18E-02	1.73E-02	1.72E-03	2.06E-03	5.69E-04	2.64E-03	2.08E-04	7.96E-03	3.87E-04	3.39E-03	3.96E-06	4.12E-05
25.00	7.94E-03	1.20E-02	1.01E-02	1.28E-02	2.23E-03	1.74E-03	8.93E-04	2.44E-03	2.57E-03	7.12E-03	4.94E-04	3.00E-03	2.45E-06	4.67E-05
50.00	6.55E-03	9.69E-03	1.25E-02	1.61E-02	3.19E-03	1.49E-03	1.16E-03	2.15E-03	3.55E-03	6.21E-03	6.69E-04	2.60E-03	2.31E-06	4.63E-05
101.50	5.93E-03	7.11E-03	9.33E-03	7.91E-03	4.03E-03	1.15E-03	1.37E-03	1.73E-03	4.38E-03	4.92E-03	1.00E-03	2.05E-03	2.32E-07	4.55E-05
all (n=8)	flux vs 1/t^0.5													
slope=	-0.0005	0.0053	-0.0054	0.0019	-0.0011	0.0001	-0.0006	-0.0001	-0.0013	-0.0001	-0.0003	0.0003	0.0001	-1.40E-05
r^2=	0.2421	0.5708	0.6526	0.4737	0.8964	0.2963	0.8466	0.1013	0.7966	0.1827	0.8192	0.2088	0.7199	0.6886
t<5hrs (n=3)	flux vs ln(t)													
slope=	0.0008	0.0019	9.00E-04	0.0021	-0.0005	0.0003	-0.0001	0.0004	-0.0004	0.0011	-0.0001	0.0005	-2.60E-05	5.90E-06
r^2=	0.9577	0.7185	0.9187	0.7724	0.8003	0.8140	0.6103	0.8216	0.7439	0.8198	0.6907	0.8174	0.5122	0.8435
t≥5hrs (n=5)	flux vs 1/t^0.5													
slope=	0.0229	0.0367	-0.0081	0.0241	-0.0083	0.0027	-0.0029	0.0025	-0.0107	0.0087	-0.0019	0.0039	7.70E-06	-1.70E-05
r^2=	0.9943	0.9580	0.2749	0.6217	0.9123	0.8697	0.9533	0.7770	0.7609	0.8246	0.8381	0.8372	0.6006	0.7326

(continued)

APPENDIX G. (continued)

RUN#: 1	SOIL TYPE Kidman Sandy loam	TEMPERATURE (°C): 15.1
POSITION#: 3	APPLICATION: subsurface	TOTAL POROSITY: 0.45283
WASTE TYPE: Slop Oil	BULK DENSITY(g/cm^3): 1.45	AIR-FILLED POROSITY: 0.43643
LOADING: 5.36%	% MOISTURE: 1.64%	APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.00	ND	1.92E-02	ND	1.75E-02	ND	1.93E-03	ND	2.38E-03	ND	7.28E-03	ND	3.12E-03	ND	3.52E-05
0.50	5.61E-03	1.91E-02	1.45E-02	1.74E-02	NI	1.92E-03	NI	2.38E-03	1.31E-02	7.27E-03	2.92E-03	3.12E-03	2.31E-06	3.52E-05
1.00	7.76E-03	1.90E-02	9.82E-03	1.74E-02	5.57E-03	1.92E-03	NI	2.38E-03	8.33E-03	7.26E-03	1.70E-03	3.11E-03	4.01E-05	3.52E-05
2.50	5.80E-03	2.00E-02	8.39E-03	1.86E-02	3.48E-03	2.09E-03	9.78E-04	2.61E-03	3.80E-03	7.95E-03	9.06E-04	3.40E-03	2.08E-04	3.91E-05
5.00	5.03E-03	1.92E-02	7.95E-03	1.81E-02	2.88E-03	2.06E-03	1.07E-03	2.59E-03	3.33E-03	7.86E-03	7.78E-04	3.36E-03	1.37E-05	3.91E-05
10.00	ND	1.75E-02	ND	1.70E-02	ND	1.99E-03	ND	2.53E-03	ND	7.65E-03	ND	3.27E-03	ND	3.90E-05
25.00	4.50E-03	1.27E-02	4.65E-03	1.34E-02	1.47E-03	1.77E-03	4.41E-04	2.42E-03	1.36E-03	7.13E-03	2.48E-04	3.01E-03	1.04E-05	4.36E-05
50.00	4.84E-03	1.04E-02	5.41E-03	1.13E-02	1.62E-03	1.55E-03	5.28E-04	2.19E-03	1.58E-03	6.37E-03	2.92E-04	2.68E-03	5.56E-06	4.34E-05
101.50	3.09E-03	7.75E-03	4.83E-03	8.56E-03	1.87E-03	1.23E-03	5.80E-04	1.81E-03	1.74E-03	5.18E-03	3.34E-04	2.16E-03	4.19E-06	4.29E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=8)	flux vs 1/t^0.5													
slope=	0.0020	0.0071	0.0070	0.0051	0.0044	0.0003	0.0011	0.0002	0.0087	0.0008	0.0019	0.0004	1.70E-05	-6.70E-06
r^2=	0.4782	0.4922	0.9568	0.4082	0.9608	0.2555	0.7460	0.1084	0.9580	0.1713	0.9634	0.1953	0.0123	0.8282
t<5hrs (n=3)	flux vs ln(t)													
slope=		0.0006	-0.0037	0.0008		0.0001		0.0001	-0.0057	0.0004	-0.0012	0.0002	0.0001	2.50E-06
r^2=		0.7404	0.8639	0.8157		0.8157		0.8157	0.9910	0.8058	0.9600	0.7916	0.9287	0.8157
t≥5hrs (n=5)	flux vs 1/t^0.5													
slope=	0.0035	0.0229	0.0074	0.0180	0.0036	0.0014	0.0011	0.0012	0.0047	0.0044	0.0013	0.0020	0.0003	-9.50E-06
r^2=	0.6597	0.8564	0.8961	0.8155	0.8993	0.7324	0.7460	0.6337	0.9043	0.6805	0.9152	0.6910	0.6863	0.6901

RUN#: 1	SOIL TYPE 30 mesh sand	TEMPERATURE (°C): 15.1
POSITION#: 4	APPLICATION: subsurface	TOTAL POROSITY: 0.445283
WASTE TYPE: Slop Oil	BULK DENSITY(g/cm^3): 1.47	AIR-FILLED POROSITY: 0.445283
LOADING: 5.12%	% MOISTURE: 0.00%	APPLICATION AREA (cm^2): 45.6

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.00	7.16E-03	1.94E-02	1.68E-02	1.76E-02	NI	1.94E-03	NI	2.40E-03	1.01E-02	7.33E-03	1.67E-03	3.15E-03	1.73E-06	3.54E-05
0.50	7.51E-03	1.90E-02	1.05E-02	1.74E-02	NI	1.93E-03	NI	2.39E-03	6.65E-03	7.30E-03	1.45E-03	3.13E-03	4.52E-06	3.54E-05
1.00	7.69E-03	1.87E-02	1.36E-02	1.73E-02	NI	1.92E-03	NI	2.38E-03	5.21E-03	7.27E-03	9.92E-04	3.12E-03	2.82E-05	3.54E-05
2.50	ND	1.90E-02	ND	1.79E-02	ND	2.05E-03	ND	2.58E-03	ND	7.82E-03	ND	3.35E-03	ND	3.90E-05
5.00	6.07E-03	1.77E-02	7.40E-03	1.71E-02	2.69E-03	2.00E-03	1.06E-03	2.53E-03	3.45E-03	7.67E-03	7.90E-04	3.28E-03	8.95E-05	3.89E-05
10.00	7.32E-04	1.56E-02	1.01E-03	1.55E-02	3.08E-04	1.88E-03	1.61E-04	2.44E-03	5.06E-04	7.33E-03	1.16E-04	3.12E-03	7.84E-06	3.89E-05
25.00	ND	1.15E-02	ND	1.24E-02	ND	1.71E-03	ND	2.42E-03	ND	7.03E-03	ND	2.95E-03	ND	4.81E-05
50.00	3.78E-03	9.25E-03	5.13E-03	1.02E-02	1.91E-03	1.44E-03	7.67E-04	2.11E-03	2.38E-03	6.07E-03	5.14E-04	2.54E-03	4.62E-06	4.77E-05
101.50	4.17E-03	6.74E-03	5.46E-03	7.53E-03	1.94E-03	1.11E-03	7.66E-04	1.68E-03	2.44E-03	4.74E-03	5.98E-04	1.97E-03	NP	4.67E-05
all (n=8)	flux vs 1/t^0.5													
slope=	0.0037	0.0081	0.0064	0.0061	0.0006	0.0004	0.0002	0.0003	0.0037	0.0011	0.0007	0.0005	-1.00E-05	-1.00E-05
r^2=	0.5451	0.6012	0.5732	0.5197	0.0008	0.3566	0.0099	0.1752	0.7906	0.2549	0.7355	0.2837	0.0230	0.6928
t<2hrs (n=3)	flux vs ln(t)													
slope=		2.00E-05		0.0003		0.0001		0.0001		0.0003		0.0001		2.00E-06
r^2=		0.0064		0.6813		0.7592		0.7801		0.7766		0.7850		0.8157
t>5hrs (n=5)	flux vs 1/t^0.5													
slope=	-0.0163	0.0311	-0.0214	0.0264	-0.0080	0.0023	-0.0030	0.0020	-0.0094	0.0072	-0.0022	0.0033	0.0003	-3.00E-05
r^2=	0.9935	0.9578	0.9862	0.9284	0.9720	0.8315	0.9659	0.6565	0.9756	0.7377	0.9996	0.7664	0.7064	0.7730

(continued)

RUN#: 2
POSITION#: 1
WASTE TYPE: Slop Oil
LOADING: 4.02%

SOIL TYPE: 30 mesh sand
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.35
% MOISTURE: 0.00%

TEMPERATURE (°C): 16.9
TOTAL POROSITY: 0.490566
AIR-FILLED POROSITY: 0.490566
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	8.44E-02	1.70E-01	1.09E-01	1.93E-01	3.41E-02	2.96E-02	1.34E-02	4.74E-02	4.38E-02	1.31E-01	1.43E-02	5.40E-02	3.47E-06	3.98E-03
0.50	3.45E-02	1.20E-01	7.63E-02	1.37E-01	2.66E-02	2.09E-02	1.06E-02	3.35E-02	3.46E-02	9.26E-02	1.14E-02	3.82E-02	1.96E-04	2.81E-03
1.00	3.46E-02	8.50E-02	5.55E-02	9.66E-02	2.30E-02	1.48E-02	8.86E-03	2.37E-02	2.90E-02	6.55E-02	9.53E-03	2.70E-02	2.68E-04	1.99E-03
2.00	2.61E-02	4.77E-02	3.86E-02	5.42E-02	1.89E-02	8.30E-03	6.97E-03	1.33E-02	2.28E-02	3.67E-02	6.79E-03	1.51E-02	2.33E-04	1.11E-03
4.00	1.54E-02	3.37E-02	2.65E-02	3.83E-02	1.55E-02	5.87E-03	5.52E-03	9.40E-03	1.80E-02	2.60E-02	5.71E-03	1.07E-02	7.04E-05	7.89E-04
8.17	8.47E-03	2.38E-02	1.29E-02	2.71E-02	9.33E-03	4.15E-03	3.03E-03	6.65E-03	9.93E-03	1.84E-02	3.15E-03	7.57E-03	1.23E-04	5.58E-04
20.25	5.85E-03	1.29E-02	7.16E-03	1.46E-02	5.43E-03	2.24E-03	1.80E-03	3.59E-03	5.63E-03	9.93E-03	1.70E-03	4.09E-03	1.51E-04	3.01E-04
45.25	6.90E-03	8.15E-03	6.42E-03	9.26E-03	1.24E-03	1.42E-03	1.40E-03	2.27E-03	4.41E-03	6.28E-03	1.15E-03	2.59E-03	4.90E-05	1.91E-04
69.58	4.49E-03	6.90E-03	4.55E-03	7.83E-03	NI	1.20E-03	1.19E-03	1.92E-03	3.56E-03	5.31E-03	1.09E-03	2.19E-03	8.92E-05	1.61E-04
93.58	7.27E-03	5.76E-03	6.82E-03	6.55E-03	1.27E-03	1.00E-03	1.54E-03	1.61E-03	4.55E-03	4.44E-03	1.31E-03	1.83E-03	5.72E-05	1.35E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=10)													(t≥1 hr)	
slope=	0.0379	0.0885	0.0565	0.1006	0.0166	0.0154	0.0067	0.0247	0.0220	0.0682	0.0073	0.0281	0.0002	0.0002
r^2=	0.9174	0.9960	0.9970	0.9959	0.9218	0.9960	0.9581	0.9960	0.9566	0.9959	0.9621	0.9958	0.4398	0.9958

RUN#: 2
POSITION#: 2
WASTE TYPE: Slop Oil
LOADING: 4.04%

SOIL TYPE: 30 mesh sand
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.35
% MOISTURE: 0.00%

TEMPERATURE (°C): 16.9
TOTAL POROSITY: 0.490566
AIR-FILLED POROSITY: 0.490566
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	4.84E-02	1.66E-01	8.34E-02	1.88E-01	2.47E-02	2.88E-02	1.07E-02	4.62E-02	3.22E-02	1.28E-01	1.05E-02	5.26E-02	2.29E-05	3.87E-03
0.50	ND	1.17E-01	ND	1.33E-01	ND	2.04E-02	ND	3.26E-02	ND	9.02E-02	ND	3.72E-02	ND	2.74E-03
1.00	3.26E-02	8.28E-02	5.96E-02	9.41E-02	2.19E-02	1.44E-02	9.07E-03	2.31E-02	2.74E-02	6.38E-02	8.89E-03	2.63E-02	1.31E-04	1.94E-03
2.00	1.92E-02	4.87E-02	3.38E-02	5.54E-02	1.65E-02	8.48E-03	6.45E-03	1.36E-02	1.95E-02	3.75E-02	6.22E-03	1.55E-02	2.41E-04	1.14E-03
4.00	1.53E-02	3.44E-02	2.92E-02	3.92E-02	1.56E-02	6.00E-03	6.15E-03	9.60E-03	1.85E-02	2.65E-02	6.07E-03	1.10E-02	2.17E-04	8.06E-04
8.17	1.06E-02	2.44E-02	1.57E-02	2.77E-02	1.07E-02	4.24E-03	3.54E-03	6.79E-03	1.13E-02	1.88E-02	3.63E-03	7.73E-03	1.93E-04	5.70E-04
20.25	6.23E-03	1.31E-02	7.13E-03	1.49E-02	5.29E-03	2.28E-03	1.77E-03	3.65E-03	5.48E-03	1.01E-02	1.67E-03	4.16E-03	1.47E-04	3.06E-04
45.25	7.26E-03	8.28E-03	7.02E-03	9.41E-03	1.30E-03	1.44E-03	1.43E-03	2.30E-03	4.62E-03	6.38E-03	1.13E-03	2.63E-03	2.99E-05	1.94E-04
69.58	6.33E-03	6.70E-03	5.63E-03	7.96E-03	NI	1.22E-03	1.31E-03	1.95E-03	3.84E-03	5.39E-03	1.17E-03	2.22E-03	1.03E-04	1.64E-04
93.58	7.11E-03	5.86E-03	6.51E-03	6.66E-03	1.27E-03	1.02E-03	1.49E-03	1.63E-03	4.26E-03	4.51E-03	1.46E-03	1.86E-03	1.05E-04	1.37E-04
all (n=10)													(t≥1 hr)	
slope=	0.0234	0.0855	0.0438	0.0969	0.0125	0.0149	0.0054	0.0238	0.0162	0.0659	0.0053	0.0271	0.0003	0.0020
r^2=	0.9732	0.9974	0.9533	0.9974	0.7651	0.9974	0.8540	0.9974	0.8522	0.9974	0.8491	0.9975	0.7636	0.9974

(continued)

RUN#: 2
POSITION#: 3
WASTE TYPE: Slop Oil
LOADING: 4.06%

SOIL TYPE Kidman sandy loam
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.35
% MOISTURE: 1.64%

TEMPERATURE (°C): 16.9
TOTAL POROSITY: 0.490566
AIR-FILLED POROSITY: 0.474166
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	7.92E-02	2.59E-01	8.46E-02	2.94E-01	2.29E-02	4.51E-02	NI	7.22E-02	4.27E-02	1.99E-01	1.02E-02	8.22E-02	4.77E-05	6.06E-03
0.50	5.03E-02	1.83E-01	7.31E-02	2.08E-01	2.50E-02	3.19E-02	NI	5.10E-02	4.17E-02	1.41E-01	1.02E-02	5.81E-02	2.28E-05	4.28E-03
1.00	3.14E-02	1.29E-01	7.81E-02	1.47E-02	2.47E-02	2.25E-02	NI	3.61E-02	4.27E-02	9.97E-02	1.04E-02	4.11E-02	6.60E-05	3.03E-03
2.00	3.26E-02	7.98E-02	6.53E-02	9.07E-02	2.23E-02	1.39E-02	NI	2.23E-02	3.75E-02	6.15E-02	9.07E-03	2.53E-02	1.97E-04	1.87E-03
4.00	2.22E-02	5.64E-02	4.50E-02	6.42E-02	1.95E-02	9.82E-03	NI	1.57E-02	3.23E-02	4.35E-02	8.10E-03	1.79E-02	1.66E-04	1.32E-03
8.17	1.47E-02	3.99E-02	2.69E-02	4.54E-02	1.60E-02	6.94E-03	NI	1.11E-02	2.45E-02	3.07E-02	5.96E-03	1.27E-02	1.66E-04	9.33E-04
20.25	5.84E-03	2.10E-02	1.16E-02	2.39E-02	8.55E-03	3.66E-03	2.98E-03	5.89E-03	9.54E-03	1.62E-02	2.70E-03	6.70E-03	1.44E-04	4.92E-04
45.25	1.12E-02	1.33E-02	9.82E-03	1.51E-02	NI	2.31E-03	2.46E-03	3.71E-03	7.62E-03	1.03E-02	2.24E-03	4.20E-03	1.59E-04	3.11E-04
69.58	7.44E-03	1.12E-02	7.15E-03	1.28E-02	NI	1.96E-03	1.81E-03	3.13E-03	5.51E-03	8.66E-03	1.64E-03	3.60E-03	1.28E-04	2.63E-04
93.58	7.80E-03	9.40E-03	8.85E-03	1.07E-02	NI	1.64E-03	2.04E-03	2.62E-03	6.45E-03	7.25E-03	1.91E-03	3.00E-03	1.53E-04	2.20E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=10)													(t≥1 hr)	
slope=	0.0362	0.1331	0.0451	0.1387	0.0065	0.0232	0.0092	0.0371	0.0214	0.1023	0.0050	0.0422	0.0001	0.0031
r^2=	0.9712	0.9986	0.8163	0.8314	0.4998	0.9986	0.8757	0.9980	0.7061	0.9986	0.6975	0.9985	0.7432	0.9986

RUN#: 2
POSITION#: 4
WASTE TYPE: Slop Oil
LOADING: 4.02%

SOIL TYPE Kidman sandy loam
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.35
% MOISTURE: 1.64%

TEMPERATURE (°C): 16.9
TOTAL POROSITY: 0.490566
AIR-FILLED POROSITY: 0.474166
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	7.98E-02	2.21E-01	8.73E-02	2.52E-01	3.93E-02	3.85E-02	NI	6.17E-02	4.47E-02	1.71E-01	1.10E-02	7.03E-02	3.88E-05	5.18E-03
0.50	4.62E-02	1.56E-01	4.85E-02	1.78E-01	1.60E-02	2.72E-02	NI	4.36E-02	2.76E-02	1.21E-01	6.92E-03	4.97E-02	1.37E-04	3.66E-03
1.00	3.73E-02	1.11E-01	7.20E-02	1.26E-01	2.23E-02	1.93E-02	NI	3.09E-02	3.88E-02	8.53E-02	9.30E-03	3.51E-02	7.89E-05	2.59E-03
2.00	3.58E-02	6.78E-02	7.11E-02	7.70E-02	2.27E-02	1.18E-02	NI	1.89E-02	3.90E-02	5.22E-02	1.04E-02	2.15E-02	9.72E-06	1.56E-03
4.00	2.44E-02	4.79E-02	4.60E-02	5.45E-02	1.92E-02	8.34E-03	NI	1.34E-02	3.19E-02	3.69E-02	7.72E-03	1.52E-02	NP	1.12E-03
8.17	1.45E-02	3.39E-02	2.72E-02	3.85E-02	1.59E-02	5.90E-03	NI	9.44E-03	2.47E-02	2.61E-02	5.99E-03	1.08E-02	1.59E-04	7.93E-04
20.25	ND	1.86E-02	ND	2.11E-02	ND	3.23E-03	ND	5.17E-03	ND	1.43E-02	ND	5.90E-03	ND	4.34E-04
45.25	1.09E-02	1.17E-02	1.11E-02	1.33E-02	8.60E-03	2.04E-03	2.73E-03	3.27E-03	8.48E-03	9.04E-03	2.50E-03	3.70E-03	1.59E-04	2.75E-04
69.58	7.59E-03	9.92E-03	7.31E-03	1.13E-02	NI	1.73E-03	1.83E-03	2.77E-03	5.58E-03	7.64E-03	1.69E-03	3.10E-03	1.19E-04	2.32E-04
93.58	8.72E-03	8.30E-03	9.38E-03	9.43E-03	NI	1.44E-03	2.26E-03	2.31E-03	7.08E-03	6.39E-03	2.08E-03	2.60E-03	1.52E-04	1.94E-04
all (n=10)					(t≥1 hr)				(t≥1 hr)		(t≥1 hr)			
slope=	0.0352	0.1134	0.0388	0.1293	0.0250	0.0198	0.0127	0.0317	0.0578	0.0870	0.0145	0.0361	-4.60E-06	0.0027
r^2=	0.9662	0.9984	0.7105	0.9983	0.9630	0.9984	0.4193	0.9984	0.9699	0.9983	0.9907	0.9984	0.3098	0.9980

(continued)

APPENDIX G. (continued)

RUN#: 3
POSITION#: 5
WASTE TYPE: Separator Sludge
LOADING: 3.60%

SOIL TYPE: 30 mesh sand
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.45
% MOISTURE: 0.00%

TEMPERATURE (°C): 16.9
TOTAL POROSITY: 0.4528302
AIR-FILLED POROSITY: 0.4528302
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	1.03E-03	7.73E-03	7.94E-04	5.25E-03	2.90E-04	6.61E-04	3.76E-04	1.10E-03	1.23E-03	2.90E-03	4.27E-04	1.89E-03	1.62E-05	4.66E-05
0.58	ND	7.68E-03	ND	5.23E-03	ND	6.60E-04	ND	1.10E-03	ND	2.90E-03	ND	1.89E-03	ND	4.66E-05
1.00	1.19E-03	7.62E-03	8.77E-04	5.21E-03	1.72E-04	6.58E-04	2.28E-04	1.10E-03	7.10E-04	2.89E-03	2.15E-04	1.89E-03	3.58E-05	4.66E-05
1.92	1.53E-03	7.60E-03	1.05E-03	5.26E-03	1.95E-04	6.73E-04	2.61E-04	1.13E-03	7.74E-04	2.97E-03	2.43E-04	1.93E-03	9.50E-06	4.83E-05
4.00	4.57E-03	7.22E-03	4.52E-03	5.08E-03	8.61E-04	6.60E-04	1.06E-03	1.14E-03	3.05E-03	2.93E-03	9.93E-04	1.91E-03	6.91E-06	4.82E-05
8.92	1.03E-03	6.48E-03	6.28E-04	4.70E-03	1.60E-04	6.32E-04	1.58E-04	1.08E-03	5.38E-04	2.83E-03	1.47E-04	1.84E-03	2.89E-05	4.82E-05
20.00	1.62E-04	5.48E-03	3.06E-04	4.17E-03	1.63E-04	5.94E-04	3.00E-04	1.05E-03	7.28E-04	2.72E-03	2.49E-04	1.76E-03	5.27E-06	4.99E-05
49.33	4.86E-05	4.03E-03	1.99E-04	3.21E-03	3.16E-04	4.92E-04	5.13E-04	9.21E-04	2.16E-03	2.33E-03	7.33E-04	1.49E-03	7.98E-05	4.96E-05
72.67	ND	3.52E-03	ND	2.85E-03	1.55E-04	4.48E-04	ND	8.56E-04	9.05E-05	2.15E-03	8.23E-05	1.37E-03	2.41E-06	4.94E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all	(n=7)	(n=9)												
slope=	0.0001	0.0019	-4.00E-05		0.0010	7.10E-06	0.0001	-0.0001	0.0001	0.0003	4.90E-06	0.0020	-5.50E-06	-1.80E-06
r^2=	0.0027	0.5422	0.0003		0.4829	0.0004	0.3926	0.0150	0.2911	0.3414	0.0001	0.3490	0.0183	0.7581
t≤4hrs (n=5) flux vs ln(t)														
slope=	0.0011	-0.0002	0.0011	-4.70E-05	0.0002	1.50E-06	0.0002	1.60E-05	0.0005	1.50E-05	0.0002	1.20E-05	-4.30E-06	7.10E-07
r^2=	0.5919	0.7481	0.5331	0.4686	0.3415	0.0705	0.3390	0.7791	0.2899	0.3726	0.2486	0.4723	0.1498	0.7100
t≥4hrs (n=5) flux vs 1/t^0.5														
slope=	0.0129	0.0096	0.0121	0.0057	0.0015	0.0005	0.0016	0.0007	0.0046	0.0019	0.0014	0.0013	-0.0001	-4.20E-06
r^2=	0.8864	0.9162	0.8118	0.8827	0.5959	0.8224	0.3796	0.8376	0.3400	0.7952	0.2848	0.8013	0.1024	0.6682

RUN#: 3
POSITION#: 6
WASTE TYPE: Separator Sludge
LOADING: 3.57%

SOIL TYPE: 30 mesh sand
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.45
% MOISTURE: 0.00%

TEMPERATURE (°C): 16.9
TOTAL POROSITY: 0.4528302
AIR-FILLED POROSITY: 0.4171302
APPLICATION AREA (cm^2): 45.6

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	2.09E-03	8.18E-02	1.35E-03	6.93E-02	2.86E-04	1.21E-02	3.42E-04	2.61E-02	1.24E-03	6.23E-02	4.27E-04	3.91E-02	9.11E-05	6.28E-03
0.58	8.62E-04	5.36E-02	3.90E-03	4.54E-02	8.44E-03	7.94E-03	2.10E-03	1.71E-02	7.33E-03	4.08E-02	2.50E-03	2.56E-02	1.55E-04	4.11E-03
1.00	1.54E-04	4.09E-02	5.06E-04	3.47E-02	NI	6.06E-03	1.57E-03	1.31E-02	4.39E-03	3.11E-02	1.71E-03	1.95E-02	1.92E-04	3.14E-03
1.92	1.32E-04	2.21E-02	5.47E-04	1.88E-02	NI	3.28E-03	8.23E-04	7.06E-03	3.03E-03	1.69E-02	1.21E-03	1.06E-02	4.06E-05	1.70E-03
4.00	4.37E-04	1.57E-02	7.02E-04	1.33E-02	NI	2.32E-03	8.08E-04	4.99E-03	2.85E-03	1.19E-02	1.15E-03	7.48E-03	3.79E-05	1.20E-03
8.92	4.02E-04	1.04E-02	2.06E-04	8.85E-03	1.90E-04	1.55E-03	1.80E-04	3.33E-03	9.87E-04	7.95E-03	3.83E-04	4.98E-03	1.86E-04	8.00E-04
20.00	7.23E-04	7.00E-03	4.14E-05	5.93E-03	1.39E-05	1.04E-03	2.19E-06	2.23E-03	7.28E-06	5.33E-03	1.14E-05	3.34E-03	4.86E-05	5.38E-04
49.33	3.37E-04	4.43E-03	1.80E-04	3.75E-03	3.08E-05	6.56E-04	5.00E-05	1.41E-03	2.37E-04	3.37E-03	8.04E-05	2.12E-03	7.61E-05	3.40E-04
72.67	9.11E-05	3.74E-03	8.26E-05	3.17E-03	NI	5.55E-04	NI	1.19E-03	8.49E-05	2.85E-03	8.15E-05	1.79E-03	6.82E-06	2.87E-04
all (n=9)														
slope=	0.0008	0.0432	0.0012	0.0358	0.0017	0.0063	0.0005	0.0135	0.0020	0.0322	0.0007	0.0202	3.80E-05	0.0032
r^2=	0.5985	0.9923	0.3952	0.9924	0.1384	0.9923	0.1970	0.9922	0.2555	0.9924	0.2339	0.9924	0.1229	0.9923

(continued)

RUN#: 3
POSITION#: 7
WASTE TYPE: Separator Sludge
LOADING: 3.60%

SOIL TYPE: Kidman sandy loam
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.52
% MOISTURE: 1.64%

TEMPERATURE (°C): 16.9
TOTAL POROSITY: 0.4264151
AIR-FILLED POROSITY: 0.4100151
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	1.25E-04	6.52E-03	5.44E-05	4.43E-03	1.12E-05	5.56E-04	5.60E-06	9.25E-04	5.43E-06	2.44E-03	8.68E-06	1.59E-03	5.44E-06	3.92E-05
0.58	4.39E-04	6.51E-03	2.13E-05	4.42E-03	1.12E-05	5.56E-04	5.60E-06	9.25E-04	5.43E-06	2.44E-03	8.68E-06	1.59E-03	4.58E-08	3.92E-05
1.00	1.68E-03	6.50E-03	5.38E-05	4.42E-03	1.12E-05	5.56E-04	1.87E-06	9.25E-04	5.43E-06	2.44E-03	4.43E-06	1.59E-03	1.77E-06	3.92E-05
1.92	1.31E-03	6.65E-03	9.30E-05	4.54E-03	1.12E-05	5.74E-04	3.73E-07	9.56E-04	5.43E-06	2.52E-03	4.86E-06	1.64E-03	NP	4.06E-05
4.00	3.93E-03	6.54E-03	7.59E-04	4.49E-03	9.13E-06	5.70E-04	1.52E-05	9.53E-04	3.03E-05	2.51E-03	1.04E-05	1.64E-03	1.59E-06	4.06E-05
8.92	4.06E-03	6.28E-03	2.72E-03	4.37E-03	1.65E-04	5.62E-04	NI	9.45E-04	4.22E-04	2.48E-03	5.36E-05	1.62E-03	NP	4.06E-05
20.00	1.83E-03	5.87E-03	8.43E-04	4.27E-03	3.54E-05	5.73E-04	3.59E-05	9.84E-04	1.85E-04	2.57E-03	4.92E-06	1.67E-03	NP	4.38E-05
49.33	ND	4.74E-03	ND	3.62E-03	ND	5.17E-04	ND	9.19E-04	ND	2.37E-03	ND	1.53E-03	ND	4.37E-05
72.67	1.91E-03	4.28E-03	6.89E-04	3.32E-03	2.58E-04	4.87E-04	NI	8.82E-04	3.44E-04	2.26E-03	NP	1.46E-03	NP	4.36E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all	(n=8)	(n=9)												
slope=	-0.0016	0.0008	-0.0008	0.0004	-0.0001	1.50E-05	-1.30E-05	-3.90E-06	-0.0020	1.70E-05	-9.50E-06	1.60E-05	2.40E-06	-2.50E-06
r^2=	0.4814	0.3733	0.3077	0.2955	0.3308	0.1124	0.3647	0.0073	0.4487	0.0140	0.1110	0.0249	0.4410	0.6473
t≤4hrs (n=5) flux vs. ln(t)														
slope=	0.0013	2.50E-05	0.0020	3.40E-05	-6.20E-07	6.70E-06	2.20E-06	1.30E-05	7.40E-06	3.20E-05		2.20E-05	-1.00E-06	6.12E-07
r^2=	0.8001	0.1956	0.5553	0.4747	0.5102	0.6451	0.1606	0.6972	0.5102	0.6869		0.7272	0.2709	0.7222
t≥4hrs (n=5)ux vs 1/t^0.5														
slope=	0.0064	0.0056	0.0011	0.0028	-0.0005	0.0002	-0.0001	0.0001	-0.0006	0.0005	-1.80E-06	0.0004		-9.60E-06
r^2=	0.7151	0.8103	0.0324	0.7364	0.4785	0.5593		0.2782	0.3466	0.4014	0.0001	0.4619		0.7801

RUN#: 3
POSITION#: 8
WASTE TYPE: Separator Sludge
LOADING: 3.64%

SOIL TYPE: Kidman sandy loam
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.47
% MOISTURE: 1.64%

TEMPERATURE (°C): 16.9
TOTAL POROSITY: 0.445283
AIR-FILLED POROSITY: 0.428883
APPLICATION AREA (cm^2): 45.6

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	1.78E-02	1.20E-01	1.42E-02	1.02E-01	1.31E-02	1.78E-02	4.04E-03	3.84E-02	1.39E-02	9.16E-02	4.42E-03	5.75E-02	4.71E-05	9.24E-03
0.58	ND	7.88E-02	ND	6.68E-02	ND	1.17E-02	ND	2.51E-02	ND	6.00E-02	ND	3.76E-02	ND	6.05E-03
1.00	9.03E-03	6.02E-02	1.34E-02	5.10E-02	1.18E-02	8.92E-03	3.70E-03	1.92E-02	1.26E-02	4.58E-02	4.14E-03	2.87E-02	2.64E-04	4.62E-03
1.92	6.01E-03	3.98E-02	1.07E-02	3.37E-02	9.19E-03	5.90E-03	2.91E-03	1.27E-02	1.00E-02	3.03E-02	3.30E-03	1.90E-02	7.73E-05	3.06E-03
4.00	9.31E-03	2.81E-02	1.42E-02	2.39E-02	9.28E-03	4.17E-03	3.15E-03	8.98E-03	1.03E-02	2.14E-02	3.35E-03	1.34E-02	4.83E-05	2.16E-03
8.92	9.72E-03	1.88E-02	1.29E-02	1.59E-02	NI	2.78E-03	2.23E-03	5.99E-03	1.21E-02	1.43E-02	4.11E-03	9.00E-03	1.61E-05	1.44E-03
20.00	3.93E-03	1.07E-02	3.56E-03	9.10E-03	5.73E-03	1.59E-03	1.52E-03	3.42E-03	5.06E-03	8.17E-03	1.87E-03	5.10E-03	1.52E-04	8.24E-04
49.33	5.55E-03	6.79E-03	7.71E-03	5.75E-03	NI	1.01E-03	1.66E-03	2.17E-03	NI	5.17E-03	NI	3.20E-03	6.18E-05	5.21E-04
72.67	1.30E-03	5.74E-03	9.55E-04	4.86E-03	6.10E-04	8.50E-04	6.96E-04	1.83E-03	2.70E-03	4.37E-03	8.94E-04	2.70E-03	1.74E-04	4.40E-04
all (n=10)														
slope=	0.0069	0.0612	0.0050	0.0520	0.0054	0.0091	0.0015	0.0191	0.0046	0.0467	0.0014	0.0293	-8.20E-06	0.0047
r^2=	0.7658	0.9993	0.3849	0.9993	0.6765	0.9993	0.7113	0.9994	0.5231	0.9993	0.4676	0.9994	0.0038	0.9994

(continued)

RUN#: 4
POSITION#: 5
WASTE TYPE: Separator Sludge
LOADING: 3.57%

SOIL TYPE 30 mesh sand
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.45
% MOISTURE: 0.00%

TEMPERATURE (°C): 19.6
TOTAL POROSITY: 0.4528302
AIR-FILLED POROSITY: 0.4528302
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	6.99E-03	2.13E-02	1.83E-03	4.36E-03	6.15E-05	4.95E-04	2.31E-05	8.09E-04	4.59E-04	2.51E-03	1.16E-04	1.49E-03	1.22E-04	3.16E-05
0.50	7.50E-03	2.12E-02	2.47E-03	4.36E-03	1.20E-04	4.94E-04	4.72E-05	8.09E-04	6.04E-04	2.51E-03	1.33E-04	1.49E-03	4.63E-05	3.16E-05
1.00	6.33E-03	2.12E-02	2.56E-03	4.36E-03	9.81E-05	4.94E-04	3.03E-05	8.08E-04	8.27E-04	2.51E-03	1.85E-04	1.49E-03	BDL	3.16E-05
2.00	5.53E-03	1.88E-02	2.49E-03	4.25E-03	1.63E-04	4.88E-04	9.71E-05	8.03E-04	1.11E-03	2.48E-03	2.83E-04	1.48E-03	BDL	3.16E-05
4.00	5.10E-03	1.70E-02	2.13E-03	4.15E-03	1.86E-04	4.83E-04	1.10E-04	7.97E-04	1.04E-03	2.46E-03	2.81E-04	1.46E-03	4.98E-04	3.16E-05
8.00	4.03E-03	1.46E-02	1.71E-03	3.96E-03	9.47E-05	4.71E-04	4.60E-05	7.86E-04	7.42E-04	2.41E-03	2.39E-04	1.43E-03	BDL	3.16E-05
20.00	3.11E-03	1.91E-02	1.16E-03	3.51E-03	NP	4.42E-04	3.89E-05	7.54E-04	4.28E-04	2.28E-03	2.04E-04	1.35E-03	NP	3.15E-05
50.00	3.86E-04	7.51E-03	4.21E-04	2.84E-03	NP	3.87E-04	NI	6.90E-04	ND	2.03E-03	1.34E-04	1.21E-03	3.22E-06	3.14E-05
76.50	9.44E-05	6.08E-03	4.83E-05	2.45E-03	BDL	3.48E-04	4.23E-05	6.40E-04	3.78E-04	1.84E-03	1.84E-04	1.10E-03	4.60E-05	3.13E-05
101.00	2.72E-05	5.49E-03	2.98E-05	2.26E-03	NP	3.28E-04	NI	6.12E-04	ND	1.74E-03	1.05E-04	1.04E-03	6.21E-06	3.13E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
slope=	0.0040	0.0070	0.0010	0.0010	-4.60E-05	7.00E-05	1.60E-05	0.00E+00	-3.50E-05	3.20E-04	-2.60E-05	1.90E-04	1.60E-05	1.29E-07
r^2=	0.7060	0.5460	0.4160	0.5310	0.3720	0.4820	0.1050	0.4580	0.0070	0.4710	0.0640	0.4730	0.0040	0.4120
t≤1hrs (n=3) flux vs ln(t)														
slope=	0.0010	0.0001	-0.0010		-4.10E-05	1.00E-06	-9.50E-06	9.30E-07	-3.60E-04		-6.60E-05		1.30E-04	
r^2=	0.2290	0.8300	0.9060		0.4810	0.8300	0.1470	0.6600	0.9520		0.8600			
t≥1hrs (n=7) flux vs 1/t^0.5														
slope=	0.0070	0.0160	0.0030	0.0020	-2.97E-05	1.67E-04	1.40E-05	1.90E-04	1.00E-03	1.00E-03	9.80E-05	4.50E-04	1.00E-03	3.24E-07
r^2=	0.8180	0.6430	0.8230	0.7210	0.0330	0.6580	0.0190	0.6290	0.4850	0.6460	0.2470	0.6550	0.9820	0.6000

RUN#: 4
POSITION#: 6
WASTE TYPE: Separator Sludge
LOADING: 3.56%

SOIL TYPE 30 mesh sand
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.45
% MOISTURE: 0.00%

TEMPERATURE (°C): 19.6
TOTAL POROSITY: 0.4528302
AIR-FILLED POROSITY: 0.4528302
APPLICATION AREA (cm^2): 45.6

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	1.91E-02	1.48E-01	2.10E-02	6.91E-02	NI	1.15E-02	6.42E-03	2.45E-02	2.74E-02	6.34E-02	6.49E-03	3.79E-02	BDL	5.66E-03
0.50	2.18E-02	1.05E-01	1.44E-02	4.89E-02	1.90E-02	8.11E-03	5.05E-03	1.73E-02	2.37E-02	4.48E-02	6.10E-03	2.68E-02	2.84E-04	4.00E-03
1.00	1.59E-02	7.42E-02	1.14E-02	3.46E-02	8.54E-04	5.74E-03	3.25E-03	1.22E-02	1.73E-02	3.17E-02	5.08E-03	1.90E-02	3.71E-04	2.83E-03
2.00	5.87E-03	4.02E-02	7.16E-03	1.87E-02	9.97E-04	3.11E-03	8.79E-03	6.63E-03	1.09E-02	1.72E-02	3.20E-03	1.03E-02	2.22E-04	1.53E-03
4.00	3.52E-03	2.84E-02	3.54E-03	1.32E-02	5.66E-04	2.20E-03	1.13E-03	4.69E-03	7.38E-03	1.21E-02	2.49E-03	7.30E-03	3.73E-04	1.08E-03
8.00	1.15E-03	2.01E-02	1.30E-03	9.35E-03	3.15E-04	1.55E-03	6.58E-04	3.31E-03	4.54E-03	8.58E-03	1.55E-03	5.10E-03	2.69E-04	7.66E-04
20.00	1.70E-04	1.27E-02	8.70E-05	5.92E-03	4.60E-05	9.80E-04	NP	2.10E-03	5.63E-04	5.43E-03	4.20E-04	3.20E-03	7.94E-05	4.85E-04
50.00	3.17E-05	8.03E-03	BDL	3.74E-03	BDL	6.20E-04	4.44E-06	1.33E-03	3.54E-04	3.43E-03	1.52E-04	2.10E-03	8.99E-05	3.07E-04
76.50	3.00E-05	6.35E-03	BDL	2.96E-03	BDL	4.90E-04	BDL	1.05E-03	1.18E-04	2.71E-03	6.32E-05	1.60E-03	5.76E-05	2.42E-04
101.00	1.78E-05	5.68E-03	BDL	2.65E-03	BDL	4.40E-04	BDL	9.40E-04	5.19E-05	2.43E-03	3.06E-05	1.50E-03	4.11E-05	2.17E-04
all (n=10)														
slope=	0.0130	0.0760	0.0120	0.0360	0.0140	0.0060	0.0030	0.0130	0.0160	0.0030	0.0040	0.0140	0.0002	0.0030
r^2=	0.8790	0.9940	0.9860	0.9930	0.6590	0.9940	0.4010	0.9940	0.9710	0.9940	0.9220	0.9940	0.5070	0.9930

(continued)

RUN#: 4
POSITION#: 7
WASTE TYPE: Separator Sludge
LOADING: 3.46%

SOIL TYPE Kidman sandy loam
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.52
% MOISTURE: 1.64%

TEMPERATURE (°C): 19.6
TOTAL POROSITY: 0.4264151
AIR-FILLED POROSITY: 0.4100151
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	6.46E-04	2.56E-02	3.48E-05	5.26E-03	BDL	5.96E-04	3.68E-04	9.75E-04	3.48E-04	3.02E-03	BDL	1.80E-03	NP	3.81E-05
0.50	3.19E-04	2.55E-02	8.66E-06	5.26E-03	BDL	5.96E-04	BDL	9.74E-04	BDL	3.02E-03	BDL	1.80E-03	BDL	3.81E-05
1.00	4.87E-04	2.53E-02	2.45E-05	5.25E-03	BDL	5.95E-04	BDL	9.74E-04	BDL	3.02E-03	BDL	1.80E-03	BDL	3.81E-05
2.00	1.34E-03	2.74E-02	1.32E-05	6.03E-03	7.44E-05	6.90E-04	3.99E-04	1.13E-03	3.98E-04	3.50E-03	7.37E-05	2.08E-03	BDL	4.45E-05
4.00	ND	2.54E-02	ND	5.92E-03	ND	6.84E-04	ND	1.13E-03	ND	3.48E-03	ND	2.07E-03	ND	4.44E-05
8.00	3.64E-03	2.25E-02	4.03E-05	5.72E-03	BDL	6.72E-04	BDL	1.12E-03	BDL	3.43E-03	BDL	2.04E-03	5.65E-05	4.44E-05
20.00	2.11E-03	1.73E-02	1.24E-05	5.48E-03	BDL	6.84E-04	BDL	1.16E-03	BDL	3.52E-03	BDL	2.10E-03	1.64E-04	4.84E-05
50.00	2.67E-03	1.20E-02	9.40E-04	4.48E-03	5.13E-05	6.05E-04	BDL	1.07E-03	BDL	3.16E-03	2.08E-05	1.88E-03	1.17E-04	4.83E-05
76.50	1.84E-03	9.76E-03	3.95E-04	3.88E-03	1.70E-04	5.48E-04	2.24E-04	1.00E-03	5.47E-04	2.89E-03	1.03E-05	1.72E-03	BDL	4.81E-05
101.00	1.19E-03	8.81E-03	3.79E-04	3.60E-03	NI	5.17E-04	1.07E-04	9.58E-04	6.55E-04	2.74E-03	1.50E-04	1.64E-03	BDL	4.80E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all	(n=9)	(n=10)												
slope=	-0.0010	0.0080	-0.0003	0.0005	-0.0001		1.10E-04	-5.30E-05	-1.30E-04	-6.30E-05	1.30E-05	-3.80E-05	-3.30E-04	-6.30E-06
r^2=	0.4410	0.4880	0.2720	0.1360	0.1370		0.4870	0.1750	0.7130	0.0200	0.0040	0.0210	0.4400	0.8310
t<4hrs (n=4)	flux vs ln(t)													
slope=	3.20E-04	2.20E-04	-7.00E-06	3.00E-04		3.80E-05	1.50E-05	6.70E-05	2.40E-05	2.00E-04		1.20E-04		2.70E-06
r^2=	0.4200	0.0730	0.2900	0.6990		0.7270		0.7470		0.7390		0.7410		0.7460
t≥4hrs (n=6)	flux vs l/t^0.5													
slope=	0.0070	0.0420	-0.0020	-0.0020	-0.0040	0.0004	0.0080	0.0004	-0.0070	0.0020	-0.0030	0.0010	-0.0003	-1.10E-05
r^2=	0.7230	0.9500	0.3780	0.3780		0.6370		0.4940		0.5920	0.5270	0.5860	0.4400	0.8060

RUN#: 4
POSITION#: 8
WASTE TYPE: Separator Sludge
LOADING: 3.37%

SOIL TYPE Kidman sandy loam
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.47
% MOISTURE: 1.64%

TEMPERATURE (°C): 19.6
TOTAL POROSITY: 0.445283
AIR-FILLED POROSITY: 0.428883
APPLICATION AREA (cm^2): 45.6

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	3.38E-02	2.72E-01	2.17E-02	1.27E-01	NI	2.11E-02	5.50E-03	4.49E-02	2.39E-02	1.16E-01	6.19E-03	6.96E-02	2.91E-04	1.04E-02
0.50	2.88E-02	1.93E-01	2.08E-02	8.97E-02	NI	1.49E-02	5.06E-03	3.18E-02	2.00E-02	8.22E-02	5.59E-03	4.92E-02	3.17E-04	7.35E-03
1.00	2.46E-02	1.36E-01	1.79E-02	6.34E-02	NI	1.05E-02	4.13E-03	2.25E-02	1.81E-02	5.82E-02	4.70E-03	3.48E-02	2.23E-04	5.19E-03
2.00	1.17E-02	8.79E-02	1.11E-02	4.09E-02	NI	6.80E-03	3.33E-03	1.45E-02	1.42E-02	3.75E-02	3.82E-03	2.25E-02	7.00E-05	3.35E-03
4.00	9.58E-03	6.21E-02	9.16E-03	2.89E-02	2.84E-04	4.80E-03	2.54E-03	1.03E-02	1.15E-02	2.65E-02	3.44E-03	1.59E-02	3.21E-04	2.37E-03
8.00	7.74E-03	4.39E-02	5.28E-03	2.05E-02	3.59E-04	3.40E-03	1.63E-03	7.25E-03	6.91E-03	1.88E-02	2.21E-03	1.12E-02	1.13E-03	1.68E-03
20.00	4.74E-03	2.27E-02	2.99E-03	1.06E-02	4.19E-04	1.75E-03	1.76E-04	3.74E-03	3.82E-03	9.69E-03	1.25E-03	5.80E-03	1.79E-04	8.66E-04
50.00	1.60E-03	1.44E-02	9.63E-04	6.68E-03	2.53E-05	1.11E-03	2.03E-04	2.37E-03	1.63E-03	6.13E-03	5.70E-04	3.70E-03	8.66E-05	5.48E-04
76.50	7.44E-04	1.13E-02	4.88E-04	5.28E-03	6.87E-06	8.80E-04	2.25E-04	1.87E-03	1.24E-03	4.85E-03	4.28E-04	2.90E-03	1.17E-04	4.33E-04
101.00	3.76E-04	1.01E-02	3.27E-04	4.73E-03	1.70E-05	7.80E-04	1.46E-04	1.67E-03	9.88E-04	4.33E-03	3.41E-04	2.60E-03	5.54E-05	3.87E-04
all (n=10)														
slope=	0.0190	0.1390	0.0130	0.0650	0.0010	0.0110	0.0030	0.0230	0.0127	0.0594	0.0032	0.0356	2.80E-05	0.0053
r^2=	0.9540	0.9990	0.9090	0.9990	0.4710	0.9990	0.8960	0.9930	0.9083	0.9993	0.8863	0.9993	0.0034	0.9993

(continued)

RUN#: 7
POSITION#: 1
WASTE TYPE: Slop Oil
LOADING: 3.96%

SOIL TYPE: Durant clay loam
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.11
% MOISTURE: 4.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.5811321
AIR-FILLED POROSITY: 0.5411321
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	4.94E-04	6.82E-02	3.65E-05	1.88E-03	2.57E-05	1.88E-03	BDL	2.29E-03	3.32E-06	8.21E-03	BDL	3.20E-03	1.42E-03	3.11E-05
0.50	3.22E-04	6.76E-02	3.85E-05	1.88E-03	BDL	1.88E-03	BDL	2.28E-03	BDL	8.21E-03	BDL	3.20E-03	BDL	3.11E-05
1.00	4.83E-04	6.63E-02	1.46E-04	1.87E-03	4.53E-05	1.87E-03	6.52E-05	2.28E-03	2.14E-04	8.19E-03	8.22E-05	3.20E-03	BDL	3.11E-05
2.00	1.26E-03	6.43E-02	8.54E-06	1.96E-03	NI	1.96E-03	NP	2.39E-03	4.71E-06	8.58E-03	2.06E-05	3.30E-03	BDL	3.29E-05
4.50	6.78E-03	5.58E-02	2.40E-03	1.92E-03	3.01E-03	1.92E-03	1.66E-03	2.37E-03	5.35E-03	8.45E-03	1.85E-03	3.30E-03	BDL	3.29E-05
8.00	5.17E-03	4.99E-02	7.92E-05	1.89E-03	BDL	1.89E-03	BDL	2.34E-03	BDL	8.32E-03	BDL	3.20E-03	BDL	3.29E-05
21.25	1.00E-02	3.35E-02	7.40E-04	1.79E-03	BDL	1.79E-03	NP	2.32E-03	BDL	8.01E-03	BDL	3.10E-03	BDL	3.50E-05
41.25	7.35E-03	2.48E-02	1.35E-03	1.58E-03	6.59E-06	1.58E-03	BDL	2.13E-03	BDL	7.16E-03	BDL	2.80E-03	BDL	3.48E-05
79.45	5.97E-03	1.80E-02	2.40E-03	1.32E-03	7.40E-05	1.32E-03	2.87E-05	1.85E-03	6.85E-05	6.06E-03	6.58E-06	2.40E-03	BDL	3.46E-05
117.50	5.06E-03	1.49E-02	2.50E-03	1.15E-03	1.33E-04	1.15E-03	5.97E-05	1.66E-03	1.39E-04	5.34E-03	1.95E-05	2.10E-03	BDL	3.44E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=10)														
slope=	-0.0043	0.027	-0.001					0.0002	-0.0006	0.0009		0.0003		
r^2=	0.629	0.651	0.407	0.303	0.196	303		0.1951	0.036	0.2685	0.0005	0.2848		0.7777
t≥8 hrs														
slope=	0.0389	0.1493	-0.0151	0.005	-0.0019	0.005	-0.0016	0.0052	-0.0035	0.021	-0.0006	0.0078		
r^2=	0.9959	0.9994	0.9594	0.9667	0.9704	0.9667		0.9493		0.963		0.9515		0.9532

RUN#: 7
POSITION#: 2
WASTE TYPE: Slop Oil
LOADING: 4.00%

SOIL TYPE: Durant clay loam
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.1
% MOISTURE: 4.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.5849057
AIR-FILLED POROSITY: 0.5449057
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	2.18E-03	6.81E-02	4.48E-04	1.89E-02	2.21E-04	1.87E-03	2.76E-04	2.28E-03	8.99E-04	8.19E-03	2.78E-04	3.20E-03	BDL	3.11E-05
0.50	1.11E-03	6.75E-02	3.44E-04	1.88E-02	2.76E-05	1.87E-03	2.32E-05	2.28E-03	2.03E-04	8.18E-03	4.42E-05	3.20E-03	1.08E-04	3.11E-05
1.00	2.87E-04	6.63E-02	NP	1.88E-02	5.52E-05	1.87E-03	NI	2.28E-03	ND	8.17E-03	2.06E-05	3.20E-03	1.28E-05	3.11E-05
2.00	2.41E-03	6.35E-02	1.25E-04	1.91E-02	BDL	1.92E-03	BDL	2.35E-03	2.57E-05	8.42E-03	2.78E-07	3.30E-03	NP	3.23E-05
4.50	8.27E-03	5.54E-02	9.48E-05	1.85E-02	BDL	1.89E-03	BDL	2.33E-03	BDL	8.30E-03	BDL	3.20E-03	BDL	3.23E-05
8.00	8.16E-03	4.98E-02	2.19E-04	1.79E-02	BDL	1.86E-03	BDL	2.30E-03	2.25E-05	8.19E-03	BDL	3.20E-03	BDL	3.23E-05
21.25	1.26E-02	3.45E-02	1.56E-03	1.60E-02	NP	1.81E-03	4.75E-06	2.33E-03	6.21E-05	8.07E-03	1.13E-05	3.20E-03	BDL	3.50E-05
41.25	9.88E-03	2.57E-02	2.40E-03	1.33E-02	2.15E-05	1.61E-03	BDL	2.15E-03	1.04E-05	7.26E-03	BDL	2.80E-03	BDL	3.48E-05
79.45	8.27E-03	1.87E-02	3.96E-03	1.05E-02	1.44E-04	1.35E-03	6.96E-05	1.89E-03	1.61E-04	6.19E-03	2.36E-05	2.40E-03	BDL	3.46E-05
117.50	6.66E-03	1.54E-02	3.85E-03	8.93E-03	1.44E-04	1.18E-03	8.40E-05	1.70E-03	2.46E-04	5.48E-03	2.47E-05	2.10E-03	BDL	3.44E-05
all (n=10)														
slope=	-0.005	0.0267	-0.0014	0.0039		0.0002		0.0002		0.0008	.	0.0003		
r^2=	0.5883	0.6567	0.3295	0.4317		0.3053		0.2017		0.2782		0.2771		0.6865
t≥8hrs														
slope=	0.0456	0.1531	-0.024	0.0561	-0.0021	0.0049	-0.0006	0.0049	-0.0015	0.0203	-0.0001	0.0086		0.0000046
r^2=	0.9869	0.9989	0.9358	0.9857	0.9056	0.9627	0.9995	0.946	0.5901	0.9604	0.9943	0.9753		0.9532

(continued)

APPENDIX G. (continued)

RUN#: 7
POSITION#: 3
WASTE TYPE: Slop Oil
LOADING: 3.85%

SOIL TYPE: Durant clay loam
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.13
% MOISTURE: 4.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.573585
AIR-FILLED POROSITY: 0.533585
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	1.84E-01	4.61E-01	1.67E-01	2.88E-01	7.28E-02	4.19E-02	3.20E-02	6.65E-02	8.56E-02	1.99E-01	3.08E-02	7.83E-02	6.32E-04	5.36E-03
0.58	2.18E-01	3.26E-01	1.46E-01	2.04E-01	6.96E-02	2.96E-02	3.09E-02	4.70E-02	8.13E-02	1.41E-01	2.98E-02	5.54E-02	8.12E-04	3.79E-03
1.00	1.84E-01	2.30E-01	1.25E-01	1.44E-01	NI	2.09E-02	2.65E-02	3.33E-02	7.06E-02	9.97E-02	2.57E-02	3.92E-02	6.57E-04	2.68E-03
2.00	1.26E-01	1.52E-01	9.06E-02	9.53E-02	NI	1.38E-02	1.77E-02	2.20E-02	5.24E-02	6.59E-02	1.75E-02	2.59E-02	2.32E-04	1.77E-03
4.00	8.39E-02	1.08E-01	7.08E-02	6.74E-02	NI	9.79E-03	1.88E-02	1.56E-02	5.14E-02	4.66E-02	1.85E-02	1.83E-02	1.29E-03	1.25E-03
7.50	5.74E-02	7.62E-02	4.79E-02	4.76E-02	NI	6.92E-03	1.22E-02	1.10E-02	3.53E-02	3.30E-02	1.23E-02	1.30E-02	5.29E-04	8.87E-04
20.50	4.25E-02	4.42E-02	3.13E-02	2.76E-02	8.26E-03	4.02E-03	9.28E-03	6.38E-03	2.57E-02	1.91E-02	9.66E-03	7.50E-03	3.61E-04	5.15E-04
41.00	1.84E-02	3.13E-02	1.46E-02	1.96E-02	3.67E-03	2.84E-03	4.31E-03	4.51E-03	1.28E-02	1.35E-02	4.32E-03	5.30E-03	1.68E-04	3.64E-04
79.25	4.14E-03	2.21E-02	7.40E-03	1.38E-02	NI	2.01E-03	2.98E-03	3.19E-03	9.20E-03	9.56E-03	3.08E-03	3.80E-03	2.58E-04	2.57E-04
117.50	5.51E-03	1.81E-02	5.31E-03	1.13E-02	NI	1.64E-03	2.43E-03	2.61E-03	7.81E-03	7.81E-03	2.57E-03	3.10E-03	2.58E-04	2.10E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=10)														
slope=	0.1807	0.2382	0.119	0.1489	0.0405	0.0216	0.0233	0.0344	0.0609	0.1029	0.223	0.0405	0.003	0.0028
r^2=	0.9901	0.9969	0.9798	0.9968	0.9208	0.9969	0.947	0.997	0.9407	0.9969	0.9403	0.9969	0.568	0.9969

RUN#: 7
POSITION#: 4
WASTE TYPE: Slop Oil
LOADING: 4.01%

SOIL TYPE: Durant clay loam
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.11
% MOISTURE: 4.00%

TEMPERATURE (°C): 22
TOTAL POROSITY: 0.581132
AIR-FILLED POROSITY: 0.541132
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	2.07E-01	4.71E-01	1.35E-01	2.95E-01	2.04E-02	4.28E-02	2.54E-02	6.80E-02	6.74E-02	2.04E-01	2.47E-02	8.01E-02	3.09E-04	5.48E-03
0.58	1.49E-01	3.33E-01	8.96E-02	2.08E-01	NI	3.03E-02	1.66E-02	4.81E-02	4.92E-02	1.44E-01	1.64E-02	5.66E-02	3.48E-04	3.88E-03
1.00	1.06E-01	2.36E-01	7.92E-02	1.47E-01	NI	2.14E-02	1.44E-02	3.40E-02	4.49E-02	1.02E-01	1.44E-02	4.01E-02	4.38E-04	2.74E-03
2.00	8.62E-02	1.56E-01	6.67E-02	9.74E-02	1.42E-02	1.42E-02	1.66E-02	2.25E-02	4.28E-02	6.74E-02	1.54E-02	2.65E-02	7.48E-04	1.81E-03
4.00	6.55E-02	1.10E-01	5.10E-02	6.89E-02	NI	1.00E-02	1.10E-02	1.59E-02	3.42E-02	4.77E-02	1.13E-02	1.87E-02	5.29E-04	1.28E-03
7.50	ND	7.79E-02	ND	4.87E-02	ND	7.08E-03	ND	1.12E-02	ND	3.37E-02	ND	1.32E-02	ND	9.07E-04
20.50	3.33E-02	4.52E-02	2.29E-02	2.83E-02	6.45E-03	4.11E-03	6.52E-03	6.53E-03	1.93E-02	1.96E-02	6.99E-03	7.70E-03	9.28E-05	5.26E-04
41.00	1.15E-02	3.20E-02	1.03E-02	2.00E-02	3.00E-03	2.90E-03	3.31E-03	4.61E-03	1.02E-02	1.38E-02	3.29E-03	5.40E-03	1.55E-04	3.72E-04
79.25	6.20E-03	2.26E-02	6.25E-03	1.41E-02	2.76E-03	2.05E-03	3.09E-03	3.26E-03	8.56E-03	9.78E-03	3.39E-03	3.80E-03	3.35E-04	2.63E-04
117.50	3.22E-03	1.85E-02	3.13E-03	1.15E-02	NI	1.68E-03	1.66E-03	2.66E-03	5.35E-03	7.99E-03	1.75E-03	3.10E-03	1.80E-04	2.15E-04
all (n=10)														
slope=	0.1068	0.2434	0.0678	0.1523	0.0091	0.0221	0.0116	0.0351	0.0314	0.1054	0.0112	0.0414	0.0001	0.0028
r^2=	0.9861	0.997	0.9652	0.9971	0.8841	0.9969	0.9066	0.9969	0.909	0.997	0.9155	0.997	0.0686	0.9968

(continued)

RUN#: 8
POSITION#: 5
WASTE TYPE: Slop Oil
LOADING: 3.21%

SOIL TYPE: Kidman sandy loam
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.38
% MOISTURE: 12.50%

TEMPERATURE (°C): 20
TOTAL POROSITY: 0.4792453
AIR-FILLED POROSITY: 0.3542453
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	1.38E-01	1.67E-01	1.01E-01	1.04E-01	NI	1.52E-02	2.32E-02	2.41E-02	6.31E-02	7.22E-02	2.36E-02	2.84E-02	1.19E-03	1.94E-03
0.50	1.15E-01	1.18E-01	8.65E-02	7.38E-02	NI	1.07E-02	1.99E-02	1.70E-02	5.67E-02	5.11E-02	1.95E-02	2.01E-02	7.09E-04	1.37E-03
1.00	7.35E-02	8.35E-02	7.08E-02	5.22E-02	NI	7.59E-03	1.44E-02	1.21E-02	5.14E-02	3.61E-02	1.75E-02	1.42E-02	2.97E-04	9.71E-04
2.00	4.71E-02	3.60E-02	3.85E-02	2.25E-02	9.39E-03	3.26E-03	1.10E-02	5.18E-03	3.32E-02	1.55E-02	1.23E-02	6.10E-03	5.29E-04	4.18E-04
4.80	2.18E-02	2.32E-02	2.08E-02	1.45E-02	2.98E-03	2.11E-03	5.97E-03	3.35E-03	1.93E-02	1.00E-02	6.89E-03	3.90E-03	1.68E-03	2.70E-04
8.00	2.07E-02	1.80E-02	1.77E-02	2.30E-03	1.44E-03	1.63E-03	5.41E-03	2.59E-03	1.71E-02	7.77E-03	5.76E-03	3.10E-03	5.41E-04	2.09E-04
24.00	ND	1.04E-02	ND	6.48E-03	ND	9.40E-04	ND	1.50E-03	ND	4.49E-03	ND	1.80E-03	ND	1.21E-04
48.00	5.28E-03	7.34E-03	4.38E-03	4.58E-03	1.66E-03	6.70E-04	1.55E-03	1.06E-03	4.60E-03	3.17E-03	1.54E-03	1.20E-03	3.22E-04	8.53E-05
72.00	6.20E-03	5.99E-03	NI	3.74E-03	NI	5.40E-04	NI	8.60E-04	NI	2.59E-03	NI	1.00E-03	1.68E-04	6.97E-05
101.50	5.06E-03	5.05E-03	2.92E-03	3.15E-03	NI	4.60E-04	1.66E-03	7.30E-04	4.82E-03	2.18E-03	1.95E-03	9.00E-04	6.57E-04	5.87E-05
124.00	2.99E-03	4.57E-03	1.25E-03	2.85E-03	NI	4.10E-04	4.42E-04	6.60E-04	1.50E-03	1.97E-03	5.14E-04	8.00E-04	4.13E-04	5.31E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=11)														
slope=	0.0753	8.65E-02	0.0569	0.0545	0.0142	0.0079	0.0124	0.0125	0.0348	0.0374	0.0126	0.0147	0.0003	0.001
r^2=	0.9853	0.9838	0.9621	0.9744	0.7821	0.9837	0.9728	0.9836	0.9218	0.9835	0.9453	0.9855	0.5574	0.9838

RUN#: 8
POSITION#: 6
WASTE TYPE: Slop Oil
LOADING: 3.25%

SOIL TYPE: Kidman sandy loam
APPLICATION: surface
BULK DENSITY(g/cm^3): 1.38
% MOISTURE: 12.50%

TEMPERATURE (°C): 20
TOTAL POROSITY: 0.4792453
AIR-FILLED POROSITY: 0.3542453
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	1.14E-01	1.02E-01	8.13E-02	6.40E-02	NI	9.29E-03	2.10E-02	1.48E-02	5.67E-02	4.43E-02	2.16E-02	1.74E-02	8.90E-04	1.19E-03
0.50	5.74E-02	7.24E-02	4.79E-02	4.52E-02	NI	6.57E-03	1.10E-02	1.04E-02	3.42E-02	3.13E-02	1.13E-02	1.23E-02	6.96E-04	8.42E-04
1.00	5.51E-02	5.12E-02	4.27E-02	3.20E-02	NI	4.65E-03	1.02E-02	7.38E-03	3.10E-02	2.21E-02	1.01E-02	8.70E-03	7.35E-04	5.95E-04
2.00	2.87E-03	3.62E-02	3.33E-03	2.26E-02	9.83E-04	3.29E-03	9.39E-04	5.22E-03	2.78E-03	1.57E-02	8.84E-04	6.10E-03	BDL	4.21E-04
4.80	1.38E-02	2.34E-02	1.25E-02	1.46E-02	NI	2.12E-03	4.42E-03	3.37E-03	1.39E-02	1.01E-02	5.04E-03	4.00E-03	6.32E-04	2.72E-04
8.00	1.61E-02	1.81E-02	1.35E-02	1.13E-02	3.75E-03	1.64E-03	4.31E-03	2.61E-03	1.39E-02	7.82E-03	4.73E-03	3.10E-03	1.68E-03	2.10E-04
24.00	4.83E-04	1.05E-02	ND	6.53E-03	NI	9.50E-04	1.22E-04	1.51E-03	3.53E-04	4.52E-03	4.42E-05	1.80E-03	BDL	1.22E-04
48.00	6.09E-03	7.39E-03	4.79E-03	4.62E-03	NI	6.70E-04	1.33E-03	1.07E-03	3.42E-03	3.19E-03	1.34E-03	1.30E-03	NP	8.59E-05
72.00	5.51E-03	6.03E-03	3.75E-03	3.77E-03	6.96E-04	5.50E-04	7.84E-04	8.70E-04	2.57E-03	2.61E-03	7.61E-04	1.00E-03	1.25E-04	7.01E-05
101.50	4.14E-03	5.08E-03	4.27E-03	3.17E-03	NI	4.60E-04	1.66E-03	7.30E-04	4.92E-03	2.20E-03	1.64E-03	9.00E-04	2.06E-04	5.91E-05
124.00	2.87E-03	4.60E-03	1.77E-03	2.87E-03	4.75E-04	4.20E-04	5.08E-04	6.60E-04	1.61E-03	1.99E-03	5.35E-04	8.00E-04	9.54E-05	5.34E-05
all (n=11)														
slope=	0.0537	0.0511	0.0393	0.0320	0.0010	0.0046	0.0097	0.0074	0.0272	0.0221	0.0100	0.0087	0.0004	0.0006
r^2=	0.8950	1.0000	0.9092	1.0000	0.0435	1.0000	0.8936	1.0000	0.8954	1.0000	0.8884	1.0000	0.7980	1.0000

(continued)

RUN#: 8 | SOIL TYPE: Kidman sandy loam | TEMPERATURE (°C): 20

POSITION#: 7 | APPLICATION: subsurface | TOTAL POROSITY: 0.5207547

WASTE TYPE: Slop Oil | BULK DENSITY(g/cm^3): 1.27 | AIR-FILLED POROSITY: 0.4007547

LOADING: 3.54% | % MOISTURE: 12.00% | APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.28	2.53E-03	2.85E-02	2.29E-03	7.85E-03	4.64E-04	7.80E-04	4.64E-04	9.50E-04	1.39E-03	3.41E-03	3.80E-04	1.30E-03	1.29E-04	1.29E-05
0.60	2.76E-03	2.84E-02	3.23E-03	7.85E-03	9.72E-04	7.80E-04	7.73E-04	9.50E-04	2.25E-03	3.41E-03	7.40E-04	1.30E-03	8.25E-05	1.29E-05
1.00	2.87E-03	2.82E-02	3.44E-03	7.84E-03	8.39E-04	7.80E-04	9.17E-04	9.50E-04	2.89E-03	3.40E-03	9.36E-04	1.30E-03	BDL	1.29E-05
2.08	2.41E-03	2.74E-02	3.02E-03	7.79E-03	7.29E-04	7.80E-04	7.40E-04	9.50E-04	2.03E-03	3.40E-03	6.89E-04	1.30E-03	BDL	1.29E-05
4.92	2.30E-03	2.59E-02	3.02E-03	7.70E-03	7.18E-04	7.70E-04	7.73E-04	9.40E-04	2.14E-03	3.38E-03	7.09E-04	1.30E-03	BDL	1.29E-05
8.13	2.53E-03	2.45E-02	3.33E-03	7.60E-03	1.10E-03	7.70E-04	1.09E-03	9.40E-04	3.10E-03	3.36E-03	1.13E-03	1.30E-03	BDL	1.29E-05
24.18	4.02E-03	1.77E-02	ND	6.87E-03	ND	7.30E-04	NI	9.10E-04	9.85E-03	3.22E-03	3.50E-03	1.30E-03	BDL	1.29E-05
48.18	ND	1.40E-02	ND	6.18E-03	ND	6.90E-04	1.02E-03	8.80E-04	3.10E-03	3.06E-03	1.02E-03	1.20E-03	BDL	1.29E-05
72.00	1.01E-03	1.19E-02	1.25E-03	5.66E-03	7.51E-04	6.50E-04	4.42E-04	8.50E-04	1.28E-03	2.92E-03	4.42E-04	1.10E-03	BDL	1.29E-05
101.65	1.38E-03	1.03E-02	1.56E-03	5.18E-03	8.17E-04	6.10E-04	7.73E-04	8.10E-04	2.03E-03	2.77E-03	7.61E-04	1.10E-03	BDL	1.29E-05
124.17	1.15E-03	9.40E-03	1.35E-03	4.88E-03	6.40E-04	5.90E-04	6.52E-04	7.90E-04	1.61E-03	2.67E-03	6.48E-04	1.10E-03	BDL	1.29E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all (n=11)														
slope=	1.00E-03	1.00E-02	1.00E-03	1.00E-03	-8.40E-06	8.40E-05	-9.40E-05	6.80E-05	-1.00E-03	3.20E-04	-4.20E-04	9.40E-05	7.80E-05	
r^2=	0.13	6.12E-01	0.207	0.495	0.081	0.454	0.073	0.448	0.057	0.456	0.082	0.358		
≤24hrs (n=7)														
slope=	1.80E-04	-2.00E-03	1.70E-04	-1.93E-04	9.50E-05	-9.40E-06	1.20E-04	-7.80E-06	1.00E-03	-3.60E-05	1.00E-03		-6.10E-05	
r^2=	0.2540	0.7770	0.2760	0.6760	0.2990	0.6490	0.5460	0.6950	0.5470	0.6770	0.5800		-0.0001	
≥24hrs (n=5)														
slope=	0.0260	0.0730	-0.0050	0.0170	0.0030	0.0010	0.0050	0.0010	0.0730	0.0050	0.0250	0.0020		
r^2=	0.9130	0.9930	0.9270	0.9600	0.2150	0.9310	0.2590	0.8960	0.8730	0.9260	0.8420	0.9440		

RUN#: 8 | SOIL TYPE: Kidman sandy loam | TEMPERATURE (°C): 20

POSITION#: 8 | APPLICATION: subsurface | TOTAL POROSITY: 0.5207547

WASTE TYPE: Slop Oil | BULK DENSITY(g/cm^3): 1.27 | AIR-FILLED POROSITY: 0.4007547

LOADING: 3.39% | % MOISTURE: 12.00% | APPLICATION AREA (cm^2): 45.6

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.28	1.06E-03	2.85E-02	8.65E-04	7.85E-03	5.30E-04	7.80E-04	5.97E-04	9.50E-04	1.93E-03	3.41E-03	6.99E-04	1.33E-03	3.74E-05	1.29E-05
0.60	4.14E-04	2.84E-02	3.02E-04	7.85E-03	1.66E-04	7.80E-04	1.77E-04	9.50E-04	6.85E-04	3.41E-03	2.47E-04	1.33E-03	1.80E-04	1.29E-05
1.00	5.17E-04	2.82E-02	4.17E-04	7.84E-03	2.54E-04	7.80E-04	2.54E-04	9.50E-04	9.52E-04	3.40E-03	3.50E-04	1.33E-03	3.22E-05	1.29E-05
2.08	7.01E-04	2.73E-02	7.19E-04	7.79E-03	3.98E-04	7.80E-04	3.87E-04	9.50E-04	1.39E-03	3.40E-03	5.04E-04	1.33E-03	5.80E-05	1.29E-05
4.92	6.09E-04	2.59E-02	6.15E-04	7.70E-03	4.75E-04	7.70E-04	4.42E-04	9.40E-04	1.39E-03	3.38E-03	5.86E-04	1.32E-03	7.22E-05	1.29E-05
8.13	1.05E-03	2.45E-02	9.58E-04	7.59E-03	4.75E-04	7.70E-04	4.97E-04	9.40E-04	1.50E-03	3.36E-03	5.65E-04	1.31E-03	2.71E-05	1.29E-05
24.18	1.10E-02	1.76E-02	8.23E-03	6.85E-03	1.66E-03	7.30E-04	1.77E-03	9.10E-04	5.57E-03	3.21E-03	1.85E-03	1.26E-03	9.67E-05	1.29E-05
48.18	5.86E-03	1.39E-02	5.10E-03	6.15E-03	9.50E-04	6.90E-04	1.66E-03	8.80E-04	4.39E-03	3.05E-03	1.75E-03	1.19E-03	1.11E-05	1.29E-05
72.00	3.79E-03	1.18E-02	3.02E-03	5.64E-03	8.28E-04	6.50E-04	6.85E-04	8.50E-04	1.93E-03	2.91E-03	6.37E-04	1.14E-03	BDL	1.29E-05
101.65	2.30E-04	1.02E-02	1.46E-04	5.15E-03	3.42E-05	6.10E-04	2.32E-05	8.10E-04	1.71E-04	2.76E-03	3.39E-05	1.08E-03	BDL	1.29E-05
124.17	5.28E-03	9.32E-03	3.02E-03	4.85E-03	1.55E-03	5.90E-04	1.22E-03	7.90E-04	3.32E-03	2.66E-03	1.23E-03	1.04E-03	BDL	1.29E-05
all (n=11)														
slope=	-3.00E-03	1.10E-02	-2.00E-03	1.00E-03	-3.90E-04	8.40E-05	-4.00E-04	6.80E-05	-1.00E-03	3.30E-04	-3.60E-04	1.30E-04	2.00E-05	
r^2=	0.2150	0.6130	0.2070	0.4960	0.1880	0.4540	0.1590	0.4480	0.1260	0.4590	0.1270	0.4510	0.0500	
≥24hrs (n=5)														
slope=	0.0730	0.0720	0.0600	0.0170	0.007	0.0010	0.0110	0.0010	0.0360	0.0050	0.0120	0.0020	0.0010	
r^2=	0.7180	0.9930	0.8290	0.9600	0.233	0.9310	0.4700	0.8960	0.5910	0.9260	0.4860	0.9350		

(continued)

RUN#: 9
POSITION#: 1
WASTE TYPE: Slop Oil
LOADING: 7.99%

SOIL TYPE Kidman sandy loam
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.42
% MOISTURE: 2.36%

TEMPERATURE (°C): 20
TOTAL POROSITY: 0.464151
AIR-FILLED POROSITY: 0.440551
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	2.62E-03	1.18E-01	2.25E-04	3.35E-02	NP	3.34E-03	3.79E-06	4.07E-03	3.66E-05	1.46E-02	1.23E-06	5.70E-03	5.47E-06	5.56E-05
1.25	4.01E-03	1.03E-01	1.99E-03	3.25E-02	NP	3.29E-03	7.21E-05	4.03E-03	2.10E-04	1.44E-02	7.66E-05	5.60E-03	BDL	5.56E-05
34.25	4.52E-03	2.64E-02	4.84E-03	1.65E-02	NP	2.40E-03	2.53E-03	3.81E-03	8.22E-03	1.14E-02	3.04E-03	4.50E-03	3.02E-05	5.56E-05
48.50	7.63E-03	2.22E-02	1.20E-02	1.39E-02	1.34E-03	2.02E-03	3.91E-03	3.20E-03	1.62E-02	9.60E-03	6.58E-03	3.80E-03	4.68E-04	2.58E-04
60.25	3.00E-03	1.99E-02	4.15E-03	1.25E-02	1.37E-03	1.81E-03	2.71E-03	2.87E-03	7.71E-03	8.62E-03	3.42E-03	3.40E-03	5.14E-04	2.31E-04
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all														
slope=	-0.0013	0.0550	-0.0039	0.0113		0.0007	-0.0018	0.0005	-0.0063	0.0028	-0.0026	0.0011	-0.0002	-0.0001
r^2=	0.2884	0.8533	0.4847	0.7857		0.7291	0.7099	0.4956	0.5827	0.6964	0.5843	0.6950	0.3844	0.3530
t≤34.25hrs														
slope=	0.0004	-0.0193	0.0009	-0.0037		-0.0002	0.0005	-0.0001	0.0018	-0.0007	0.0007	-0.0003	5.00E-06	
r^2=	0.8042	0.9703	0.9961	0.9267		0.9240	0.9111	0.9668	0.9081	0.9285	0.9099	0.9381	1.0000	
t≥34.25hrs														
slope=	0.0174	0.1545	-0.0185	0.0952		0.1400	-0.0101	0.2240	-0.0260	0.0661	-0.0241	0.0261	-0.0121	-0.0046
r^2=	0.0246	1.0000	0.0082	1.0000		1.0000	0.0821	1.0000	0.0136	1.0000	0.0702	0.9998	0.9303	0.7896

RUN#: 9
POSITION#: 2
WASTE TYPE: Slop Oil
LOADING: 7.97%

SOIL TYPE Kidman sandy loam
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.42
% MOISTURE: 2.36%

TEMPERATURE (°C): 20
TOTAL POROSITY: 0.464151
AIR-FILLED POROSITY: 0.440551
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	7.82E-03	7.64E-02	2.64E-04	2.13E-02	NI	2.11E-03	3.83E-05	2.57E-03	1.47E-04	9.24E-03	3.66E-05	3.60E-03	3.40E-05	3.51E-05
1.25	1.55E-03	7.21E-02	1.26E-04	2.10E-02	BDL	2.10E-03	BDL	2.56E-03	BDL	9.20E-03	BDL	3.60E-03	NP	3.51E-05
34.25	2.77E-03	2.56E-02	3.42E-03	1.59E-02	NI	2.31E-03	5.80E-04	3.65E-03	1.50E-03	1.10E-02	3.47E-04	4.30E-03	BDL	2.22E-04
48.50	7.90E-03	2.15E-02	1.70E-02	1.34E-02	3.38E-03	1.94E-03	7.57E-03	3.08E-03	2.02E-02	9.25E-03	7.20E-03	3.60E-03	BDL	2.00E-04
60.25	4.93E-03	1.93E-02	6.07E-03	1.20E-02	3.07E-03	1.75E-03	3.15E-03	2.77E-03	8.50E-03	8.31E-03	2.71E-03	3.30E-03	NP	1.86E-04
all														
slope=	0.0010	0.0318	-0.0051	0.0045	0.0210	0.0001	-0.0020	-0.0003	-0.0054	-0.0001	-0.0019	-0.0001	ND	-0.0001
r^2=	0.0771	0.8089	0.3575	0.7158		0.0711	0.3031	0.3798	0.3014	0.0148	0.2696	0.0239	ND	0.7488
t≤34.25hrs														
slope=	-0.0008	-0.0109	0.0007	-0.0012		4.00E-05	0.0001	0.0002	0.0003	0.0004	0.0001	0.0002		4.00E-05
r^2=	0.3814	0.9378	0.8735	0.9252		0.8701		0.8922		0.8850		0.8971		0.8971
t≥34.25hrs														
slope=	-0.0685	0.1499	-0.1174	0.0926	0.0210	0.0134	-0.0855	0.0209	-0.2314	0.0640	-0.0806	0.0240		0.0009
r^2=	0.3216	1.0000	0.1211	0.9999		0.9998	0.2663	1.0000	0.2730	1.0000	0.2439	0.9968		0.9982

(continued)

APPENDIX G. (continued)

RUN#: 9
POSITION#: 3
WASTE TYPE: Slop Oil
LOADING: 7.55%

SOIL TYPE: Durant clay loam
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.09
% MOISTURE: 8.95%

TEMPERATURE (°C): 20
TOTAL POROSITY: 0.588679
AIR-FILLED POROSITY: 0.499179
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	2.67E-03	5.79E-02	4.18E-04	1.60E-02	NP	1.59E-03	NP	1.94E-03	2.84E-05	6.96E-03	BDL	2.70E-03	1.48E-05	2.64E-05
1.25	3.60E-03	5.59E-02	2.21E-03	1.59E-02	2.10E-04	1.59E-03	1.86E-04	1.93E-03	5.57E-04	6.94E-03	1.13E-04	2.70E-03	BDL	2.64E-05
34.25	2.86E-03	2.44E-02	2.89E-03	1.28E-02	NI	1.57E-03	6.23E-04	2.12E-03	1.72E-03	7.12E-03	5.27E-04	2.80E-03	BDL	3.50E-05
48.50	3.72E-03	2.08E-02	5.85E-03	1.14E-02	NI	1.44E-03	2.13E-03	1.99E-03	5.77E-03	6.58E-03	1.96E-03	2.60E-03	BDL	3.50E-05
60.25	2.53E-03	1.88E-02	2.76E-03	1.05E-02	7.19E-04	1.35E-03	6.41E-04	1.90E-03	1.72E-03	6.21E-03	5.46E-04	2.40E-03	BDL	3.48E-05
R.E.:	87.04%		96.00%		90.56%		90.52%		93.44%		97.27%		77.57%	
all														
slope=	-0.0001	0.0215	-0.0019	0.0026	-0.0007	0.0001	-0.0013	-3.65E-05	-0.0018	0.0002	-0.0012	0.0001		-5.00E-06
r^2=	0.0405	0.7929	0.6006	0.7090		0.3836	0.3165	0.1167	0.4014	0.1903	0.3164	0.1113		0.7673
t≤34.25hrs														
slope=	-4.83E-07	-0.0072	0.0005	-0.0007		-0.000004	0.0001	0.00004	0.0003	0.00004	0.0001	0.00002		0.000002
r^2=	0.0000	0.9271	0.8099	0.9132		0.8971		0.8670	0.9997	0.8277		0.8971		0.8971
t≥34.25hrs														
slope=	0.0029	0.1331	-0.0109	0.0543		0.0052	-0.0073	0.0052	-0.0186	0.0214	-0.007	0.0092		0.000004
r^2=	0.0103	1.0000	0.0176	0.9979		0.9957	0.0323	0.9957	0.0287	0.9961	0.0327	0.9713		0.5910

RUN#: 9
POSITION#: 4
WASTE TYPE: Slop Oil
LOADING: 7.49%

SOIL TYPE: Durant clay loam
APPLICATION: subsurface
BULK DENSITY(g/cm^3): 1.09
% MOISTURE: 8.95%

TEMPERATURE (°C): 20
TOTAL POROSITY: 0.588679
AIR-FILLED POROSITY: 0.499179
APPLICATION AREA (cm^2): 45.6

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.25	3.63E-03	5.34E-02	5.82E-04	1.48E-02	NP	1.47E-03	NP	1.79E-03	4.93E-05	6.43E-03	BDL	2.50E-03	3.38E-06	2.44E-05
1.25	5.51E-03	5.14E-02	3.55E-03	1.47E-02	3.94E-04	1.46E-03	3.24E-04	1.79E-03	9.01E-04	6.41E-03	1.92E-04	2.50E-03	BDL	2.44E-05
34.25	4.57E-03	2.37E-02	4.23E-03	1.18E-02	NI	1.39E-03	9.58E-04	1.83E-03	2.61E-03	6.26E-03	8.28E-04	2.40E-03	BDL	2.87E-05
48.50	4.50E-03	2.03E-02	6.83E-03	1.07E-02	NI	1.30E-03	2.53E-03	1.75E-03	6.87E-03	5.88E-03	2.34E-03	2.30E-03	1.47E-05	2.86E-05
60.25	3.39E-03	1.84E-02	3.53E-03	9.92E-03	NI	1.23E-03	8.76E-04	1.68E-03	2.39E-03	5.61E-03	7.75E-04	2.20E-03	1.09E-05	2.86E-05
all														
slope=	-0.0001	0.0191	-0.0023	0.0024		0.0001	-0.0015	2.28E-05	-0.0022	0.0003	-0.0015	0.0001	-5E-06	-2.5E-06
r^2=	0.0179	0.7956	0.6878	0.7227		0.5769	0.3604	0.1072	0.4791	0.4803	0.3798	0.5568	0.8869	0.7672
t≤34.25hrs														
slope=	0.0001	-0.0064	0.0007	-0.0006		-0.000017	0.0002	8.7E-06	0.0005	-0.000036	0.002	-2.2E-05		9.37E-07
r^2=	0.1029	0.9307	0.7317	0.9142		0.9559		0.8971	1	0.9529	1	0.8971		0.8971
t≥34.25hrs														
slope=	0.0249	0.1259	0.0026	0.0442		0.0037	-0.0055	0.0035	-0.015	0.0153	-0.0058	0.0046	0.003	2.5E-06
r^2=	0.6424	0.9999	0.001	0.9948		0.9904	0.0159	0.9827	0.016	0.9947	0.0196	0.9713	1	0.8803

NI= not integrated NP= no peak recognized ND= no data BDL= below detectable limits

APPENDIX H FIELD TEMPERATURE DATA
BACKGROUND BEFORE TILLING-1•

Sample Date 6/25/85

Purge Start Time 12:45 pm Sample # BBT1A

TIME:	12:45	1:03	1:12
Ambient	32.5		
Shroud Air	59	74	78
1/4 " Soil	65	77	82
2" Soil	37.1	38.6	40
CONDITION	PS	MS	ES

Purge Start Time 1:28 pm Sample # BBT1B

TIME:	1:27	1:28	1:38	1:43	1:48
Ambient	33				
Shroud Air		50	71	78.6	75
1/4 " Soil	58.6	57	63	67.6	67
2" Soil	38.2	40	41	41.6	42.4
CONDITION	PRE	PS	SS	MS	ES

Purge Start Time 1:56 pm Sample # BBT1C

TIME:	1:57	2:05	2:10	2:17
Ambient				
Shroud Air	47.5	71	76.5	78
1/4 " Soil	51.5	71	76.5	77.6
2" Soil	39.8	39.8	40.2	40.5
CONDITION	PS	SS	MS	ES

Purge Start Time 2:09 pm Sample # BBT1D

TIME:	2:09	2:20	2:28	2:32
Ambient				
Shroud Air	45	70.4	72.1	73
1/4 " Soil	54.5	68.4	72.7	73
2" Soil	39.8	40.5	41.3	41.8
CONDITION	PS	SS	MS	ES

Purge Start Time 2:47 pm Sample # BBT1E

TIME:	2:47	2:57	3:05	3:07
Ambient				
Shroud Air	56	72.6	77	77.7
1/4 " Soil	59	70.8	74.7	75.3
2" Soil	42.8	42.7	43.4	43.7
CONDITION	PS	SS	MS	ES

Purge Start Time 2:38 pm Sample # BBT1F

TIME:	2:38	2:53	2:58	3:03
Ambient				
Shroud Air	44	68	73	74.3
1/4 " Soil	49	66	70.4	71.4
2" Soil	32	33.2	34.2	34.7
CONDITION	PS	SS	MS	ES

(continued)

APPENDIX H (continued)
BACKGROUND AFTER TILLING-1•

Sample Date 6/25/85

Purge Start Time	7:52 pm	Sample #	BAT1A	
TIME:	7:52	7:57	8:01	8:07
Ambient				29
Shroud Air	31.4	32	30.4	32
1/4 " Soil	32.5	32	30.5	32.3
2" Soil	37.7	37.5	37.4	37.3
CONDITION	PS	MP	SS	MS

Purge Start Time	5:15 pm	Sample #	BAT1B	
TIME:	5:19	5:27	5:31	5:40
Ambient	32			
Shroud Air	52	55.6	54.8	52.2
1/4 " Soil	54	57.4	56.4	53.2
2" Soil	36.3	36.4	36.8	37.4
CONDITION	MP	MP	SS	ES

Purge Start Time	5:30 pm	Sample #	BAT1C
TIME:	5:41	5:53	
Ambient			
Shroud Air	47.7	51.6	
1/4 " Soil	49.6	53	
2" Soil	43.7	51.4	
CONDITION	SS	SE	

Purge Start Time	6:32 pm	Sample #	BAT1D	
TIME:	6:32	6:42	6:53	7:03
Ambient	32		30.2	
Shroud Air	36.6	44	45	43.1
1/4 " Soil	39	46.3	47.2	45.1
2" Soil	36.9	37.1	37.2	37.6
CONDITION	PS	MP	SS	ES

Purge Start Time	7:12 pm	Sample #	BAT1E	
TIME:	6:35	6:40	6:55	7:22
Ambient	32	30.3	30.3	30.5
Shroud Air	37.7	36	38.1	41.1
1/4 " Soil	38.5	36.9	37.3	38.7
2" Soil	37.5	37.5	37.2	37.4
CONDITION	PS	MP	MP	SS

Purge Start Time	6:44 pm	Sample #	BAT1F
TIME:	6:53	7:08	
Ambient	30.2	30.3	
Shroud Air	41	41.7	
1/4 " Soil	41	41.5	
2" Soil	30	30.7	
CONDITION	SS	ES	

APPENDIX H (continued)
BACKGROUND AFTER TILLING-2•

Sample Date 6/26/85

Purge Start Time 10:30 am Sample # BAT2A

TIME:	10:30	10:33	10:43	10:53
Ambient	28.5		28.5	28.5
Shroud Air		37.6	57.4	61.6
1/4 " Soil	40.3	42.5	55.1	58.3
2" Soil	33.4	33.4	34	34.5
CONDITION	PRE	PS	SS	POST

Purge Start Time 10:09 am Sample # BAT2B

TIME:	10:03	10:10	10:22	10:31
Ambient	28		28.5	
Shroud Air		40	58.2	61
1/4 " Soil	35.7	36.7	53	62
2" Soil	29	29.5	PROBE OUT OF SOIL	
CONDITION	PRE	PS	SS	POST

Purge Start Time 11:25 am Sample # BAT2C

TIME:	11:20	11:26	11:35	11:42	11:45
Ambient	30.5		30.5		
Shroud Air		50	64.7	68	69.3
1/4 " Soil	40	48.7	56	58.8	60
2" Soil	34.4	44.5		PROBE OUT OF SOIL	
CONDITION	PRE	PS	SS	ES	POST

Purge Start Time 9:45 am Sample # BAT2D

TIME:	9:44	9:47	9:57	10:05
Ambient	28		28	
Shroud Air		38.8	50.7	54.6
1/4 " Soil	36.8	39.1	44.4	48.1
2" Soil	31.5	31.6	32	32.7
CONDITION	PRE	PS	SS	ES

Purge Start Time 10:56 am Sample # BAT2E

TIME:	10:55	10:56	11:07	11:12	11:17
Ambient	28.5				
Shroud Air		40.2	61.5	64	66
1/4 " Soil	42.8	40.1	48.7	46.1	47.6
2" Soil	32	32.3	32.9	33.3	33.6
CONDITION	PRE	PS	SS	MS	ES

Purge Start Time 9:27 am Sample # BAT2F

TIME:	8:51	9:25	9:27	9:32	9:41	9:51
Ambient	27	26.5			28	28
Shroud Air			37.7	45.2	49.8	52.4
1/4 " Soil	31.2	33.2	35.7	37.4	40.3	43
2" Soil	25.7	26.7	26.6	26.6	26.9	27.5
CONDITION	PRE	PRE	PS	MP	SS	ES

(continued)

APPENDIX H (continued)
WASTE BEFORE TILLING-1•

Sample Date 6/26/85

Purge Start Time	NO PURGE	Sample #	WBT1A	
TIME:	4:00 pm	4:12	4:26	4:32
Ambient Shroud Air		51.2	56.6	58.3
1/4 " Soil	38.5	40.1	41.3	41.3
2" Soil	40.1	40.1	40.2	40.3
CONDITION	PA	MS	ES	POST

Purge Start Time	NO PURGE	Sample #	WBT1B
TIME:	3:59 pm	4:08	4:20
Ambient Shroud Air		53	57
1/4 " Soil	50	44.8	46.2
2" Soil	39.3	39.5	39.5
CONDITION	PA	MS	ES

Purge Start Time	NO PURGE	Sample #	WBT1C
TIME:	2:06 pm	2:11	
Ambient Shroud Air	46.7	59	
1/4 " Soil	46.6	48.8	
2" Soil	40	40.1	
CONDITION	SS	ES	

Purge Start Time	NO PURGE	Sample #	WBT1D
TIME:	2:06 pm	2:11	
Ambient Shroud Air	51	52.7	
1/4 " Soil	45	45.8	
2" Soil	40	40.3	
CONDITION	SS	ES	

Purge Start Time	NO PURGE	Sample #	WBT1E	
TIME:	2:08 pm	2:19	2:24	2:31
Ambient Shroud Air	55	58	62.7	64.2
1/4 " Soil	43.7	45.7	47	48.1
2" Soil	39	39.6	40	40.5
CONDITION	PS	MS	es	POST

Purge Start Time	NO PURGE	Sample #	WBT1F
TIME:	3:57 pm	4:07:30	4:19
Ambient Shroud Air		46	57.1
1/4 " Soil	46.6	43	45.1
2" Soil	34	35	35.8
CONDITION	PA	SS	POST

(continued)

WASTE BEFORE TILLING-2-

Sample Date	6/26/85		
Purge Start Time_	4:15 pm	Sample #	WBT2A
TIME:	4:26	4:32	
Ambient			
Shroud Air	56.6	58.3	
1/4 " Soil	41.3	41.3	
2" Soil	40.2	40.3	
CONDITION	SS	ES	
Purge Start Time_	4:17 pm	Sample #	WBT2B
TIME:	4:20	4:27	4:36
Ambient			
Shroud Air	57	59.2	59.6
1/4 " Soil	46.2	48	48.6
2" Soil	39.5	39.9	40.3
CONDITION	MP	EP	ES
Purge Start Time_	2:11 pm	Sample #	WBT2C
TIME:	2:21	2:26	
Ambient			
Shroud Air	62.2	63.9	
1/4 " Soil	51.9	53	
2" Soil	40.6	41	
CONDITION	SS	ES	
Purge Start Time_	2:11 pm	Sample #	WBT2D
TIME:	2:24	2:29	
Ambient			
Shroud Air	55	56.3	
1/4 " Soil	48.2	49.2	
2" Soil	40.9	41.2	
CONDITION	SS	ES	
Purge Start Time_	2:23 pm	Sample #	WBT2E
TIME:	2:24		
Ambient			
Shroud Air	55.8		
1/4 " Soil	43.5		
2" Soil	40.6		
CONDITION	SS		
Purge Start Time_	4:12 pm	Sample #	WBT2F
TIME:	4:19	4:25	
Ambient			
Shroud Air	57.1	57	
1/4 " Soil	45.1	41.3	
2" Soil	35.8	40.2	
CONDITION	MP	MS	

(continued)

APPENDIX H (continued)
WASTE BEFORE TILLING-3•

Sample Date 6/26/85

Purge Start Time	5:22 pm	Sample #	WBT3A
TIME:	5:22	5:35	5:40
Ambient		31.4	
Shroud Air	47.5	53.8	54.7
1/4 " Soil	36.4	35.8	35.5
2" Soil	39.6	39.2	39
CONDITION	PS	SS	ES

Purge Start Time	5:17 pm	Sample #	WBT3B
TIME:	5:17	5:29	5:36
Ambient			
Shroud Air	38.4	45	50.8
1/4 " Soil	38	39.8	41.3
2" Soil	39.3	38.5	38.5
CONDITION	PS	SS	POST

Purge Start Time	3:07 pm	Sample #	WBT3C
TIME:	3:07	3:19	3:24
Ambient		30.5	
Shroud Air	41.2	51.2	53
1/4 " Soil	41.9	48.5	50.1
2" Soil	42.1	41.8	42
CONDITION	PS	SS	ES

Purge Start Time	3:00 pm	Sample #	WBT3D
TIME:	3:10	3:20	
Ambient			
Shroud Air	44.4	61.4	
1/4 " Soil	44.2	46.4	
2" Soil	42.2	42	
CONDITION	SS	POST	

Purge Start Time	3:16 pm	Sample #	WBT3E
TIME:	3:34		
Ambient			
Shroud Air	59.8		
1/4 " Soil	45.8		
2" Soil	40.4		
CONDITION	ES		

Purge Start Time	5:03 pm	Sample #	WBT3F
TIME:	5:03	5:13	5:17
Ambient	29		
Shroud Air	45.3	49.5	51.6
1/4 " Soil	38.5	41	41.8
2" Soil	37	37.2	37.1
CONDITION	MP	SS	ES

(continued)

APPENDIX H (continued)
WASTE BEFORE TILLING-4

Sample Date 6/26/85

Purge Start Time	8:15 pm	Sample #	WBT4A
TIME:	8:15	8:28	
Ambient		31.4	
Shroud Air	27.7	29	
1/4 " Soil	30.8	30.5	
2" Soil	35.2	35	
CONDITION	PS	MS	

Purge Start Time	8:00 pm	Sample #	WBT4B
TIME:	8:01	8:16	
Ambient		25.4	
Shroud Air	28	28.7	
1/4 " Soil	29.6	30.2	
2" Soil	33.2	32.8	
CONDITION	PS	SS	

Purge Start Time	7:25 pm	Sample #	WBT4C
TIME:	7:29	7:37	7:44
Ambient	29.4		
Shroud Air	33.5	34.3	33
1/4 " Soil	32.5	34.4	34.4
2" Soil	37	36.7	36.6
CONDITION	MP	MS	POST

Purge Start Time	7:41pm	Sample #	WBT4D
TIME:	7:42	7:52	7:57
Ambient			
Shroud Air	30.2	31.3	31.4
1/4 " Soil	33.1	33.6	33.7
2" Soil	36.7	36.5	36.3
CONDITION	PS	SS	ES

Purge Start Time	7:44 pm	Sample #	WBT4E
TIME:	7:45	7:55	8:05
Ambient			
Shroud Air	29.1	30.6	30.7
1/4 " Soil	32.2	32.5	32.7
2" Soil	33.6	33.4	33.2
CONDITION	PS	SS	ES

Purge Start Time	8:25 pm	Sample #	WBT4F
TIME:	8:25	8:36	8:41
Ambient			
Shroud Air	26.7	27.3	27.4
1/4 " Soil	28.2	28.9	29.1
2" Soil	32.8	32.6	32.5
CONDITION	PS	SS	ES

(continued)

APPENDIX H (continued)
WASTE BEFORE TILLING-5•

Sample Date 6/26/85

Purge Start Time	9:29 pm	Sample #	WBT5A
TIME:	9:30	9:41	9:45
Ambient			
Shroud Air	24.6	25.8	26.2
1/4 " Soil	28.3	28	28
2" Soil	33.5	33.3	33.2
CONDITION	PS	MS	ES

Purge Start Time	9:16 pm	Sample #	WBT5B
TIME:	9:23	9:30	
Ambient			
Shroud Air	25.4	25.8	
1/4 " Soil	27.2	27.5	
2" Soil	31.3	31	
CONDITION	MP	MS	

Purge Start Time	8:47 pm	Sample #	WBT5C
TIME:	8:47	9:00	
Ambient			
Shroud Air	26.1	28.9	
1/4 " Soil	29.8	30.6	
2" Soil	35.3	35	
CONDITION	PS	MS	

Purge Start Time	8:57pm	Sample #	WBT5D
TIME:	8:58	9:13	
Ambient	25.6		
Shroud Air	27.2	28.5	
1/4 " Soil	30.8	31.5	
2" Soil	35	33.7	
CONDITION	PS	ES	

Purge Start Time	9:05 pm	Sample #	WBT5E
TIME:	9:03	9:19	9:22
Ambient	24.4	23.5	
Shroud Air	26.2	27.5	27.5
1/4 " Soil	29.7	29.9	29.2
2" Soil	31.9	31.5	30.6
CONDITION	PS	MS	ES

Purge Start Time	9:54 pm	Sample #	WBT5F
TIME:	9:57	10:05	10:08
Ambient	22.5		22.2
Shroud Air	24	24.4	24.4
1/4 " Soil	26.2	26.6	26.6
2" Soil	31.1	30.9	30.9
CONDITION	MP	ES	POST

(continued)

APPENDIX H (continued)
WASTE BEFORE TILLING-6•

Sample Date 6/27/85

Purge Start Time	1:26pm	Sample #	WBT6A	
TIME:	1:26	1:28	1:41	1:45
Ambient		23.3		
Shroud Air		40.8	54.1	55.2
1/4 " Soil	40.4	35.5	39.9	41.2
2" Soil	32.1	32.6	33.3	33.8
CONDITION	PRE	PS	SS	MS

Purge Start Time	1:45 pm	Sample #	WBT6B
TIME:	1:45	1:55	2:04
Ambient		24	
Shroud Air	42	55	57.5
1/4 " Soil	37	39.3	41.7
2" Soil	31.5	32	32.7
CONDITION	PS	SS	POST

Purge Start Time	3:51 pm	Sample #	WBT6C	
TIME:	3:50	3:52	4:04	4:11
Ambient	27.5			
Shroud Air		39.7	56	58.1
1/4 " Soil	42.8	42.9	49.7	51.5
2" Soil	36.4	36.5	36.7	36.7
CONDITION	PRE	MP	MS	POST

Purge Start Time	4:15pm	Sample #	WBT6D
TIME:	4:15	4:25	
Ambient			
Shroud Air	37	48.6	
1/4 " Soil	32.7	32.6	
2" Soil	35.8	36	
CONDITION	PS	SS	

Purge Start Time	3:56 pm	Sample #	WBT6E	
TIME:	3:54	3:56	4:08	4:12
Ambient				
Shroud Air		45	52.4	56
1/4 " Soil	40	40.3	43.2	44.1
2" Soil	35.5	35.5	35.8	35.9
CONDITION	PRE	PS	MS	ES

Purge Start Time	1:59 pm	Sample #	WBT6F
TIME:	1:59	2:09	2:14
Ambient			
Shroud Air	41.2	54.2	55.7
1/4 " Soil	36.8	40.9	42.5
2" Soil	30.5	30.6	30.8
CONDITION	PS	SS	ES

(continued)

APPENDIX H (continued)
WASTE AFTER TILLING-1*

Sample Date 6/27/85

Purge Start Time	2:36 pm	Sample #	WAT1A
TIME:	2:38	2:47	2:51
Ambient			
Shroud Air	32.5	49.9	51.8
1/4 " Soil	34.7	42.3	44.2
2" Soil	30.6	32.1	32.4
CONDITION	MP	MS	ES

Purge Start Time	2:37 pm	Sample #	WAT1B
TIME:	2:38	2:48	2:53
Ambient			
Shroud Air	37.3	51.4	53.6
1/4 " Soil	32.9	37.4	39.5
2" Soil	33	32.8	33
CONDITION	MP	MS	POST

Purge Start Time	4:42 pm	Sample #	WAT1C	
TIME:	4:44	4:50	4:56	5:01
Ambient	26.5			
Shroud Air	34.6	43.5	49.9	48.4
1/4 " Soil	34.6	37.1	40.6	42
2" Soil	36.6	36.2	36.1	36.2
CONDITION	MP	MP	MS	POST

Purge Start Time	4:42 pm	Sample #	WAT1D
TIME:	4:45	4:57	
Ambient			
Shroud Air	33.9	46.4	
1/4 " Soil	34.5	38.7	
2" Soil	35.1	35.1	
CONDITION	MP	MS	

Purge Start Time	4:45 pm	Sample #	WAT1E
TIME:	4:45	4:55	4:59
Ambient			
Shroud Air	34.6	48.8	51.5
1/4 " Soil	34.6	36.9	38.8
2" Soil	35	34.8	34.8
CONDITION	MP	MS	ES

Purge Start Time	2:41 pm	Sample #	WAT1F
TIME:	2:42	2:54	
Ambient	25.5		
Shroud Air	35.9	50.1	
1/4 " Soil	31'.8	41.3	
2" Soil	31.3	32	
CONDITION	MP	MS	

(continued)

APPENDIX H (continued)
WASTE AFTER TILLING-2 SHADED!!•

Sample Date	6/27/85				
Purge Start Time	2:51 pm No Shade	Sample #	WAT2A		
TIME:	2:56	2:58	3:02		
Ambient		27.4			
Shroud Air	53.4	45.5	40.6		
1/4 " Soil	46.2	44.2	41.8		
2" Soil	32.9	33.3	33.3		
CONDITION	MP	MP	MS		
Purge Start Time	2:52 pm	Sample #	WAT2B		
TIME:	2:53	2:58	3:02	3:07	
Ambient		25	25.5	25.5	
Shroud Air	53.6	54	45.1	41.2	
1/4 " Soil	39.5	42.1	42.1	41.3	
2" Soil	33	33.3	33.9	34.5	
CONDITION	MP	MP	SS	ES	
Purge Start Time	4:57 pm	Sample #	WAT2C		
TIME:	5:08	5:12			
Ambient	27.2				
Shroud Air	41.5	40.2			
1/4 " Soil	41	40.5			
2" Soil	36.4	36			
CONDITION	MS	ES			
Purge Start Time	4:57 pm	Sample #	WAT2D	Only 3 min. purge!	
TIME:	4:58	5:05			
Ambient					
Shroud Air	49	41.4			
1/4 " Soil	40.6	39.8			
2" Soil	35.1	35.3			
CONDITION	MP	ES			
Purge Start Time	4:57 pm	Sample #	WAT2E	Only 5 min. purge!	
TIME:	5:03				
Ambient					
Shroud Air	43.2				
1/4 " Soil	39.4				
2" Soil	34.9				
CONDITION	MS				
Purge Start Time	2:56 pm	Sample #	WAT2F	Only 5 min. purge!	
TIME:	3:01	3:05			
Ambient	25	25.5			
Shroud Air	41.7	37.7			
1/4 " Soil	40.9	39			
2" Soil	33.3	34			
CONDITION	SS	MS			

(continued)

APPENDIX H (continued)
WASTE AFTER TILLING-3•

Sample Date 6/27/85

Purge Start Time 8:37 pm Sample # WAT3A

TIME:	8:34	8:44	8:47	8:52
Ambient		19.8		
Shroud Air	20.2		21.7	21.9
1/4 " Soil	22.2		24.1	24.3
2" Soil	29		28.7	28.6
CONDITION	PS	MP	SS	ES

Purge Start Time 8:32 pm Sample # WAT3B

TIME:	8:34	8:42	8:49
Ambient	21.1		
Shroud Air	20.5	22.2	22.3
1/4 " Soil	25.6	26	26.2
2" Soil	29	29	28.8
CONDITION	SP	SS	ES

Purge Start Time 9:23 pm Sample # WAT3C

TIME:	9:25	9:33	9:38
Ambient			
Shroud Air	17.7	18.8	18.8
1/4 " Soil	22.2	22.8	23
2" Soil	28.8	28.6	28.4
CONDITION	SP	SS	ES

Purge Start Time 10:03 pm Sample # WAT3D

TIME:	10:03	10:13	10:18
Ambient			
Shroud Air	17.3	19	19.4
1/4 " Soil	19.5	20.8	21.2
2" Soil	28.1	27.8	27.8
CONDITION	PS	SS	ES

Purge Start Time 9:46 pm Sample # WAT3E

TIME:	9:47	9:57	10:01
Ambient		18.5	
Shroud Air	17.3	19.1	19.2
1/4 " Soil	22	22.5	22.8
2" Soil	27.8	27.6	27.5
CONDITION	PS	SS	ES

Purge Start Time 9:01 pm Sample # WAT3F

TIME:	9:01	9:10	9:15
Ambient	19.2		19.2
Shroud Air	18.1	19.3	19.4
1/4 " Soil	20.2	21.2	21.5
2" Soil	24.7	24.7	24.7
CONDITION	PS	SS	ES

(continued)

WASTE AFTER TILLING-4•

Sample Date 6/28/85

Purge Start Time 11:54 am Sample # WAT4A

TIME:	11:54	12:04	12:11
Ambient	27		
Shroud Air	45	65.5	69.1
1/4 " Soil	48.9	58.5	61.9
2" Soil	32.7	33.2	34.1
CONDITION	PS	SS	POST

Purge Start Time 11:56 am Sample # WAT4B

TIME:	11:56	12:06	12:13
Ambient	28		
Shroud Air	52	67	70.7
1/4 " Soil	38.5	41.6	44.2
2" Soil	32.9	33.6	34.4
CONDITION	PS	SS	POST

Purge Start Time 1:41 pm Sample # WAT4C

TIME:	1:40	1:41	1:51	1:55
Ambient				
Shroud Air		44.4	68.9	70.6
1/4 " Soil	45.4	44.7	47.1	48
2" Soil	35.2	35.3	35.7	35.8
CONDITION	PRE	PS	SS	ES

Purge Start Time 1:00 pm Sample # WAT4D

TIME:	12:57	1:00	1:10	1:18•
Ambient				
Shroud Air		40	67	60
1/4 " Soil	52.6	51.7	60.3	55.6
2" Soil	32.8	32.9	33.7	34.2
CONDITION	PRE	PS	SS	POST

• Shade put on during this period.

Purge Start Time 12:53 pm Sample # WAT4E

TIME:	12:54	1:02	1:06
Ambient	29		28.5
Shroud Air	45.5	65.9	68.4
1/4 " Soil	41.1	44	45.6
2" Soil	32.3	32.9	33.1
CONDITION	MP	MP	MS

Purge Start Time 12:00 N Sample # WAT4F

15 MINUTE PURGE TIME!

TIME:	11:59	12:00	12:15	12:20
Ambient				
Shroud Air		40	61.4	62.6
1/4 " Soil	47.5	49	58.8	60.5
2" Soil	33.2	33.2	35.4	36.9
CONDITION	PRE	PS	SS	ES

(continued)

APPENDIX H (continued)
WASTE AFTER TILLING-5 SHADED!!•

Sample Date 6/28/85

Purge Start Time	12:09 pm	Sample #	WAT5A	
	No Shade			
TIME:	12:11	12:21	12:26	
Ambient				
Shroud Air	69.1	47.3	43.2	
1/4 " Soil	61.9	48.1	44.6	
2" Soil	34.1	35.2	35.6	
CONDITION	MP	SS	ES	

Purge Start Time	12:11 pm	Sample #	WAT5B	
TIME:	12:13	12:21	12:27	
Ambient	No Shade	29		
Shroud Air	70.7	49.8	44.9	
1/4 " Soil	44.2	43.2	41.4	
2" Soil	34.4	35.3	35.5	
CONDITION	MP	SS	POST	

Purge Start Time	1:55 pm	Sample #	WAT5C	
	No Shade			
TIME:	1:55	2:00	2:05	
Ambient				
Shroud Air	70.6	57	50.1	
1/4 " Soil	48	47.5	45.9	
2" Soil	35.8	36.1	36.5	
CONDITION	PS	SS	ES	

Purge Start Time	1:15 pm	Sample #	WAT5D	
	No Shade			
TIME:	1:18	1:25	1:30	
Ambient				
Shroud Air	60	49.1	45.4	
1/4 " Soil	55.6	48.4	46	
2" Soil	34.2	34.5	35	
CONDITION	MP	SS	ES	

Purge Start Time	1:07 pm	Sample #	WAT5E	
TIME:	1:09	1:12	1:17	1:21
Ambient			29.5	
Shroud Air	61.6	55.7	49.3	45
1/4 " Soil	46.1	45.9	44.9	43.3
2" Soil	33.3	33.4	33.8	34.3
CONDITION	MP	MP	SS	MS

Purge Start Time	12:20 pm	Sample #	WAT5F	
TIME:	12:29	12:31	12:37	
Ambient				
Shroud Air	49.1	46.4	43.2	
1/4 " Soil	49.7	47.9	45	
2" Soil	37.8	38.1	37.9	
CONDITION	SS	MS	POST	

(continued)

APPENDIX H (continued)
WASTE AFTER TILLING-6 SHADED!!•

Sample Date 6/29/85

Purge Start Time 11:01 am Sample # WAT6A

TIME:	11:02	11:15	11:17
Ambient		27.5	
Shroud Air	40	39.5	39
1/4 " Soil	44	40	39.6
2" Soil	31.9	32.4	32.5
CONDITION	PS	MS	ES

Purge Start Time 11:13 am Sample # WAT6B

TIME:	11:10	11:15	11:25	11:30
Ambient	27.5	27.5		
Shroud Air		47.4	42.4	41.2
1/4 " Soil	39.5	40	38.2	37.6
2" Soil	31.8	32.2	32.5	32.4
CONDITION	PRE	MP	MS	POST

Purge Start Time 11:23 am Sample # WAT6C

TIME:	11:22	11:23	11:32	11:38
Ambient	27	27		
Shroud Air		39.5	39	39
1/4 " Soil	41	41.4	38.8	38
2" Soil	31	31	31.4	31.7
CONDITION	PRE	PS	SS	ES

Purge Start Time 11:37 am Sample # WAT6D

TIME:	11:34	11:37	11:47	11:50
Ambient				
Shroud Air		36.5	41	40.5
1/4 " Soil	45	43.7	40.5	40
2" Soil	33.3	33.2	33.7	33.8
CONDITION	PRE	PS	SS	MS

Purge Start Time 11:39 am Sample # WAT6E

TIME:	11:38	11:39	11:49	11:54
Ambient				
Shroud Air		37.4	41	40.5
1/4 " Soil	38.2	38.4	37.2	36.9
2" Soil	31.5	31.5	31.8	32.1
CONDITION	PRE	PS	SS	ES

Purge Start Time 11:58 am Sample # WAT6F

TIME:	11:56	11:59	12:07	12:13
Ambient	27.5	27.5	28.8	
Shroud Air		44.4	42.5	41.1
1/4 " Soil	51.9	49.6	42.9	40.9
2" Soil	30.3	30.4	31.3	31.4
CONDITION	PRE	PS	SS	ES

(continued)

APPENDIX H (continued)
WASTE AFTER TILLING-7 SHADED!!•

Sample Date	7/2/85					
Purge Start Time	11:41 am	Sample #	WAT7A			
TIME:	11:38	11:42	11:47	11:52	11:54:30	11:57
Ambient	29.6					
Shroud Air		41.3	41.7	41.6	41.3	41.0
1/4 " Soil	44.7	44.8	43.2	41.9	41.6	41.3
2" Soil	33.1	33.3	33.3	33.4	33.5	33.6
CONDITION	PRE	PS	MP	SS	MS	ES
Purge Start Time	12:08 pm	Sample #	WAT7B			
TIME:	12:07	12:09	12:14	12:29	12:21:30	12:24
Ambient	32.8					
Shroud Air		43.1	44.4	44.4	44.0	44.6
1/4 " Soil	41.5	41.3	40.2	39.7	39.4	39.3
2" Soil	34.0	34.1	34.3	34.5	34.5	34.7
CONDITION	PRE	PS	MP	SS	MS	ES
Purge Start Time	12:40 pm	Sample #	WAT7C			
TIME:	12:35	12:41	12:45	12:50	12:52:20	12:56
Ambient	34.5					
Shroud Air		43.1	45.2	45.9	45.2	44.9
1/4 " Soil	52.2	51	47.2	45	44.3	43.8
2" Soil	35	35.3	35.4	35.6	35.6	35.6
CONDITION	PRE	PS	MP	SS	MS	ES
Purge Start Time	1:08 pm	Sample #	WAT7D			
TIME:	1:07	1:08	1:13	1:18	1:20:30	1:23
Ambient	31.2	31.2				
Shroud Air		39.9	43.9	44.7	44.7	44.6
1/4 " Soil	49.0	49.8	48.8	46.9	46.8	46.2
2" Soil	35.7	35.7	35.8	36.0	36.1	36.4
CONDITION	PRE	PS	MP	SS	MS	ES
Purge Start Time	1:31 pm	Sample #	WAT7E			
TIME:	1:29	1:33	1:38	1:43	1:45:30	1:48
Ambient	30.2					
Shroud Air		51.2	50.8	49.8	49.6	49.3
1/4 " Soil	48	47.9	47.3	46.2	46	45.5
2" Soil	35.7	35.7	36.2	36.3	36.5	36.5
CONDITION	PRE	PS	MP	SS	MS	ES
Purge Start Time	1:52 pm	Sample #	WAT7F			
TIME:	1:51	1:53	1:57	2:03	2:06	2:08
Ambient	33.2					
Shroud Air		39.6	43.6	44.3	44.2	44.1
1/4 " Soil	54.6	54.3	51.8	49.3	49.0	47.7
2" Soil	35.6	35.9	36.0	36.2	36.2	36.1
CONDITION	PRE	PS	MP	SS	MS	ES

(continued)

APPENDIX H (continued)
WASTE AFTER TILLING-8 SHADED!!•

Sample Date 7/3/85

Purge Start Time 11:45 am Sample # WAT8A

TIME:	11:44	11:46	11:50	11:55	12:00 N
Ambient	33.0				
Shroud Air		45.2	46.4	45.1	42.8
1/4 " Soil	51.2	51.0	48.7	46.8	45.4
2" Soil	34.5	34.5	34.8	35.0	35.2
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 11:29 am Sample # WAT8B

TIME:	11:28	11:29	11:34	11:39	11:44
Ambient					
Shroud Air		44.6	46.0	45.4	44.3
1/4 " Soil	45.0	44.3	42.9	42.3	41.4
2" Soil	33.5	33.6	33.7	34.1	33.9
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 11:22:30 am Sample # WAT8C

TIME:	11:11	11:13	11:18	11:23	11:27
Ambient					
Shroud Air		37.5	41.9	41.5	41.5
1/4 " Soil	39.6	39.6	38.4	37.7	37.6
2" Soil	32.8	32.5	32.6	32.5	32.7
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 11:02 am Sample # WAT8D

TIME:	11:01	11:02	11:07	11:14	11:17
Ambient	28.5				
Shroud Air		38.3	41.1	41.1	40.4
1/4 " Soil	43.9	43.5	42.0	41.0	40.6
2" Soil	33.6	33.6	33.9	34.2	34.2
CONDITION	PRE	PS	MP	MS	ES

Purge Start Time 10:43 am Sample # WAT8E

TIME:	10:42	10:44	10:48	10:53	10:58
Ambient					
Shroud Air		40	41.4	40.8	40.3
1/4 " Soil	40	40.4	39.4	38.4	37.7
2" Soil	31.1	31.2	31.2	31.4	31.7
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 10:44 am Sample # WAT8F

TIME:	10:33	10:35	10:39	10:44	10:49
Ambient	24.5				
Shroud Air		33.8	36.3	36.2	36.1
1/4 " Soil	45.7	44.4	41.6	40.2	39.3
2" Soil	34.1	39.1	40.2	39.2	38.7
CONDITION	PRE	PS	MP	SS	ES

(continued)

WASTE AFTER SECOND TILLING-1 SHADED!!•

Sample Date 7/3/85

Purge Start Time _ 2:40 pm Sample # WST1A

TIME:	2:39	2:42	2:45	2:50	2:55
Ambient	31.2				
Shroud Air		44.2	45.3	44.9	44.0
1/4 " Soil	47.3	47.3	46.7	46.0	45.6
2" Soil	43.0	43.0	42.9	42.7	42.6
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time _ 12:59:30 pm Sample # WST1B

TIME:	12:59	1:00	1:07	1:10	1:15
Ambient	30.5				
Shroud Air		38.2	38.5	38.5	38.8
1/4 " Soil	39.1	38.7	38.4	38.5	38.5
2" Soil	37.1	37.8	37.9	38.1	38.0
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time _ 1:05:30 pm Sample # WST1C

TIME:	1:04	1:06	1:11	1:16	1:24:30
Ambient	33.2				
Shroud Air		38.6	39.5	40.0	40.1
1/4 " Soil	38.9	39.5	39.6	39.9	40.0
2" Soil	37.4	37.3	37.5	37.6	37.9
CONDITION	PRE	PS	MP	SS	POST

Purge Start Time _ 1:23 pm Sample # WST1D

TIME:	1:21	1:23	1:35	1:38
Ambient	30.7			
Shroud Air		38.7	40.6	40.6
1/4 " Soil	40.5	41.5	40.2	40.2
2" Soil	36.9	37.0	37.1	37.3
CONDITION	PRE	PS	MS	ES

Purge Start Time _ 1:23 pm Sample # WST1E

				WITHOUT SHADE	
TIME:	1:34:30	1:40	1:45	1:51	1:54:45
Ambient	32.3				
Shroud Air	42.1	41.7	41.5	55.8	58.1
1/4 " Soil	43.2	42.4	42.2	55.4	58.2
2" Soil	39.3	39.6	39.8	40.1	40.5
CONDITION	MP	SS	ES		

Purge Start Time _ 1:48:40 pm Sample # WST1F

TIME:	1:48	1:49:40	1:53:40	2:01	2:06
Ambient	32.3				
Shroud Air		39.9	40.5	40.3	40.8
1/4 " Soil	42.0	40.2	39.6	39.4	39.6
2" Soil	35.4	35.4	35.7	35.9	36.2
CONDITION	PRE	PS	MP	SS	ES

(continued)

APPENDIX H (continued)
WASTE AFTER SECOND TILLING-2 SHADED!F

Sample Date 7/5/85

Purge Start Time 12:30 pm Sample # WST2A

TIME:	12:17:30	12:21:30	12:25	12:30	12:31
Ambient	30.5				
Shroud Air		42.3	43.1	42.1	41.3
1/4 " Soil	47.0	36.8	45.6	44.3	43.3
2" Soil	39.5	39.6	39.9	40.0	40.0
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 12:07:55 pm Sample # WST2B

TIME:	11:52	11:56	12:00	12:08	12:13
Ambient	30.2				
Shroud Air		43.4	41.2	39.2	38.5
1/4 " Soil	46.4	48.2	44.6	43.4	44.0
2" Soil	36.8	37.2	37.4	37.8	38.0
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 11:30 am Sample # WST2C

TIME:	11:29	11:31:30	11:36	11:42	11:46:40
Ambient	33.7				
Shroud Air		37.3	38.6	37.9	37.4
1/4 " Soil	43.4	39.3	39.1	38.9	38.1
2" Soil	35.3	35.5	35.7	36.0	36.0
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 11:09 am Sample # WST2D

TIME:	11:07:30	11:10	11:14	11:40	11:24:30
Ambient	32.5				
Shroud Air		38.2	38.5	37.8	37.3
1/4 " Soil	43.7	39.7	38.4	37.4	37.0
2" Soil	34.2	34.1	34.2	34.4	34.6
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 11:48:30 am Sample # WST2E

TIME:	10:46	10:49:30	10:53	10:59	11:03:30
Ambient	32.9				
Shroud Air		34.8	35.6	35.4	35.3
1/4 " Soil	36.7	36.8	36.6	35.8	35.7
2" Soil	32.8	32.8	33.2	33.1	33.4
CONDITION	PRE	PS	MP	SS	ES

Purge Start Time 10:28 am Sample # WST2F

TIME:	10:26	10:29	10:33	10:38	10:43
Ambient	30.5				
Shroud Air		38.2	36.5	34.7	33.9
1/4 " Soil	37.5	39.8	37.8	36.1	35.3
2" Soil	30.4	30.6	30.8	30.6	30.8
CONDITION	PRE	PS	MP	SS	ES

• PA=Pre-Waste Application MP=Mid-Purge ES=End Sample
PRE=Pre-Shroud SS=Start Sample POST=Post Sample
PS=Purge Start MS=Mid-Sample

APPENDIX I. FIELD WEATHER DATA

TABLE I-1. JUNE 1985 LOCAL CLIMATOLOGICAL DATA, MONTHLY SUMMARY

INTERNATIONAL AIRPORT

LATITUDE 36°12' LONGITUDE 95°54' ELEVATION (GROUND) 650 FEET TIME ZONE CENTRAL 13968

DATE	TEMPERATURE °F: MAXIMUM	MINIMUM	AVERAGE	DEPARTURE FROM NORMAL	AVERAGE DEW POINT	DEGREE DAYS BASE 65°F: HEATING (SEASON BEGINS WITH JUL)	COOLING (SEASON BEGINS WITH JAN)	WEATHER TYPES (1 FOG, 2 HEAVY FOG, 3 THUNDERSTORM, 4 ICE PELLETS, 5 HAIL, 6 GLAZE, 7 DUSTSTORM, 8 SMOKE, HAZE, 9 BLOWING SNOW)	SNOW ICE PELLETS OR ICE ON GROUND AT 0600 INCHES	PRECIPITATION: WATER EQUIVALENT (INCHES)	SNOW, ICE PELLETS (INCHES)	AVERAGE STATION PRESSURE IN INCHES ELEV. 676 FEET ABOVE M.S.L.	WIND (M.P.H.): RESULTANT DIR.	RESULTANT SPEED	AVERAGE SPEED	FASTEST MILE: SPEED	FASTEST MILE: DIRECTION	SUNSHINE: MINUTES	PERCENT OF TOTAL POSSIBLE	SKY COVER (TENTHS): SUNRISE TO SUNSET	MIDNIGHT TO MIDNIGHT	DATE
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
01	92	66	79	5	65	0	14	3	0	0.16	0.0	29.080	19	7.6	10.2	29	28	318	37	9	8	01
02	93	69	81	7	71	0	16		0	0.00	0.0	29.060	18	11.8	13.5	21	21	580	67	5	7	02
03	88	73	81	7	71	0	16		0	T	0.0	29.150	16	6.6	9.8	16	18	280	32	10	9	03
04	88	67	78	3	70	0	13	3	0	2.87	0.0	29.170	17	2.2	9.3	21	20	234	27	9	9	04
05	73	66	70	-5	68	0	5	1	0	0.37	0.0	29.210	06	2.9	4.9	14	08	0	0	10	10	05
06	78	67	73	-2	69	0	8	1 3	0	0.63	0.0	29.200	06	0.7	1.6	12	05	41	5	10	9	06
07	85	65	75	0	68	0	10	2	0	0.00	0.0	29.270	09	1.3	3.3	7	13	595	68	5	4	07
08	94*	70	82	6	71	0	17		0	0.00	0.0	29.150	17	10.9	11.0	17	17	873	100	3	2	08
09	91	70	81	5	69	0	16		0	0.00	0.0	29.140	05	2.1	8.0	16	03	372	43	9	7	09
10	83	68	76	0	69	0	11	3	0	0.21	0.0	29.160	08	4.2	9.0	22	05	92	11	10	10	10
11	80	62	71	-6	61	0	6	3	0	0.04	0.0	29.250	32	8.8	10.1	18	29	281	32	9	8	11
12	73	56	65	-12	48	0	0		0	0.00	0.0	29.410	34	7.8	8.6	17	33	788	90	2	2	12
13	78	52*	65*	-12	52	0	0		0	0.00	0.0	29.310	17	6.3	6.6	14	19	710	81	4	3	13
14	85	64	75	-2	58	0	10	3	0	T	0.0	29.140	17	13.0	15.3	29	03	706	81	2	3	14
15	87	64	76	-2	63	0	11	1 3	0	1.45	0.0	29.150	06	1.5	6.3	29	03	690	79	4	4	15
16	91	68	80	2	69	0	15		0	T	0.0	29.130	17	8.5	9.6	20	18	469	56	5	5	16
17	86	65	76	-2	67	0	11	3	0	0.03	0.0	29.190	30	1.4	11.0	20	18	237	27	9	9	17
18	83	63	73	-6	54	0	8		0	T	0.0	29.330	33	5.3	5.9	15	32	496	57	8	7	18
19	81	59	70	-9	53	0	5		0	0.00	0.0	29.330	01	2.0	4.4	10	01	818	93	0	0	19
20	86	65	76	-3	58	0	11		0	0.00	0.0	29.175	18	13.4	13.9	22	19	673	77	7	5	20
21	85	70	78	-1	66	0	13		0	0.00	0.0	29.090	18	15.5	15.8	23	18	514	59	6	5	21
22	86	67	77	-2	69	0	12	3	0	1.67	0.0	29.250	16	5.9	7.0	17	18	391	45	8	7	22
23	90	73	82	2	69	0	17		0	0.00	0.0	29.280	19	11.8	12.4	21	20	581	66	3	2	23
24	90	75	83	3	68	0	18		0	0.00	0.0	29.280	18	10.6	11.3	18	22	697	79	3	3	24
25	90	75	83*	3	67	0	18		0	0.00	0.0	29.220	17	12.5	12.7	21	16	668	76	3	2	25
26	91	68	80	0	67	0	15	1	0	0.10	0.0	29.200	18	9.0	12.4	20	17	694	79	2	3	26
27	78	62	70	-11	56	0	5	1	0	0.10	0.0	29.410	34	8.5	8.8	14	36	468	53	6	6	27
28	85	58	72	-9	54	0	7		0	0.00	0.0	29.400	36	0.6	4.2	10	12	877	100	0	0	28
29	88	63	76	-5	59	0	11		0	0.00	0.0	29.360	18	6.7	7.3	13	20	876	100	1	1	29
30	90	67	79	-2	62	0	14		0	0.00	0.0	29.330	09	2.7	7.2	9	05	788	90	4	3	30
	SUM 2568	SUM 1976				TOTAL 0	TOTAL 333	NUMBER OF DAYS		TOTAL 7.53	TOTAL 0.0	FOR THE MONTH: 29.230	18	3.9	9.0	29	03	TOTAL 15827	% FOR MONTH	SUM 166	SUM 153	
	AVG. 85.6	AVG. 65.9	AVG. 75.8	DEP. -1.9	AVG. 63.7	DEP. 0	DEP. -48	PRECIPITATION ≥ .01 INCH	11	DEP. 3.06						DATE: 15+		POSSIBLE 26248	60	AVG. 5.5	AVG. 5.1	

NUMBER OF DAYS: MAXIMUM TEMP. ≥ 90°	MAXIMUM TEMP. ≤ 32°	MINIMUM TEMP. ≤ 32°	MINIMUM TEMP. ≤ 0°	SEASON TO DATE: HEATING TOTAL	COOLING TOTAL
10	0	0	0	3591	596
				DEP. -140	DEP. -11

NUMBER OF DAYS	
PRECIPITATION ≥ .01 INCH	11
SNOW, ICE PELLETS ≥ 1.0 INCH	0
THUNDERSTORMS	9
HEAVY FOG	1
CLEAR 10, PARTLY CLOUDY 9, CLOUDY 11	

GREATEST IN 24 HOURS AND DATES: PRECIPITATION	DATES	SNOW, ICE PELLETS	GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE
3.24	04-05	0.0	0

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
\+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. ONE OF THREE WIND SPEEDS IS GIVEN UNDER FASTEST MILE: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED (A / APPEARS IN THE DIRECTION COLUMN). ERRORS WILL BE CORRECTED AND NOTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, NORTH CAROLINA, 28801

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NATIONAL CLIMATIC DATA CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION — NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE — NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

TABLE I-1. (continued)

OBSERVATIONS AT 3-HOUR INTERVALS

JUN 1985 TULSA, OKLAHOMA 13968

Hour L.S.T.	Sky cover (tenths)	Ceiling in hundreds of feet	Visibility: Whole miles	Visibility: 16ths mile	Weather	Temperature: Air °F	Temperature: Wet bulb °F	Temperature: Dew point °F	Rel humidity %	Wind: Direction	Wind: Speed (knots)
					JUN 1st						
03	5	UNL	15			69	63	59	71	00	0
06	10	90	15			68	63	60	76	20	5
09	10	80	15			73	67	64	74	10	6
12	8	250	15			83	72	66	57	18	9
15	6	250	15			90	77	71	54	21	17
18	10	38	10		RW	85	77	73	67	23	8
21	8	250	12			69	66	64	84	15	7
24	10	45	12			69	67	65	87	15	8
					JUN 4th						
03	9	38	15			73	72	71	94	00	0
06	10	UNL	15			76	73	71	85	17	12
09	7	22	15			82	75	72	72	23	11
12	8	28	15			88	77	73	61	20	10
15	10	20	7		TRW	71	70	69	93	00	0
18	10	5	1	8	TRW	70	70	70	100	01	13
21	10	18	5		RW	69	68	67	93	07	12
24	10	28	7		RW	67	67	67	100	00	0
					JUN 7th						
03	6	14	7			66	66	66	100	00	0
06	10	11	4		F	67	67	67	100	00	0
09	5	UNL	8			71	68	66	84	34	3
12	4	UNL	12			80	72	68	67	00	0
15	4	UNL	12			85	74	68	57	04	4
18	0	UNL	15			84	74	70	63	10	5
21	0	UNL	15			77	74	72	85	14	5
24	0	UNL	15			74	71	70	87	16	3
					JUN 10th						
03	10	250	15			70	65	62	76	05	8
06	10	30	10		RW	68	67	67	97	28	3
09	10	20	10			68	66	65	90	06	8
12	10	120	15			72	68	66	82	09	5
15	10	200	15			82	76	73	74	14	8
18	8	UNL	10			83	77	75	77	10	6
21	10	25	8		TRW	80	77	75	85	17	8
24	10	22	5		TRW	72	68	66	82	29	16
					JUN 13th						
03	0	UNL	15			54	52	50	86	00	0
06	0	UNL	20			54	52	50	86	00	0
09	5	UNL	15			66	56	48	53	18	7
12	4	UNL	15			71	53	49	46	24	4
15	3	UNL	15			77	62	52	42	16	11
18	6	UNL	15			77	63	54	45	17	9
21	1	UNL	15			71	62	56	59	16	7
24	0	UNL	15			66	60	56	70	16	7
					JUN 16th						
03	1	UNL	15			68	66	65	90	00	0
06	10	90	12			69	67	65	87	00	0
09	7	250	10			76	70	67	74	19	10
12	5	UNL	10			85	75	71	63	15	7
15	2	UNL	10			91	79	74	58	17	13
18	0	UNL	12			90	77	71	54	18	14
21	5	UNL	12			85	76	72	65	18	12
24	9	250	10			83	75	71	67	18	17

Hour L.S.T.	Sky cover (tenths)	Ceiling in hundreds of feet	Visibility: Whole miles	Visibility: 16ths mile	Weather	Temperature: Air °F	Temperature: Wet bulb °F	Temperature: Dew point °F	Rel humidity %	Wind: Direction	Wind: Speed (knots)
					JUN 2nd						
03	9	250	15			69	68	67	93	11	9
06	5	UNL	10			69	68	68	97	15	7
09	8	70	12			80	74	71	74	19	12
12	2	UNL	15			86	76	72	63	20	15
15	1	UNL	15			92	78	73	54	18	10
18	7	UNL	15			90	79	74	59	20	13
21	10	110	10			84	75	71	65	17	11
24	10	250	10			80	[illegible]	70	72	17	5
					JUN 5th						
03	10	45	12		RW	67	67	67	100	00	0
06	10	32	7		RW	67	67	67	100	32	3
09	10	6	5		RF	67	67	67	100	04	3
12	10	8	7			70	68	67	90	09	5
15	10	18	8			72	69	68	87	06	5
18	10	22	7			73	71	70	90	03	5
21	10	22	7			71	70	69	93	00	0
24	10	250	15			70	69	69	97	00	0
					JUN 8th						
03	0	UNL	15			72	70	69	90	17	5
06	1	UNL	10			71	70	69	93	15	4
09	1	UNL	15			81	74	71	72	17	10
12	6	UNL	15			90	77	72	56	17	12
15	5	UNL	15			92	77	71	50	18	12
18	0	UNL	15			91	78	73	56	18	12
21	0	UNL	15			84	77	74	72	17	13
24	0	UNL	15			81	74	71	72	18	7
					JUN 11th						
03	10	80	10		R	67	64	62	84	25	5
06	10	250	10			66	64	63	90	28	6
09	7	UNL	15			73	68	65	76	31	11
12	9	20	15			79	70	65	62	31	15
15	10	16	15			71	66	63	76	34	14
18	10	22	15			69	62	57	66	34	11
21	7	38	15			67	60	55	66	35	7
24	0	UNL	15			62	59	56	81	31	5
					JUN 14th						
03	1	UNL	15			65	59	55	70	17	8
06	2	UNL	15			64	58	53	68	17	10
09	4	UNL	15			72	61	54	53	18	17
12	3	UNL	15			80	65	55	42	18	17
15	4	UNL	15			83	63	59	44	17	11
18	0	UNL	15			83	68	60	46	17	15
21	3	UNL	15			77	68	62	60	18	14
24	10	20	10		TRW	70	66	64	81	03	25
					JUN 17th						
03	10	45	10			81	73	69	67	18	9
06	10	45	7			78	72	69	74	18	11
09	8	80	12			83	74	69	63	24	11
12	10	80	8			85	75	70	61	28	7
15	10	17	7		RW	75	72	70	85	01	15
18	7	UNL	15			79	69	63	58	03	11
21	8	80	15			71	64	59	66	02	6
24	2	UNL	15			65	62	60	84	34	4

Hour L.S.T.	Sky cover (tenths)	Ceiling in hundreds of feet	Visibility: Whole miles	Visibility: 16ths mile	Weather	Temperature: Air °F	Temperature: Wet bulb °F	Temperature: Dew point °F	Rel humidity %	Wind: Direction	Wind: Speed (knots)
					JUN 3rd						
03	10	80	15			79	73	70	74	18	7
06	10	80	15			76	72	70	82	15	4
09	10	250	15			80	75	72	77	15	10
12	10	20	15			83	75	72	70	17	13
15	10	28	15			86	75	70	59	17	10
18	10	38	10			86	76	71	61	16	8
21	8	250	10			81	75	73	77	08	7
24	8	38	15			73	71	70	90	08	7
					JUN 6th						
03	10	22	12		RW	70	70	70	100	15	4
06	10	70	5		RF	69	69	69	100	00	0
09	10	90	5		F	71	70	70	97	00	0
12	10	18	10			76	71	69	79	34	8
15	10	20	5		RWF	67	67	67	100	00	0
18	10	80	10			70	69	68	93	00	0
21	8	250	8			69	68	68	97	00	0
24	0	UNL	15			67	67	67	100	00	0
					JUN 9th						
03	0	UNL	15			78	73	70	77	19	7
06	7	250	15			76	72	70	82	16	5
09	10	70	12			80	75	72	77	01	5
12	8	250	15			90	78	73	58	15	3
15	8	250	10			89	79	75	63	01	5
18	9	250	15			81	71	66	60	03	14
21	8	UNL	15			74	66	61	64	36	10
24	10	250	15			70	64	60	71	33	4
					JUN 12th						
03	6	90	15			62	57	53	73	33	7
06	1	UNL	15			57	53	49	75	33	5
09	2	UNL	20			69	57	47	46	29	12
12	3	UNL	20			71	57	44	38	33	14
15	3	UNL	20			72	57	44	37	35	13
18	1	UNL	15			69	56	45	42	01	10
21	0	UNL	15			62	55	49	63	35	4
24	0	UNL	15			56	52	49	78	00	0
					JUN 15th						
03	8	20	12		T	67	65	64	90	18	8
06	10	60	10			68	64	52	81	16	3
09	6	UNL	15			75	69	65	71	33	4
12	3	UNL	15			80	71	57	55	36	6
15	1	UNL	15			85	71	64	50	04	8
18	0	UNL	15			85	57	57	39	04	9
21	0	UNL	15			77	69	64	64	09	4
24	3	UNL	15			74	68	65	74	19	4
					JUN 18th						
03	7	55	15			65	61	58	78	00	0
06	9	55	15			56	63	61	84	34	4
09	10	250	15			73	64	58	60	33	8
12	6	UNL	15			81	61	46	29	01	9
15	8	UNL	15			83	61	44	25	32	13
18	8	250	15			80	61	47	31	35	9
21	5	UNL	15			69	61	55	61	00	0
24	0	UNL	15			65	60	56	73	26	3

TABLE I-1. (continued)

OBSERVATIONS AT 3-HOUR INTERVALS

JUN 1985 13968
TULSA, OKLAHOMA

			VISIBILITY			TEMPERATURE				WIND				VISIBILITY			TEMPERATURE				WIND				VISIBILITY			TEMPERATURE				WIND	
HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	WHOLE MILES	16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	DIRECTION	SPEED (KNOTS)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	WHOLE MILES	16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	DIRECTION	SPEED (KNOTS)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	WHOLE MILES	16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW POINT °F	REL HUMIDITY %	DIRECTION	SPEED (KNOTS)
	JUN 19th											JUN 20th											JUN 21st										
03	0	UNL	15			59	57	55	87	33	4	0	UNL	15			66	60	56	70	18	5	0	UNL	15			70	63	59	68	17	10
06	0	UNL	15			60	57	55	84	00	0	5	UNL	15			66	61	57	73	16	9	5	UNL	15			70	66	64	81	17	9
09	0	UNL	15			70	61	54	57	01	7	9	UNL	15			77	65	58	52	19	11	6	UNL	15			78	71	68	72	18	17
12	0	UNL	15			76	62	53	45	33	5	8	UNL	15			83	69	61	48	21	11	9	25	15			83	72	67	59	18	18
15	1	UNL	15			79	62	50	36	00	0	8	UNL	15			85	68	58	40	21	15	6	28	15			85	73	67	55	18	18
18	0	UNL	15			79	63	51	38	34	5	3	UNL	15			83	67	58	43	18	18	5	UNL	15			84	73	67	57	19	16
21	0	UNL	15			71	62	56	59	13	6	2	UNL	15			76	65	58	54	18	14	8	32	15			82	74	70	67	15	11
24	0	UNL	15			68	60	54	61	17	4	0	UNL	15			71	63	58	64	17	11	8	40	15			80	73	70	72	17	14
	JUN 22nd											JUN 23rd											JUN 24th										
03	10	22	7		TRW	67	66	66	97	03	8	0	UNL	15			75	71	69	82	19	6	5	UNL	15			76	71	69	79	16	7
06	10	45	15			69	68	67	93	19	10	0	UNL	10			73	70	68	84	18	10	9	250	15			75	71	69	82	17	10
09	9	UNL	15			73	69	67	82	00	0	1	UNL	15			80	74	71	74	20	11	1	UNL	15			81	74	70	69	20	12
12	10	17	15			81	74	70	69	00	0	3	UNL	15			85	74	69	59	22	15	3	UNL	15			88	75	69	53	22	16
15	9	38	15			83	73	68	61	15	8	6	35	15			89	75	69	52	18	17	3	UNL	15			89	74	67	48	18	12
18	5	UNL	15			85	75	70	61	18	7	5	UNL	15			87	75	69	55	17	11	2	UNL	15			88	73	65	47	17	10
21	2	UNL	15			78	75	73	85	14	8	1	UNL	15			83	74	69	63	17	10	0	UNL	15			81	72	68	65	16	6
24	0	UNL	15			78	74	72	82	18	5	0	UNL	15			79	72	68	69	16	6	0	UNL	15			79	71	67	67	15	19
	JUN 25th											JUN 26th											JUN 27th										
03	0	UNL	15			76	71	68	76	17	6	1	UNL	15			75	69	66	74	17	8	10	4	15		R	65	64	63	93	34	9
06	0	UNL	15			75	70	68	79	17	8	0	UNL	15			73	69	67	82	16	9	10	80	15			63	61	60	90	32	8
09	1	UNL	15			82	74	71	69	20	13	0	UNL	15			82	73	69	65	18	12	9	80	15			67	61	57	70	33	12
12	4	UNL	15			88	74	68	52	16	18	2	UNL	15			89	75	68	50	19	12	8	90	15			73	61	52	48	36	12
15	4	UNL	15			89	73	66	47	17	15	3	UNL	15			91	74	66	44	18	14	2	UNL	15			78	63	52	41	33	10
18	3	UNL	15			87	73	66	50	18	13	5	UNL	15			88	73	65	47	17	14	3	UNL	15			78	62	50	38	34	8
21	1	UNL	15			82	71	65	57	16	11	10	32	15			76	70	66	71	35	13	1	UNL	15			69	60	54	59	32	4
24	0	UNL	15			79	71	66	65	17	8	10	45	5		RWF	68	67	67	97	34	5	1	UNL	15			63	59	56	78	30	3
	JUN 28th											JUN 29th											JUN 30th										
03	2	UNL	15			60	57	54	81	27	3	0	UNL	15			68	64	61	78	00	0	0	UNL	15			68	65	63	84	12	4
06	1	UNL	15			59	56	54	84	01	4	0	UNL	15			65	61	59	81	00	0	2	UNL	15			68	64	62	81	11	8
09	0	UNL	15			71	62	56	59	35	6	3	UNL	15			78	65	57	49	18	10	3	UNL	15			79	68	62	56	16	5
12	0	UNL	15			79	63	51	38	00	0	0	UNL	15			84	68	58	41	18	8	3	UNL	15			87	70	60	40	28	8
15	0	UNL	15			83	64	52	34	33	4	1	UNL	15			87	69	58	38	18	8	5	UNL	15			88	70	60	39	31	6
18	0	UNL	15			84	65	53	35	09	3	2	UNL	15			86	68	58	39	18	10	2	UNL	15			88	71	62	42	05	3
21	0	UNL	15			75	64	57	54	14	6	1	UNL	15			79	68	61	54	14	6	2	UNL	15			79	71	66	65	04	7
24	0	UNL	15			70	62	57	64	18	5	2	UNL	15			72	66	63	73	14	6	2	UNL	15			74	68	64	71	06	7

WEATHER CODES

* TORNADO	ZL FREEZING DRIZZLE	IPW ICE PELLET SHOWERS	BN BLOWING SAND
T THUNDERSTORM	S SNOW	A HAIL	BS BLOWING SNOW
Q SQUALL	SW SNOW SHOWERS	F FOG	BY BLOWING SPRAY
R RAIN	SG SNOW GRAINS	IF ICE FOG	K SMOKE
RW RAIN SHOWERS	SP SNOW PELLETS	GF GROUND FOG	H HAZE
ZR FREEZING RAIN	IC ICE CRYSTALS	BD BLOWING DUST	D DUST
L DRIZZLE	IP ICE PELLETS		

CEILING: UNL INDICATES UNLIMITED
WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM
SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXPRESSED IN KNOTS (MPH=KNOTS X 1.151).

TABLE I-1. (continued)

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES) JUN 1985 TULSA, OKLAHOMA 13968

DATE	A.M. HOUR ENDING AT												P.M. HOUR ENDING AT												DATE
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	
01																		T	0.11	T			T	0.05	01
02																									02
03								T																	03
04													T	0.05	0.16	0.01	0.92	1.02	0.24	0.09	0.14	0.09	0.06	0.09	04
05	0.01	0.01	0.01	0.01	0.01	0.03	0.06	0.06	0.12	0.02	T		0.03							T	T				05
06	T	T	T	0.01	0.01	0.01	T			T	T		0.36	0.10	0.08	0.05	0.01								06
07																									07
08																									08
09																									09
10				0.05	0.04	0.03	0.08	T													T	T	T	0.01	10
11	0.03	0.01	T	T	T																				11
12																									12
13																									13
14																								T	14
15	1.30	0.15																							15
16								T																	16
17				0.01	T		T	T					T	T	0.02	T									17
18							T																		18
19																									19
20																									20
21																									21
22		0.05	1.10	0.50	0.02	T																			22
23																									23
24																									24
25																									25
26																					T	0.02	0.03	0.05	26
27	0.04	0.03	0.02	0.01	T																				27
28																									28
29																									29
30																									30

MAXIMUM SHORT DURATION PRECIPITATION

TIME PERIOD (MINUTES)	5	10	15	20	30	45	60	80	100	120	150	180
PRECIPITATION (INCHES)	0.25	0.45	0.58	0.80	0.88	1.06	1.30	1.54	1.94	2.01	2.05	2.18
ENDED: DATE	15	04	15	15	15	04	15	04	04	04	04	04
ENDED: TIME	0011	1640	0011	0011	0015	1715	0055	1750	1806	1821	1853	1859

THE PRECIPITATION AMOUNTS FOR THE INDICATED TIME INTERVALS MAY OCCUR AT ANY TIME DURING THE MONTH. THE TIME INDICATED IS THE ENDING TIME OF THE INTERVAL. DATE AND TIME ARE NOT ENTERED FOR TRACE AMOUNTS.

TABLE I-2. JULY 1985 LOCAL CLIMATOLOGICAL DATA, MONTHLY SUMMARY

INTERNATIONAL AIRPORT

LATITUDE 36°12' LONGITUDE 95°54' ELEVATION (GROUND) 650 FEET TIME ZONE CENTRAL 13968

DATE 1	TEMPERATURE °F MAXIMUM 2	MINIMUM 3	AVERAGE 4	DEPARTURE FROM NORMAL 5	AVERAGE DEW POINT 6	DEGREE DAYS BASE 65°F HEATING (SEASON BEGINS WITH JUL) 7A	COOLING (SEASON BEGINS WITH JAN) 7B	WEATHER TYPES 1 FOG 2 HEAVY FOG 3 THUNDERSTORM 4 ICE PELLETS 5 HAIL 6 GLAZE 7 DUSTSTORM 8 SMOKE, HAZE 9 BLOWING SNOW 8	SNOW ICE PELLETS OR ICE ON GROUND AT 0600 INCHES 9	PRECIPITATION WATER EQUIVALENT (INCHES) 10	SNOW, ICE PELLETS (INCHES) 11	AVERAGE STATION PRESSURE IN INCHES ELEV. 676 FEET ABOVE M.S.L. 12	WIND (M.P.H.) RESULTANT DIR. 13	RESULTANT SPEED 14	AVERAGE SPEED 15	FASTEST MILE SPEED 16	FASTEST MILE DIRECTION 17	SUNSHINE MINUTES 18	PERCENT OF TOTAL POSSIBLE 19	SKY COVER (TENTHS) SUNRISE TO SUNSET 20	MIDNIGHT TO MIDNIGHT 21	DATE 22
01	83	66	75*	-6	65	0	10		0	T	0.0	29.380	03	2.3	3.9	12	06	438	50	9	6	01
02	90	64*	77	-5	62	0	12	1 8	0	0.00	0.0	29.380	05	2.4	4.4	10	05	771	88	7	6	02
03	90	69	80	-2	65	0	15		0	0.00	0.0	29.305	19	5.6	7.0	16	18	731	84	5	3	03
04	92	69	81	-1	66	0	16	3	0	0.05	0.0	29.180	19	9.5	11.0	18	17	721	83	2	3	04
05	89	66	79	-4	58	0	13		0	0.00	0.0	29.185	36	4.3	7.3	14	05	872	100	0	1	05
06	90	65	78	-4	59	0	13		0	0.00	0.0	29.280	02	3.3	5.7	10	36	872	100	0	0	06
07	91	66	79	-3	62	0	14		0	0.00	0.0	29.350	18	3.9	5.5	12	21	871	100	0	0	07
08	94	74	84	1	67	0	19		0	0.00	0.0	29.350	20	11.4	12.1	17	18	871	100	0	0	08
09	96	75	86	3	67	0	21		0	0.00	0.0	29.230	20	9.7	10.5	18	23	763	88	6	5	09
10	98	75	87	4	66	0	22		0	0.00	0.0	29.220	02	6.5	7.7	15	02	799	92	1	1	10
11	100	71	86	3	69	0	21		0	0.00	0.0	29.220	23	2.8	4.3	8	21	771	89	1	1	11
12	100*	79	90*	7	69	0	25		0	0.00	0.0	29.190	21	10.4	11.0	15	19	759	88	3	3	12
13	96	78	87	4	67	0	22		0	0.00	0.0	29.200	19	10.5	10.7	16	19	767	89	1	0	13
14	97	79	88	5	67	0	23		0	0.00	0.0	29.220	19	10.4	10.6	14	20	762	98	0	0	14
15	96	73	85	2	71	0	20	3	0	0.59	0.0	29.260	36	0.4	7.1	23	36	524	61	7	7	15
16	93	74	84	1	70	0	19		0	0.00	0.0	29.290	08	5.2	7.8	17	14	691	80	7	7	16
17	90	72	81	-2	70	0	16		0	0.00	0.0	29.300	13	7.7	8.3	14	10	740	96	4	3	17
18	95	74	85	1	69	0	20		0	0.00	0.0	29.270	16	11.7	11.9	17	15	763	89	2	1	18
19	97	76	87	3	67	0	22		0	0.00	0.0	29.310	17	8.8	9.2	15	20	749	87	3	1	19
20	98	74	86	2	68	0	21	8	0	0.00	0.0	29.285	17	5.2	6.7	16	22	729	85	0	0	20
21	96	73	85	1	69	0	20	3 8	0	0.01	0.0	29.195	17	4.4	6.5	25	36	738	86	6	6	21
22	92	72	82	-2	71	0	17	1 8	0	0.01	0.0	29.190	36	1.8	3.5	7	30	598	70	7	7	22
23	96	75	86	2	70	0	21	1	0	0.00	0.0	29.145	15	5.7	6.9	15	11	714	84	5	5	23
24	95	74	85	1	70	0	20		0	0.00	0.0	29.100	18	12.4	12.7	20	18	746	88	6	5	24
25	84	74	79	-5	74	0	14	1 3	0	1.62	0.0	29.180	11	1.6	6.6	16	18	0	0	10	10	25
26	89	70	80	-4	67	0	15	1	0	0.00	0.0	29.330	36	7.0	7.6	16	01	742	87	7	6	26
27	88	66	77	-7	63	0	12		0	0.00	0.0	29.310	34	3.7	4.4	8	33	847	100	1	1	27
28	89	69	79	-5	69	0	14		0	0.00	0.0	29.240	15	3.1	5.1	12	16	769	91	7	5	28
29	92	75	84	0	71	0	19	1 8	0	0.00	0.0	29.270	11	5.6	7.0	14	13	662	78	6	6	29
30	99	78	89	5	71	0	24		0	0.00	0.0	29.230	19	10.4	11.5	16	21	842	100	4	3	30
31	98	80	89	5	68	0	24		0	0.00	0.0	29.215	20	8.8	9.4	14	21	784	93	0	0	31
	SUM	SUM				TOTAL	TOTAL	NUMBER OF DAYS		TOTAL	TOTAL	FOR THE MONTH:						TOTAL	% FOR MONTH	SUM	SUM	
	2893	2245				0	564			2.38	0.0	29.250	18	3.7	7.9	25	36	22410		117	102	
	AVG.	AVG.	AVG.	DEP	AVG.	DEP.	DEP.	PRECIPITATION		DEP.						DATE: 21		POSSIBLE		AVG.	AVG	
	93.3	72.4	82.9	-0.3	67.3	0	0	≥ .01 INCH.	5	-1.13								26682	84	3.8	3.3	

NUMBER OF DAYS				SEASON TO DATE				GREATEST IN 24 HOURS AND DATES				GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
				TOTAL	TOTAL	SNOW, ICE PELLETS ≥ 1.0 INCH	0						
MAXIMUM TEMP.		MINIMUM TEMP.		0	1160	THUNDERSTORMS	4	PRECIPITATION		SNOW, ICE PELLETS			
≥ 90°	≤ 32°	≤ 32°	≤ 0°	DEP	DEP.	HEAVY FOG	0	1.62	25	0.0			0
25	0	0	0	0	-11	CLEAR 15	PARTLY CLOUDY 14	CLOUDY 2					

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT.
+ ALSO ON EARLIER DATE(S).
HEAVY FOG: VISIBILITY 1/4 MILE OR LESS.
BLANK ENTRIES DENOTE MISSING OR UNREPORTED DATA.

DATA IN COLS 6 AND 12-15 ARE BASED ON 21 OR MORE OBSERVATIONS AT HOURLY INTERVALS. RESULTANT WIND IS THE VECTOR SUM OF WIND SPEEDS AND DIRECTIONS DIVIDED BY THE NUMBER OF OBSERVATIONS. ONE OF THREE WIND SPEEDS IS GIVEN UNDER FASTEST MILE: FASTEST MILE - HIGHEST RECORDED SPEED FOR WHICH A MILE OF WIND PASSES STATION (DIRECTION IN COMPASS POINTS). FASTEST OBSERVED ONE MINUTE WIND - HIGHEST ONE MINUTE SPEED (DIRECTION IN TENS OF DEGREES). PEAK GUST - HIGHEST INSTANTANEOUS WIND SPEED (A / APPEARS IN THE DIRECTION COLUMN). ERRORS WILL BE CORRECTED AND NOTED IN SUBSEQUENT PUBLICATIONS.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, NORTH CAROLINA, 28801

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DIRECTOR
NATIONAL CLIMATIC DATA CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION — NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE — NATIONAL CLIMATIC DATA CENTER ASHEVILLE NORTH CAROLINA

TABLE I-2. (continued)

OBSERVATIONS AT 3-HOUR INTERVALS

JUL 1985 TULSA, OKLAHOMA 13968

Date	Hour L.S.T.	Sky Cover (Tenths)	Ceiling in Hundreds of Feet	Visibility Whole Miles	Visibility 16ths Mile	Weather	Temperature Air °F	Temperature Wet Bulb °F	Temperature Dew Point °F	Rel Humidity %	Wind Direction	Wind Speed (Knots)
JUL 1st	03	3	UNL	15			70	65	62	76	00	0
	06	6	250	15			67	65	63	87	00	0
	09	10	70	7			74	68	64	71	01	5
	12	10	70	7			79	71	66	65	06	9
	15	10	80	8			92	68	50	47	00	0
	16	5	UNL	15			80	70	65	60	02	6
	21	3	UNL	15			73	70	63	84	26	6
	24	0	UNL	15			70	67	65	87	00	0
JUL 2nd	03	4	UNL	6		F	66	65	65	97	35	4
	06	7	UNL	6		F	65	64	63	93	00	0
	09	5	UNL	5		H	79	70	65	62	00	0
	12	8	UNL	6		H	86	68	58	39	11	6
	15	8	UNL	7			89	59	58	35	06	4
	16	7	UNL	10			87	69	58	38	06	5
	21	5	UNL	10			79	71	67	67	19	5
	24	2	UNL	10			75	70	67	76	18	6
JUL 3rd	03	0	UNL	10			72	69	67	84	16	6
	06	8	250	10			69	66	64	84	23	6
	09	9	250	10			75	69	66	74	20	8
	12	4	UNL	15			84	73	68	59	15	8
	15	3	UNL	15			69	73	65	45	20	4
	16	1	UNL	15			89	71	61	39	00	0
	21	0	UNL	15			82	71	65	57	18	8
	24	0	UNL	15			76	69	65	69	19	10
JUL 4th	02	0	UNL	15			72	68	65	73	21	8
	06	7	250	15			69	67	65	87	17	7
	09	2	UNL	15			78	71	68	72	21	7
	12	0	UNL	15			87	73	67	52	19	10
	15	0	UNL	15			91	73	65	42	21	11
	18	3	UNL	15			90	73	65	44	20	10
	21	10	60	10		TRW	81	73	69	67	05	10
	24	10	80	15			71	65	61	71	23	12
JUL 5th	02	4	UNL	15			70	53	59	68	28	5
	06	0	UNL	15			66	54	62	87	30	3
	09	0	UNL	15			80	69	62	54	33	6
	12	0	UNL	15			85	64	50	30	05	12
	15	0	UNL	15			88	57	54	31	03	10
	18	0	UNL	15			88	67	53	30	36	7
	21	0	UNL	15			78	67	60	54	00	0
	24	0	UNL	15			71	66	63	76	07	3
JUL 6th	02	0	UNL	12			67	63	61	81	30	5
	06	0	UNL	10			66	62	60	81	00	0
	09	0	UNL	10			77	63	62	60	32	5
	12	0	UNL	10			86	57	55	35	36	9
	15	0	UNL	15			90	70	59	35	05	5
	18	0	UNL	15			98	68	57	35	09	6
	21	0	UNL	15			90	67	60	51	08	4
	24	0	UNL	15			73	67	53	71	00	0
JUL 7th	03	0	UNL	15			70	65	63	79	34	3
	06	0	UNL	10			58	65	63	84	00	0
	09	0	UNL	12			82	69	62	51	20	5
	12	0	UNL	15			89	70	60	38	22	6
	15	1	UNL	15			91	70	59	34	20	8
	18	0	UNL	15			89	70	59	36	21	10
	21	0	UNL	15			81	68	61	51	14	6
	24	0	UNL	15			77	69	64	64	17	5
JUL 8th	03	0	UNL	15			75	70	67	76	19	7
	06	0	UNL	7			75	70	68	79	17	9
	09	0	UNL	10			84	74	69	61	21	10
	12	0	UNL	15			91	74	65	42	18	15
	15	0	UNL	15			93	72	62	36	22	12
	18	0	UNL	15			91	74	66	44	22	13
	21	0	UNL	15			85	72	66	53	20	11
	24	0	UNL	15			81	73	69	67	17	11
JUL 9th	03	0	UNL	15			78	71	68	72	19	9
	06	0	UNL	15			75	70	67	76	21	4
	09	3	UNL	15			84	74	69	61	21	10
	12	7	UNL	15			93	76	68	44	22	12
	15	8	250	15			95	76	67	40	21	12
	18	10	80	15			92	74	66	42	19	9
	21	9	UNL	15			86	74	68	55	22	6
	24	0	UNL	15			82	74	70	67	22	8
JUL 10th	03	4	UNL	15			77	72	70	79	00	0
	06	6	UNL	15			75	70	67	76	34	7
	09	2	UNL	15			83	74	69	63	04	10
	12	0	UNL	15			92	77	70	49	04	10
	15	0	UNL	15			97	74	62	32	05	11
	18	0	UNL	15			95	72	60	31	04	8
	21	0	UNL	15			87	72	64	46	07	4
	24	0	UNL	15			77	72	69	76	00	0
JUL 11th	03	0	UNL	15			73	70	68	84	00	0
	06	3	UNL	7			72	69	67	84	00	0
	09	0	UNL	7			85	75	71	53	00	0
	12	2	UNL	7			94	75	67	41	24	5
	15	2	UNL	7			98	78	69	39	23	6
	18	0	UNL	10			98	76	66	35	27	5
	21	0	UNL	10			89	76	71	55	00	0
	24	0	UNL	10			94	76	72	67	21	7
JUL 12th	03	0	UNL	10			80	74	71	74	24	8
	06	4	UNL	10			79	74	71	77	23	7
	09	3	UNL	10			88	76	70	55	24	10
	12	0	UNL	10			96	79	72	46	20	12
	15	5	UNL	10			99	76	65	33	21	10
	18	3	UNL	12			95	76	67	40	21	10
	21	7	250	12			88	74	68	52	19	10
	24	0	UNL	12			84	74	69	61	19	9
JUL 13th	03	0	UNL	15			81	72	68	65	19	10
	06	3	UNL	15			78	71	67	69	20	6
	09	1	UNL	15			84	73	67	57	19	10
	12	0	UNL	15			92	75	68	46	20	12
	15	0	UNL	15			95	76	57	40	19	12
	18	1	UNL	15			93	76	68	44	20	8
	21	0	UNL	15			88	74	63	52	18	6
	24	0	UNL	15			84	71	65	53	18	8
JUL 14th	03	0	UNL	15			80	70	64	58	20	6
	06	0	UNL	15			79	70	65	62	18	8
	09	0	UNL	15			86	74	68	55	22	9
	12	0	UNL	15			93	77	70	47	20	12
	15	0	UNL	15			95	76	67	39	19	12
	18	0	UNL	15			94	74	65	39	20	12
	21	1	UNL	15			88	74	68	52	18	7
	24	0	UNL	15			84	73	67	57	19	5
JUL 15th	03	9	60	15			81	72	67	63	18	5
	06	5	UNL	15			78	71	68	72	16	5
	09	6	UNL	15			86	75	70	59	20	8
	12	6	UNL	15			94	77	69	44	34	7
	15	10	32	2		TRW	73	72	71	94	33	12
	18	10	60	12			83	78	76	80	04	10
	21	9	250	12			82	75	74	77	04	7
	24	10	90	12			79	74	71	77	03	5
JUL 16th	03	10	80	15			76	71	68	76	04	7
	06	7	80	15			74	71	69	85	05	8
	09	8	90	15			80	74	71	74	07	3
	12	8	90	12			87	77	73	63	06	7
	15	4	UNL	15			90	76	69	50	36	5
	19	7	UNL	15			91	75	67	45	09	5
	21	5	250	15			90	73	70	72	17	5
	24	2	UNL	15			74	73	72	94	12	3
JUL 17th	03	3	UNL	15			73	72	71	94	16	6
	06	5	UNL	7			72	71	71	97	12	5
	09	8	20	3			80	75	73	79	12	7
	12	6	20	7			86	76	71	61	16	8
	15	3	UNL	8			90	75	68	48	15	10
	19	1	UNL	12			89	74	67	48	10	12
	21	0	UNL	12			83	72	67	59	13	8
	24	0	UNL	12			79	72	69	72	15	4
JUL 18th	03	0	UNL	12			77	72	69	76	18	5
	06	4	UNL	7			74	69	67	79	16	8
	09	3	UNL	8			81	72	68	65	15	14
	12	2	UNL	10			88	75	70	55	16	12
	15	1	UNL	10			94	78	71	47	17	13
	19	0	UNL	12			93	77	70	47	17	12
	21	0	UNL	12			87	75	70	57	16	9
	24	0	UNL	12			84	74	69	61	18	12

OBSERVATIONS AT 3-HOUR INTERVALS

JUL 1985 TULSA, OKLAHOMA 13968

HOUR L.S.T.	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)	SKY COVER (TENTHS)	CEILING IN HUNDREDS OF FEET	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE AIR °F	TEMPERATURE WET BULB °F	TEMPERATURE DEW POINT °F	REL HUMIDITY %	WIND DIRECTION	WIND SPEED (KNOTS)
	JUL 19th											JUL 20th											JUL 21st										
03	0	UNL	12			80	72	68	67	19	8	0	UNL	12			78	71	68	72	36	3	0	UNL	10			78	73	70	77	18	8
06	4	UNL	12			78	71	68	72	17	6	0	UNL	5		H	76	71	69	79	00	0	4	UNL	6		H	75	72	70	85	18	7
09	2	UNL	10			84	73	67	57	15	12	0	UNL	7			87	76	71	59	16	3	6	UNL	10			84	73	66	59	21	5
12	3	UNL	8			91	76	69	49	19	8	0	UNL	7			94	77	69	44	19	6	10	250	10			91	76	70	50	00	0
15	7	UNL	8			95	75	65	37	17	9	2	UNL	7			96	73	62	33	15	10	5	UNL	12			94	75	67	41	00	0
18	0	UNL	7			94	74	65	39	17	11	0	UNL	7			96	73	62	33	14	5	6	UNL	10			93	76	69	44	17	13
21	0	UNL	7			87	74	67	52	12	5	0	UNL	7			86	75	70	59	20	10	8	250	10			86	76	71	61	16	10
24	0	UNL	15			83	73	68	61	19	3	0	UNL	12			81	75	72	74	18	8	10	22	15			74	71	70	87	01	4
	JUL 22nd											JUL 23rd											JUL 24th										
03	10	70	15			74	72	71	90	07	4	2	UNL	10			76	74	73	91	00	0	2	UNL	15			76	72	70	82	17	7
06	10	14	5		H	73	72	71	94	36	5	3	UNL	4		F	76	73	71	85	15	4	3	UNL	15			75	72	70	85	17	7
09	10	40	3		F	75	73	72	90	35	4	0	UNL	10			85	77	73	67	14	5	4	UNL	15			84	76	72	67	17	12
12	5	UNL	8			85	75	70	61	00	0	5	UNL	10			92	76	69	47	12	10	3	90	15			90	77	72	56	18	14
15	7	250	10			90	75	69	50	25	3	7	250	15			95	76	67	40	11	13	8	90	12			94	77	70	46	19	16
18	9	UNL	10			90	74	67	47	30	4	9	40	12			92	73	64	40	14	8	3	UNL	12			93	76	68	44	19	14
21	4	UNL	10			84	74	69	61	00	0	7	UNL	15			93	74	69	63	16	6	3	UNL	15			87	73	66	50	16	7
24	3	UNL	10			80	76	74	82	00	0	0	UNL	15			79	72	69	72	17	7	10	50	15			84	74	69	61	16	12
	JUL 25th											JUL 26th											JUL 27th										
03	10	50	15			82	74	71	69	18	12	10	28	6		F	74	74	74	100	00	0	0	UNL	15			68	66	65	90	31	4
06	10	16	2	8	TRWF	75	75	75	100	24	7	10	20	7			73	72	71	94	34	4	1	UNL	15			66	64	63	90	32	3
09	10	33	5		F	75	75	75	100	04	7	5	UNL	15			79	72	69	72	03	9	0	UNL	15			76	70	66	71	01	4
12	10	5	5		RWF	75	75	75	100	12	6	7	250	15			85	72	66	53	02	10	0	UNL	15			85	68	57	39	00	0
15	10	5	6		RWF	76	75	75	97	05	6	7	UNL	15			87	70	61	42	36	5	1	UNL	15			88	69	53	36	33	6
18	10	6	5		RF	75	74	74	97	02	6	6	UNL	15			85	70	61	45	35	6	1	UNL	15			88	70	60	39	00	0
21	10	10	7			75	75	75	100	00	0	0	UNL	15			78	70	65	64	01	5	1	UNL	15			78	70	66	67	35	4
24	7	50	7			74	73	73	97	30	3	0	UNL	15			70	68	67	90	00	0	0	UNL	15			73	70	68	84	32	7
	JUL 28th											JUL 29th											JUL 30th										
03	3	UNL	15			72	68	66	82	00	0	10	80	15			75	72	71	87	09	3	2	UNL	12			80	74	71	74	16	9
06	2	UNL	8			71	69	68	90	09	4	10	80	8			76	71	69	79	21	4	7	UNL	10			79	75	73	82	16	9
09	9	40	10			77	70	67	71	17	9	10	50	6		H	79	72	68	69	00	0	5	UNL	15			86	77	73	65	19	13
12	7	250	12			85	74	69	59	26	8	5	UNL	7			88	77	73	61	12	11	6	UNL	15			94	78	72	49	25	10
15	8	100	12			88	76	70	55	18	4	3	UNL	10			91	76	70	50	10	7	4	UNL	15			96	78	71	45	21	14
18	8	UNL	12			88	75	69	53	10	6	2	UNL	10			90	78	73	58	09	9	0	UNL	15			97	78	70	42	22	10
21	7	UNL	12			82	73	69	65	12	5	1	UNL	15			83	75	72	70	09	6	0	UNL	15			91	75	68	47	19	9
24	2	UNL	15			79	73	70	74	12	6	6	UNL	15			81	74	71	72	15	7	0	UNL	15			86	74	69	57	18	8
	JUL 31st																																
03	0	UNL	15			82	71	66	59	18	8																						
06	0	UNL	15			80	70	65	50	17	5																						
09	0	UNL	15			86	74	68	55	22	8																						
12	0	UNL	15			95	78	71	46	21	12																						
15	0	UNL	15			98	77	68	38	21	10																						
18	0	UNL	15			97	77	69	40	21	9																						
21	1	UNL	15			91	76	70	50	18	8																						
24	0	UNL	15			87	74	68	53	21	9																						

WEATHER CODES

*	TORNADO	ZL	FREEZING DRIZZLE	IPW	ICE PELLET SHOWERS	BN	BLOWING SAND
T	THUNDERSTORM	S	SNOW	A	HAIL	BS	BLOWING SNOW
Q	SQUALL	SW	SNOW SHOWERS	F	FOG	BY	BLOWING SPRAY
R	RAIN	SG	SNOW GRAINS	IF	ICE FOG	K	SMOKE
RW	RAIN SHOWERS	SP	SNOW PELLETS	GF	GROUND FOG	H	HAZE
ZR	FREEZING RAIN	IC	ICE CRYSTALS	BD	BLOWING DUST	D	DUST
L	DRIZZLE	IP	ICE PELLETS				

CEILING: UNL INDICATES UNLIMITED

WIND DIRECTION: DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. AN ENTRY OF 00 INDICATES CALM

SPEED: THE OBSERVED AVERAGE ONE-MINUTE VALUE, EXPRESSED IN KNOTS (MPH=KNOTS X 1.151).

APPENDIX J. FIELD FLUX DATA - MEASURED VERSUS THEORETICAL

FIELD SITE WBTA

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.17	1.03E-02	1.74E-02	1.57E-02	3.53E-02	5.47E-04	9.70E-04	ND	1.29E-03	2.49E-03	6.93E-03	7.82E-04	1.92E-03	3.42E-06	1.27E-03
0.42	1.65E-02	1.11E-02	2.58E-02	2.25E-02	8.52E-04	6.17E-04	4.57E-05	8.19E-04	4.28E-03	4.41E-03	1.27E-03	1.22E-03	8.95E-06	8.05E-04
1.60	1.14E-02	5.06E-03	1.00E-02	1.01E-02	1.87E-03	2.74E-04	9.30E-06	3.64E-04	2.48E-03	1.96E-03	4.87E-04	5.40E-04	2.15E-06	3.40E-04
4.03	4.08E-03	2.84E-03	4.85E-03	5.61E-03	8.53E-04	1.50E-04	1.58E-04	1.98E-04	9.26E-04	1.07E-03	1.97E-04	2.94E-04	4.95E-05	1.76E-04
5.32	1.84E-03	1.76E-03	2.07E-03	3.46E-03	1.24E-04	9.17E-05	5.63E-05	1.21E-04	4.22E-04	6.53E-04	1.04E-04	1.79E-04	1.82E-05	1.05E-04
21.49	5.29E-04	9.90E-04	1.53E-03	1.96E-03	4.96E-04	5.30E-05	5.91E-05	7.00E-05	4.12E-04	3.80E-04	8.91E-05	1.00E-04	1.79E-06	6.40E-05
slope=	0.0049	0.0076	0.0081	0.0156	0.0026	0.0004	0.0003	0.0006	0.0013	0.0031	0.0004	0.0009	0.0001	0.0006
r^2=	0.7685	0.9974	0.9653	0.9973	0.6918	0.9971	0.4242	0.9971	0.8624	0.9970	0.9678	0.9972	0.7852	0.9962

FIELD SITE WBTB

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.02	2.00E-02	5.40E-02	2.18E-02	1.11E-01	9.67E-04	3.06E-03	2.71E-05	4.06E-03	2.42E-03	2.19E-02	7.98E-04	6.07E-03	2.70E-06	4.12E-03
0.26	1.79E-02	1.46E-02	2.44E-02	3.00E-02	1.41E-03	8.37E-04	8.13E-05	1.11E-03	3.30E-03	5.99E-03	1.14E-03	1.67E-03	5.00E-06	1.16E-03
1.27	6.78E-03	5.59E-03	1.01E-02	1.13E-02	1.48E-03	3.09E-04	4.26E-05	4.10E-04	3.30E-03	2.21E-03	4.07E-04	6.11E-04	1.06E-05	3.98E-04
3.93	3.67E-03	2.59E-03	3.07E-03	5.10E-03	5.09E-04	1.36E-04	9.61E-05	1.80E-04	5.42E-04	9.70E-04	1.36E-04	2.67E-04	2.07E-05	1.60E-04
5.17	2.12E-03	1.60E-03	1.48E-03	3.13E-03	2.35E-04	8.30E-05	5.71E-05	1.10E-04	3.56E-04	5.91E-04	5.50E-05	1.62E-04	7.96E-06	9.46E-05
21.73	1.32E-03	1.01E-03	4.84E-03	2.04E-03	1.01E-03	5.60E-05	1.68E-05	7.40E-05	1.03E-03	4.00E-04	2.07E-04	1.10E-04	1.43E-05	7.10E-05
slope=	0.0098	0.0078	0.0130	0.0161	0.0005	0.0004	0.0000	0.0006	0.0017	0.0032	0.0006	0.0009	-5.6E-06	0.0006
r^2=	0.9932	0.9995	0.9305	0.9995	0.3791	0.9993	0.201	0.9993	0.6195	0.9993	0.9327	0.9992	0.4051	0.9987

FIELD SITE WBTC

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.02	1.49E-05	4.65E-02	2.41E-05	9.51E-02	1.56E-05	2.63E-03	1.30E-05	3.50E-03	5.20E-05	1.88E-02	2.27E-05	5.22E-03	1.00E-07	3.55E-03
0.25	7.10E-04	1.41E-02	2.20E-04	2.93E-02	4.60E-06	8.27E-04	7.40E-06	1.10E-03	3.50E-05	5.93E-03	1.35E-05	1.65E-03	1.30E-06	1.19E-03
1.22	1.80E-05	5.85E-03	1.18E-05	1.21E-02	2.15E-06	3.37E-04	5.96E-06	4.47E-04	2.71E-05	2.41E-03	9.83E-06	6.70E-04	2.50E-06	4.68E-04
5.55	3.28E-03	6.50E-03	2.91E-03	1.30E-02	6.25E-04	3.50E-04	1.22E-04	4.63E-04	6.96E-04	2.49E-03	1.57E-04	6.88E-04	2.43E-05	4.27E-04
6.82	1.65E-03	1.91E-03	1.90E-03	3.77E-03	4.97E-04	1.01E-04	7.37E-05	1.33E-04	5.12E-04	7.18E-04	1.08E-04	1.98E-04	2.40E-05	1.19E-04
26.00	1.44E-03	1.45E-03	1.77E-03	3.01E-03	6.80E-04	8.40E-05	1.15E-04	1.10E-04	6.89E-04	6.00E-04	1.52E-04	1.70E-04	2.43E-05	1.20E-04
slope=	0.0042	0.0065	0.0056	0.0132	-0.0004	0.0004	-0.0001	0.0005	-0.0004	0.0026	-0.0001	0.0007	-0.000014	0.0005
r^2=	0.2896	0.9920	0.2591	0.9924	0.6980	0.9927	0.6342	0.9928	0.6771	0.9928	0.6530	0.9929	0.7357	0.9927

(continued)

APPENDIX J. (continued)

FIELD SITE WBTD

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.02	7.50E-03	5.19E-02	1.13E-03	1.06E-01	5.07E-04	2.95E-03	2.53E-04	3.92E-03	1.32E-03	2.11E-02	6.42E-04	5.86E-03	1.47E-05	4.01E-03
0.30	1.69E-02	1.31E-02	2.50E-02	2.70E-02	1.03E-03	7.55E-04	1.26E-04	1.00E-03	4.29E-03	5.40E-03	1.51E-03	1.50E-03	3.15E-05	1.06E-03
1.15	1.35E-02	6.32E-03	2.98E-02	1.30E-02	1.36E-03	3.60E-04	1.04E-03	4.78E-04	4.70E-03	2.58E-03	1.05E-03	7.16E-04	3.31E-05	4.92E-04
5.77	3.32E-03	2.17E-03	3.13E-03	4.31E-03	5.43E-04	1.16E-04	1.31E-04	1.54E-04	6.31E-04	8.27E-04	1.50E-04	2.28E-04	2.33E-05	1.41E-04
7.03	2.40E-03	2.10E-03	2.67E-03	4.15E-03	4.62E-04	1.11E-04	1.30E-04	1.47E-04	5.08E-04	7.93E-04	1.31E-04	2.18E-04	1.07E-05	1.32E-04
26.23	1.63E-03	1.11E-03	2.51E-03	2.21E-03	8.88E-04	5.90E-05	1.32E-04	7.90E-05	8.45E-04	4.20E-04	1.88E-04	1.20E-04	4.45E-05	7.10E-05
slope=	0.0102	0.0074	0.0165	0.0152	0.0003	0.0004	0.0001	0.0006	0.0026	0.0030	0.0009	0.0008	2.00E-06	0.0006
r^2=	0.8917	0.9999	0.6474	0.9998	0.2792	0.9998	0.0223	0.9998	0.6838	0.9998	0.9188	0.9998	0.0115	0.9994

FIELD SITE WBTE

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.02	1.79E-02	4.20E-02	1.19E-02	8.64E-02	8.58E-04	2.40E-03	ND	3.19E-03	3.04E-03	1.72E-02	9.49E-04	4.78E-03	7.28E-07	3.30E-03
0.12	1.49E-02	1.46E-02	1.47E-02	2.98E-02	9.17E-04	8.22E-04	4.85E-05	1.09E-03	5.08E-03	5.88E-03	1.23E-03	1.63E-03	1.19E-04	1.09E-03
1.05	1.57E-02	5.17E-03	2.61E-02	1.06E-02	2.10E-03	2.94E-04	8.95E-04	3.90E-04	3.90E-03	2.10E-03	1.08E-03	5.84E-04	1.17E-05	4.00E-04
5.57	3.55E-03	1.70E-03	3.03E-03	3.38E-03	5.66E-04	9.07E-05	1.42E-04	1.20E-04	6.94E-04	6.46E-04	1.66E-04	1.78E-04	1.59E-05	1.09E-04
6.15	1.06E-03	1.71E-03	1.63E-03	3.38E-03	3.99E-04	9.01E-05	8.60E-05	1.19E-04	3.64E-04	6.42E-04	9.91E-05	1.77E-04	1.38E-05	1.05E-04
25.68	1.61E-03	9.50E-04	3.58E-03	1.91E-03	1.02E-03	5.20E-05	9.59E-05	6.80E-05	9.65E-04	3.70E-04	1.76E-04	1.00E-04	1.55E-05	6.40E-05
slope=	0.0050	0.0060	0.0046	0.0123	0.0001	0.0003	0.0000	0.0005	0.0017	0.0024	0.0004	0.0007	4.00E-05	0.0005
r^2=	0.5789	0.9969	0.2373	0.9966	0.0194	0.9963	0.0049	0.9963	0.7766	0.9963	0.7038	0.9962	0.9152	0.9949

FIELD SITE WBTF

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.02	4.92E-03	4.04E-02	5.88E-03	8.22E-02	2.95E-04	2.27E-03	2.40E-04	3.01E-03	8.15E-04	1.62E-02	3.00E-04	4.49E-03	4.97E-05	3.00E-03
2.25	1.32E-02	3.36E-03	2.23E-02	6.81E-03	1.07E-03	1.87E-04	9.81E-05	2.48E-04	2.49E-03	1.34E-03	1.11E-03	3.70E-04	1.14E-05	2.44E-04
3.12	8.10E-03	2.83E-03	1.19E-02	5.74E-03	1.36E-03	1.57E-04	7.88E-05	2.09E-04	1.96E-03	1.13E-03	5.31E-04	3.11E-04	3.72E-05	2.05E-04
6.52	2.47E-03	1.51E-03	2.50E-03	2.97E-03	2.27E-04	7.90E-05	8.91E-05	1.05E-04	3.93E-04	5.62E-04	1.09E-04	1.55E-04	2.45E-05	9.13E-05
7.96	9.54E-04	1.45E-03	9.79E-04	2.84E-03	1.09E-04	7.51E-05	3.00E-05	9.93E-05	2.05E-04	5.34E-04	5.07E-05	1.47E-04	1.10E-05	8.48E-05
24.07	1.35E-03	1.14E-03	1.67E-03	2.31E-03	6.44E-04	6.30E-05	5.63E-05	8.40E-05	4.71E-04	4.50E-04	1.01E-04	1.30E-04	1.32E-05	8.20E-05
slope=	0.0270	0.0058	0.0459	0.0118	0.0019	0.0003	0.0001	0.0004	0.0051	0.0003	0.0022	0.0004	1.80E-05	0.0023
r^2=	0.8590	0.9998	0.8248	0.9997	0.4222	0.9997	0.4365	0.9997	0.8048	0.9997	0.7865	0.9997	0.0820	0.9997

(continued)

FIELD SITE: WATA

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.01	1.22E-03	8.97E-03	3.02E-03	2.31E-02	1.03E-03	7.41E-04	9.86E-05	1.05E-03	7.64E-04	5.68E-03	1.72E-04	1.64E-03	4.52E-06	1.28E-03
0.18	8.78E-04	2.15E-03	2.97E-03	5.58E-03	8.96E-04	1.79E-04	4.91E-05	2.54E-04	6.05E-04	1.37E-03	1.31E-04	3.97E-04	5.08E-06	3.12E-04
6.02	1.16E-04	3.39E-04	1.15E-04	8.67E-04	4.29E-05	2.75E-05	2.40E-06	3.89E-05	6.11E-05	2.11E-04	6.70E-06	6.08E-05	1.13E-06	4.58E-05
21.33	1.05E-04	2.38E-04	4.59E-05	6.17E-04	9.45E-05	1.98E-05	1.37E-05	2.81E-05	1.34E-04	1.52E-04	2.52E-05	4.40E-05	1.07E-05	3.46E-05
21.58	7.32E-05	2.47E-04	2.24E-05	6.42E-04	6.43E-05	2.07E-05	7.53E-06	2.94E-05	9.45E-05	1.59E-04	1.89E-05	4.60E-05	5.01E-06	2.70E-05
44.43	ND	1.90E-04	3.47E-06	4.80E-04	1.07E-05	1.60E-05	2.71E-07	2.20E-05	1.79E-05	1.20E-04	2.72E-06	3.40E-05	1.57E-06	2.70E-05
105.10	ND	1.60E-04	ND	4.10E-04	ND	1.30E-05	1.86E-07	1.90E-05	4.37E-06	1.00E-04	9.57E-07	2.90E-05	9.23E-07	2.30E-05
129.15	ND	1.69E-04	ND	4.40E-04	4.33E-07	1.42E-05	ND	2.01E-05	1.53E-06	1.09E-04	3.02E-07	3.15E-05	1.09E-07	2.52E-05
slope=	0.0004	0.0009	0.0014	0.0023	0.0004	0.0001	2.05E-05	0.0001	0.0003	0.0006	0.0001	0.0002	9.31E-07	0.0001
r^2=	0.996	0.9999	0.9951	0.9999	0.9853	0.9999	0.9199	0.9999	0.9607	0.9999	0.9599	0.9999	0.0420	0.9998

FIELD SITE: WATB

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.01	2.51E-03	6.01E-03	6.12E-03	1.77E-02	8.01E-04	6.09E-04	1.32E-07	8.84E-04	1.52E-03	4.80E-03	1.99E-04	1.41E-03	1.05E-05	1.18E-03
0.24	3.43E-03	1.26E-03	7.88E-03	3.72E-03	1.46E-03	1.28E-04	ND	1.86E-04	3.96E-03	1.01E-03	3.84E-05	2.96E-04	1.80E-05	2.51E-04
5.94	1.93E-04	2.27E-04	1.62E-04	6.63E-04	5.54E-05	2.25E-05	9.33E-06	3.26E-05	1.10E-04	1.77E-04	2.18E-05	5.19E-05	3.19E-06	4.20E-05
21.34	1.39E-04	1.42E-04	7.16E-05	4.20E-04	2.18E-04	1.44E-05	1.94E-05	2.10E-05	2.31E-04	1.14E-04	5.10E-05	3.34E-05	6.53E-06	2.83E-05
21.57	1.09E-04	1.47E-04	3.05E-05	4.35E-04	1.11E-04	1.50E-05	1.36E-05	2.18E-05	1.46E-04	1.19E-04	3.00E-05	3.48E-05	5.47E-06	2.99E-05
44.62	8.32E-06	1.00E-04	ND	3.00E-04	3.24E-05	1.00E-05	3.24E-06	1.50E-05	4.05E-05	8.20E-05	7.95E-06	2.40E-05	2.40E-06	2.00E-05
105.52	8.66E-06	8.40E-05	7.56E-06	2.50E-04	2.81E-06	8.60E-06	1.64E-06	1.20E-05	1.39E-05	6.80E-05	2.11E-06	2.00E-05	1.11E-06	1.70E-05
128.85	8.81E-06	7.99E-05	2.92E-06	2.37E-04	2.11E-06	8.14E-06	ND	1.18E-05	1.37E-05	6.42E-05	2.00E-06	1.89E-05	3.29E-06	1.60E-05
slope=	0.0018	0.0006	0.0042	0.0018	0.0007	0.0001	2.34E-05	0.0001	0.0021	0.0005	1.20E-05	0.0001	7.70E-06	0.0001
r^2=	0.9895	0.9999	0.9816	0.9999	0.9710	0.9999	0.1430	0.9999	0.9820	0.9999	0.1994	0.9999	0.9038	0.9999

FIELD SITE: WATC

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.01	8.81E-04	1.46E-02	1.15E-03	3.43E-02	4.75E-04	1.05E-03	8.03E-05	1.46E-03	4.22E-04	7.91E-03	1.37E-04	2.27E-03	1.03E-05	1.74E-03
0.18	9.49E-04	3.44E-03	1.33E-03	8.08E-03	5.33E-04	2.47E-04	9.46E-05	3.44E-04	5.26E-04	1.86E-03	1.16E-04	5.33E-04	6.96E-06	1.08E-04
4.60	1.27E-04	5.79E-04	6.21E-05	1.33E-03	1.41E-05	3.99E-05	1.78E-05	5.56E-05	5.05E-05	3.00E-04	2.03E-05	8.56E-05	2.19E-06	6.13E-05
20.90	6.90E-05	3.61E-04	5.45E-05	8.46E-04	7.42E-05	2.58E-05	1.05E-05	3.60E-05	1.15E-04	1.95E-04	2.38E-05	5.58E-05	7.83E-06	4.26E-05
21.06	6.29E-05	3.62E-04	5.64E-05	8.51E-04	6.64E-05	2.60E-05	8.67E-05	3.63E-05	8.81E-05	1.96E-04	2.06E-05	5.61E-05	5.33E-06	4.31E-05
42.61	ND	2.60E-04	ND	6.00E-04	8.28E-06	1.80E-05	8.76E-07	2.50E-05	1.80E-05	1.40E-04	3.47E-06	3.90E-05	1.85E-06	2.90E-05
103.91	ND	2.50E-04	ND	5.90E-04	ND	1.80E-05	8.88E-08	2.50E-05	3.68E-06	1.40E-04	3.82E-07	3.90E-05	4.41E-07	3.00E-05
126.43	ND	1.73E-04	7.50E-06	4.03E-04	4.90E-07	1.22E-05	ND	1.70E-05	3.85E-06	9.19E-05	5.13E-07	2.63E-05	ND	1.95E-05
slope=	0.0004	0.0015	0.0006	0.0034	0.0002	0.0001	3.40E-05	0.0001	0.0002	0.0008	4.90E-05	0.0002	1.61E-06	0.0002
r^2=	0.9978	0.9999	0.9862	0.9998	0.9591	0.9998	0.4579	0.9998	0.9537	0.9998	0.9683	0.9998	0.2208	0.9679

(continued)

APPENDIX J. (continued)

FIELD SITE: WATD

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.01	2.64E-03	1.91E-02	8.76E-03	4.32E-02	1.39E-03	1.29E-03	ND	1.77E-03	3.91E-03	9.58E-03	4.35E-04	2.72E-03	1.72E-06	2.00E-03
0.13	3.61E-03	5.30E-03	9.33E-03	1.20E-02	1.85E-03	3.57E-04	ND	4.93E-04	4.24E-03	2.67E-03	4.88E-04	7.57E-04	1.15E-06	5.56E-04
5.35	5.00E-04	7.02E-04	3.40E-04	1.56E-03	8.18E-05	4.55E-05	8.20E-06	6.27E-05	1.09E-04	3.39E-04	2.32E-05	9.58E-05	3.44E-06	6.57E-05
20.35	2.31E-04	4.37E-04	8.15E-05	9.87E-04	8.33E-05	2.93E-05	4.29E-06	4.04E-05	1.12E-04	2.18E-04	1.77E-05	6.19E-05	3.70E-06	4.49E-05
20.55	2.49E-04	4.43E-04	2.69E-04	1.00E-03	1.29E-04	2.97E-05	1.04E-05	4.10E-05	1.66E-04	2.22E-04	2.99E-05	6.30E-05	2.83E-06	4.60E-05
44.88	1.22E-05	3.20E-04	1.35E-06	7.10E-04	1.66E-05	2.10E-05	2.21E-06	2.90E-05	2.54E-05	1.60E-04	5.56E-06	4.50E-05	1.52E-06	3.20E-05
104.43	2.48E-07	2.90E-04	2.90E-06	6.50E-04	5.43E-07	1.90E-05	8.25E-08	2.70E-05	4.18E-06	1.50E-04	4.26E-07	4.10E-05	5.13E-07	3.00E-05
126.39	1.35E-04	2.43E-04	2.99E-05	5.49E-04	2.64E-07	1.63E-05	7.23E-07	2.25E-05	1.08E-05	1.21E-04	3.80E-06	3.45E-05	5.00E-07	2.50E-05
slope=	0.0013	0.0019	0.0035	0.0043	0.0007	0.0001	2.45E-05	0.0002	0.0016	0.0010	0.0002	0.0003	2.31E-07	0.0002
r^2=	0.9976	0.9999	0.9925	0.9999	0.9919	0.9999	0.5513	0.9999	0.9905	0.9999	0.9928	0.9999	0.0278	0.9998

FIELD SITE: WATE

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.01	1.95E-03	9.50E-03	3.06E-03	2.27E-02	9.11E-04	6.99E-04	1.26E-04	9.76E-04	8.86E-04	5.28E-03	1.57E-04	1.51E-03	3.24E-06	1.16E-03
0.07	3.93E-03	3.60E-03	8.26E-03	8.60E-03	2.35E-03	2.65E-04	2.06E-04	3.70E-04	1.19E-03	2.00E-03	2.70E-04	5.74E-04	9.43E-07	4.39E-04
5.04	2.12E-04	3.61E-04	2.19E-04	8.46E-04	1.36E-05	2.56E-05	9.37E-06	3.57E-05	9.72E-05	1.93E-04	1.76E-05	5.50E-05	3.11E-06	3.93E-05
20.12	1.85E-04	2.35E-04	4.06E-05	5.58E-04	9.92E-05	1.71E-05	1.17E-05	2.39E-05	1.34E-04	1.29E-04	2.46E-05	3.70E-05	6.85E-06	2.78E-05
20.37	1.56E-04	2.38E-04	8.66E-05	5.67E-04	9.30E-05	1.74E-05	2.46E-05	2.43E-05	1.24E-04	1.32E-04	3.50E-05	3.77E-05	7.08E-06	2.85E-05
42.92	2.65E-06	1.80E-04	9.75E-06	4.30E-04	1.79E-05	1.30E-05	5.42E-07	1.80E-05	2.18E-05	9.80E-05	3.03E-06	2.80E-05	1.35E-06	2.10E-05
104.79	ND	1.80E-04	ND	4.40E-04	ND	1.40E-05	ND	1.90E-05	9.91E-06	1.00E-04	1.05E-06	3.00E-05	8.14E-07	2.30E-05
125.95	ND	1.69E-04	ND	4.01E-04	ND	1.22E-05	1.57E-07	1.71E-05	3.12E-06	9.24E-05	5.42E-07	2.64E-05	2.93E-07	1.96E-05
slope=	0.0011	0.0009	0.0017	0.0023	0.0006	..0001	0.0001	0.0001	0.0003	0.0005	0.0001	0.0002	-5.9E-07	0.0001
r^2=	0.9976	0.9998	0.9982	0.9998	0.9915	0.9998	0.9872	0.9998	0.9904	0.9998	0.9866	0.9998	0.0705	0.9997

FIELD SITE: WATF

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.01	2.73E-03	1.40E-02	6.98E-03	3.21E-02	9.57E-04	9.63E-04	9.53E-06	1.33E-03	1.22E-03	7.21E-03	1.47E-04	2.05E-03	1.48E-05	1.49E-03
0.18	2.79E-03	3.44E-03	5.19E-03	7.95E-03	2.35E-03	2.40E-04	4.34E-05	3.32E-04	7.07E-04	1.79E-03	1.39E-04	5.11E-04	8.65E-06	3.77E-04
6.35	1.80E-04	4.70E-04	1.06E-03	1.06E-03	ND	3.12E-05	2.40E-07	4.31E-05	3.68E-05	2.33E-04	7.64E-06	6.59E-05	2.09E-06	4.45E-05
21.43	8.84E-05	3.86E-04	4.31E-05	8.97E-04	4.87E-05	2.71E-05	2.00E-06	3.76E-05	6.55E-05	2.03E-04	1.17E-05	5.79E-05	2.38E-06	4.33E-05
21.71	1.09E-04	5.90E-04	6.54E-05	1.38E-03	2.32E-05	4.20E-05	4.82E-06	5.82E-05	6.33E-05	3.15E-04	1.36E-05	8.98E-05	2.94E-06	6.87E-05
45.32	ND	2.80E-04	ND	6.50E-04	1.62E-06	2.00E-05	8.59E-08	2.70E-05	4.11E-06	1.50E-04	5.91E-07	4.20E-05	1.39E-06	3.00E-05
107.23	3.28E-06	3.10E-04	ND	7.10E-04	ND	2.20E-05	8.84E-08	3.00E-05	4.88E-07	1.60E-04	ND	4.60E-05	1.87E-06	3.50E-05
127.92	1.25E-06	3.31E-04	1.43E-07	7.76E-04	ND	2.37E-05	8.90E-08	3.28E-05	1.64E-07	1.78E-04	7.65E-08	5.07E-07	1.88E-06	3.92E-05
slope=	0.0013	0.0014	0.0023	0.0032	0.0011	0.0001	0.0000194	0.0001	0.0003	0.0007	0.0001	0.0002	3.00E-06	0.0001
r^2=	0.9940	0.9995	0.9832	0.9994	0.9966	0.9993	0.9824	0.9993	0.9901	0.9993	0.9910	0.9990	0.9740	0.9990

(continued)

APPENDIX J. (continued)

FIELD SITE WSTA

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
1.92	1.44E-04	4.29E-04	9.21E-05	1.88E-03	BDL	8.15E-05	1.34E-05	1.27E-04	1.35E-04	6.98E-04	2.46E-05	2.17E-04	1.80E-06	2.57E-04
45.60	4.84E-05	7.76E-05	8.68E-07	3.37E-04	BDL	1.46E-05	ND	2.27E-05	1.14E-05	1.24E-04	1.52E-06	3.86E-05	BDL	4.48E-05

FIELD SITE WSTB

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.40	1.30E-04	5.08E-04	9.94E-05	2.35E-03	8.58E-05	1.05E-04	2.05E-05	1.68E-04	2.02E-04	9.18E-04	3.14E-05	2.88E-04	BDL	3.45E-04
46.97	2.85E-05	4.53E-05	5.26E-06	2.09E-04	3.94E-07	9.38E-06	3.99E-07	1.49E-05	1.42E-05	8.17E-05	2.68E-06	2.56E-05	BDL	3.07E-05

FIELD SITE WSTC

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.38	2.79E-04	1.80E-03	3.57E-04	5.41E-03	BDL	1.95E-04	2.90E-05	2.89E-04	2.31E-04	1.58E-03	4.43E-05	4.72E-04	ND	4.61E-04
46.37	2.24E-05	1.68E-04	7.14E-06	5.02E-04	BDL	1.81E-05	5.15E-07	2.68E-05	9.25E-06	1.46E-04	1.92E-06	4.36E-05	1.92E-06	4.20E-05

FIELD SITE WSTD

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.68	2.97E-04	2.16E-03	2.25E-04	6.05E-03	5.94E-07	2.09E-04	1.45E-05	3.04E-04	1.56E-04	1.65E-03	3.12E-05	4.89E-04	9.97E-07	4.49E-04
45.80	ND	2.50E-04	1.40E-07	6.96E-04	ND	2.38E-05	2.63E-07	3.47E-05	3.96E-06	1.89E-04	9.81E-07	5.57E-05	BDL	5.00E-05

FIELD SITE WSTE

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
0.80	1.32E-04	1.11E-03	5.76E-05	3.45E-03	3.24E-07	1.27E-04	4.87E -6	1.90E-04	7.04E-05	1.03E-03	1.39E-05	3.11E-04	BDL	3.13E-04
45.32	3.92E-06	1.31E-04	5.32E-07	4.03E-04	ND	1.46E-05	8.93E-08	2.18E-05	9.05E-07	1.19E-04	3.07E-07	3.55E-05	BDL	3.38E-05

FIELD SITE WSTF

FLUX COMPARISON (ug/cm^2/sec)

TIME	BENZENE FLUX		TOLUENE FLUX		ETHLYBENZENE FLUX		P-XYLENE FLUX		M-XYLENE FLUX		O-XYLENE FLUX		NAPTHALENE FLUX	
(HRS)	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.	MEASURE	THEOR.
1.22	3.32E-04	4.31E-04	1.95E-04	1.92E-03	3.65E-07	8.13E-05	6.41E-06	1.26E-04	7.92E-05	6.90E-04	1.65E-05	2.13E-04	BDL	2.31E-04
44.62	1.84E-05	6.84E-05	1.57E-06	3.01E-04	ND	1.26E-05	8.93E-08	1.95E-05	9.05E-07	1.06E-04	3.07E-07	3.27E-05	BDL	3.38E-05

APPENDIX K. FIELD FLUX DATA-BACKGROUND BEFORE WASTE APPLICATION

Mean Flux (ug/cm^2-sec)

Sample	Benzene	Toluene	Ethylbenzene	p-Xylene	m-Xylene	o-Xylene	Napthalene
BBT1A	1.07E-05	2.87E-06	3.95E-07	0.00E+00	3.01E-06	4.59E-06	0.00E+00
BBT1B	2.01E-05	6.87E-06	0.00E+00	0.00E+00	2.40E-07	0.00E+00	0.00E+00
BBT1C	1.03E-05	1.31E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BBT1D	0.00E+00	5.60E-07	3.46E-07	2.10E-07	3.87E-07	1.21E-07	0.00E+00
BBT1E	0.00E+00	2.30E-06	3.28E-07	5.59E-07	8.09E-07	1.37E-07	0.00E+00
BBT1F	9.03E-05	3.36E-05	3.47E-07	7.91E-06	1.31E-06	2.27E-07	0.00E+00
BAT1A	8.26E-04	2.98E-04	1.58E-06	9.62E-07	1.31E-05	4.55E-06	0.00E+00
BAT1B	0.00E+00	1.10E-04	2.51E-06	0.00E+00	0.00E+00	3.36E-07	0.00E+00
BAT1C	5.58E-05	1.36E-04	1.42E-07	2.30E-07	8.68E-06	1.98E-06	0.00E+00
BAT1D	0.00E+00	0.00E+00	2.30E-07	1.40E-07	2.13E-06	2.47E-06	0.00E+00
BAT1E	0.00E+00	0.00E+00	1.88E-07	5.70E-07	0.00E+00	0.00E+00	1.80E-05
BAT1F	1.20E-04	2.76E-05	1.17E-07	0.00E+00	5.91E-07	2.45E-07	0.00E+00
BAT2A	1.84E-06	0.00E+00	0.00E+00	0.00E+00	2.25E-07	3.16E-07	0.00E+00
BAT2B	4.58E-06	7.77E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BAT2C	1.38E-05	5.35E-06	0.00E+00	1.12E-07	5.14E-08	4.32E-07	0.00E+00
BAT2D	4.46E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
BAT2E	7.26E-07	2.67E-07	0.00E+00	0.00E+00	0.00E+00	2.88E-07	0.00E+00
BAT2F	1.26E-06	1.26E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

APPENDIX L. Theoretical Flux Calculation Example

EXAMPLE. Field benzene flux calculation using site specific data and temperature corrections.

Given data:

site properties, as measured at Field Site B 15.6 minutes after surface waste application:

temperature at 2 cm soil depth (T) = 48 °C
soil bulk density (bd) = 1.04 g/ cm^3
soil moisture content = 22.96%
application area (A) = 4560 cm^2
waste loading (L) = 1.0945 g/ cm^2
waste penetration depth (h_p) = 5 cm
soil effective particle size (d) = 0.023 cm
soil particle density (ρ_d) = 2.65 g/cm^3

compound/waste properties for benzene:

molecular weight (MW) = 78.12 g/mole
solubility @ 20° C (S) = .0218 moles/liter
molar volumn (V_B) = 96 cm^3/g-mole
vapor pressure @ 20° C (P) = 0.114 atm
boiling point (Tb) = 353.2° K
diffusivity @ 20° C (D_{Ai}) = 0.0821 cm^2/sec
waste benzene concentration (C_{io}) = 249.2 µg/g waste
waste density (ρ_o) = 0.9806 g/cm^3

Step 1. Correct P, viscosity (η_s), diffusivity (D_{Ai} and D_A), and Henry's law constant (H_C and H_C') for temperature.

P.

Using Equation 26,

$$\frac{\Delta Hvb}{Tb} = Kf \cdot (8.75 + R \cdot \ln Tb) \qquad (26)$$

$$\frac{\Delta Hvb}{Tb} = 1 \cdot (8.75 + 1.987 \cdot \ln(353.2))$$

$$= 20.41 \text{ cal/mole} \cdot {}^{\circ}K$$

and from Equation 27,

$$\ln P = \frac{\Delta Hvb \cdot (Tb - C_2)^2}{\Delta Zb \cdot R \cdot Tb^2}\left[\frac{1}{(Tb - C_2)} - \frac{1}{(T - C_2)}\right] \qquad (27)$$

$$C_2 = -18 + 0.19 \cdot 353.2 = 49.11$$

$$\ln P = \frac{20.41 \cdot (353.2 - 49.11)^2}{0.97 \cdot 1.987 \cdot 353.2} \cdot \left[\frac{1}{(353.2 - 49.11)} - \frac{1}{((48 + 273.2) - 49.11)} \right]$$

$\ln P = -1.07214$

$P = 0.3423$ atm

η_S.

From Equation 25,

$$\log \eta_S = -2.32417 + 758.56/(T - 0.4148 \cdot T + 196.8806) \quad (25)$$

$$\log \eta_S = -2.32417 + 758.56/(48 - 0.4148 \cdot 48 + 196.8806)$$

$\eta_S = 11.16$ cP

D_{Ai} and D_A.

From Equation 28,

$$D_{T2} = D_{T1} \cdot \frac{(T2)^{3/2}}{(T1)^{3/2}} \quad (28)$$

$$D_{Ai} \text{ @ } 48^\circ \text{ C} = \frac{0.0821 \cdot (321.2)^{3/2}}{(293.2)^{3/2}} = 0.0941 \text{ cm}^2/\text{sec}$$

and from Equation 20,

$$D_A = D_{Ai} \cdot (S_a^{10/3})/S_t^2 \quad (20)$$

$$D_A = 0.941 \cdot (S_a^{10/3})/S_t^2$$

where,
$S_t = 1 - bd/2.65 = 0.6075$ and
$S_a = S_t$ - decimal moisture content $= 0.3779$

$D_A = 9.95 \cdot 10^{-3}$ cm^2/sec

H_C and H_C'.

$$H_c = \frac{\text{molar concentration in water}}{\text{molar concentration in air}}$$

$$= \frac{0.342 \text{ atm}}{\frac{0.0821 \text{ atm l/mole} \cdot {}^\circ\text{K} \cdot (48+273.2^\circ\text{K})}{0.0218 \text{ moles/l}}}$$

$H_C = 0.5956$ cm^3 water/cm^3 air

and $H_C' = H_C/K_{sw}$ (23)

where,

$$\log K_{ow} = \frac{\log 1/S + 0.339}{0.996} = 2.009 \quad (22)$$

$$\log K_{sw} = 0.541 \cdot \log K_{ow} + 1.203 = 2.29 \quad (21)$$

$H_C' = 0.5956/(10^{2.29}) = 3.06 \cdot 10^{-3}$ cm^3 oil/ cm^3 air

Step 2. Calculate the oil-layer diffusion length (Zo), the interfacial area (a_s), and the oil diffusion coefficient (D_o). Based on the observed soil and waste characteristics, the film form for Zo and a_s is used.

Zo.

From Equation 14,

$$Zo = \frac{d \cdot \rho_p \cdot f}{6 \cdot \rho_o} \quad (14)$$

$$Zo = \frac{0.023 \cdot 2.65 \cdot 0.3779}{6 \cdot 0.9806} = .00391 \text{ cm}$$

a_s.

and from Equation 16,

$$a_s = 6/d \quad (16)$$

$a_s = 6/0.023 = 260.87$ cm^{-1}

D_o.

Using Equation 24,

$$D_o = \frac{7.4 \cdot 10^{-8} \cdot (\phi \cdot MW)^{1/2} \cdot T}{\eta_s \cdot V_B^{0.6}} \quad (24)$$

$$D_o = \frac{7.4 \cdot 10^{-8} \cdot (1 \cdot 78.12)^{1/2} \cdot (48 + 273.2)}{11.16 \cdot (96)^{0.6}} = 1.22 \cdot 10^{-6} \text{ cm}^2\text{/ sec}$$

Step 3. Calculate the concentration of benzene in the air filled pore spaces (C_A^*) and the benzene flux from the soil surface.

C_A^*.

From Equation 13,

$$C_A^* = \frac{H_{C'}}{1 + H_{C'} \cdot \dfrac{6 \cdot D_A \cdot Zo}{D_o \cdot a_s \cdot (h_p^2 + h_p \cdot h_s - 2 h_s^2)}} \cdot C_{io} \qquad (13)$$

$$C_A^* = \frac{0.00306}{1 + 0.00306 \cdot \dfrac{6 \cdot 0.00995 \cdot 0.00391}{1.22 \cdot 10^{-6} \cdot 260.87 \cdot (5)^2}} \cdot 249.2$$

$$= 0.762 \ \mu g/cm^3$$

Flux.

Using Equation 8,

$$F_A = \frac{D_A \cdot C_A^*}{\left(h_s^2 + \dfrac{2 \cdot D_A \cdot t \cdot A \cdot (h_p - h_s) \cdot C_A^*}{M_A}\right)^{1/2}} \qquad (8)$$

and,

$M_A = C_{io} \cdot L \cdot A = 249.2 \cdot 1.0945 \cdot 4560 = 1243737$ µg benzene

$$F_A = \frac{0.00995 \cdot 0.762}{\left(\dfrac{2 \cdot 0.00995 \cdot 15.6 \cdot 60 \cdot 4560 \cdot 5 \cdot 0.762}{1243737}\right)^{1/2}}$$

Benzene Flux = $1.49 \cdot 10^{-2}$ µg/cm^2/sec