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Attachment 1e

REMEDIAL INVESTIGATION
McKESSON CORPORATION PROPERTY
9005 SORENSEN AVENUE
SANTA FE SPRINGS, CALIFORNIA

HLA Project No. 11136-168

Prepared for

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VOLUME V

APPENDIX

O RISK ASSESSMENT

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BASELINE RISK ASSESSMENT
McKESSON-SANTA FE SPRINGS
9005 Sorensen Avenue
Santa Fe Springs, California

October, 1992

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EXECUTIVE SUMMARY

This baseline health risk assessment evaluates the potential human health risks associated with exposure to chemicals at the McKesson site in Santa Fe Springs, California. The baseline health risk assessment was prepared in a manner consistent with USEPA's Risk Assessment Guidance for Superfund Volume I (USEPA, 1989a) and Guidance for Establishing Target Cleanup Levels for Soils at Hazardous Waste Sites (USEPA, 1988b) and Cal-EPA's (formerly the California Department of Health Services) draft Scientific and Technical Standards for Hazardous Waste Sites (Cal-EPA, 1990). The key elements of this document are summarized below.

Chemicals of Concern

For the purposes of the risk assessment, the former "high activity" areas of the site are segregated into three areas: Area A (the railroad spur), Area B (the solvent storage area) and Area C (corrosive/oxidizer area). Any chemical detected in greater than 5% of the soil samples taken from these areas is considered a soil chemical of concern. This selection criterion yields twelve soil chemicals of concern which are quantitatively evaluated in this assessment. It is known that upgradient contamination has contributed to the presence of chemicals in groundwater at the McKesson site and downgradient from the McKesson site. Since the degree of contribution of on-site vs. off-site activities to the presence of chemicals in groundwater has not yet been assessed, it is not yet possible to establish the site-related health risks associated with groundwater. Nonetheless, health risks associated with groundwater exposure are assessed using existing groundwater concentrations.

Potentially Exposed Populations and Exposure Pathways

Based on a consideration of the current site conditions, potential future uses of the site property, and the known fate and transport characteristics of the chemicals of concern, the following exposure pathways are assessed for a future on-site residential and future on-site occupational exposure scenario: soil ingestion, dermal contact with soil, and vapor inhalation. Site data are used to establish representative soil concentrations for assessing exposure via direct soil contact (soil ingestion and dermal contact) and as input to the vapor emission models. The impacted aquifer at the McKesson site is not currently used as a drinking water source and will likely not be used as such in the foreseeable future due to elevated concentrations of total dissolved solids. Accordingly, on- and off-site incidental residential exposure to groundwater via ingestion and dermal contact (for example, if the aquifer were used as an irrigation source) is assessed to determine the risks associated with groundwater under current conditions. In order to ensure that groundwater related health risks are not under-estimated, the maximum detected chemical concentrations in any on-site or off-site well are used as representative groundwater concentrations. Age-specific exposure estimates (children and adults) are incorporated into the residential and occupational exposure scenarios. Where applicable, suggested regulatory default values of contaminant concentrations and exposure estimates are used to assess uptake in order to approximate a "reasonable maximal scenario." Although off-site populations could theoretically be exposed to site-related chemicals via vapor inhalation this pathway is not quantitatively evaluated because the distance between on-site vapor emission sources and off-site populations is such that significant exposure to site-related vapors is unlikely to occur.

Health Risk Estimates

Soil Exposure Pathways

For the soil pathways of exposure (vapor inhalation, soil ingestion, and dermal contact with soil), the total noncancer hazard indices (including all chemicals) are 1.0 or less for residents and workers. These results suggest that the soil chemicals of concern do not pose a significant noncancer hazard, according to the assumptions used in this assessment. Estimated increased cancer risks are 8×10^{-6} and 2×10^{-5} for the occupational and on-site residential scenarios, respectively. These estimated cancer risks are well within the range of increased cancer risks that have typically been considered "insignificant" for large populations at both the State and Federal levels.

Groundwater Exposure Pathways

For the groundwater pathways of exposure (incidental dermal contact and ingestion), the hazard indices range from 0.1 (dermal contact by adults) to 11.0 (ingestion for children). The estimated increased cancer risks are 3×10^{-3} for incidental groundwater ingestion and 1×10^{-4} for incidental dermal contact. While these estimated risks and hazard indices exceed levels that have typically been considered "acceptable" by regulators, it is not yet known to what degree site-related chemicals contribute to these estimates.

Uncertainty Analysis

The conservatism present in the above estimates is quantitatively evaluated using a Monte Carlo analysis of probability distribution frequencies, rather than "point" default estimates, to describe a reasonable range of values for each exposure parameter. This uncertainty

analysis demonstrates that the health risk estimates derived for the "reasonable maximal scenario" are actually orders of magnitude greater than the health risks posed to a significant fraction of the potentially exposed populations. Hence, the uncertainty analysis quantitatively confirms that there is a large degree of conservatism in the health risk estimates estimated for the "reasonable maximal scenario."

1.0 INTRODUCTION

This health risk assessment has been prepared on behalf of the McKesson Chemical Company (McKesson), a former division of McKesson Corporation. The assessment fulfills the requirements for a baseline risk assessment of McKesson's Santa Fe Springs site as described in Consent Agreement Number 89/90-07 executed on January 9, 1990. The assessment has been prepared in a manner consistent with the California Environmental Protection Agency (Cal-EPA) (formerly the California Department of Health Services) guidance document draft Scientific and Technical Standards for Hazardous Waste Sites (Cal-EPA, 1990), the United States Environmental Protection Agency (USEPA) Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A) Interim Final (USEPA, 1989a), and the USEPA's Guidance for Establishing Target Cleanup Levels for Soils at Hazardous Waste Sites (USEPA, 1988b). The document also incorporates input from Cal-EPA regarding the scope and technical approach of the assessment.

The purpose of this baseline risk assessment is to assess the nature and extent of potential human health risks associated with current conditions and potential future uses of the McKesson site in Santa Fe Springs, California. McKesson operated a bulk chemical repacking facility at the site from 1976 until its closure on November 1, 1986. Solvents, hydrogen peroxide, and corrosive chemicals were stored in both aboveground and underground tanks and piped to packaging areas as needed. Bulk chemicals were transported to and from the facility by rail and by truck. Finished products were generally transported from the facility by truck. At the time of closure, all tanks were emptied. Previous investigations have demonstrated the presence of petroleum hydrocarbons and volatile organic chemicals in site soil and groundwater (HLA, 1990). Currently, the facility

stands dismantled; no aboveground tanks or equipment are on the property, and the pavement and buildings remain intact.

This assessment quantitatively evaluates the potential health impacts associated with human exposure to chemicals measured on- and off-site. Soil and groundwater data collected during the 1990-1991 remedial investigation are used to establish representative contaminant concentrations. Where appropriate, environmental fate and transport models are used to estimate ambient air concentrations of volatile chemicals and potential migration of site-related chemicals from soils to groundwater.

Current USEPA and Cal-EPA guidance suggests that it is appropriate to consider a "reasonable maximal exposure" when assessing the health risks associated with exposure to environmental contaminants. A reasonable maximal exposure (RME), as defined by the agencies, is assessed by using "upperbound" values wherever possible to represent environmental contaminant concentrations and exposure estimates. Specifically, the agencies suggest the use of the 95th percent upper confidence limit of the arithmetic mean of the measured contaminant concentrations and the 90th or 95th percentile value of the reported estimates of contact rate and duration (e.g., soil ingestion rates, breathing rates, etc.). As has been discussed extensively in the literature, the major shortcoming inherent in this approach is that repeated use of upperbound values throughout an exposure assessment is more likely to result in an unrealistic "worst-case" estimate rather than a "reasonable maximum" (Whipple, 1986; Harrington and Maxim, 1984; Maxim, 1989; Paustenbach, 1989; Nichols and Zeckhauser, 1988). As an alternative, several recent papers have suggested that health risk assessments would be much improved if probability distribution frequencies (PDFs) (in addition to the standard RME approach), rather than "point" exposure estimates, were incorporated into the exposure assessment process (Paustenbach, 1990; Finkel, 1990). Instead of single values to represent chemical concentrations and exposure estimates

(thereby deriving a single value as the dose estimate), a range of measured chemical concentrations and reasonable exposure estimates are used to develop a range of chemical doses and their associated probabilities. In this assessment, some of the key exposure pathways are evaluated using PDFs (in addition to the standard RME approach) to provide more reasonable estimates of exposure and to assess the degree of conservatism associated with the use of the default assumptions.

The remainder of this document is organized into the following sections:

Section 2.0 Site Characterization - the history of the site and characterization of soil and groundwater are discussed in this section.

Section 3.0 Identification of Chemicals of Concern - the rationale(s) for selecting the chemicals of concern for soil and groundwater are presented in this section.

Section 4.0 Exposure Assessment - the exposure assumptions and equations used to assess contaminant uptake are presented in this section.

Section 5.0 Environmental Fate and Transport Modeling - the fate and transport methodology used to estimate emissions of volatile contaminants from soil and the resultant ambient air concentrations are discussed in this section.

Section 6.0 Toxicity Assessment - a brief summary of the toxicity of each chemical of concern as well as the toxicity values used to characterize risk is presented in this section.

Section 7.0 Dose Calculations and Health Risk Estimates - the contaminant doses and associated health risks are calculated in this section.

Section 8.0 Risk Characterization - this section interprets the magnitude of the estimated health risks with respect to typically "acceptable" levels and provides a quantitative evaluation of the degree of conservatism in the health risk estimates.

Section 9.0 References.

2.0 SITE CHARACTERIZATION

This section briefly reviews the site settings and conditions that are relevant to risk assessment concerns. The information in this section is excerpted from the Harding Lawson Associates (HLA), Remedial Investigation, McKesson Corporation Property (1992). Additional detailed information concerning the current site conditions may be found in this document.

The former McKesson facility is at 9005 Sorenson Avenue in the city of Santa Fe Springs, Los Angeles County, California (Figure 2-1). The site is fenced and occupies approximately 4.3 acres in an industrialized area. Three homes are approximately one quarter of a mile southwest of the site. The site is bounded on the east by Sorenson Avenue, on the south by Fontaine Trucking Equipment Center, on the west by a small agricultural field, and on the north by an unlined drainage channel and Angeles Chemical Company.

The facility was divided into four areas for the purpose of chemical packaging. Each section is delineated by berms. At the time of closure, all the tanks were emptied. In November 1990, the aboveground storage tanks were dismantled. Three buildings currently remain empty on the property, which include the main building (containing the office, warehouse, and packing and storage area) and two yard offices. The site also contains truck scales, a truck pit, loading platforms, and a drum wash shed. The majority of the site is paved, with the exception of a lawn and planter area near the main office and the bermed solvent aboveground storage tank areas. The site also contains a hazardous waste drum storage area, which is bermed, paved, and covered and has undergone closure under Resource Conservation and Recovery Act (RCRA) regulations.

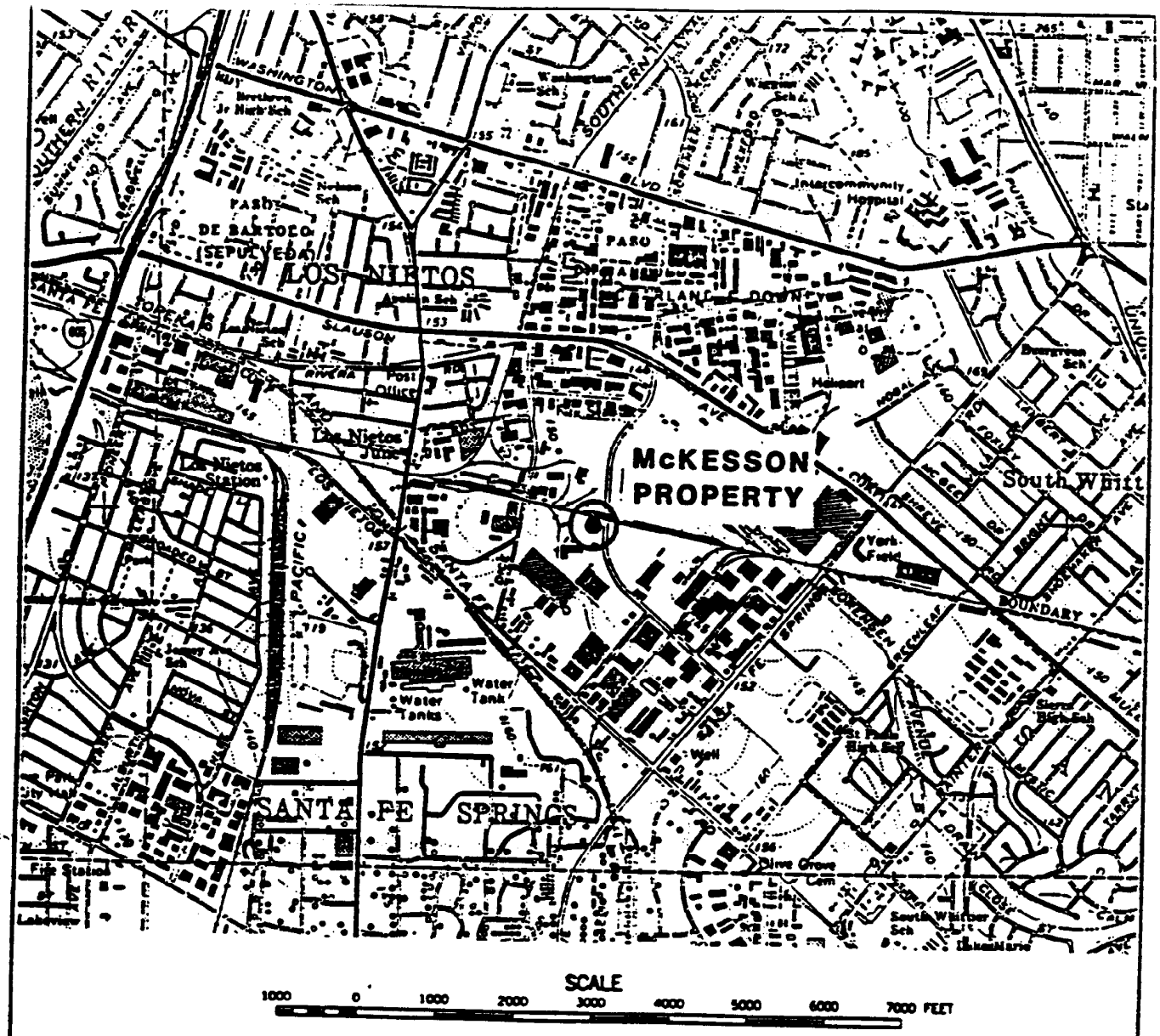

FIGURE 2-1 SITE LOCATION MAP*

-N-

* Taken from HLA Workplan (Rev. 3) RI/FS for McKesson Corporation Property (April, 1990)

Reference: USGS 7.5-minute quadrangle, Whittier, California (photorevised 1981)

GENERAL LOCATION MAP
McKesson Corporation Property
Santa Fe Springs, California

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2.1 Site History

Historic land uses were reviewed by studying available aerial photographs obtained at the Fairchild Aerial Photography Collection, at Whittier College, and from Aerial map Industries, Santa Ana, California. The time period examined was from 1927 to 1974. The site was undeveloped from 1927 until McKesson constructed their facility.

Railroad tracks were visible along the northern property boundary as early as 1927. Activities in the surrounding area included agricultural, primarily to the north, and oil production to the south of the site.

Industrial activities expanded into the general vicinity by 1965. The railroad spur west of the site is visible in 1970.

Beginning in 1976, McKesson utilized the Santa Fe Springs facility for packaging bulk chemicals. The facility ceased operations on November 1, 1986. The property is leased by McKesson from Harvey and Joseph Sorkin, Seymour Moslin, and Paul Moslin.

2.2 Facility Operations

Chemicals were stored in both aboveground and underground tanks and piped to packaging areas as needed. All processes were done by batch in aboveground tanks. Organic solvents, glycol, sulfuric acid, hydrochloric acid, acetic acid, sodium hydroxide, and potassium hydroxide were handled on-site.

2.3 Soil and Groundwater Characterization

The McKesson site is located on the Santa Fe Springs Plain of the Los Angeles Coastal Plain. The Santa Fe Springs Plain generally dips to the northeast in this area. Prominent area features include the Puente and Coyote Hills to the northeast, east, and southeast and the San Gabriel River to the west of the plain. In the vicinity of the site, the Santa Fe Springs Plain consists of Pleistocene alluvium of the Lakewood Formation. The formation unconformably overlies the San Pedro Formation. Local geologic and hydrogeologic investigations have been conducted at the McKesson site and nearby sites. Shallow, near-surface materials underlying the site consist predominantly of silty sand, with minor amounts of silt and clay. Poorly sorted, fine- to coarse-grained sand (locally with gravel) underlie the fine-grained surficial deposits from depths between 15 and 25 to 30 feet bgs. This upper sand zone is interpreted to be the Gage Aquifer which is stratigraphically positioned at the bottom of the Lakewood formation. Groundwater was not encountered in this unit except in the northeast corner of the site for a limited time in the aboveground solvent storage area. Below the upper sand unit a zone of discontinuous silt, clay, and silty sand units are encountered to depths of approximately 45 to 50 feet bgs. Beneath this zone of discontinuous units, a fine- to medium-grained sand is present. This sand unit, referred to as the aquifer sand, is continuous across the site and is approximately 75 feet thick, extending to depths of 126 feet bgs. This aquifer sand is water-bearing, (groundwater being encountered at depths between 48 and 50 feet bgs), and is interpreted as being the Hollydale aquifer, the upper-most aquifer of the San Pedro formation.

2.4 Preliminary Investigations

Preliminary investigations of site soil and groundwater in 1984, 1986, and 1989 were conducted at the request of Cal-EPA. Soil and groundwater sampling locations for these

previous investigations may be found in Figure 4 of the Remedial Investigation. In 1984, McKesson conducted two investigations of the Santa Fe Springs facility. The first investigation involved shallow subsurface sampling in the aboveground solvent storage area to depths ranging from 1 to 6 feet. In addition, one surface water sample was collected from water in the diked storage area. The analytical results, summarized in Table 2-1, indicate that volatile organic chemicals were detected in the soil samples. The surface water sample contained glycols, butyl cellosolve, and ethanols. The second investigation involved subsurface soil samples collected from the corrosive chemicals storage area at approximately 0.5 and 1 foot below ground surface. The samples were analyzed for USEPA Extraction Procedure (EP) Toxic compounds. Analytical results, presented in Table 2-2, demonstrate that EP Toxic compounds were not detected.

In 1986, McKesson conducted another investigation in the aboveground solvent storage area. Soil and groundwater samples from soil borings and groundwater monitoring wells were collected and analyzed for volatile organic chemicals, nonhalogenated volatile organic chemicals, and polynuclear aromatic hydrocarbons. The analytical results, presented in Table 2-3, indicate that volatile organic chemicals and petroleum hydrocarbons were detected in both soil and perched groundwater.

In 1989, Harding Lawson Associates (HLA) conducted an investigation in the vicinity of the hazardous waste drum storage area in which soil samples were collected at approximately 0.5 foot below ground surface. The samples were tested for pH, glycol, volatile organic chemicals, and semivolatile organic chemicals. Analytical results, presented in Table 2-4, indicate that the soil contained relatively low concentrations of tetrachloroethene and trichlorethane underlying the drum storage area.

TABLE 2-1

McKesson Environmental Data
June 1984

Soil

	Concentration (mg/kg)									
Boring No. / Depth (ft)	B-2 / 1	B-2 / 3	B-2 / 6	B-3 / 1	B-3 / 3	B-3 / 6	B-4 / 1	B-4 / 3	B-4 / 6	B-5 / 3
Acetone	50	ND	1.5	0.80	ND	0.24	7.0	ND	ND	0.03
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.001
2-butanone (MEK)	36	ND	ND	ND	ND	2.10	ND	ND	ND	ND
Chloroform	1	ND	0.75	0.80	ND	ND	1.0	ND	ND	ND
1,1-dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.002
1,2-dichloroethane	ND	3.9	ND	ND	0.6	0.02	ND	ND	0.8	0.004
1,1-dichloroethene	ND	6.5	ND	ND	2.5	ND	ND	ND	0.8	0.002
Ethyl benzene	ND	ND	0.06	ND	ND	0.03	ND	ND	0.85	ND
Isopropanol	45	ND	ND	ND	ND	0.2	ND	ND	ND	ND
Methylene chloride	ND	ND	ND	ND	ND	1.1	ND	ND	2.5	0.10
Tetrachloroethene	ND	18	0.89	0.22	70	0.67	ND	1.5	64	0.085
Toluene	0.12	ND	0.1	ND	ND	0.07	ND	ND	2.0	ND
1,1,1-trichloroethane	0.20	200	0.2	ND	60	0.18	ND	0.25	10.0	0.085
1,1,2-trichloroethene	ND	ND	ND	ND	0.93	ND	ND	ND	ND	ND
Trichloroethene	ND	4	0.03	ND	33	0.07	ND	ND	ND	0.008
Xylenes	ND	ND	0.32	ND	ND	0.09	ND	ND	5.8	ND

Notes:
Samples B-2, B-3, and B-4 were collected from Aboveground Solvent Storage area; Sample B-5 was collected from unlined drainage ditch.
mg/kg = milligrams per kilogram
ND = Not detected; available information indicates that detection limits are variable.
Data Source: McKesson Environmental Services (1984a)

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TABLE 2-1
(Continued)

McKesson Environmental Data
June 1984

Surface Water

Chemical	Concentration (ug/ml)
Butyl cellosolve (2-butoxyethanol)	2,700
Hexylene glycol	1,100
Diethylene glycol	11,000
Butyl carbitol (butoxyethoxy ethanol)	9,400
Phenyl cellosolve (2-phenoxyethanol)	2,300
[ethanediyl bis(oxy)]bis-ethanol	23,000
Methyl carbitol acetate (methoxyethoxy ethanol acetate)	110
Phenyl carbitol (phenoxyethoxy ethanol)	1,500

Notes:

Sample collected from aboveground solvent storage area
ug/ml = micrograms per milliliter
Data source: McKesson Environmental Services (1984a)

TABLE 2-2

McKesson Environmental Data
October 1984

Soil

		Concentration (mg/kg)				
	Sample No. / Depth (inches)	1A / 0-6	1B / 12-18	2A / 0-6	2B / 12-18	3A / 0-6
Pesticides						
Y-BHC		(0.26)	(0.26)	(0.26)	(0.26)	(0.26)
Endrin		(0.26)	(0.26)	(0.26)	0.26	(0.26)
2,4-D		(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
2,4,5-TP		(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
Toxaphene		(12)	(12)	(12)	(12)	(12)
Metal						
Arsenic		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Barium		(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Cadmium		(0.02)	(0.02)	(0.02)	(0.02)	(0.5)
Chromium		(0.1)	(0.1)	(0.1)	(0.1)	(0.1)
Lead		(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Mercury		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Selenium		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Silver		(0.05)	(0.05)	(0.05)	(0.05)	(0.05)

Notes:

Samples collected from corrosive storage area
Samples analyzed for EP toxic compounds
mg/kg = milligrams per kilogram
( ) indicates not detected below enclosed detection limit
Data source: McKesson Corporation (1984b)

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TABLE 2-3

McKesson Environmental Data
March 1986

Boring/Well No.	Soil Concentration (mg/kg)						Groundwater Concentration (mg/L)		
	B-1	B-1	B-1	B-2	B-3	MW-2	MW-1	MW-3	MW-4
Depth (ft)	25	30	37	35	36	25			
Acetone	23	200	60	2.7	1.4	5.4	430	23	160
Butyl cellosolve (2-butoxyethanol)	(50)	390	87	(50)	(50)	(50)	130	(0.002)	270
2-(2 butoxyethoxy) ethanol	--	44	--	--	--	--	--	--	--
1,1-dichloroethane	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	2.5	(0.001)	5
1,1-dichloroethene	0.93	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	32	7.5	34
1,2-dichloroethane	--	--	--	--	--	--	(0.001)	(0.001)	11
Ethylbenzene	0.63	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	--	--	--
Freon	0.78	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	0.5	(0.001)	(0.001)
Isopropanol	--	--	--	--	--	--	130	(0.010)	(0.010)
Methanol	2	11	5	9	8	(1)	--	--	--
Methylene chloride	0.20	4.3	1.8	2.2	3.5		430	67	730
Methyl ethyl ketone	(0.125)	130	51	2.0	(0.125)	(0.125)	210	(0.005)	(0.005)

Notes:

Samples collected in the aboveground solvent area.
Samples analyzed for purgeable organics by EPA Method 624/8240; total hydrocarbons by EPA Method 6010/8100; methanol by EPA Method 8015; and extractable organics by EPA Method 8270.
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
( ) indicates not detected below enclosed detection limits
--- = not tested
Data Source: McKesson Corporation (1986)

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TABLE 2-3
(Continued)

McKesson Environmental Data
March 1986

Boring/Well No.	Soil Concentration (mg/kg)						Groundwater Concentration (mg/L)		
	B-1	B-1	B-1	B-2	B-3	MW-2	MW-1	MW-3	MW-4
1-(2-methoxy-1-methylethoxy)-2-propanol	--	20	--	--	--	--	--	--	--
Naphthalene	(0.2)	0.2	(0.2)	(0.2)	(0.2)	(0.2)	(0.010)	(0.010)	0.24
2-phenoxy ethanol	--	49	--	--	--	--	--	--	--
Tetrachloroethene	94	2.2	0.13	0.05	0.18	0.05	110	22	96
Toluene	3.7	0.20	(0.025)	(0.025)	(0.025)	(0.025)	18	(0.001)	38
Total Hydrocarbons (low tomed BP)	14	37	(1)	(1)	(1)	(1)	(0.050)	0.051	7
Total Hydrocarbons (as diesel)	--	--	--	--	--	--	(0.100)	0.25	(0.100)
1,1,1-trichloroethane	56	2.0	0.08	0.03	1.1	(0.025)	880	220	740
Trichloroethene	0.55	0.10	(0.025)	(0.025)	(0.025)	(0.025)	4.5	1.5	31
Xylenes	2.7	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.001)	(0.001)	3

Notes:
Samples collected in the aboveground solvent area.
Samples analyzed for purgeable organics by EPA Method 624/8240; total hydrocarbons by EPA Method 6010/8100; methanol by EPA Method 8015; and extractable organics by EPA Method 8270.
mg/kg = milligrams per kilogram
mg/L = milligrams per liter
( ) indicates not detected below enclosed detection limits
--- = not tested
Data Source: McKesson Corporation (1986)

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TABLE 2-4

McKesson Environmental Data
October 1989

Sample No.	Concentration mg/kg				
Parameter	SP-1	SP-2	SP-3	SP-4	SP-5
pH*	8	8.3	8.3	8.0	7.7
Tetrachloroethene	0.50	0.45	0.09	0.42	0.20
Trichloroethene	0.10	0.09	(0.05)	0.11	(0.05)

Notes:

Samples collected at RCRA drum storage area
mg/kg = milligrams per kilogram
( ) indicates not detected below enclosed detection limit.
* = pH results are in units
Data Source: Harding Lawson Associates (1990a)

2.5 Remedial Investigation

In 1990 and 1991, HLA conducted the remedial investigation (RI). The investigation included the monitoring of ambient meteorological conditions and air quality, drilling of soil borings, drilling and installation of groundwater monitoring wells, cone penetrometer testing (CPT)/HydroPunch groundwater sampling, the collection and analysis of surface and subsurface soil samples, and the collection and analysis of surface water and groundwater samples. All field work and physical testing of soil samples was performed by HLA geologists, engineers, and technicians under the direct oversight of a registered geologist and/or professional engineer. Analytical testing of air, soil, and water samples was performed by a state-certified laboratory.

HLA's RI of surface and subsurface soil and vadose zone conditions at the McKesson site was conducted in two phases. The first phase of the investigation was conducted from June to August 1990. Thirty-one soil borings were drilled and sampled during the first phase. Samples were also collected from four surface locations. Following review of the data collected during the first phase of the investigation, a second phase soil and vadose zone investigation was conducted in January and February of 1991, during which an additional ten soil borings were drilled and sampled.

Soil samples collected from borings drilled in the first phase of the investigation in the UST area, the aboveground storage tank area, and the Freon-blending area were analyzed for volatile and semivolatile organic compounds, glycols, and petroleum hydrocarbons. Based on the results from the first-phase borings, the samples collected from the three additional borings in the aboveground solvent-storage area were only analyzed for volatile organic compounds.

Soil samples collected in the corrosive and hydrogen peroxide bermed storage area were analyzed for pH and selected ions and metals, with the exception of the two samples that were additionally analyzed for volatile and semivolatile organics, glycols, and petroleum hydrocarbons. This area was not sampled extensively for organic chemicals because these types of compounds were not used in this area. However, there does not appear to be any reason to believe that 'unique' chemicals other than those analyzed would be present in this area.

The groundwater investigation program consisted of the installation, monitoring, and sampling of a total of 18 on-site groundwater monitoring wells. Two wells were installed in a discontinuous perched-water zone encountered at two locations within the site. Twelve wells were installed in the upper portion of the underlying aquifer zone. Four additional wells were installed in the aquifer, two at an intermediate depth, and two at the bottom of the aquifer, to assess vertical hydraulic and chemical distribution characteristics. The monitoring well program was augmented by the collection of water samples using a HydroPunch sampling device. HydroPunch samples were collected at five on-site locations and twelve off-site locations.

The results of the RI are summarized below.

2.5.1 Chemicals in the Soil

Approximately 100 soil samples were collected throughout the site and analyzed by EPA Method 8240 for volatile organic chemicals (VOCs). Samples were collected at depths ranging from 0.5 to 129 feet; the majority of the samples were taken at depths ranging from 20 to 40 feet. Several VOCs were not detected in any samples: 1,1,2-trichloroethane, 1,2-dichloropropane, 2-hexanone, 4-methyl-2-pentanone, bromodichloromethane, bromoform,

bromomethane, carbon disulfide, chloromethane, chloroform, chloroethane, cis-1,3-dichloropropene, dibromochloromethane, styrene, trans-1,3-dichloropropene, vinyl acetate, and vinyl chloride. Limits of detection for these compounds were very low, ranging from 50 ppb to 1 ppm. Hence, these compound are probably not present in site soils, which is an important consideration given that some of these chemicals are present in groundwater and may be indicative of upgradient contamination.

The following VOCs were detected in one or more samples: 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethane, cis- and trans-1,2-dichloroethene, 2-butanone, acetone, carbon tetrachloride, chlorobenzene, ethylbenzene, methylene chloride, tetrachloroethene, toluene, xylenes, and trichloroethene. Chemical concentrations in soil ranged from 0.06 mg/kg (1,2-dichloroethane) to 3,500 mg/kg (1,1,1-trichloroethane). The data is summarized in Table A-1 located in Appendix A.

In order to calculate representative soil concentrations in this assessment, the site was divided into three separate areas based on a general consideration of the activities and processes that took place on-site. These areas are (1) Area "A," which is comprised primarily of the railroad spur area along the northern boundary, (2) Area "B," which is comprised primarily of the solvent storage tank area, and (3) Area "C," which is comprised primarily of the corrosive/oxidizer area. These areas are delineated in Figure 2-2. In general, the soil samples taken outside these areas (e.g., SB-32, SB-1, MW-2, SB-12, and MW-1) were free of detectable levels of any contaminants. The soil analyses for each area are summarized below and in Table 2-5. The arithmetic mean and 95% upper confidence limits of the surficial (0-2' depth) and subsurficial (>2' depth) chemical concentrations for all identified chemicals measured in all three areas combined are also presented in Table 2-5. The arithmetic mean and upper 95% confidence limits of the chemicals of concern are presented in Table 2-6.

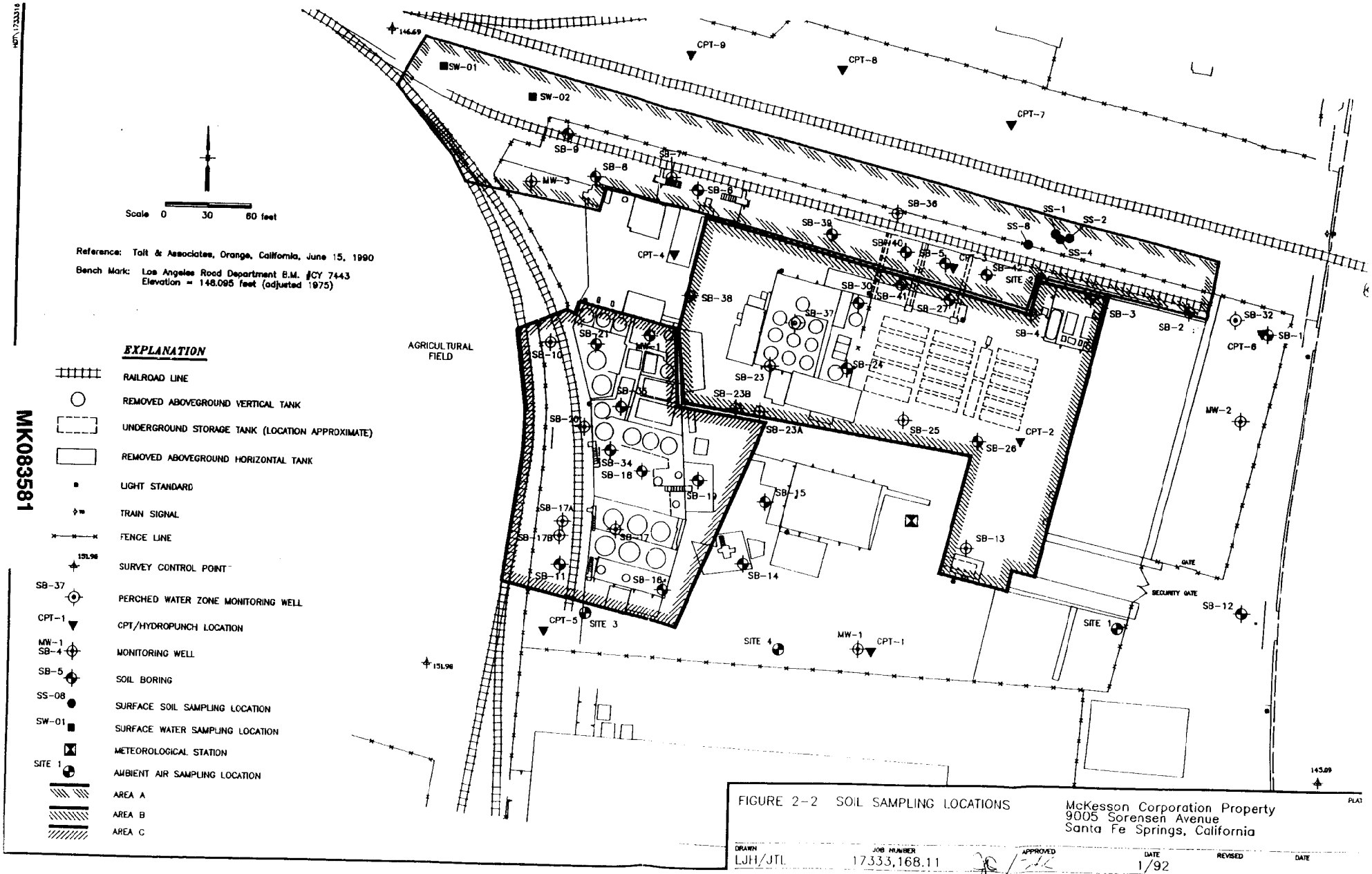

FIGURE 2-2 SOIL SAMPLING LOCATIONS

McKesson Corporation Property
9005 Sorensen Avenue
Santa Fe Springs, California

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
LJH/JTL	17333,168.11		1/92		

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TABLE 2-5

DETECTION FREQUENCIES AND
CHEMICAL CONCENTRATIONS FOR ALL IDENTIFIED CHEMICALS
IN THE DELINEATED AREAS[1]

	AREA A[a]		AREA B[b]		AREA C[c]		Surficial Soil*		Subsurface Soil*	
	Freq. of Detection	Max. Detection (mg/kg)	Freq. of Detection	Max. Detection (mg/kg)	Freq. of Detection	Max. Detection (mg/kg)	Mean	95% UCL	Mean	95% UCL
1,1,1-trichloroethane	9/34	33	23/39	3500	3/12	0.3	332.89	1039.39	12.08	27.37
1,1,2,2-tetrachloroethane	0/34	<0.05 (ND)	2/39	31	0/12	<0.05 (ND)	2.84	9.12	0.10	0.26
1,1-dichloroethane	0/34	<0.05 (ND)	13/39	0.63	0/12	<0.05 (ND)	0.04	0.08	0.06	0.08
1,1-dichloroethene	4/34	0.35	13/39	5.4	3/12	0.10	0.24	0.34	0.28	0.48
1,2-dichloroethane	4/34	2	17/39	32	0/12	<0.05 (ND)	2.95	9.42	0.28	0.54
1,2-dichloroethene	0/22	<0.05 (ND)	3/23	0.6	0/11	<0.05 (ND)	0.03	0.03	0.05	0.08
2-butanone	3/34	13	6/39	65	0/12	<1.0 (ND)	0.50	0.50	1.90	3.68
Acetone	3/34	95	5/39	120	0/12	<1.0 (ND)	0.50	0.50	5.44	9.85
Benzene	0/34	<0.05 (ND)	1/39	0.07	0/12	<0.05 (ND)	0.03	0.03	0.03	0.03

* = Areas A, B, and C combined
ND = Not Detected (value represents the limit of detection)

[1] Represents only those chemicals detected in one or more samples.
[a] Samples taken from MW-03, SB-02, SB-05 to SB-09, SB-36, SB-39 to SB-42, SS-01 to SS-04
[b] Samples taken from SB-03, SB-04, SB-13, SB-23, SB-23A to SB-27, SB-28, SB-30, SB-37, SB-38
[c] Samples taken from SB-10, SB-11, SB-17, SB-17A, SB-19 to SB-21

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TA E 2-5

DETECTION FREQUENCIES AND CHEMICAL CONCENTRATIONS FOR ALL IDENTIFIED CHEMICALS IN THE DELINEATED AREAS[1]

	AREA A[a]		AREA B[b]		AREA C[c]		Surficial Soil*		Subsurface Soil*	
	Freq. of Detection	Max. Detection (mg/kg)	Freq. of Detection	Max. Detection (mg/kg)	Freq. of Detection	Max. Detection (mg/kg)	Mean	95% UCL	Mean	95% UCL
Carbon tetrachloride	0/34	<0.25 (ND)	4/39	550	0/12	<0.05 (ND)	50.02	161.44	1.54	3.39
Chlorobenzene	0/34	<0.25 (ND)	2/39	170	0/12	<0.05 (ND)	16.48	50.76	0.03	0.03
Cis-1,2-dichloroethene	1/12	0.13	1/16	0.1	0/1	<0.05 (ND)	0.03	0.03	0.03	0.04
Ethylbenzene	0/34	<0.25 (ND)	4/39	50	0/12	<0.05 (ND)	4.57	14.69	0.67	1.59
Methylene Chloride	2/34	3.3	27/39	380	1/12	1.1	35.67	112.43	5.30	9.00
Tetrachloroethene	14/34	12	25/39	2900	4/12	0.70	272.66	858.29	23.43	55.06
Toluene	1/34	0.1	12/39	130	0/12	<0.10 (ND)	17.13	43.12	3.16	7.29
Xylenes	0/34	<0.25 (ND)	8/39	160	0/12	<0.05 (ND)	8.21	26.43	3.12	7.70
Trans-1,2-dichloroethene	0/12	<0.25 (ND)	2/16	0.63	0/1	<0.05 (ND)	0.03	0.03	0.06	0.11
Trichloroethene	6/34	2	3/39	60	3/12	0.3	5.83	17.92	0.92	1.93

* = Areas A, B, and C combined
ND = Not Detected (value represents the limit of detection)

[1] Represents only those chemicals detected in one or more samples.
[a] Samples taken from MW-03, SB-02, SB-05 to SB-09, SB-36, SB-39 to SB-42, SS-01 to SS-04
[b] Samples taken from SB-03, SB-04, SB-13, SB-23, SB-23A to SB-27, SB-28, SB-30, SB-37, SB-38
[c] Samples taken from SB-10, SB-11, SB-17, SB-17A, SB-19 to SB-21

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TABLE 2-6

MEAN AND 95% UCL SOIL CONCENTRATIONS OF SOIL CHEMICALS OF CONCERN IN AREAS A, B, AND C

Chemical	Mean	95% UCL
Surficial Soil Concentrations		
1,1-Dichloroethane	0.041	0.076
1,2-Dichloroethane	2.95	9.42
Methylene Chloride	35.67	112.43
Tetrachloroethene	272.66	858.29
Trichloroethene	5.83	17.92
1,1,1-Trichloroethane	332.89	1039.39
Toluene	17.13	43.12
Xylenes	8.21	26.43
1,1-Dichloroethene	0.24	0.34
1,2-Dichloroethene	0.03	0.03
2-Butanone (MEK)	0.50	0.50
Acetone	0.50	0.50
Subsurface Soil Concentrations (used in vapor modeling)		
1,1-Dichloroethane	0.06	0.08
1,2-Dichloroethane	0.28	0.54
Methylene Chloride	5.29	9.00
Tetrachloroethene	23.44	55.06
Trichloroethene	12.08	27.37
1,1,1-Trichloroethane	0.92	1.93
Toluene	3.16	7.29
Xylenes	3.12	7.70
1,1-Dichloroethene	0.28	0.48
1,2-Dichloroethene	0.05	0.08
2-Butanone (MEK)	1.90	3.68
Acetone	5.44	9.85

Area A

The following VOCs were detected in one or more soil samples collected in Area A (MW-03, SB-02, SB-05 to SB-09, SB-36, SB-39 to SB-42, SS-01 to SS-04): 1,1,1-trichloroethane, 1,1-dichloroethene, 1,2-dichloroethane, 1,2-dichloroethene, methylene chloride, tetrachloroethene, toluene, and trichloroethene. Concentrations ranged from 0.1 mg/kg (toluene) to 95 mg/kg (acetone). Less than 50 percent of the soil samples contained detectable levels of any VOC, and a great majority of the detected concentrations were less than 1 mg/kg.

Area B

The following VOCs were detected in one or more soil samples collected in Area B (SB-03, SB-04, SB-13, SB-23A, SB-23 to SB-27, SB-30, SB-37, SB-38): 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethane, cis- and trans-1,2-dichloroethene, 2-butanone, acetone, carbon tetrachloride, chlorobenzene, ethylbenzene, methylene chloride, tetrachloroethene, toluene, xylenes, and trichloroethene. Concentrations ranged from 0.1 mg/kg (cis-1,2-dichloroethene) to 3,500 mg/kg (1,1,1-trichloroethane). A majority of the soil samples contained detectable concentrations of one or more VOCs.

Area C

The following VOCs were detected in one or more soil samples collected in Area C (MW-01, SB-10, SB-11, SB-16, SB-17, SB-17A, SB-18 to SB-21; SB-34, and SB-35): 1,1,1-trichloroethane, 1,1-dichloroethene, methylene chloride, tetrachloroethene, and trichloroethene. Concentrations ranged from 0.3 mg/kg (1,1,1-trichloroethane) to 4.0 mg/kg

(methylene chloride). Less than 50 percent of the samples contained detectable levels of any VOC, and a majority of the detected concentrations were less than 1 mg/kg.

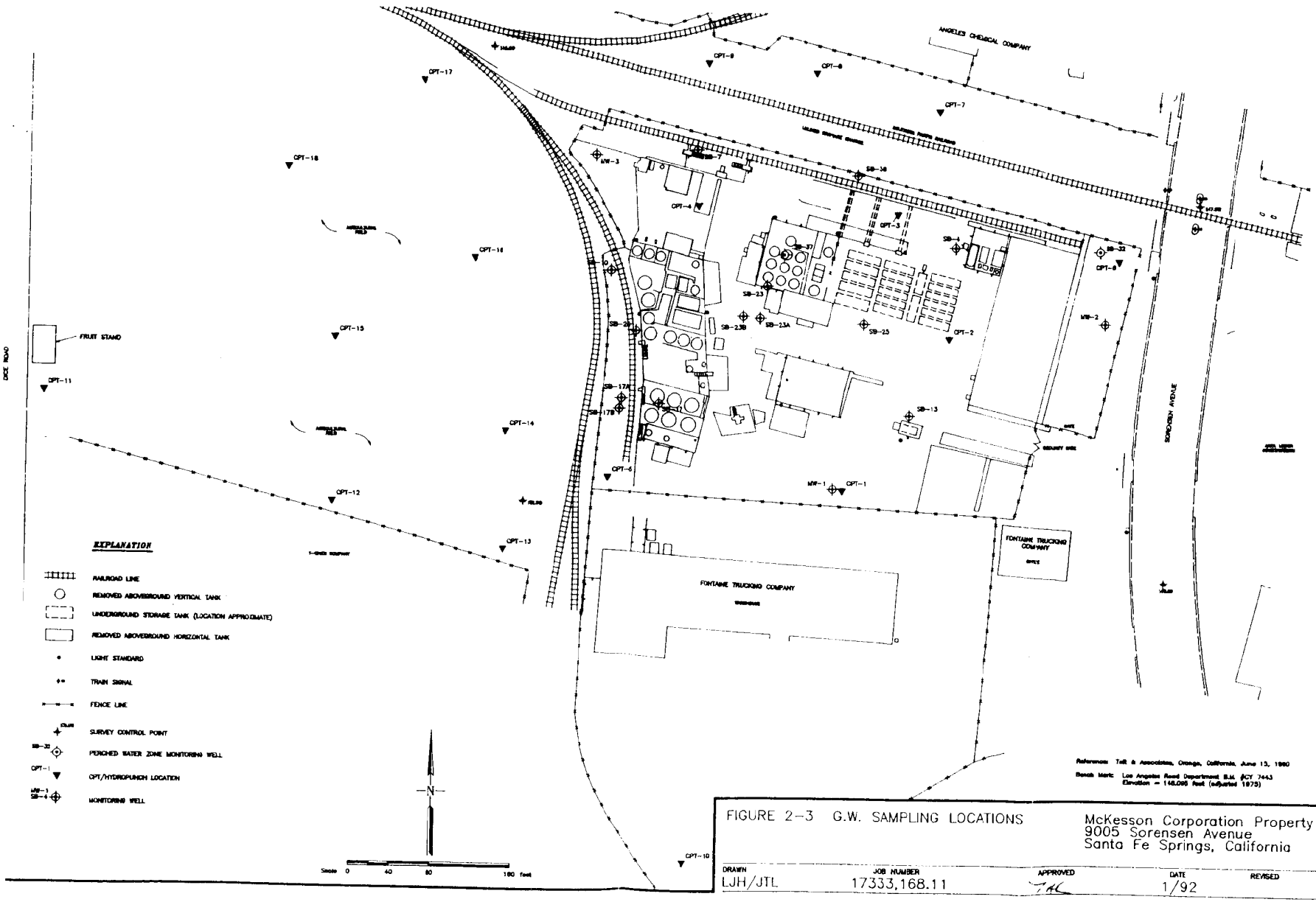
In summary, soil samples taken outside the three delineated areas did not contain significant levels of any VOCs. The bulk of the site soil contamination appears to be confined to Area B; approximately 90 percent of the samples taken outside Area B contained less than 10 ppm total of all VOCs.

2.5.2 Chemicals in Groundwater

As identified in Figure 2-3, groundwater samples were collected from several wells on-site and in selected locations off-site.

On-Site

Forty-four groundwater samples were collected from eighteen different locations on-site(MW-1 through MW-3; SB-4, SB-7, SB-10, SB-13, SB-17, SB-17A, SB-17B, SB-20, SB-23, SB-23A, SB-23B, SB-25, and SB-36; and CPT-1 through CPT-6) and analyzed for VOCs (EPA Method 624/8240). The results are summarized in Table A-2 in Appendix A. The following VOCs were not detected in any samples: 1,1,2-trichloroethane, 1,1,2,2-tetrachloroethane, 1,2-dichloropropane, 2-butanone, 2-hexanone, 4-methyl-2-pentanone, bromodichloromethane, bromoform, bromomethane, carbon disulfide, carbon tetrachloride, chloropropene, styrene, trans-1,3-dichloropropene, and vinyl acetate. The following VOCs were detected in one or more groundwater samples: 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethane, cis- and trans-1,2-dichloroethene, acetone, benzene, chloroform, dibromochloromethane, ethylbenzene, methylene chloride,



References: Tetra & Associates, Orange, California, June 15, 1990

Bench Mark: Los Angeles Road Department B.M. (CY 7443 Elevation = 148.096 feet (adjusted 1975)

FIGURE 2-3 G.W. SAMPLING LOCATIONS

McKesson Corporation Property
9005 Sorensen Avenue
Santa Fe Springs, California

DRAWN	JOB NUMBER	APPROVED	DATE	REVISED	DATE
LJH/JTL	17333,168.11	JAL	1/92		

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tetrachloroethene, toluene, xylenes, trichloroethene, trichlorofluoromethane, and vinyl chloride. As mentioned previously, the distinction between chemicals present in the groundwater is those that are not detected may be important to distinguish on-site vs. upgradient contributions.

Off-Site

Fifteen groundwater samples (including duplicates) were collected from eight locations in the agricultural field adjacent to the western boundary of the site (CPT-11 through CPT-18), three locations north of the property (CPT-7 through CPT-9) and one location south of the site (CPT-10), and analyzed for VOCs (EPA Method 8240).

The results are also summarized in Table A-2. The following VOCs were not detected in any samples: 1,1,2,2-tetrachloroethane, 1,2-dichloropropane, 2-hexanone, acetone, bromodichloromethane, bromoform, bromomethane, carbon disulfide, carbon tetrachloride, chlorobenzene, chloroethane, chloroform, chloromethane, cis-1,3-dichloropropene, dibromochloromethane, styrene, trans-1,2-dichloroethene, trans-1,3-dichloropropene, vinyl acetate, and vinyl chloride. The following VOCs were detected in one or more groundwater samples: 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethane, 2-butanone, 4-methyl-2-pentanone, benzene, cis-1,2-dichloroethene, ethylbenzene, methylene chloride, tetrachloroethene, toluene, trichloroethene, xylenes, acetone, dichlorofluoromethane, trichlorofluoromethane and trichlorotrifluoroethane.

As described in detail in the remedial investigation report, it is clear that there is off-site contribution to the groundwater contaminant levels measured in the on-site samples.

2.6 Summary

- The former McKesson facility in Santa Fe Springs, California, operated from 1976 to November 1, 1986. Bulk chemical packaging took place on-site.
- Previous investigations of site soil and groundwater have been conducted at the request of Cal-EPA. The most recent investigations were conducted by HLA in 1990 and 1991 which are described below.
- Approximately 100 soil samples were collected at depths ranging from 0.5 to 129 feet and analyzed for VOCs.
- Soil chemicals detected in the highest frequencies and concentrations were reported in "Area B," which is comprised primarily of the solvent storage tank area.
- Approximately 75 groundwater samples including duplicates were collected on-site and in selected locations off-site and analyzed for VOCs.
- On-site groundwater chemicals detected in the highest frequencies and concentrations were reported in "Area B."
- Off-site groundwater chemicals detected in the highest frequencies and concentrations were reported to the north of the site (CPT-8 and CPT-9) and in the western portion of the agricultural field (CPT-13 and CPT-16).
- Site groundwater has been adversely impacted as a result of both on-site and off-site activities.

3.0 IDENTIFICATION OF CHEMICALS OF CONCERN

The following sections identify the chemicals of concern selected for this assessment. These chemicals are selected from the soil and groundwater data collected during the 1990-1991 remedial investigation (See Section 2.5).

3.1 Soil Chemicals of Concern

As described in current Cal-EPA and USEPA guidance, the purpose of selecting chemicals of concern is to focus the assessment on those chemicals that could reasonably be expected to pose a significant risk. Criteria for establishing chemicals of concern typically include consideration of the toxicity, physical properties, concentration, and frequency of detection of each detected chemical. Current USEPA guidance indicates that it is appropriate to "consider the chemical as a candidate for elimination from the quantitative risk assessment if: (1) it is detected infrequently in one or perhaps two environmental media, (2) it is not detected at high concentrations" (USEPA, 1989a p. 5-22). In addition, page 5-20 of the current USEPA risk assessment guidance (USEPA, 1989a) states:

> "Carrying a large number of chemicals through a quantitative risk assessment may be complex, and it may consume significant amounts of time and resources. The resulting risk assessment report, with its large, unwieldy tables and text, may be difficult to read and understand, and it may distract from the dominant risks presented by the sites."

As described earlier, the analytical soil data have been segregated into three sets in this assessment: data from the soil borings collected in (1) Area "A," which is primarily the railroad spur area, (2) Area "B," which is primarily the solvent storage area, and (3) Area "C," which is primarily the corrosive/oxidizer area. Figure 2-2 delineates these areas. As

previously discussed in Section 2.5, the highest frequencies of detection and chemical concentrations occurred in the solvent storage tank area.

For the purposes of this assessment, any chemical detected in greater than 5% of the soil samples taken from throughout these three areas will be considered as a soil chemical of concern. This is a reasonable and conservative selection criterion since if a chemical is present in less than 5% of the samples, it is likely to have a very low mean concentration, due to the significant number of nondetected values in the data set. Based on this set of criteria, the chemicals of concern in soil are summarized in Table 3-1.

3.2 Groundwater Chemicals of Concern

As described in detail in the remedial investigation report, there appears to be a significant amount of off-site contribution to contaminant levels measured in groundwater samples collected on-site. The relative degree of on-site and off-site contribution has not yet been quantified and, therefore, insufficient information is available to accurately identify chemicals of concern for the purposes of assessing risks directly related to the site associated with groundwater. However, at the request of Cal-EPA, exposure to groundwater is quantitatively evaluated in this assessment. In order to ensure that potential risks are not under-estimated, all chemicals detected in on- and off-site wells are included as groundwater chemicals of concern. Table 3-2 summarized these chemicals and their maximum detected concentration.

TABLE 3-1

SOIL CHEMICALS OF CONCERN

Chemical	% Detection Frequency in Areas A, B, and C
1,1,1-trichloroethane	40.4
1,1-dichloroethane	14.6
1,1-dichloroethene	23.6
1,2-dichloroethane	23.6
1,2-dichloroethene	5.0
2-butanone	10.1
Acetone	8.9
Methylene Chloride	35.9
Tetrachloroethene	49.4
Toluene	14.0
Trichloroethene	8.9
Xylenes	35.9

TABLE 3-2

CHEMICALS OF CONCERN IN GROUNDWATER AND THEIR MAXIMUM DETECTED CONCENTRATION (mg/L)

Chemical	Maximum Concentration	Sample Location
1,1,1-Trichloroethane	88	CPT-13
1,1-Dichloroethane	110	SB-23
1,1-Dichloroethene	50	CPT-13
1,2-Dichloroethane	20	SB-20
1,2-Dichloroethene	1	SB-23
Acetone	5.7	SB-25
Benzene	0.21	SB-25
Chloroform	0.034	SB-04
cis-1,2-Dichloroethene	4	CPT-13
Dibromochloromethane	0.012	SB-13
Ethylbenzene	0.44	SB-23
Methylene Chloride	100	SB-23
Tetrachloroethene	45	SB-17
Toluene	3	SB-23
Xylenes	1.3	SB-36
trans-1,2-Dichloroethene	0.008	CPT-1
Trichloroethene	11	CPT-13
Trichlorofluoromethane	0.036	CPT-6
Vinyl Chloride	0.078	SB-32
1,1,2-Trichloroethane	0.001	CPT-17
2-Butanone	2.1	CPT-16
4-Methyl-2-Pentanone	0.74	CPT-16
Copper	0.002	SB-23A
Manganese	9.0×10^{-5}	TW-1
Zinc	2.62	SB-23A

ND = Not detected and therefore, was not assessed in this risk assessment.

4.0 EXPOSURE ASSESSMENT

The exposure assessment section of a risk assessment identifies the potential pathways of exposure to the chemicals of concern, the potentially exposed populations, and reasonable estimates of the frequency and duration of contact with the contaminated media. The exposure scenarios and potentially exposed populations considered in this assessment are described in detail in Section 4.1. Sections 4.2 and 4.3 identify the exposure pathways and exposure parameters, respectively, that are considered for each scenario. Most of the assumptions regarding potentially exposed populations and estimates of exposure frequency and duration are taken directly from current Cal-EPA and USEPA risk assessment guidance. Where applicable, an appropriate mix of 50th and 95th percentile default exposure assumptions are used to estimate potential contaminant uptake, as suggested by current Cal-EPA and USEPA guidance. This scenario is referred to as the "reasonable maximal scenario" in this assessment.

4.1 Exposure Scenarios

The exposure scenarios considered in this assessment address both current and potential future conditions at the McKesson site.

Current Conditions

Under current conditions, there are no on-site activities. Therefore, potentially exposed individuals under current conditions consist of nearby off-site occupational and residential populations. The nearest residential receptor is 402 meters southwest of the site. The nearest occupational receptor is 22 meters south of the solvent storage area on the McKesson-Fontaine Trucking Company fenceline. Theoretically, off-site populations could

be exposed to site-related contaminants via contact with groundwater contaminants that have migrated off-site or inhalation of vapors that have been emitted by on-site sources. The distance between the nearest potential off-site receptor and the primary emission source area (Area B), approximately 22 meters, is such that inhalation of site vapors by off-site populations is likely to be negligible. As described further in subsequent portions of this assessment, this conclusion is borne out by on-site sampling for vapors and vapor emission estimates provided by fate and transport models. Potential incidental residential exposure to groundwater at off-site locations is considered in this assessment, although presently it is unclear to what degree the McKesson site has contributed to off-site groundwater contamination.

Future Uses

Future uses of the site will likely involve occupational activity. It is reasonable to expect that residential use of the site will not occur in the future; however, at the request of Cal-EPA, a potential residential scenario is included in this assessment. In summary, for the purposes of this assessment, the representative exposure scenarios are as follows:

- An on-site occupational scenario that assumes adult exposure during a typical 40-hour work week.
- An on-site residential scenario that assumes daily exposure and accounts for age-specific exposures (adults and children).
- An off-site residential scenario that assumes incidental contact with groundwater.

4.2 Exposure Pathways

Pathways of exposure are the means through which an individual may come into contact with a contaminant. These are determined by environmental conditions, potential for a contaminant to move from one medium to another, and the population's general lifestyles. Although several potential pathways may exist, usually only a few contribute significantly to the total exposure. For a complete exposure pathway to exist, each of the following elements must be present (USEPA, 1989a):

- A source and mechanism for chemical release,
- An environmental transport medium (e.g., air, water, soil),
- A point of potential human contact with the medium, and
- A route of exposure (e.g., inhalation, ingestion, dermal contact).

In general, the potential pathways of exposure to environmental contaminants consist of ingestion of contaminated soil and groundwater, inhalation of vapors and particulates, and dermal contact with contaminated soil and groundwater.

At certain portions of the McKesson site (the former solvent storage area) the soil contains elevated levels of VOCs. Therefore, inhalation of vapors emitted from the soil will be considered for future on-site populations. Direct contact with contaminants in surficial site soil via soil ingestion and dermal contact with soil could also occur and will be considered for future on-site occupational and residential populations. The contaminated aquifer at the McKesson site is not used as a drinking water source due to factors other than the presence of site-related contamination. Hence, direct ingestion of groundwater from the aquifer is not a viable exposure pathway. However, it is theoretically possible that a well could be placed in the aquifer and be used for nondrinking purposes (e.g., vegetable garden or

landscape irrigation, cleaning vehicles or other equipment, etc.). Accordingly, on- and off-site incidental residential exposure to groundwater via ingestion and dermal contact is considered in this assessment. For the purposes of this analysis, these groundwater exposure pathways are not considered for the future on-site worker, since occupational exposures to groundwater are unlikely.

Due to their high volatility and susceptibility to photo and microbial degradation, the primary soil contaminants (VOCs) are usually not present in the fine surficial soil particles that can become suspended in air. Therefore, inhalation of soil particulates is not considered a significant exposure pathway for on- or off-site locations and is not addressed in this assessment.

In summary, soil ingestion, dermal contact with soil, and vapor inhalation are considered for future on-site residential and occupational populations. Incidental residential exposure to groundwater on-site and off-site is also considered. Table 4-1 summarizes the pathways that are considered in this assessment and the justification used for excluding certain pathways.

4.3 Exposure Parameters

Consistent with current Cal-EPA and USEPA guidance, the following general dose equation is used to assess uptake for each exposure pathway considered in this assessment:

$$ADD = \frac{C \times IR \times EF \times ED \times B}{BW \times AT}$$

Where:

ADD = Average daily dose (mg/kg-day)

C = Chemical concentration in environmental medium (mg/kg)

TABLE 4-1

EXPOSURE PATHWAYS CONSIDERED FOR FUTURE ON-SITE USES AND POTENTIAL OFF-SITE EXPOSURES

	Occupational		Residential	
	On-Site	Off-Site	On-Site	Off-site
Soil ingestion	X	O[a]	X	O[a]
Dermal contact with soil	X	O[a]	X	O[a]
Vapor inhalation	X	O[a]	X	O[a]
Incidental groundwater ingestion	O[a]	O[a]	X	X
Incidental dermal contact with groundwater	O[a]	O[a]	X	X
Particulate inhalation	O[b]	O[b]	O[b]	O[b]

X = pathway is considered in health risk assessment
O = pathway is not considered in health risk assessment

a = pathway not considered due to incomplete exposure pathway
b = pathway not considered due to insignificance

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IR	=	Intake rate (mg/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
B	=	Bioavailability (unitless)
BW	=	Body weight (kg)
AT	=	Averaging time (days)
		For noncarcinogenic effects, AT = Exposure duration x 365 days/year
		For carcinogenic effects, AT = 70 years x 365 days/year

It is well known that rates and duration of contact with environmental media can differ significantly with age. Accordingly, age-specific estimates of exposure (child and adult) are used to evaluate contaminant uptake for the residential scenario. The exposure estimates used to calculate contaminant uptake via the potential exposure pathways are described below and summarized in Tables 4-2, 4-3 and 4-4. Calculation of representative contaminant concentrations is described in Sections 5.0 and 7.0.

4.3.1 Receptor Characterization Factors

Body Weight

The standard body weight given in the Cal-EPA's (formerly the California Department of Health Services) draft Scientific and Technical Standards for Hazardous Waste Sites Book II, Volume 4, Chapter 1, Section 2.0 (Cal-EPA, 1990) is 70 kilograms for adults. This value

TABLE 4-2

EXPOSURE ASSESSMENT PARAMETERS FOR THE PATHWAYS DEVELOPED FOR EXISTING OFF-SITE AND FUTURE ON-SITE RESIDENT*
(CHILD 0-6 YEARS OLD)

	Parameter	Value	Approximate Percentile	Reference
Human Characteristics	Body Weight (BW)	15 kg	50th	USEPA Supplemental, 1991
	Exposure Time (ET)	24 hours/day	Maximum	USEPA Supplemental, 1991
	Exposure Frequency (EF)	350 days/year	95th	USEPA Supplemental, 1991
	Exposure Duration (ED)	6 years	95th	USEPA Supplemental, 1991
	Averaging Time (AT)	25550 days - carcinogenic effects 2190 days - noncarcinogenic effects		Cal - EPA, 1990
Inhalation of Vapors	Inhalation Rate (IR)	0.44 m^3/hour	50th	USEPA, 1989b (avg. ml/min. for infant and child 6 years old = 0.44 m^3/hr.)
	Bioavailability (B)	1.0	Maximum	defined value
Dermal Contact With Soil	Soil to Skin Adherence Factor (AF)	0.5 mg/cm^2 day	50th	USEPA, 1992
	Surface Area (SA)	1520 cm^2	50th	USEPA, 1989b
	Bioavailability (B)	0.10	50th	CAL-EPA, 1992
	Conversion Factor (CF)	1.0×10^{-6} kg/mg		-
Soil Ingestion	Ingestion Rate (IR)	200 mg/day	Upperbound	USEPA Supplemental, 1991
	Bioavailability (B)	1.0	Maximum	defined value
	Conversion Factor (CF)	1.0×10^{-6} kg/mg		-
Incidental Ingestion of Groundwater	Ingestion Rate (IR)	0.05 L/day	95th	USEPA, 1989a
	Exposure Frequency (EF)	52 days/year	90th	USEPA, 1989a
Dermal Contact With Groundwater	Surface Area (SA)	1520 cm^2	50th	USEPA, 1989b
	Exposure Time (ET)	1 hour/day	50th	Defined Value
	Permeability Coefficient (PC)	8.4×10^{-4}cm/hr	Maximum	USEPA, 1989a
	Exposure Frequency (EF)	52 days/year	90th	USEPA, 1989a

* Groundwater exposure pathways only apply to exiting off-site resident

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TABLE 4-3

EXPOSURE ASSESSMENT PARAMETERS FOR THE PATHWAYS DEVELOPED FOR EXISTING OFF-SITE AND FUTURE ON-SITE RESIDENT (ADULT)*

	Parameter	Value	Approximate Percentile	Reference
Human Characteristics	Body Weight (BW)	70 kg	50th	USEPA Supplemental, 1991
	Exposure Time (ET)	24 hours/day	Maximum	USEPA Supplemental, 1991
	Exposure Frequency (EF)	350 days/year	95th	USEPA Supplemental, 1991
	Exposure Duration (ED)	24 years	95th	USEPA Supplemental, 1991
	Averaging Time (AT)	25550 days - carcinogenic effects 8760 days - noncarcinogenic effects		Cal - EPA, 1990
Inhalation of Vapors	Inhalation Rate (IR)	0.83 m^3/hour	50th	USEPA Supplemental, 1991
	Bioavailability (B)	1.0	Maximum	defined value
Dermal Contact With Soil	Soil to Skin Adherence Factor (AF)	0.5 mg/cm^2 day	50th	USEPA, 1992
	Surface Area (SA)	3900 cm^2	50th	USEPA, 1989b
	Bioavailability (B)	0.10	50th	CAL-EPA, 1992
	Conversion Factor (CF)	1.0×10^{-6} kg/mg		-
Soil Ingestion	Ingestion Rate (IR)	100 mg/day	Upperbound	Cal-EPA, 1990
	Bioavailability (B)	1.0	Maximum	defined value
	Conversion Factor (CF)	1.0×10^{-6} kg/mg		-
Incidental Ingestion of Groundwater	Ingestion Rate (IR)	0.05 L/day	95th	USEPA, 1989a
	Exposure Frequency (EF)	52 days/year	90th	USEPA, 1989a
Dermal Contact with Groundwater	Surface Area (SA)	3900 cm^2	50th	USEPA, 1989b
	Exposure Time (ET)	1 hour/day	50th	Defined Value
	Permeability Coefficient (PC)	8.4×10^{-4}	Maximum	USEPA, 1989
	Exposure Frequency (EF)	52 days/year	90th	USEPA, 1989

* Groundwater exposure pathways only apply to existing off-site resident.

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TABLE 4-4

EXPOSURE ASSESSMENT PARAMETERS FOR THE PATHWAYS DEVELOPED FOR A FUTURE ONSITE ADULT WORKER

	Parameter	Value	Approximate Percentile	Reference
Human Characteristics	Body Weight (BW)	70 kg	50[a]	USEPA Supplemental, 1991
	Exposure Time (ET)	8 hours/day	Maximum	USEPA Supplemental, 1991
	Exposure Frequency (EF)	250 days/year	59[a]	USEPA Supplemental, 1991
	Exposure Duration (ED)	4.2 years	50[a]	U.S. Bureau of Labor Statistics, 1978
	Averaging Time (AT)	25550 days - carcinogenic effects 1533 days - noncarcinogenic effects		Cal - EPA, 1990
Inhalation of Vapors	Inhalation Rate (IR)	1.25 m^3/hour	50[a]	USEPA, 1989b
	Bioavailability (B)	1.0	Maximum	defined value
Dermal Contact With Soil	Soil to Skin Adherence Factor (AF)	0.5 mg/cm^2 day	50[a]	USEPA, 1992
	Surface Area (SA)	3900 cm^2	50[a]	USEPA, 1989b
	Bioavailability (B)	0.10	50[a]	CAl-EPA, 1992
	Conversion Factor (CF)	1.0×10^6 kg/mg		-
Soil Ingestion	Ingestion Rate (IR)	50 mg/day	Upperbound	USEPA Supplemental, 1991
	Bioavailability (B)	1.0	Maximum	defined value
	Conversion Factor (CF)	1.0×10^6 kg/mg		-

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represents the average of the median (50th percentile) body weight for an adult male and female. The USEPA Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance (USEPA, 1991a) suggests a value of 15 kilograms as the median (50th percentile) body weight for boys and girls ages 0-6 years. These values are used to represent age-specific body weights in this assessment.

Exposure Frequency

Exposure frequency represents the rate at which an individual may come in contact with a contaminated medium. For the purposes of this assessment, a working individual is assumed to be present on-site for 8 hours per day, 5 days per week, 50 weeks per year (250 days per year) during job tenure. A resident is assumed to be present on-site 24 hours per day, 7 days per week, 50 weeks per year (350 days per year). This latter assumption is a very conservative "upperbound" estimate since most individuals (children and adults) spend a significant amount of the day away from the home. An exposure frequency of 365 days per year was originally recommended by the USEPA (USEPA, 1989a); however, consideration of time spent away from home as vacation (2 weeks) is recommended in the USEPA's supplemental guidance (USEPA, 1991a).

Exposure Duration

Exposure duration is a measure of the length of time an individual may be in contact with a contaminated medium. For the purposes of this assessment, occupational tenure is based on recent data from the Bureau of Labor Statistics (1987), which indicates that the median (50th percentile) job tenure with the current employer is 4.2 years. An exposure duration of 30 years is used for the residential scenario. This value represents the 90th percentile of residence time in the same home (USEPA, 1989a). For the purposes of this assessment, 6

of the residential years will be assumed to be a child; 24 years will be assumed to be an adult. This is a conservative assumption since children are typically considered to be more sensitive to the potential health effects of environmental contaminants (due to higher rates of contact and lower body weights). Addressing a 30-year exposure duration in such a manner is consistent with current USEPA guidance (USEPA, 1991a).

4.3.2 Pathway-Specific Parameters

The following subsections discuss the rationale for the exposure parameter values used in this assessment.

4.3.2.1 Dermal Contact with Soil

Skin Surface Area

"Skin surface area" represents the amount of exposed skin that may come into contact with contaminated soil. For this assessment, a skin surface area of 3,900 cm^2 is used for adult workers and residents. This value represents the median (50th percentile) skin surface area for hands and arms as referenced in the USEPA's Exposure Factors Handbook (USEPA, 1989b). A value of 1,520 cm^2 is used for children; this value also represents the median (50th percentile) skin surface area for hands and arms for children aged 6-7 years as referenced by USEPA (USEPA, 1989b).

Soil to Skin Adherence Factor

Numerous studies have evaluated the amount of soil that is likely to be in contact with skin on a daily basis. Roels (1980) estimated that approximately 1.0 milligram of soil per square

centimeter of skin adheres to a child's hand after play in and around the home. Several other studies suggest that soil adheres to skin to a lesser degree. Using adhesive tape to sample a defined area of skin, it has been suggested that the amount of soil adhering to human skin is approximately 0.5 milligram per square centimeter (Lepow, 1975). In a different study, using a variety of soil of different particle size, an average of 0.2 milligram per square centimeter of soil adhered to the hand of small adults (Que Hee, 1985).

For the purposes of this assessment, a value of 0.5 mg/cm^2 per day is used as the soil adherence factor. This value approximates the median of the above studies and is also the midpoint of the values suggested by USEPA's February, 1992 "New Interim Region IV Guidance" memorandum which states:

> "The soil to skin adherence factors given in EPA's Risk Assessment Guidance to Superfund (RAGS) are 1.45 mg/cm^2 to 2.77 mg/cm^2. Because of new data in this area, this range should be changed to 0.2 to 1.0 mg/cm^2."

Bioavailability

Bioavailability is a measure of the degree to which a chemical is systemically absorbed following contact (Paustenbach, 1987). It is important to consider the bioavailability of a chemical in its environmental matrix (e.g., soil, water, or food), as the amount of chemical absorbed from a matrix will often be less than the amount absorbed when the chemical is administered in its pure form. Bioavailability is typically reported as the percentage of the applied or administered dose of a chemical that is ultimately absorbed. For example, absorption of 10 milligram of chemical upon dermal contact with 100 milligrams of soil-bound chemical represents a dermal bioavailability of 10 percent.

Current USEPA and Cal-EPA guidance indicates that it is appropriate to account for chemical bioavailability when assessing dermal uptake of chemicals from soil. For this assessment, a bioavailability factor of 10 percent is used for all chemicals. This value represents a reasonable estimate of dermal uptake of organic chemicals from soil.

4.3.2.2 Inhalation of Vapors

Inhalation Rate

For the purposes of this assessment, an inhalation rate of 1.25 m^3 per hour is assumed for workers (equivalent to 10 m^3 per 8-hour workday). This value approximates the mean (50th percentile) of the inhalation rates for adult males engaged in heavy or moderate activity, as referenced in USEPA's Exposure Factors Handbook (USEPA, 1989b). For an adult resident, an inhalation rate of 0.83 m^3 per hour (20 m^3 per 24-hour day) approximates the 50th percentile value as referenced in the USEPA's Risk Assessment Guidance for Superfund. Volume I. Human Health Evaluation Manual (Part A) Interim Final (1989a). A value of 0.44 m^3 per hour (11 m^3 per 24-hour day) is used to estimate an inhalation rate for a child (0 to 6 years of age). This value was calculated from activity data presented in the USEPA's Exposure Factors Handbook (1989b) and represents the sum of the mean inhalation rates for an infant's resting rate and a 6-year-old child's light activity rate.

Bioavailability

For this assessment, all the chemicals of concern are assumed to be 100 percent bioavailable via inhalation. This is a reasonable assumption because inhaled vapors are easily absorbed into the lungs.

4.3.2.3 Soil Ingestion

Soil Ingestion Rate

Incidental soil ingestion occurs at all ages, primarily as result of hand-to-mouth contact and ingestion of soil particulates that have been deposited on foods and surfaces. It is widely believed that children approximately 1 to 4 years of age are the only age group that consumes a potentially significant amount of soil (Calabrese et al., 1989; Van Wijnen et al., 1990). As a result, numerous studies of soil ingestion rates in children have been conducted. Current USEPA guidance suggests the use of 200 mg/day as a conservative estimate of "average" soil ingestion rates for children (USEPA, 1991a). This value, which is the median value obtained in "tracer" studies conducted by Binder (1986) and Clausing (1987), is used to assess contaminant uptake in soil ingested by children in this assessment. In Section 8.0, a wide range of other possible values are used to evaluate the conservatism in this estimate.

While numerous studies have attempted to measure or estimate rates of soil ingestion for children, information regarding adult soil ingestion is limited. The USEPA currently suggests an adult soil ingestion rate for an 18-year-old varying between 1 to 100 milligrams of soil per day (USEPA, 1991a). The highest figure is based on Centers for Disease Control (CDC) estimates and represents an abnormal tendency to ingest soil. The value of 100 milligrams of soil per day is used in this assessment for the adult resident and is an overestimation of the actual amount of soil ingested by adults.

For an occupational receptor, incidental ingestion of soil and dust depends upon the type of work performed. A study by Calabrese et al. (1990), limited by the number of test subjects, is the only published study that examined uptake in workers via tracer studies.

From this study, USEPA guidance (USEPA, 1991a) suggests using a value of 50 milligrams of soil per day as an upperbound estimate value. This value is used in this assessment.

Bioavailability

For the purposes of this assessment, it is assumed that soil-bound chemicals are absorbed 100 percent following ingestion. This is a fairly conservative estimate, since ingested soil-bound chemicals are typically absorbed with much less than 100-percent efficiency.

4.3.2.4 Incidental Exposure to Groundwater

Although the impacted aquifer is not a source of potable water, it is possible that a well could be placed in the aquifer at a future date for use as an irrigation source or other non-potable uses. In this event, incidental exposure to groundwater could occur as a result of ingestion or dermal contact. An incidental groundwater ingestion rate of 0.05 L/day is assumed in this evaluation, based on the estimated ingestion rate of 0.05 L/hr recommended by USEPA for ingestion of chemicals in surface water while swimming (USEPA, 1989a). For the purposes of this assessment, this would seem to be a reasonable conservative estimate since it is highly unlikely that an individual would incidentally consume as much water during irrigation or other activities as one does when completely immersed in a body of water (i.e. swimming).

As described in Section 4.3.2.1, a skin surface of 1,520 cm^2 and 3,900 cm^2 approximates the median (50th percentile) skin surface area for children and adult hands and arms (respectively) as referenced in USEPA's Exposure Factors Handbook (1989b). Consistent with current USEPA guidance for assessing chemical uptake via dermal contact with water (USEPA, 1989a), because chemical-specific permeability constant values for water are not

available for the chemicals of concern, the dermal permeability constant for water (8.4×10^{-4} cm/hr) is used as a default value for absorption (Blank et al.,1984). Dermal contact with water is assumed to occur for 1 hour per day.

The frequency of oral and dermal exposure to water from the impacted aquifer is assumed to be 1 day per week, or 52 days per year. This is a reasonable, yet conservative estimate. All of the above assumptions are taken to be applicable to either an on-site or an off-site residential exposure scenario.

5.0 ENVIRONMENTAL FATE AND TRANSPORT MODELING

This section describes the methodology used to estimate (1) the emissions of volatile contaminants from soil and (2) the ambient air concentrations associated with these emissions. For the purposes of this assessment, Jury's version of the "Behavior Assessment Model" (BAM) is used to determine the vapor emission rates of various organic chemicals from the soil in Areas A, B, and C of the McKesson site. The Box Model is then used to estimate the ambient air concentrations associated with these emission rates. Both of these models are discussed in USEPA's Superfund Exposure Assessment Manual (USEPA, 1988) as appropriate for vapor emission modeling.

5.1 Vapor Emission Modeling

The transport of chemicals from contaminated media to the atmosphere is a complex process. The physical properties of the chemical (e.g., vapor pressure, solubility, soil adsorption), physical properties of the soil matrix (e.g., bulk density, porosity, fraction of organic carbon, moisture content), and environmental factors (e.g., temperature, humidity, depth to contamination, annual precipitation, wind speed) all govern the emission rate. The vapor emission model used in this assessment and the predicted vapor emission rates for the McKesson site are discussed in detail below.

Jury Behavior Assessment Model

The Jury BAM is a one-dimensional model that assumes the vapor, aqueous, and sorbed or solid phases are in equilibrium, as prescribed by Henry's Law for liquid-vapor partitioning and equilibrium-linear partitioning for liquid-solid partitioning (Jury et al., 1983). The soil is assumed to have been contaminated with a miscible chemical to a depth "L" with an

initial chemical concentration "Co." If more than one chemical is present, the model assumes that there are no interactions between chemicals and that all chemicals are subject to the same hydraulic and soil conditions.

The vapor emission rates predicted by the model are based on several conservative loss pathways, such as transport of a chemical subject to volatilization at the soil surface and leaching in the soil column via evapotranspiration. In addition, the model always conserves mass; that is, the model takes into account the time-dependent depletion of the chemical of concern in soil, since only a finite amount of chemical is initially present.

The Jury BAM has been validated in the laboratory and in field studies using soil-incorporated pesticides from the upper root zone. However, since this model uses contaminant-specific parameters (e.g., Henry's constant, organic soil binding coefficient, soil-gas diffusion coefficient), it is also applicable to more volatile compounds. The Jury BAM can incorporate a microbial or chemical decay rate specific to the contaminants of concern in estimating vapor flux from soil. However, for the purposes of this assessment, this factor is conservatively set equal to zero (i.e., no decay).

For purposes of this assessment, the 4.2-year and 30-year average flux rates are computed for each soil chemical of concern. These flux rates correspond to an occupational and residential exposure duration, respectively, as described in Section 4.0. The average flux rates for these two periods are calculated by numerically integrating the predicted flux rates in double precision over the duration periods and then dividing by the 4.2-year and 30-year time periods. A Gauss Legend quadrature scheme (Stroud, 1966) is used with 104 integration points to ensure at least a 5-digit accurate integration of the model's equation.

Information needed for estimating the vapor emission rate includes soil porosity, soil bulk density, thickness of the contaminated soil, soil moisture content, concentration of the chemical of concern in all three phases (total soil solute concentration), and the diffusion coefficient of the chemical of concern in air. Table 5-1 contains a summary of the physical characteristics of the site soils as determined by HLA. The following site-specific data are averages of soil parameters measured at soil samples SB-6 taken at a depth of 25.5 feet and SB-11 taken at a depth of 20.5 feet.

- Soil bulk density (Rho) = 1.58 g/cm^3
- Total porosity (Pt) = 0.42 cm^3/cm^3
- Vol. water content (Pw) = 0.20 cm^3/cm^3
- Vol. air content (Pa) = 0.22 cm^3/cm^3
- Grav. water content (Grav) = 0.127 g/g.

Sample Soil taken at 30.5 feet and sample SB-9 taken at 35.5 feet had high volumetric water content that would indicate that the samples were taken in saturated soil; therefore, they were not used in this analysis.

The depth of contamination was assumed to be 40 feet for all chemicals of concern. This corresponds to the average maximum depth at which chemicals were detected in the soil.

The initial chemical concentration, Co, also referred to as the total soil solute concentration Ct, can be approximated by the following equation:

TABLE 5-1

WEIGHT/VOLUME RELATIONSHIPS OF SOILS
ANALYSIS RESULTS[a]

BORING LOCATION:	SB-6	SB-6	SB-9	SB-11
SAMPLE DEPTH (FT):	25.5	30.5	35.5	20.5
SOIL CLASSIFICATION:	(SP-SM)	(ML)	(CL)	(SM)
MOISTURE CONTENT (%):	9.4	28.8	15.9	13.7
DRY DENSITY (PCF):	101.0	93.9	116.4	94.6
WEIGHT OF DRY SOIL (GM):	246.4	228.8	283.5	230.5
SPECIFIC GRAVITY:	2.68	2.72	2.74	2.73
VOLUME OF SOLID (CC):	91.9	84.1	103.5	84.4
VOLUME OF VOIDS (CC):	60.0	67.9	48.5	67.5
VOID RATIO:	0.653	0.807	0.469	0.800
VOLUME OF WATER (CC):	23.1	65.8	45.2	31.6
VOLUMETRIC WATER CONTENT[b] (%):	15.2	43.3	29.7	20.8
VOLUMETRIC AIR CONTENT[c] (%):	24.3	1.4	2.2	23.7
TOTAL POROSITY:	0.395	0.447	0.319	0.444

[a] Performed by HLA Testing Services, September 6, 1991
[b] Volumetric Water Content is calculated as Volume of Water divided by Total Volume.
[c] Volumetric Air Content is calculated as Volume of Voids minus Volume of Water divided by Total Volume.

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$$Ct = \frac{(Soil)(Rho)(1 + Grav)}{1000\ g/kg} \qquad \text{(Equation 1)}$$

Where:

Soil = Average concentration of contaminant in soil (mg/kg)

Rho = Dry bulk density (1.58 g/cm^3)

Grav = Gravimetric water content (0.127 g/g).

The 95th percent upper confidence limits of the arithmetic mean soil concentrations of the subsurface samples (greater than 2-foot depth) in Areas A, B, and C are used as a representative concentration of contaminant in soil. The sample borings in Areas A, B, and C, and the subsurface chemical concentrations measured in these borings, have been summarized previously in Section 2.0. These concentrations are used to obtain total soil solute concentrations, via equation #1 above. The total soil solute concentrations are then entered into the Jury BAM to obtain soil flux rates. The 95th percent upper confidence limits of the subsurface soil samples are presented in Table 2-6. The values for Koc, Henry's Constant, air-gas diffusion coefficient, and total soil solute concentration for the chemicals of concern are presented in Appendix B.

Jury BAM input parameters and results for each chemical of are presented in Appendix B. Appendix B also contains a detailed sample calculation of emission rates using acetone as an example. The flux rates predicted by the Jury BAM for the residential and occupational scenarios are presented in Appendix B and provide the basis for estimating on-site ambient air concentrations.

5.2 Air Dispersion Modeling

To evaluate potential contaminant uptake via inhalation, the ambient air concentrations for the chemicals of concern are determined from the emission rates. As described below, the Box Model is used to estimate on-site ambient air concentrations.

5.2.1 Box Model

A variety of methods and model adaptions can be used to predict on-site concentrations. Some of the approaches, generally those easiest to apply, are overly simplistic and result in considerable overestimation of actual concentrations. However, these simplistic models can be used as screening tools to determine whether on-site exposure to vapors represents a potential human health hazard.

One of the simplest approaches to the prediction of on-site concentrations is what is commonly called a "box" model. A box model is a simple mass-balance equation that uses the concept of a theoretically enclosed space or box over the area of interest. The model assumes the emission of compounds into a box, with their removal based on wind speed (conservatively assumed to be 2 m/sec). Airborne concentrations for this enclosed space can then be calculated and used as the on-site air contaminant concentration. The box model fails to fully take into account the various processes of dispersion and may lead to the prediction of relatively high-exposure concentrations even at relatively small flux rates. The exposure concentration in the theoretical box is calculated using the following equation:

$$\text{Box Concentration } (mg/m^3) = (F)(A)/([u][h][l])$$

Where:

F = Flux rate of chemical of concern predicted by BAM (mg/m^2-sec)

A = Emitting area assumed to be the sum of Areas A, B, and C.

u = Wind speed (2 m/sec)

h = Height of the box (2 m)

l = Length of box (length of the site = 135 m).

The Box model input parameters and results are presented in Appendix C. The on-site airborne contaminant concentration estimates for the residential and occupational scenarios are presented in Appendix C. These concentrations are used to calculate uptake via inhalation in Section 7.0.

As shown in Appendix H of the remedial investigation report, these predicted concentrations are in some cases greater than concentrations that currently exist on the site property. For example, the predicted concentration of tetrachloroethene is 34 ppb, yet the air sampling results clearly indicate that on-site ambient concentrations of tetrachloroethene were not detectable at a limit of detection of 10 ppb. This illustrates the conservative nature of the modeling assumptions. In addition, it is important to note that the modeling conditions assume no soil cover in the form of pavement, subflooring, etc. Such a covering would likely exist in the future, especially in the event of residential development, and therefore, the emission estimates should be considered conservative.

6.0 TOXICITY ASSESSMENT

The toxicity assessment section of a risk assessment describes the regulatory dose response criteria associated with the chemicals of concern. The remainder of this section addresses dose response criteria that have been developed by Cal-EPA and USEPA for the chemicals of concern.

Dose-response assessment is the process of characterizing the relationship between the dose of an agent and the anticipated incidence of an adverse health effect in an exposed population. The bulk of our knowledge about the dose-response relationship is based on data collected from animal studies (usually rodents) and theoretical precepts about what might occur in humans. When available, human exposure data are also considered and given more weight. When animal data are considered, mathematical models are used to estimate the possible response in humans at exposure levels far below those tested in animals. These models contain conservative assumptions, which should be considered when the results (i.e., risk estimates) are evaluated. Conservatism arises in animal models because of uncertainty in extrapolating results obtained in animal research to humans and the shortcomings of extrapolating responses obtained from high-dose studies to estimate responses at very low doses. For example, humans are typically exposed to environmental contaminants at levels that are less than one thousandth of the lowest dose tested in animals. Such doses may be easily handled by the myriad of biological protective mechanisms in humans (Ames et al., 1987). This means that while we may use the results of standard rodent bioassays to understand the human biological hazard or cancer risk posed by typical exposure levels, our ability to do so is limited (Crump et al., 1976; Sielkin, 1985).

The USEPA and Cal-EPA have used dose-response data to establish "maximally acceptable" levels of daily human exposure for noncarcinogenic chemicals. For carcinogenic

chemicals, regulatory policy assumes a potential carcinogenic response at any dose. Carcinogenic potency is a measure of the relationship between dose and tumor incidence. The following sections discuss the noncarcinogenic and carcinogenic risk criteria for the chemicals of concern.

6.1 Noncarcinogenic Health Effects

All the soil chemicals of concern considered in this assessment are known to cause non-carcinogenic health effects at sufficient doses. It is widely accepted that noncarcinogenic effects from chemical substances occur after a threshold dose is reached. For the purposes of establishing health risk criteria for noncarcinogenic effects, the threshold dose is usually estimated from the no-observed adverse effect level (NOAEL) or the lowest observed adverse effect level (LOAEL) determined in chronic animal exposure studies. The NOAEL is defined as the highest dose at which no adverse effects appear. The LOAEL is defined as the lowest dose at which adverse effects begin to appear.

NOAELs and LOAELs derived from human or animal studies are used by the USEPA to establish oral and inhalation reference doses (RfDs). An RfD is a maximal daily dose that is not expected to cause adverse health effects. Uncertainty factors are used to establish RfDs in an attempt to account for limitations in the quality or quantity of available data. Similarly, the CAPCOA guidelines contain "acceptable exposure levels" (AELs) that are maximally acceptable daily air concentrations or daily doses that are not expected to cause adverse health effects. If the estimated dose or air concentration for a given set of conditions is less than the chemical-specific RfD or AEL, then it is appropriate to conclude that no significant health hazard exists under the defined set of conditions.

For the purposes of this assessment, inhalation and oral RfDs established by the USEPA are used whenever possible. These values may be found in the USEPA's 1991 Health Effects Assessment Summary Table (USEPA, 1991b). Values which have been peer-reviewed and approved by USEPA scientists also appear in the Integrated Risk Information System (IRIS). As shown in Table 6-1, the USEPA has not established an inhalation RfD for 1,1-dichloroethene, 1,2-dichloroethane, 1,2-dichloroethene, acetone, tetrachloroethene, or trichloroethene. For the purposes of this assessment, the CAPCOA AELs of 0.64 mg/m^3 for trichloroethene and 0.095 mg/m^3 for 1,2-dichloroethane are converted to inhalation RfDs of 0.18 mg/kg-day and 0.027 mg/kg-day, respectively, using the following equation:

$$\text{Inhalation RfD (mg/kg-day)} = \frac{\text{CAPCOA AEL (mg/m}^3\text{) x 20 m}^3\text{/day}}{\text{70 kg}}$$

This conversion is consistent with current Cal-EPA guidance. The USEPA oral RfD of 1×10^{-2} mg/kg-day is used as the inhalation RfD for tetrachloroethene. For the remaining chemicals for which there are no USEPA or CAPCOA inhalation criteria, noncancer hazards are not assessed (1,1-dichloroethene, 1,2-dichloroethene, and acetone). For the purposes of this assessment, the inhalation RfDs derived above for trichloroethene and 1,2-dichloroethane are also used to represent the oral RfD. This is a conservative measure, since significantly less chemical would be expected to be absorbed via soil ingestion. Since regulatory agencies have not set dermal RfDs, it is standard practice to use the oral RfDs as surrogate values for dermal RfDs. The RfDs used in this assessment for each exposure pathway are summarized in Table 6-1.

TABLE 6-1

NONCARCINOGENIC TOXICITY VALUES

Chemical	Critical Effect	Chronic RfD (mg/kg-day)	RfD Source*
Inhalation Route:			
1,1-Dichloroethane	Kidney	1.0×10^{1}	HEAST, 1991
1,1-Dichloroethene	No Data	ND	–
1,1,1-Trichloroethane	Liver toxicity	3.0×10^{1}	HEAST, 1991
1,2-Dichloroethane	Immune system, kidney, liver toxicity	2.7×10^{2}	CAPCOA AEL, adjusted from concentration to dose
1,2-Dichloroethene	No Data	ND	–
2-Butanone (MEK)	Central nervous system	9.0×10^{2}	HEAST, 1991
Acetone	No Data	ND	–
Methylene Chloride	Central nervous system, liver toxicity	8.6×10^{1}	HEAST, 1991
Tetrachloroethene	No Data	1.0×10^{2}	Oral RfD from HEAST, 1991
Toluene	Central nervous system	5.7×10^{1}	HEAST, 1991
Trichloroethene	Central nervous system, liver toxicity	1.8×10^{1}	CAPCOA AEL, adjusted from concentration to dose
Xylenes	Central nervous system	8.5×10^{2}	HEAST, 1991
Oral Route:			
1,1-Dichloroethane	Kidney	1.0×10^{1}	HEAST, 1991
1,1-Dichloroethene	Hepatic lesions	9.0×10^{3}	IRIS, 1992
1,1,1-Trichloroethane	Liver toxicity	9.0×10^{2}	HEAST, 1991
1,1,2-Trichloroethane	Clinical chemistry	4.0×10^{3}	IRIS, 1992
1,1,2,2-Tetrachloroethane	No data	ND	IRIS, 1992
1,2-Dichloropropane	No data	ND	IRIS, 1992
1,2-Dichloroethane	No Data	2.7×10^{2}	Inhalation RfD derived for this assessment
1,2-Dichloroethene	No Data	ND	–
2-Butanone (MEK)	Central nervous system	5.0×10^{2}	HEAST, 1991
2-Hexanone	No data	ND	IRIS, 1992
4-Methyl-2-Pentanone	No data	ND	IRIS, 1992
Acetone	Liver and kidney	1.0×10^{1}	IRIS, 1992
Benzene	No data	ND	IRIS, 1992
Bromodichloromethane	Renal cytomegaly	2.0×10^{2}	IRIS, 1992

* CAPCOA AEL = California Air Pollution Control Officers Association, Acceptable Exposure Level (CAPCOA, 1991)
HEAST = Health Effects Assessment Summary Table (USEPA, 1991b)
IRIS = Integrated Risk Information System (USEPA, 1991 and 1992)

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TABLE 6-1
(Continued)

NONCARCINOGENIC TOXICITY VALUES

Chemical	Critical Effect	Chronic RfD (mg/kg-day)	RfD Source*
Bromoform	Hepatic lesions	$.0 \times 10^{2}$	IRIS, 1992
Bromomethane	Neurotoxicity	1.4×10^{3}	HEAST, 1991
Carbon Disulfide	Fetal toxicity	1.0×10^{-1}	IRIS, 1992
Carbon Tetrachloride	Liver lesions	7.0×10^{-4}	IRIS, 1992
Chlorobenzene	Histopathology liver	2.0×10^{-2}	IRIS, 1992
Chloroethane	No data	ND	IRIS, 1992
Chloroform	No data	ND	IRIS, 1992
Chloromethane	No data	ND	IRIS, 1992
Cis-1,2-Dichloroethene	Blood chemistry	1.0×10^{-2}	HEAST, 1991
Cis-1,3-Dichloropropene	Increase organ weight	3.0×10^{-4}	IRIS, 1992
Copper	No data	ND	IRIS, 1992
Dibromochloroemethane	No data	ND	IRIS, 1992
Ethylbenzene	Developmental toxicity	1.0×10^{-1}	IRIS, 1992
Manganese	Respiratory disturbances	1.0×10^{-1}	IRIS, 1992
Methylene Chloride	Liver toxicity	6.0×10^{-2}	HEAST, IRIS, 1991
Styrene	Liver, blood	2.0×10^{-1}	IRIS, 1992
Tetrachloroethene	Liver toxicity	1.0×10^{-2}	HEAST, IRIS, 1991
Toluene	Liver and kidney	2.0×10^{-1}	IRIS, 1992
Trans-1,2-dichloroethene	Clinical chemistry	2.0×10^{-2}	HEAST, 1991
Trans-1,3-Dichloropropene	No data	ND	IRIS, 1992
Trichloroethene	No Data	1.8×10^{-1}	Inhalation RfD derived for this assessment
Trichlorofluoromethane	Histopathology	3.0×10^{-1}	IRIS, 1992
Vinyl Chloride	No data	ND	IRIS, 1992
Vinyl Acetate	No data	ND	IRIS, 1992
Xylenes	Liver and kidney	$2.0 \times 10^{+0}$	IRIS, 1992
Zinc	anemia	2.0×10^{-1}	HEAST, 1991
Dermal Route:			
1,1-Dichloroethane	No data	1.0×10^{-1}	Oral RfD derived for this assessment
1,1-Dichloroethene	No data	9.0×10^{-3}	Oral RfD derived for this assessment

* CAPCOA AEL = California Air Pollution Control Officers Association, Acceptable Exposure Level (CAPCOA, 1991)
HEAST = Health Effects Assessment Summary Table (USEPA, 1991b)
IRIS = Integrated Risk Information System (USEPA, 1991 and 1992)

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TABLE 6-1
(Continued)

NONCARCINOGENIC TOXICITY VALUES

Chemical	Critical Effect	Chronic RfD (mg/kg-day)	RfD Source*
1,1,1-Trichloroethane	No data	9.0×10^{-2}	Oral RfD derived for this assessment
1,1,2-Trichloroethane	No data	4.0×10^{-3}	Oral RfD derived for this assessment
1,1,2,2-Tetrachloroethane	No data	ND	Oral RfD derived for this assessment
1,2-Dichloropropane	No data	ND	Oral RfD derived for this assessment
1,2-Dichloroethane	No data	2.7×10^{-2}	Oral RfD derived for this assessment
1,2-Dichloroethene	No data	ND	Oral RfD derived for this assessment
2-Butanone (MEK)	No data	5.0×10^{-2}	Oral RfD derived for this assessment
2-Hexanone	No data	ND	Oral RfD derived for this assessment
4-Methyl-2-Pentanone	No data	ND	Oral RfD derived for this assessment
Acetone	No data	1.0×10^{-1}	Oral RfD derived for this assessment
Benzene	No data	ND	Oral RfD derived for this assessment
Bromodichloromethane	No data	2.0×10^{-2}	Oral RfD derived for this assessment
Bromoform	No data	2.0×10^{-2}	Oral RfD derived for this assessment
Bromomethane	No data	1.4×10^{-3}	Oral RfD derived for this assessment
Carbon Disulfide	No data	1.0×10^{-1}	Oral RfD derived for this assessment
Carbon Tetrachloride	No data	7.0×10^{-4}	Oral RfD derived for this assessment
Chlorobenzene	No data	2.0×10^{-2}	Oral RfD derived for this assessment
Chlorothane	No data	ND	Oral RfD derived for this assessment
Chloroform	No data	ND	Oral RfD derived for this assessment

* CAPCOA AEL = California Air Pollution Control Officers Association, Acceptable Exposure Level (CAPCOA, 1991)
HEAST = Health Effects Assessment Summary Table (USEPA, 1991b)
IRIS = Integrated Risk Information System (USEPA, 1991 and 1992)

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TABLE 6-1
(Continued)

NONCARCINOGENIC TOXICITY VALUES

Chemical	Critical Effect	Chronic RfD (mg/kg-day)	RfD Source*
Chloromethane	No data	ND	Oral RfD derived for this assessment
Cis-1,2-Dichloroethene	No data	1.0×10^{-2}	Oral RfD derived for this assessment
Cis-1,3-Dichloropropene	No data	3.0×10^{-4}	Oral RfD derived for this assessment
Copper	No data	ND	Oral RfD derived for this assessment
Dibromochloroemethane	No data	ND	Oral RfD derived for this assessment
Ethylbenzne	No data	1.0×10^{-1}	Oral RfD derived for this assessment
Manganese	No data	1.0×10^{-1}	Oral RfD derived for this assessment
Methylene Chloride	No data	6.0×10^{-2}	Oral RfD derived for this assessment
Styrene	No data	2.0×10^{-1}	Oral RfD derived for this assessment
Tetrachloroethene	No data	1.0×10^{-2}	Oral RfD derived for this assessment
Toluene	No data	2.0×10^{-1}	Oral RfD derived for this assessment
Trans-1,2-dichloroethene	No data	2.0×10^{-2}	--
Trans-1,3-dichloronopene	No data	ND	Oral RfD derived for this assessment
Trichloroethene	No data	1.8×10^{-1}	Oral RfD derived for this assessment
Trichlorofluoromethane	No data	3.0×10^{-1}	Oral RfD derived for this assessment
Vinyl Chloride	No data	ND	Oral RfD derived for this assessment
Vinyl Acetate	No data	ND	Oral RfD derived for this assessment
Xylenes	No data	$2.0 \times 10^{+0}$	Oral RfD derived for this assessment
Zinc	No data	2.0×10^{-1}	Oral RfD derived for this assessment

* CAPCOA AEL = California Air Pollution Control Officers Association, Acceptable Exposure Level (CAPCOA, 1991)
HEAST = Health Effects Assessment Summary Table (USEPA, 1991b)
IRIS = Integrated Risk Information System (USEPA, 1991 and 1992)

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6.2 Carcinogenic Health Effects

Regulatory agencies have generally assumed that carcinogenic agents should be treated as if they do not have thresholds. In short, the dose-response curve for carcinogens used for regulatory purposes only allows for zero risk at zero dose (i.e., for any dose, some risk is assumed to be present). To estimate the theoretical plausible response at low environmental doses, various mathematical models are used to extrapolate high-dose data to estimate risk at the low-dose levels. The USEPA generally uses the linearized multistage model for low dose extrapolation. This model assumes that the effect of the carcinogenic agent on tumor formation is linear. The cancer slope factor (SF) is a toxicity value that quantitatively defines the relationship between dose and response. The chemical-specific SF represents the upper bound estimate of the probability of a carcinogenic response per unit intake of a chemical over a 70-year lifetime.

The USEPA classifies chemicals into Groups A through E; Group A is designated "human carcinogen" and Group E is designated "noncarcinogen" (with "probable," "possible," and "not classifiable" as Groups B, C, and D, respectively). Quantitative carcinogenic risk assessments are performed for chemicals in Groups A and B and may be performed for those in Group C on a case-by-case basis (USEPA, 1989a). Table 6-2 summarizes the oral and inhalation slope factors that USEPA has established for each of the chemicals of concern. For the purposes of this assessment and consistency with USEPA guidance, the oral slope factors will be used to represent dermal slope factors.

TABLE 6-2

CANCER SLOPE FACTORS AND CLASSIFICATION

Chemical	Slope Factor (SF) $(mg/kg\text{-}day)^{-1}$	Weight-of-Evidence Classification	Type of Cancer	SF Source*
Inhalation Route:				
1,1-Dichloroethene	$1.2 \times 10^{+0}$	C	Kidney	IRIS, 1992
1,2-Dichloroethane	9.1×10^{-2}	B2	Circulatory System	HEAST, 1991
Methylene Chloride	1.6×10^{-3}	B2	Lung and Liver	HEAST, IRIS, 1991
Tetrachloroethene	1.8×10^{-3}	B2	Leukemia and Liver	HEAST, 1991
Trichloroethene	1.7×10^{-2}	B2	Lung	HEAST, 1991
Oral Route:				
Benzene	2.9×10^{-2}	A	Leukemia	IRIS, 1992
Chloroform	6.1×10^{-3}	B2	Kidney	IRIS, 1992
Dibromochloronethane	8.4×10^{-2}	C	Liver	IRIS, 1992
Vinyl Chloride	$1.9 \times 10^{+0}$	A	Lung	IRIS, 1992
1,1,2-Trichloroethane	5.7×10^{-2}	C	Liver	IRIS, 1992
1,1,2,2-Tetrachloroethane	2.0×10^{-1}	C	Liver	IRIS, 1992
1,2-Dichlorpropane	6.8×10^{-2}	B2	Liver	IRIS, 1992
Bromodichloroemethane	1.3×10^{-1}	B2	Kidney	IRIS, 1992
Bromoform	7.9×10^{-3}	B2	Large Intestine	IRIS, 1992
Carbon Tetrachloride	1.3×10^{-1}	B2	Liver	IRIS, 1992
Cis-1,3-Dichloropropene	1.8×10^{-1}	B2	Liver	HEAST, 1991
Styrene	3.0×10^{-2}	B2	Lung	HEAST, 1991
1,1-Dichloroethene	6.0×10^{-1}	C	Adrenal	IRIS, 1992
1,2-Dichloroethane	9.1×10^{-2}	B2	Circulatory System	HEAST, 1991
Methylene Chloride	7.5×10^{-3}	B2	Liver	HEAST, 1991
Tetrachloroethene	5.1×10^{-2}	B2	Liver	HEAST, 1991
Trichloroethene	1.1×10^{-2}	B2	Liver	HEAST, 1991
Dermal Route:				
Benzene	2.9×10^{-2}	A	Leukemia	Oral SF
Chloroform	6.1×10^{-3}	B2	Kidney	Oral SF
Dibromochloromethane	8.4×10^{-2}	C	Liver	Oral SF
Vinyl Chloride	$1.9 \times 10^{+0}$	A	Lung	Oral SF
1,1,2-Trichloroethane	5.7×10^{-2}	C	Liver	Oral SF
1,1,2,2-Tetrachloroethane	2.0×10^{-1}	C	Liver	Oral SF
1,2-Dichoropropane	6.8×10^{-2}	B2	Liver	Oral SF
Bromodichlormethane	1.3×10^{-1}	B2	Kidney	Oral SF

TABLE 6-2
(Continued)

CANCER SLOPE FACTORS AND CLASSIFICATION

Chemical	Slope Factor (SF) (mg/kg-day)$^{-1}$	Weight-of-Evidence Classification	Type of Cancer	SF Source*
Bromoform	7.9×10^{-3}	B2	Large Intestine	Oral SF
Carbon Tetrachloride	1.3×10^{-1}	B2	Liver	Oral SF
Cis-1,3-Dichloropropene	1.8×10^{-1}	B2	Liver	Oral SF
Styrene	3.0×10^{-2}	B2	Lung	Oral SF
1,1-Dichloroethene	6.0×10^{-1}	C	Adrenal	Oral SF
1,2-Dichloroethane	9.1×10^{-2}	B2	Circulatory System	Oral SF
Methylene Chloride	7.5×10^{-3}	B2	Liver	Oral SF
Tetrachloroethene	5.1×10^{-2}	B2	Liver	Oral SF
Trichloroethene	1.1×10^{-2}	B2	Liver	Oral SF

HEAST = Health Effects Assessment Summary Table (USEPA, 1991b)
IRIS = Integrated Risk Information System (USEPA, 1991 and 1992)

7.0 DOSE CALCULATIONS AND HEALTH RISK ESTIMATES

This section describes the methods used to estimate the chemical uptake (dose) and associated health risks for the exposure scenarios described in Section 4.0. Dose is defined as the average amount of chemical systemically absorbed by the body over a given period of time. For noncarcinogenic effects, the dose is averaged over the period of exposure and is referred to as the average daily dose (ADD). For carcinogenic effects, the dose is averaged over a lifetime and is referred to as the lifetime average daily dose (LADD). Subsection 7.1 describes the derivation of representative chemical concentrations in surficial soils and air. In Subsection 7.2, these chemical concentrations and the exposure estimates defined in Subsection 4.0 are input to pathway-specific dose equations to estimate contaminant uptake via each soil exposure pathway. Chemical doses associated with groundwater exposure are also calculated in section 7.2. For the purposes of this assessment, the maximum chemical concentrations detected in any single well on-site or off-site (Table 3-2) are used to assess chemical uptake via incidental groundwater exposure.

7.1 Representative Chemical Concentrations In Soil

As previously discussed in Section 5.0, the 95th percent upper confidence limit (UCL) of the arithmetic mean of the subsurface soil concentrations (sample depth greater than 2 feet) of the chemicals of concern in Areas A, B, and C was input into the Jury vapor emission model to predict vapor concentrations at breathing height. The 95th percent UCLs are summarized in Table 2-6; the data used to calculate these values are summarized in Appendix A. The representative vapor concentrations used in this assessment are summarized in Appendix C.

Similarly, the 95th percent UCLs of the surficial soil concentrations (sample depth less than 2 feet) of these chemicals in Areas A, B, and C are used as representative chemical concentrations for the soil ingestion and dermal contact exposure pathways. The 95th percent UCLs are summarized in Table 2-6 and 7-1; the data used to calculate these values are summarized in Appendix A. It is appropriate to consider surficial soil only for these pathways since this is the depth of soil where direct contact occurs. For the residential exposure scenario, which considers a 30-year exposure duration, these soil concentrations were adjusted to account for the estimated half-life of the chemicals of concern, as referenced in the Handbook of Environmental Degradation Rates (Printup et al., 1991). Accounting for chemical degradation is consistent with current USEPA guidance, which states that it is appropriate to consider degradation for chemicals or site conditions where "leaching, volatilization, photolysis, biodegradation, wind erosion, and surface runoff will reduce chemical concentrations over time" (USEPA, 1989a).

Given the highly volatile nature of the VOCs, and their susceptibility to photolysis and microbial degradation, it is reasonable to expect that any chemicals present in the upper few inches of soil at the McKesson site will be reduced with time. This is supported by the observation that the 0.5-foot samples taken directly from the runoff control sump (SS-01 through SS-04) were relatively free of detectable levels of VOCs.

Chemical degradation that follows a first-order decay process throughout a given time period is described by the following equation:

$$\frac{-dN}{dt} = kN$$

TABLE 7-1

CHEMICALS OF CONCERN HALF-LIVES IN SOIL AND SURFICIAL SOIL CONCENTRATIONS

Chemical	Half-Life (days)	Initial 95 Percent UCL Surficial Soil Concentration (mg/kg)	Final Average Surficial Soil Concentration (0-6 years) (mg/kg)	Final Average Surficial Soil Concentration (6-30 years) (mg/kg)	Reference for Half-Life
Acetone	7	0.5	1.76×10^{-17}	1.76×10^{-17}	Printup, 1991 pg. 97
1,1-Dichloroethane	154	0.076	5.00×10^{-3}	5.00×10^{-3}	Printup, 1991 pg. 148
1,2-Dichloroethane	180	9.42	4.08×10^{-1}	4.08×10^{-1}	Printup, 1991 pg. 386
1,1-Dichloroethene	180*	0.34	2.30×10^{-2}	2.30×10^{-2}	Printup, 1991*
1,2-Dichloroethene	180	0.025	1.00×10^{-3}	1.00×10^{-3}	Printup, 1991 pg. 584
2-Butanone (MEK)	7	0.5	1.76×10^{-17}	1.76×10^{-17}	Printup, 1991 pg. 186
Methylene Chloride	28	112.43	2.00×10^{-3}	2.00×10^{-3}	Printup, 1991 pg. 142
Tetrachloroethene	360	858.29	91.1	4.65×10^{-6}	Printup, 1991 pg. 502
Toluene	22	43.12	7.19×10^{-5}	7.19×10^{-5}	Printup, 1991 pg. 410
1,1,1-Trichloroethane	273	1039.39	80.3	80.3	Printup, 1991 pg. 113
Trichloroethene	360	17.92	1.89	1.89	Printup, 1991 pg. 190
Xylenes	28	26.43	5.00×10^{-4}	5.00×10^{-4}	Printup, 1991 pg. 643

* Half-life in soil was assumed to be the same time length as 1,2-Dichloroethene.

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Where:

Dn	=	amount of chemical decaying per unit time
dt	=	increment of time
k	=	rate constant (fraction degraded per time for first order reactions)
N	=	total amount of chemical present at any given time

The integrated form of this equation was used to calculate the amount of contaminant remaining halfway through the exposure duration:

$$\frac{\ln_{No}}{N} = kt$$

Where:

N_o	=	amount of chemical at t=O (100 percent)
N	=	amount of chemical remaining at time t
k	=	rate constant (0.693 ÷ t1/2)
t	=	length of time in soil

The amount of chemical in soil is expressed as a soil concentration, Csl. The following equation is used to solve for the average soil concentration ($Csl_{average}$) during the child (0-6 years) and adult (6-24 years) exposure period of the resident:

$$Csl_{average} = e^{(\ln Csl_{initial} - kt)}$$

Where:

$Csl_{average}$	=	representative soil concentration for a particular exposure period
e	=	2.718
$Csl_{initial}$	=	soil concentration at the beginning of the exposure period
k	=	decay constant $(days)^{-1}$
t	=	one-half of the exposure duration (days)

Table 7-1 summarizes the soil half-lives used in this assessment. For the purposes of assessing uptake, these half-lives were used to calculate the soil concentrations following a 0- to 6-year and 30-year degradation of the initial soil concentration. The resulting values are then used as representative soil concentrations to calculate uptake for the 0- to 6-year and 6- to 30-year exposure group, respectively. In most cases, (all except tetrachloroethene) the estimated concentrations at the 6-30 year exposure group were very low and for these chemicals the 0-6 year estimate was assumed for 6-30 years in order to ensure that risks were not underestimated. It is important to note that no chemical degradation was assumed when deriving estimates of vapor emissions and breathing zone concentrations over time. Since some degree of degradation in subsurface soil would be expected to occur, the vapor concentration estimates are conservative.

7.2 Dose Calculations

This section presents the methods used to calculate dose for each exposure pathway. The surficial soil contaminant concentrations summarized in Table 7-1, the vapor concentrations summarized in Appendix C, the groundwater contaminant concentrations summarized in Table 3-2, and the exposure estimates described in Section 4.0 are input into the equations to yield a dose estimate. The dose equations are consistent with the equations presented in Cal-EPA's (formerly the California Department of Health Services) draft Scientific and Technical Standards for Hazardous Waste Sites (Cal-EPA, 1990). Appendix D presents the dose calculation spreadsheets and health risk estimates for each exposure scenario. The health risk estimates are discussed in detail in Section 8.0.

7.2.1 Vapor Inhalation

Chemical uptake via inhalation of soil vapors is calculated according to the following equation:

$$\text{Dose} = \frac{C \times IR \times ET \times EF \times ED \times B}{BW \times AT}$$

Where:

Dose	=	Dose associated with the inhalation route for each chemical of concern (mg/kg-day)
C	=	Vapor concentration derived from the fate and transport model (mg/m^3)
IR	=	Inhalation rate (m^3/hr)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
B	=	Bioavailability (unitless)
BW	=	Body weight (kg)
AT	=	Averaging time - time period over which exposure is averaged (days)

Variable Values:

C	=	Derived from Box model for on-site concentrations
IR	=	1.25 m^3/hr. (occupational adult); 0.83 m^3/hr. (residential adult); 0.44 m^3/hr. (residential child).
ET	=	8 hrs/day (occupational adult); 24 hrs/day (residential adult and child)
EF	=	250 days/year (occupational adult); 350 days/year (residential adult and child)
ED	=	4.2 years (occupational); 30 years residential: 6 years (child); 24 years(adult)
B	=	1 (100 percent)
BW	=	70 kg (adult); 15 kg (child)
AT	=	70 years x 365 days/year (carcinogens) ED x 365 days/year (noncarcinogens)

Sample Calculation:

The lifetime average daily dose of 1,2-dichloroethane via vapor inhalation for the adult resident is calculated as follows:

$$\text{Dose} = \frac{C \times IR \times ET \times EF \times ED \times B}{BW \times AT}$$

Where:

C	=	3.12×10^{-4} mg/m^3
IR	=	0.83 m^3/hr.
ET	=	24 hrs/day
EF	=	350 days/year
ED	=	24 years
B	=	1
BW	=	70 kg
AT	=	25,550 days

Therefore:

$$\text{Dose} = \frac{(3.12 \times 10^{-4}\ \text{mg/m}^3) \times (0.83\ \text{m}^3/\text{hr.}) \times (24\ \text{hrs./day}) \times (350\ \text{days/year}) \times (24\ \text{years}) \times (1)}{(70\ \text{kg}) \times (25{,}550\ \text{days})}$$

$$= 2.92 \times 10^{-5}\ \text{mg/kg-day}$$

7.2.2 Soil Ingestion

Chemical uptake via ingestion of surficial soil is calculated according to the following equation:

$$\text{Dose} = \frac{C \times IR \times CF \times EF \times ED \times B}{BW \times AT}$$

Where:

Dose	=	Dose associated with the soil ingestion route for each chemical of concern (mg/kg-day)
C	=	Soil concentration (mg/kg)
IR	=	Soil ingestion rate (mg/day)
CF	=	Conversion factor (10^{-6} kg/mg)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
B	=	Bioavailability (unitless)
BW	=	Body weight (kg)
AT	=	Averaging time - time period over which exposure is averaged (days)

Variable values:

C	=	Soil concentration derived from the 95th percent UCL of the arithmetic mean concentration of surficial soil samples.
IR	=	50 mg/day (occupational adult); 100 mg/day (residential adult); 200 mg/day (residential child)
EF	=	250 days/year (occupational adult); 350 days/year (residential adult and child)
ED	=	4.2 years (occupational adult); 30 years residential: 6 years (child), 24 years (adult)
B	=	1 (100 percent)
BW	=	70 kg (adult); 15 kg (child)
AT	=	70 years x 365 days/year (carcinogens); ED x 365 days/year (noncarcinogens)

Sample calculation:

The lifetime average daily dose of 1,2-dichloroethane via soil ingestion for a child resident is calculated as follows:

$$\text{Dose} = \frac{C \times IR \times CF \times EF \times ED \times B}{BW \times AT}$$

Where:

C	=	4.08×10^{-1} mg/kg
IR	=	200 mg/day
CF	=	1×10^{-6} kg/mg
EF	=	350 days/year
ED	=	6 years
B	=	1
BW	=	15 kg
AT	=	25,550 days

Therefore:

$$\text{Dose} = \frac{(4.08 \times 10^{-1}\ \text{mg/kg}) \times (200\ \text{mg/day}) \times (1 \times 10^{-6}\ \text{kg/mg}) \times (350\ \text{days/year}) \times (6\ \text{years}) \times (1)}{(15\ \text{kg}) \times (25{,}550\ \text{days})}$$

$$= 4.47 \times 10^{-7}\ \text{mg/kg-day}$$

7.2.3 Dermal Contact with Soil

Chemical uptake via dermal contact with surficial site soil is calculated according to the following equation:

$$\text{Dose} = \frac{C \times SA \times CF \times EF \times ED \times AF \times B}{BW \times AT}$$

Where:

Dose	=	Dose associated with the dermal contact route for each chemical of concern (mg/kg-day)
C	=	Soil concentration (mg/kg)

SA	=	Surface area of exposed skin (cm^2)
CF	=	Conversion factor (10^{-6} kg/mg)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
AF	=	Soil to skin adherence factor (mg/cm^2-day)
B	=	Bioavailability (unitless)
BW	=	Body weight (kg)
AT	=	Averaging time - time period over which exposure is averaged (days)

Variable values:

C	=	Soil concentration derived from the 95th percent UCL of the arithmetic mean concentration of surficial soil samples.
SA	=	3,900 cm^2 (adult); 1,520 cm^2 (child)
EF	=	250 days/year (occupational adult); 350 days/year (residential adult and child)
ED	=	4.2 years (occupational adult); 30 years (residential); 6 years (child), 24 years (adult)
AF	=	0.5 mg/cm^2-day
B	=	0.1 (10 percent)
BW	=	70 kg (adult); 15 kg (child)
AT	=	70 years x 365 days/year (carcinogens); ED x 365 days/year (noncarcinogens)

Sample calculation:

The lifetime average daily dose of 1,2-dichloroethane via dermal contact with soil for a child is calculated as follows:

$$\text{Dose} = \frac{C \times SA \times CF \times EF \times ED \times AF \times B}{BW \times AT}$$

Where:

C = 4.08×10^{-1} mg/kg

SA	=	1,520 cm^2
CF	=	1×10^{-6} kg/mg
EF	=	350 days/year
ED	=	6 years
AF	=	0.5 mg/cm^2-day
B	=	0.1
BW	=	15 kg
AT	=	25,550 days

Therefore:

$$\text{Dose} = \frac{(4.08 \times 10^{-1}\ \text{mg/kg}) \times (1{,}520\ \text{cm}^2) \times (1 \times 10^{-6}\ \text{kg/mg}) \times (350\ \text{days/year}) \times (6\ \text{years}) \times (0.5\ \text{mg/cm}^2\text{-day}) \times (0.1)}{(15\ \text{kg}) \times (25{,}550\ \text{days})}$$

$$= 1 \times 10^{-7}\ \text{mg/kg-day}$$

7.2.4 Incidental Ingestion of Groundwater

Chemical uptake via incidental ingestion of groundwater is calculated according to the following equation:

$$\text{Dose} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Where:

Dose	=	Dose associated with incidental groundwater ingestion route for each chemical of concern (mg/kg-day)
C	=	Chemical concentration in groundwater(mg/L)
IR	=	Incidental ingestion rate (L/day)
ER	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging Time-time period over which exposure is averaged (days)

Variable Values:

C	=	Maximum chemical concentration measured in any on or off-site well (Table 3-2) (mg/L)
IR	=	0.05 L/day
EF	=	52 days/year
ED	=	30 years (6 years child, 24 years adult)
BW	=	70 kg (adult); 15 kg (child)
AT	=	70 years x 365 days/year (carcinogens); ED x 365 days/year (noncarcinogens)

Sample Calculation:

The lifetime average daily dose of 1,2-dichloroethane via incidental ingestion of groundwater for a child resident is calculated as follows:

$$\text{Dose} = \frac{C \times IR \times EF \times ED}{BW \times AT}$$

Where:

C	=	20 mg/L
IR	=	0.05 L/day
EF	=	52 days/year
ED	=	6 years
BW	=	15 kg
AT	=	25550 days

Therefore:

$$\text{Dose} = \frac{(20\ \text{mg/L}) \times (0.05\ \text{L/day}) \times (52\ \text{days/year}) \times (6\ \text{years})}{(15\ \text{kg}) \times (25{,}550\ \text{days})}$$

$$= 8.14 \times 10^{-4}\ \text{mg/Kg-day}$$

7.2.5 Incidental Dermal Contact with Groundwater

Chemical uptake via incidental dermal contact with groundwater is calculated by the following equation:

$$\text{Dose} = \frac{C \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where:

Dose	=	Dose associated with incidental dermal contact with groundwater (mg/kg-day)
C	=	Chemical concentration in groundwater (mg/L)
SA	=	Exposed skin surface area (cm^2)
PC	=	Permeability constant (cm/hr)
ET	=	Exposure time (hr/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
CF	=	Conversion factor (1 L/1,000 cm^3)
BW	=	Body Weight
AT	=	Averaging time- time period over which exposure is averaged (days)

Variable Values:

C	=	Maximum chemical concentration measured in any on- or off-site well (Table 3-2) (mg/L)
SA	=	3900 cm^2 (adult); 1520 cm^2 (child)
PC	=	8.4×10^{-4} cm/hr
ET	=	1 hour/day
EF	=	52 days/year
ED	=	30 years (6 years child, 24 years adult)
BW	=	70 kg (adult); 15kg (child)
AT	=	70 years x 365 days/year (carcinogen); ED x 365 days/year (noncarcinogens)

Sample Calculation:

The lifetime average daily dose of 1,2-dichloroethane via dermal contact with groundwater for a child resident is calculated as follows:

$$\text{Dose} = \frac{C \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT}$$

Where :

C	=	20 mg/L
SA	=	1520 cm^2
PC	=	8.4×10^{-4} cm/hr
ET	=	1 hour/day
EF	=	52 days/year
ED	=	6 years
CF	=	1 L/1000 cm^3
BW	=	15 kg
AT	=	25,550 days

Therefore:

$$\text{Dose} = \frac{(20\ \text{mg/L}) \times (1520\text{cm}^2) \times (8.4 \times 10^{-4}\ \text{cm/hr}) \times (1\ \text{hour/day}) \times (52\ \text{days/year}) \times 6\ \text{years}) \times (1\ \text{L}/1000\ \text{cm}^3)}{(15\ \text{kg}) \times (25{,}550\ \text{days})}$$

$$= 2.08 \times 10^{-5}\ \text{mg/kg-day}$$

Tables 7-2 through 7-6 summarizes each chemical dose by each pathway. Appendix D contains all the calculation spreadsheets for each chemical for each pathway. Exposure factors and time-dependent representative chemical concentrations for each group are clearly defined. Average daily doses (ADDs) and lifetime average daily doses (LADDs) are summed where appropriate, and the estimated health risks are summarized. Section 8.0 describes the health risk estimates in detail.

Table 7-2 Chemical Dose For Vapor Inhalation Pathway (mg/kg-day)*

Chemical	Future Onsite Worker		Future Onsite Resident (Child)		Future Onsite Resident (Adult)	
	ADD	LADD	ADD	LADD	ADD	LADD
Acetone	1.68E-03	-	4.05E-03	-	1.64E-03	-
1,1-Dichloroethane	1.25E-05	-	2.70E-05	-	1.09E-05	-
1,2-Dichloroethane	7.65E-05	4.59E-06	2.11E-04	1.81E-05	8.51E-05	2.92E-05
1,1-Dichloroethene	3.37E-06	2.02E-07	7.70E-06	6.60E-07	3.11E-06	1.07E-06
1,2-Dichloroethene	1.06E-05	-	2.42E-05	-	9.80E-06	-
2-Butanone (MEK)	4.36E-04	-	1.52E-03	-	6.14E-04	-
Methylene Chloride	2.15E-03	1.29E-04	3.55E-03	3.04E-04	1.44E-03	4.92E-04
Tetrachloroethene	5.48E-03	3.29E-04	1.30E-02	1.12E-03	5.27E-03	1.81E-03
Trichloroethene	2.12E-04	1.27E-05	5.16E-04	4.43E-05	2.09E-04	7.16E-05
Toluene	4.70E-04	-	1.31E-03	-	5.29E-04	-
1,1,1-Trichloroethane	3.37E-03	-	7.49E-03	-	3.03E-03	-
Xylenes	5.20E-04	-	1.46E-03	-	5.89E-04	-

* ADD = Average daily dose for noncarcinogenic effects.
LADD = Lifetime average daily dose for carcinogenic effects.

Table 7-3 Chemical Dose For Soil Ingestion Pathway (mg/kg-day)*

Chemical	Future Onsite Worker		Future Onsite Resident (Child)		Future Onsite Resident (Adult)	
	ADD	LADD	ADD	LADD	ADD	LADD
Acetone	2.45E-07	-	2.25E-22	-	2.41E-23	-
1,1-Dichloroethane	3.72E-08	-	6.39E-08	-	6.85E-09	-
1,2-Dichloroethane	4.61E-06	2.77E-07	5.22E-06	4.47E-07	5.59E-07	2.35E-09
1,1-Dichloroethene	1.66E-07	9.98E-09	2.94E-07	2.52E-08	3.15E-08	1.08E-08
1,2-Dichloroethene	1.22E-08	-	1.28E-08	-	1.37E-09	-
2-Butanone (MEK)	2.45E-07	-	2.25E-22	-	2.41E-23	-
Methylene Chloride	5.50E-05	3.30E-06	2.56E-08	2.19E-09	2.74E-09	9.39E-10
Tetrachloroethene	4.20E-04	2.52E-05	1.16E-03	9.98E-05	6.37E-12	2.18E-12
Trichloroethene	8.77E-06	5.26E-07	2.42E-05	2.07E-06	2.59E-06	8.88E-07
Toluene	2.11E-05	-	9.19E-10	-	9.85E-11	-
1,1,1-Trichloroethane	5.09E-04	-	1.03E-03	-	1.10E-04	-
Xylenes	1.29E-05	-	6.39E-09	-	6.85E-10	-

* ADD = Average daily dose for noncarcinogenic effects.
LADD = Lifetime average daily dose for carcinogenic effects.

Table 7-4 Chemical Dose For Dermal Contact Pathway (mg/kg-day)*

Chemical	Future Onsite Worker		Future Onsite Resident (Child)		Future Onsite Resident (Adult)	
	ADD	LADD	ADD	LADD	ADD	LADD
Acetone	9.54E-07	-	8.55E-23	-	4.70E-23	-
1,1-Dichloroethane	1.45E-07	-	2.43E-08	-	1.34E-08	-
1,2-Dichloroethane	1.80E-05	1.08E-06	1.98E-06	1.70E-07	1.09E-06	4.58E-09
1,1-Dichloroethene	6.49E-07	3.89E-08	1.12E-07	9.58E-09	6.14E-08	2.11E-08
1,2-Dichloroethene	4.77E-08	-	4.86E-09	-	2.67E-09	-
2-Butanone (MEK)	9.54E-07	-	8.55E-23	-	4.70E-23	-
Methylene Chloride	2.15E-04	1.29E-05	9.72E-09	8.33E-10	5.34E-09	1.83E-09
Tetrachloroethene	1.64E-03	9.83E-05	4.43E-04	3.79E-05	1.24E-11	4.26E-12
Trichloroethene	3.42E-05	2.05E-06	9.18E-06	7.87E-07	5.05E-06	1.73E-06
Toluene	8.23E-05	-	3.49E-10	-	1.92E-10	-
1,1,1-Trichloroethane	1.98E-03	-	3.90E-04	-	2.14E-04	-
Xylenes	5.04E-05	-	2.43E-09	-	1.34E-09	-

* ADD = Average daily dose for noncarcinogenic effects.
LADD = Lifetime average daily dose for carcinogenic effects.

Table 7-5 Chemical Dose For Incidental Groundwater Ingestion Pathway (mg/kg-day)*

Chemical	Future Onsite Resident (Child)		Future Onsite Resident (Adult)	
	ADD	LADD	ADD	LADD
1,1,1-Trichloroethane	4.18E-02	-	8.95E-03	-
1,1,2-Trichloroethane	4.75E-07	4.07E-08	1.02E-07	3.49E-08
1,1-Dichloroethene	2.37E-02	2.04E-03	5.09E-03	1.74E-03
1,2-Dichloroethane	9.50E-03	8.14E-04	2.04E-03	6.98E-04
2-Butanone	9.97E-04	-	2.14E-04	-
Acetone	2.71E-03	-	5.80E-04	-
Benzene	9.97E-05	8.55E-06	2.14E-05	7.33E-06
Chloroform	1.61E-05	1.38E-06	3.46E-06	1.19E-06
Cis-1,2-Dichloroethene	1.90E-03	-	4.07E-04	-
Dibromochloromethane	5.70E-06	4.88E-07	1.22E-06	4.19E-07
Ethylbenzene	2.09E-04	-	4.48E-05	-
Manganese	4.27E-08	-	9.16E-09	-
Methylene Chloride	4.75E-02	4.07E-03	1.02E-02	3.49E-03
Tetrachloroethene	2.14E-02	1.83E-03	4.58E-03	1.57E-03
Toluene	1.42E-03	-	3.05E-04	-
Trans-1,2-Dichloroethene	3.80E-06	-	8.14E-07	-
Trichloroethylene	5.22E-03	4.48E-04	1.12E-03	3.84E-04
Trichlorofluoromethane	1.71E-05	-	3.66E-06	-
Vinyl Chloride	3.70E-05	3.17E-06	7.94E-06	2.72E-06
Xylenes	6.17E-04	-	1.32E-04	-
Zinc	1.24E-03	-	2.67E-04	-

* ADD = Average daily dose for noncarcinogenic effects.
LADD = Lifetime average daily dose for carcinogenic effects.

Table 7-6 Chemical Dose For Incidental Dermal Contact With Groundwater Pathway (mg/kg-day)*

Chemical	Future Onsite Resident (Child)		Future Onsite Resident (Adult)	
	ADD	LADD	ADD	LADD
1,1,1-Trichloroethane	1.07E-03	-	5.87E-04	-
1,1,2-Trichloroethane	1.21E-08	1.04E-09	6.67E-09	2.29E-09
1,1-Dichloroethylene	6.06E-04	5.20E-05	3.33E-04	1.14E-04
1,2-Dichloroethane	2.43E-04	2.08E-05	1.33E-04	4.57E-05
2-Butanone	2.55E-05	-	1.40E-05	-
Acetone	6.91E-05	-	3.80E-05	-
Benzene	2.55E-06	2.18E-07	1.40E-06	4.80E-07
Chloroform	4.12E-07	3.53E-08	2.27E-07	7.77E-08
Cis-1,2-Dichloroethylene	4.85E-05	-	2.67E-05	-
Dibromochloromethane	1.46E-07	1.25E-08	8.00E-08	2.74E-08
Ethylbenzene	5.34E-06	-	2.93E-06	-
Manganese	1.09E-09	-	6.00E-10	-
Methylene Chloride	1.21E-03	1.04E-04	6.67E-04	2.29E-04
Tetrachloroethene	5.46E-04	4.68E-05	3.00E-04	1.03E-04
Toluene	3.64E-05	-	2.00E-05	-
Trans-1,2-Dichloroethylene	9.70E-08	-	5.33E-08	-
Trichloroethylene	1.33E-04	1.14E-05	7.33E-05	2.51E-05
Trichlorofluoromethane	4.37E-07	-	2.40E-07	-
Vinyl Chloride	9.46E-07	8.11E-08	5.20E-07	1.78E-07
Xylenes	1.58E-05	-	8.67E-06	-
Zinc	3.18E-05	-	1.75E-05	-

* ADD = Average daily dose for noncarcinogenic effects.
LADD = Lifetime average daily dose for carcinogenic effects.

8.0 RISK CHARACTERIZATION

This section of the risk assessment summarizes and characterizes the health risk estimates derived in Section 7.0. Subsections 8.1 and 8.2 describe the noncancer and cancer health risk estimates, respectively. Subsection 8.3 analyzes the conservatism in these estimates via an examination of the health risk estimates described by a range of reasonable exposure factors, rather than "fixed" default values.

8.1 Noncancer Hazard

The noncancer hazard is determined by summing the ratios of the average daily dose/ RfD (hazard quotient) for each chemical in each exposure pathway. The sum of the hazard quotients is referred to as the "hazard index" (HI). If this total sum is greater than 1, there may be potential health effects. This is considered conservative method. Specifically, it is more appropriate to sum the ratios of average daily dose/RfD for those chemicals that act on the same target organ (i.e., respiratory tract, liver, etc.). However, summing the average daily dose/RfD of all chemicals is used here as a conservative approach. Hazard indices were calculated for each receptor age-group (i.e., occupational adults, residential adult, and residential child). Tables 8-1 through 8-3 summarize the hazard quotients for each chemical via each exposure pathway for each scenario. These values were calculated by dividing the ADDs in Tables 7-2 through 7-6 by the RfDs in Table 6-1. Table 8-4 summarizes the hazard indices by pathway and the total hazard index for each scenario.

Future On-Site Worker

As shown in Table 8-1, individual hazard indices for the exposure pathways (vapor inhalation, dermal contact with soil, and soil ingestion) are all less than one. The total

Table 8-1 Hazard Quotients For Future On-Site Worker

Chemical	Exposure Pathway		
	Vapor Inhalation	Soil Ingestion	Dermal Contact With Soil
Acetone	-	2E-06	1E-05
1,1-Dichloroethane	1E-04	4E-07	1E-06
1,2-Dichloroethane	3E-03	2E-04	7E-04
1,1-Dichloroethene	-	2E-05	7E-05
1,2-Dichloroethene	-	-	-
2-Butanone (MEK)	5E-03	5E-06	2E-05
Methylene Chloride	3E-03	9E-04	4E-03
Tetrachloroethene	5E-01	4E-02	2E-01
Trichloroethene	1E-03	5E-05	2E-04
Toluene	8E-04	1E-04	4E-04
1,1,1-Trichloroethane	1E-02	6E-03	2E-02
Xylenes	6E-03	6E-06	3E-05
Pathway Hazard Index	**6E-01**	**5E-02**	**2E-01**

Table 8-2 Hazard Quotients For Existing Off-Site and Future On-Site Resident (Child)*

Chemical	Exposure Pathway				
	Vapor Inhalation	Soil Ingestion	Dermal Contact With Soil	Incidental Groundwater Ingestion	Incidental Dermal Contact Groundwater
1,1,1-Trichloroethane	2E-02	1E-02	4E-03	5E-01	1E-02
1,1,2-Trichloroethane	-	-	-	1E-04	3E-06
1,1-Dichloroethane	3E-04	6E-07	2E-07	-	-
1,1-Dichloroethene	-	3E-05	1E-05	3E+00	7E-02
1,2-Dichloroethane	8E-03	2E-04	7E-05	4E-01	9E-03
1,2-Dichloroethene	-	-	-	-	-
2-Butanone (MEK)	2E-02	5E-21	2E-21	2E-02	5E-04
Acetone	-	2E-21	9E-22	3E-02	7E-04
Benzene	-	-	-	5E-03	1E-04
Chloroform	-	-	-	2E-03	4E-05
Cis-1,2-Dichloroethylene	-	-	-	2E-01	5E-03
Dibromochloromethane	-	-	-	3E-04	7E-06
Ethylbenzene	-	-	-	2E-03	5E-05
Manganese	-	-	-	4E-07	1E-08
Methylene Chloride	4E-03	4E-07	2E-07	5E+00	1E-01
Tetrachloroethene	1E+00	1E-01	4E-02	2E+00	5E-02
Toluene	2E-03	5E-09	2E-09	7E-03	2E-04
Trans-1,2-Dichloroethylene	-	-	-	2E-04	5E-06
Trichloroethene	3E-03	1E-04	5E-05	3E-02	7E-04
Trichlorofluoromethane	-	-	-	6E-05	1E-06
Vinyl Chloride	-	-	-	-	-
Xylenes	2E-02	3E-09	1E-09	3E-04	8E-06
Zinc	-	-	-	6E-03	2E-04
Pathway Hazard Index	**1E+00**	**1E-01**	**5E-02**	**1E+01**	**3E-01**

* Existing off-site resident considers only groundwater exposure pathways, future on-site resident considers all exposure pathways.

Table 8-3 Hazard Quotients For Existing Off-Site and Future On-Site Resident (Adult)*

Chemical	Exposure Pathway				
	Vapor Inhalation	Soil Ingestion	Dermal Contact With Soil	Incidental Groundwater Ingestion	Incidental Dermal Contact Groundwater
1,1,1-Trichloroethane	1E-02	1E-03	2E-03	1E-01	7E-03
1,1,2-Trichloroethane	-	-	-	3E-05	2E-06
1,1-Dichloroethane	1E-04	7E-08	1E-07	-	-
1,1-Dichloroethene	-	4E-06	7E-06	6E-01	4E-02
1,2-Dichloroethane	3E-03	2E-05	4E-05	8E-02	5E-03
1,2-Dichloroethene	-	-	-	-	-
2-Butanone (MEK)	7E-03	5E-22	9E-22	4E-03	3E-04
Acetone	-	2E-22	5E-22	6E-03	4E-04
Benzene	-	-	-	1E-03	7E-05
Chloroform	-	-	-	3E-04	2E-05
Cis-1,2-Dichloroethylene	-	-	-	4E-02	3E-03
Dibromochloromethane	-	-	-	6E-05	4E-06
Ethylbenzene	-	-	-	4E-04	3E-05
Manganese	-	-	-	9E-08	6E-09
Methylene Chloride	2E-03	5E-08	9E-08	1E+00	7E-02
Tetrachloroethene	5E-01	6E-10	1E-09	5E-01	3E-02
Toluene	9E-04	5E-10	1E-09	2E-03	1E-04
Trans-1,2-Dichloroethylene	-	-	-	4E-05	3E-06
Trichloroethene	1E-03	1E-05	3E-05	6E-03	4E-04
Trichlorofluoromethane	-	-	-	1E-05	8E-07
Vinyl Chloride	-	-	-	-	-
Xylenes	7E-03	3E-10	7E-10	7E-05	4E-06
Zinc	-	-	-	1E-03	9E-05
Pathway Hazard Index	6E-01	1E-03	2E-03	2E+00	1E-01

* Existing off-site resident considers only groundwater exposure pathways, future on-site resident considers all exposure pathways.

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Table 8-4 Pathway Contribution To Total Hazard Index*

Exposure Pathway	Occupational	Residential Child	Residential Adult
Vapor Inhalation	0.6	1.0	0.6
Soil Ingestion	0.1	0.1	1E-03
Dermal Contact With Soil	0.2	0.1	2E-03
Incidental Groundwater Ingestion	-	11.0	2.0
Dermal Contact With Groundwater	-	0.3	0.1
TOTAL	0.8	12.0	3.0

* All pathway-specific values taken from Tables 8-1 through 8-3.

hazard index for the worker is 0.8 (see Table 8-4), therefore under the conditions described in this assessment the chemicals of concern would not pose a noncancer hazard.

Future On-Site Resident (Child)

Table 8-2 summarizes the individual hazard indices for the following exposure pathways: vapor inhalation, soil ingestion, dermal contact with soil, incidental ingestion of groundwater, and incidental dermal contact with groundwater. The individual hazard indices for the soil ingestion, dermal contact with soil, and incidental dermal contact with groundwater pathways are less than one. The vapor inhalation and incidental ingestion of groundwater are greater than or equal to one (1.0 and 11, respectively), therefore the total hazard index for the child may pose a significant noncancer hazard.

Future On-Site Resident (Adult)

For the adult resident, with the exception of the individual hazard index for the incidental groundwater ingestion pathway, the hazard indices are all less than one (see Table 8-3). As presented in Table 8-4, the total hazard index for the adult resident is 3.0 and is primarily due to the groundwater ingestion pathway. Since the total hazard index is greater than one, this suggests that the adult exposures to chemicals in soils and groundwater may pose a potential noncancer hazard.

8.2 Carcinogenic Risks

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. The lifetime average daily dose is multiplied by the slope factor (SF) to determine the incremental risk of an individual developing cancer. To calculate residential cancer risks, the lifetime average daily dose is calculated separately for the adult and child receptors,

summed as the total LADD, and then multiplied by the SF for each chemical in each exposure pathway. Tables 8-5 and 8-6 summarize the estimated increased cancer risks for each chemical via each pathway. These values are calculated by multiplying the LADDs in Tables 7-2 through 7-6 by the slope factors in Table 6-2. Table 8-7 summarizes the total estimated increased cancer risks for each pathway and the total cancer risks for the occupational and residential scenarios. For the soil exposure pathways, cancer risks range from 1×10^{-6} (occupational soil ingestion) to 1×10^{-5} (vapor inhalation by future on-site resident). Cancer risks associated with groundwater exposure are higher, ranging from 1×10^{-4} for incidental dermal contact to 3×10^{-3} for incidental ingestion.

The risk level of 1 in 1 million (1×10^{-6}) is often perceived as a "benchmark" (i.e., many in the scientific and regulatory community believe that a theoretical increased cancer risk of greater than 1×10^{-6} is indicative of significant risk). However, a review of the literature indicates that, in reality, theoretical risk levels in excess of 1×10^{-6} are often considered acceptable by regulatory agencies. For example, Travis et al. (1987) conducted a retrospective examination of the level of risk that triggered regulatory action in 132 decisions. Three variables were considered: (1) individual risk (an upperlimit estimate of the probability that the most highly exposed individual in a population will develop cancer as a result of a lifetime exposure), (2) population risk (an upperlimit estimate of the number of additional incidences of cancer in the exposed population), and (3) population size. The findings of Travis et al. (1987) can be summarized as follows:

(1) Every chemical with an individual lifetime risk above 4×10^{-3} received regulation. Those with values below 1×10^{-6} remained unregulated.

(2) For small populations, regulatory action never resulted for individual risks below 1×10^{-4}.

Table 8-5 Cancer Risks For Future On-Site Workers

Chemical	Exposure Pathway		
	Vapor Inhalation	Soil Ingestion	Dermal Contact With Soil
1,2-Dichloroethane	4E-07	3E-08	1E-07
1,1-Dichloroethene	2E-07	6E-09	2E-08
Methylene Chloride	2E-07	2E-08	1E-07
Tetrachloroethene	6E-07	1E-06	5E-06
Trichloroethene	2E-07	6E-09	2E-08
Total Pathway Cancer Risk	**2E-06**	**1E-06**	**5E-06**

Table 8-6 Cancer Risks For Existing Off-Site and Future On-Site Residents*

Chemical	Exposure Pathway				
	Vapor Inhalation	Soil Ingestion	Dermal Contact With Soil	Incidental Groundwater Ingestion	Incidental Dermal Contact With Groundwater
1,1,2-Trichloroethane	-	-	-	4E-09	2E-10
1,1-Dichloroethene	2E-06	2E-08	2E-08	2E-03	1E-04
1,2-Dichloroethane	4E-06	4E-08	2E-08	1E-04	6E-06
Benzene	-	-	-	5E-07	2E-08
Chloroform	-	-	-	2E-08	7E-10
Dibromochloromethane	-	-	-	8E-08	3E-09
Methylene Chloride	1E-06	2E-11	2E-11	6E-05	2E-06
Tetrachloroethene	5E-06	5E-06	2E-06	2E-04	8E-06
Trichloroethene	2E-06	3E-08	3E-08	9E-06	4E-07
Vinyl Chloride	-	-	-	1E-05	5E-07
Total Pathway Cancer Risk	**1E-05**	**5E-06**	**2E-06**	**3E-03**	**1E-04**

* Existing off-site resident considers only groundwater exposure pathways, future on-site resident considers all exposure pathways.

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Table 8-7 Pathway Contribution To Total Cancer Risk

Exposure Pathway	Occupational	Residential (Adult and Child)
Vapor Inhalation	2E-06	1E-05
Soil Ingestion	1E-06	5E-06
Dermal Contact With Soil	5E-06	2E-06
Incidental Groundwater Ingestion	-	3E-03
Dermal Contact With Groundwater	-	1E-04
TOTAL	8E-06	3E-03 (2E-05)*

* Value in parenthesis is soil exposure pathways only.

(3) For effects resulting from exposures to the entire United States population, a risk level below 1×10^{-6} never triggered action; above 3×10^{-4} always triggered action.

In short, regulatory agencies have found risks far in excess of 1×10^{-6} acceptable if experienced by small populations. In the State of California, an increased cancer risk of 1×10^{-5} for large populations has been used as an acceptable "benchmark" for setting regulatory policy. Specifically, an estimated increased cancer risk of 1×10^{-5} or less is considered insignificant under the 1986 Safe Drinking Water and Toxics Enforcement Act. In addition, increased cancer risk levels of 1×10^{-5} or less are considered insignificant for compliance with the Air Toxics "Hot Spots" Bill (AB 2588).

8.3 Probabilistic Assessment of Residential Contaminant Uptake

The state of California does not have guidance on appropriate methods for conducting probabilistic risk assessment. However, it has recently been proposed that health risk assessments would be much improved if probability distribution frequencies (PDFs), rather than conservative "point" exposure estimates, were incorporated into the exposure assessment process (Paustenbach, 1990; Finkel, 1990). In other words, instead of using single percentile values to represent chemical concentrations and exposure estimates (and thereby deriving a single value as the dose estimate), a range of measured chemical concentrations and reasonable exposure estimates are used to develop a range of chemical doses and their associated probabilities. This approach permits an evaluation of potential risks and appropriate risk management measures that is more informed than that provided by a single point estimate derived without any associated measure of confidence or probability.

Several recent papers have suggested that a Monte Carlo analysis of exposure parameter PDFs is perhaps the most sound approach to preparing a "probabilistic" risk assessment. Using this method, PDFs for the chemical concentrations and exposure parameters are generated by inputting the data distribution type (e.g., normal, lognormal, etc.) and the mean and the range of the values into an Excel spreadsheet. Commercially available software programs (e.g, @RISK™) are then used to simulate the PDF of the parameter. The Monte Carlo simulation chooses values from each PDF at a frequency relative to the "probability" of the value in the distribution. For example, in calculating contaminant uptake via soil ingestion, the 10th and 95th percentiles of the soil ingestion rate PDF are chosen approximately 10 percent of the time, while the 50th percentile is chosen approximately 50 percent of the time (assuming that the soil ingestion rates are normally distributed). If the data distribution cannot be described by a standard distribution type, the data may be input directly with no specified distribution ("bootstrapping"). Using this application, the program chooses randomly from the input data with no specified frequency.

From the concentration and exposure parameter PDFs, the Monte Carlo simulation generates a dose PDF which provides a description of the probability associated with any estimated dose. The advantage of this approach is that the assessor is not forced to rely on the repeated use of "fixed" conservative assumptions to evaluate dose and risk estimates. Instead, the full range of possible values and their likelihood of occurrence are incorporated into the analysis to produce a range and probability of expected exposure levels.

The dose and health risk estimates described in Sections 7.0 and 8.0 are based on point exposure estimates which are primarily 50th and 95th percentile values. In this section, residential contaminant uptake via soil ingestion and vapor inhalation is reevaluated using PDFs for the key exposure estimates, as described below. These two pathways were chosen

for evaluation because they comprised greater than 90 percent of the hazard index and increased cancer risk.

8.3.1 Soil Ingestion

Soil Ingestion Rate

As described in Section 4.0, children consume more soil than any other age group and, as a result, numerous studies of soil ingestion rates in children have been conducted. The most thorough and rigorous studies to date are those by Calabrese et al. (1989), Davis et al. (1990), and Van Wijnen et al. (1990). In the Calabrese study, eight different tracer elements (Al, Ba, Mn, Si, Ti, V, Y, and Zr) were quantitatively evaluated in the stools of 65 school children, age 1 to 4 years. In subsequent validation studies, Calabrese and Stanek (1991a; 1991b) developed a model to measure the precision of the soil ingestion rates calculated for each of the tracers used in their 1989 study and those used by Davis et al. The model validated the results for only two of the tracers (Zr and Ti) in the Calabrese et al. 1989 study and none of the tracers used in the Davis study. Since the confidence interval for Zr was more narrow than that for Ti, Calabrese and Stanek (1991b) concluded that the results for Zr are the most accurate. For the purposes of this evaluation, the frequency distribution of soil ingestion rates for Zr is used to represent a child's soil ingestion rate. The 50th and 95th percentile values associated with this distribution are 16 mg/day and 27 mg/day, respectively.

As described in Section 4.0, current USEPA guidance suggests the use of 200 mg/day as a conservative estimate of "average" soil ingestion rates for children (USEPA, 1991a). This value is based on the tracer studies of Binder (1986) and Clausing (1987). It is important to note that these studies predate the more rigorous studies of Calabrese and Davis, and

they did not account for non-soil contributions (food, water, toothpaste, medicines, etc.) to the level of tracers appearing in the feces. Hence, the range of values reported in the Calabrese studies appear to be the most accurate estimate to date of children's soil ingestion rate.

There are little or no reliable quantitative data available for estimating adult soil ingestion rates. As described in Section 4.0, USEPA risk assessment guidance suggests a soil ingestion rate of 100 mg/day for adults, based primarily on an estimate of 65 mg/day (Hawley, 1985). However, Hawley's estimate was not based on quantitative tracer data, and therefore, the USEPA estimate is not strongly supported by the literature. Since the validated median soil ingestion rates determined for children in the Calabrese (1991b) study are 16 mg/day and 55 mg/day for Zr and Ti, respectively, it is reasonable to expect that adult soil ingestion rates are 10 mg/day or less, as suggested by Paustenbach (1987). However, since the existing database for adult soil ingestion rates is so limited, this probabilistic evaluation considers only a child's exposure.

Soil Concentration

For the purposes of this evaluation, only tetrachloroethene is addressed for soil ingestion since it is estimated to pose the majority of the risk for this pathway. The tetrachloroethene values measured in the surface soil (0- to 2-foot depth) are given a discrete uniform distribution ("bootstrapped").

Exposure Duration

A PDF for residential tenure was generated from data described in Table IV of USEPA's Distributions and Expected Times of Residence for U.S. Households (USEPA, 1991c).

From these data, which include all households (renters and homeowners), a truncated normal PDF is derived with a median (50th percentile) value of 3.49 years and a maximum of 37 years.

Body Weight

For children and adults, a PDF of body weights was derived from body weight data given in the USEPA's Exposure Factors Handbook (USEPA, 1989b). The 50th percentile body weight for a child (males and females) is 15.4 kg with a standard deviation of 0.007 kg; the 50th percentile body weight for an adult (males and females) is 64.2 kg with a standard deviation of 13.2 kg. The PDF for adult body weight is shown in Figure 8-1.

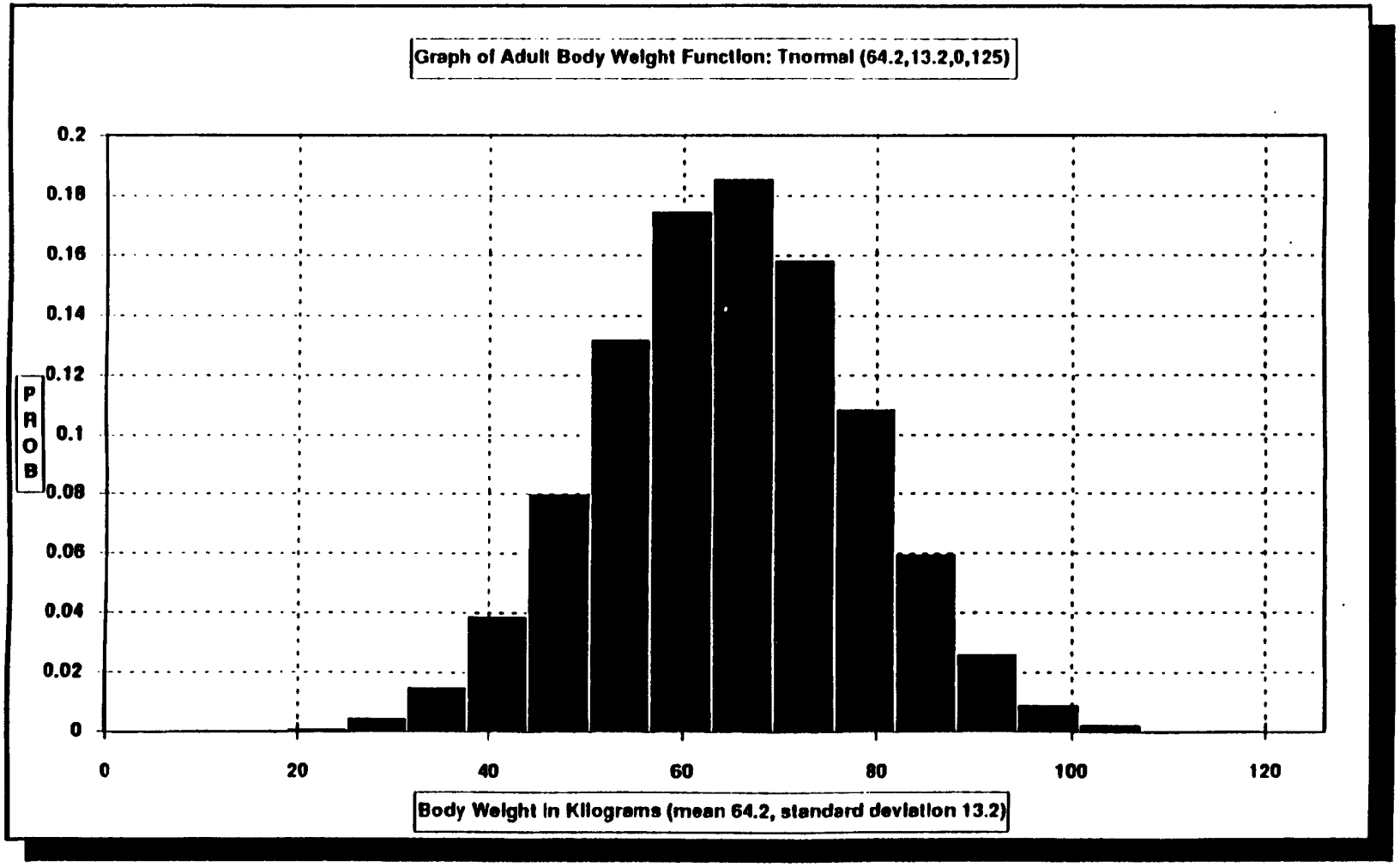
For the remaining exposure parameters (bioavailability, fraction of contaminated area, exposure frequency, and averaging time), the point estimates described previously in Section 4.0 are employed. It is important to note that no chemical degradation is assumed in the Monte Carlo analysis.

8.3.2 Vapor Inhalation

Inhalation Rates

For children and adults, uniform distribution frequencies of inhalation rates are generated from data provided in the USEPA's Exposure Factors Handbook (USEPA, 1989b). For adults, it is assumed that 50 percent of the time spent on-site is resting, 50 percent is engaged in light activity. This distribution yields a minimum value of 0.2 m^3/hr and a maximum of 0.83 m^3/hr. For children, an infant (0 to 1 years) was assumed to be resting 100 percent of the time; a child (1 to 6 years) was assumed to be resting 50 percent of the

Figure 8-1 Probability Density Function of Adult Body Weight



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time and engaged in light activity 50 percent of the time. This distribution yields a minimum value of 0.13 m^3/hr. and a maximum of 0.59 m^3/hr.

Vapor Concentrations

The chemical concentration data in the subsurface soil for all five chemicals of concern passed the modified Kolmogorov-Smirnov test for lognormality. Accordingly, a lognormal distribution of subsurface soil data was used to derive a lognormal distribution of vapor concentrations through multiple iterations of the Jury and Box models. The PDF for methylene chloride in subsurface soils is shown in Figure 8-2.

For the remaining exposure parameters (bioavailability and averaging time) the point estimates used previously were employed. The body weight and exposure duration PDFs described for soil ingestion are also used in the Monte Carlo analysis of vapor inhalation.

A Monte Carlo analysis of the above PDFs was used to solve the dose equations for approximately 3,000 to 5,000 iterations. Appendix E contains a summary of the cancer risk and hazard index percentile for each pathway examined. Figure 8-3 illustrates the cancer risk PDF for inhalation. Table 8-8 compares selected median (50th percentile) and 95th percentile hazard index and cancer risk values with the "reasonable maximal exposure" (RME) estimates that were generated in Sections 7.0 and 8.0 using point estimates. For all pathways examined, the RME is orders of magnitude greater than the 50th percentile risk and is also greater than the 95th percentile values except for the child soil ingestion hazard index which is in the same order of magnitude. The difference between the percentile values generated by probability frequencies and the RME value would be even more dramatic if chemical degradation had been considered in the Monte Carlo analysis. In

Figure 8-2 Probability Density Function of Methylene Chloride Subsurface Soil Concentrations (ppm)

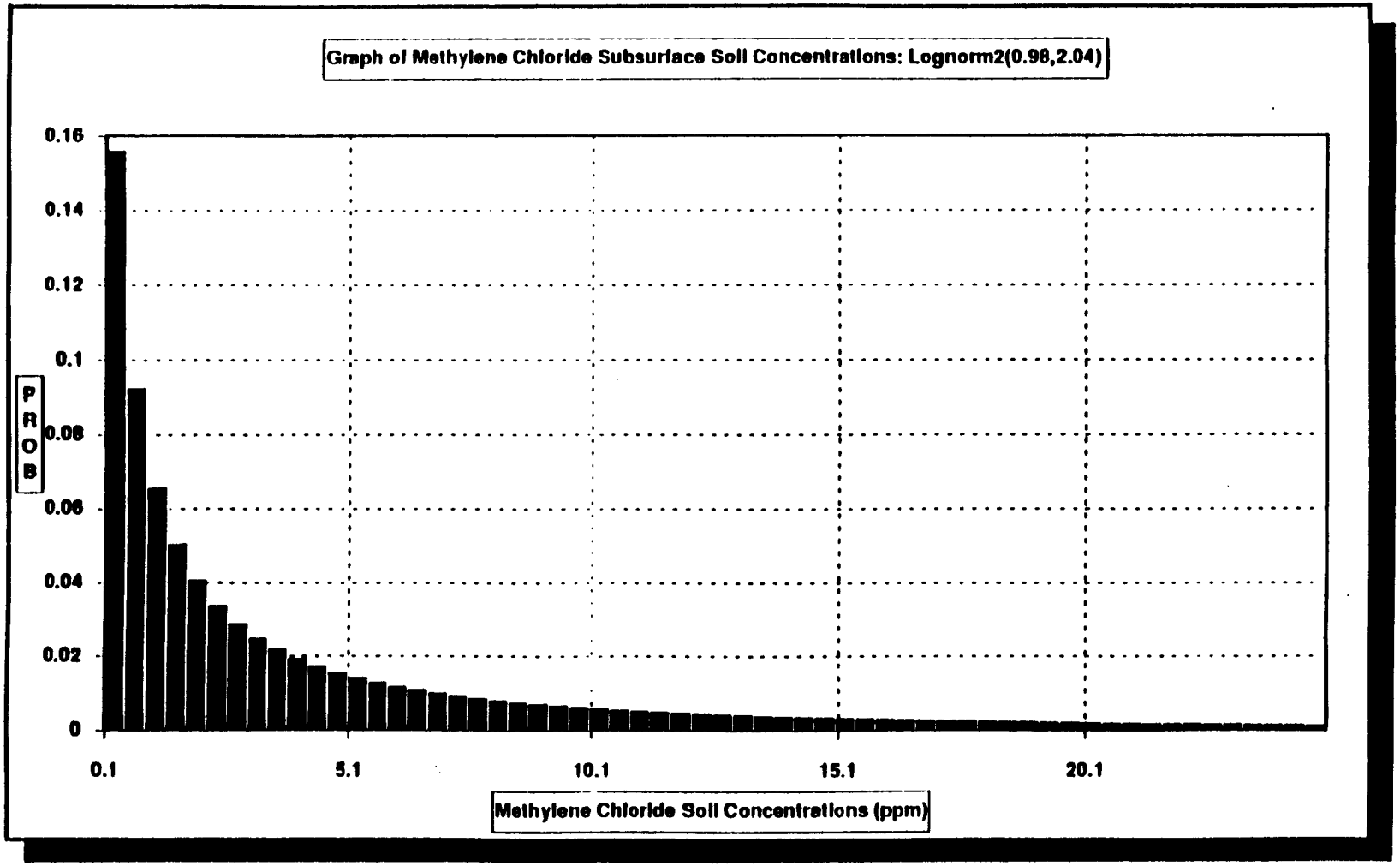

Figure 8-3 Probability Density Function of Cumulative Residential Inhalation Cancer Risk

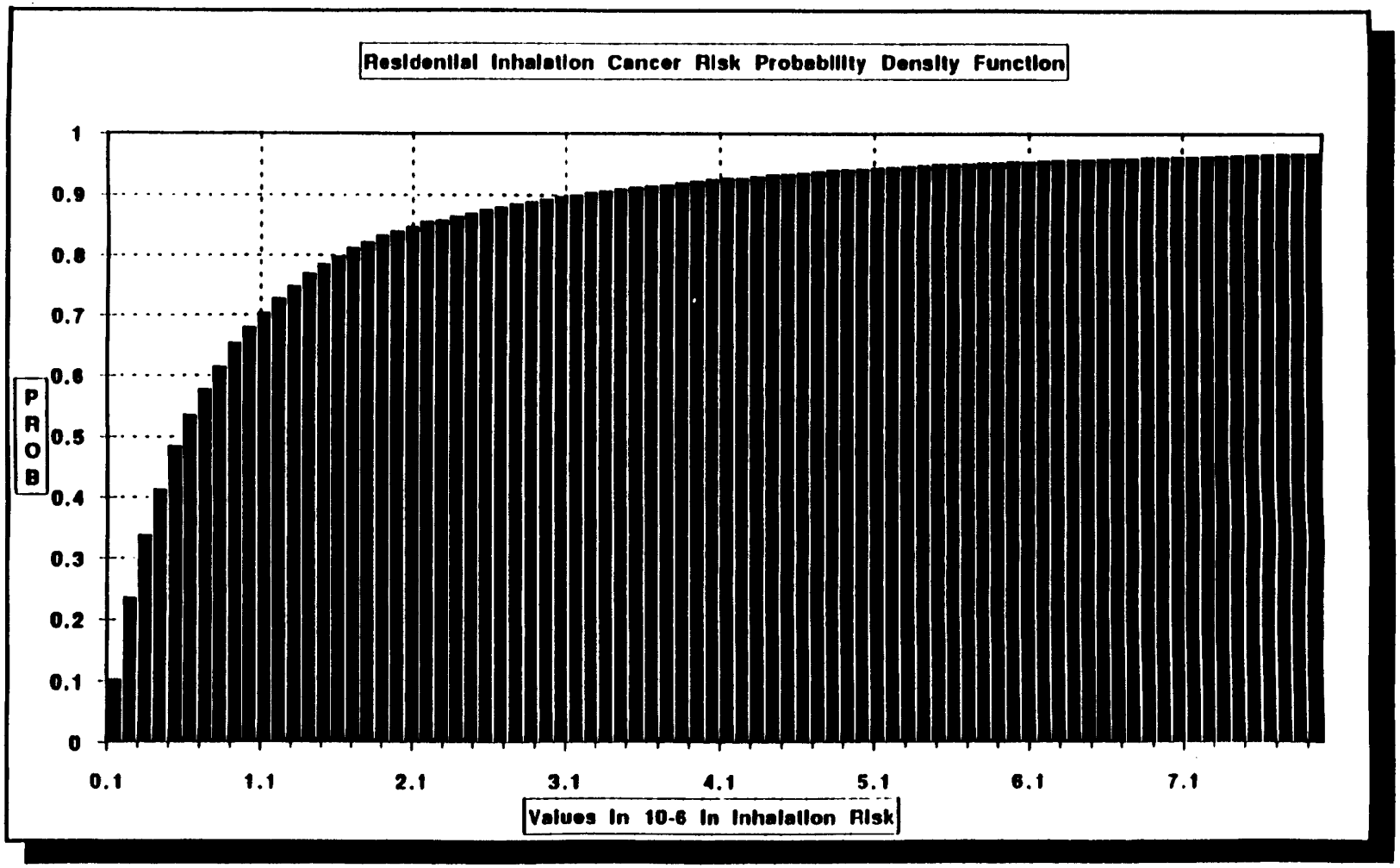

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TABLE 8-8

COMPARISON OF THE 50TH AND 95TH PERCENTILE HAZARD INDICES AND CANCER RISKS OBTAINED VIA A PROBABILISTIC ANALYSIS VS. THE RME*

	Probabilistic Approach		
Hazard Index	50th Percentile	95th Percentile	RME
Child-soil ingestion	6.0×10^{-5}	0.2	0.1
Child-inhalation	1.9×10^{-2}	0.4	1.0
Adult-inhalation	6.5×10^{-3}	0.1	0.6
Cancer Risk Residential-Inhalation	5.0×10^{-7}	5.4×10^{-6}	1.0×10^{-5}

* RME = Reasonable Maximal Exposure; RME values taken from Tables 8-1, 8-2, and 8-6.

summary, this analysis supports the conclusion that the health risk estimates described in Subsections 8.1 and 8.2 are conservative.

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APPENDIX A

SUMMARY OF SOIL AND GROUNDWATER ANALYSES

TABLE A-1

SUMMARY OF SOIL ANALYSIS - EPA METHOD 8240 COMPOUNDS
McKesson Corporation Property - Santa Fe Springs

Location ID	Sample Depth (ft)	Date Collected	1,1,1-Tri-chloro-ethane	Methylene Chloride	Tetra-chloro-ethene	Tri-chloro-ethene	1,1-Di-chloro-ethene	1,2-Di-chloro-ethene	Cis-1,2-Di-chloro-ethene	Trans-1,2-Dichloro-ethene	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	Benzen
MW-01	23.0	6/12/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
MW-01	42.0	6/12/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
MW-02	23.0	6/12/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
MW-02	45.5	6/12/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
MW-03	23.0	6/12/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
MW-03	41.0	6/12/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-01	36.0-36.5	6/18/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-01	41.0-41.5	6/18/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-02	20.5-21	6/19/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-02	41-41.5	6/19/90	0.1	<0.3	0.08	0.1	0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-03	31	7/06/90	0.16	0.92	0.25	0.50	0.20	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-03	21	7/06/90	<0.05	<0.3	<0.05	0.26	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-04	26	6/26/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-04	46	6/26/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-05	33.5	6/27/90	<0.05	3.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-05	43.5	6/27/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-06	26	6/29/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-06	46	6/29/90	0.9	<0.3	0.5	0.07	0.2	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-07	26	6/29/90	0.06	<0.3	0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-07	46	6/29/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-08	26	6/29/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-08	42.5	6/29/90	<0.05	<0.3	0.080	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-09	21	6/29/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-09	41	6/29/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-10	30.5-31	6/22/90	0.3	<0.3	0.7	0.3	0.2	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-10	46-46.5	6/22/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-11	26-26.5	6/22/90	<0.05	<0.3	TR<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-11	41-41.5	6/22/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-12	20-20.5	6/20/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-12	30.5-31	6/20/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-12	41-41.5	6/20/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05

Notes:
1. All values in milligrams per kilogram (mg/kg)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

TABLE A-1
(Continued)

SUMMARY OF SOIL ANALYSIS - EPA METHOD 8240 COMPOUNDS

Location ID	Sample Depth (ft)	Date Collected	Toluene	Ethyl Benzene	Total Xylenes	Acetone	4-Methyl-2-Pentanone (MIBK)	2-Butanone (MEK)	1,1,2,2-Tetrachloroethane	Carbon Tetrachloride	Chlorobenzene
MW-01	23.0	6/12/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
MW-01	42.0	6/12/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
MW 02	23.0	6/12/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
MW 02	45.5	6/12/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
MW 03	23.0	6/12/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
MW 03	41.0	6/12/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-01	36.0-36.5	6/18/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-01	41.0-41.5	6/18/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-02	20.5-21	6/19/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-02	41-41.5	6/19/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-03	31	7/06/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-03	21	7/06/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-04	26	6/26/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-04	46	6/26/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-05	33.5	6/27/90	0.1	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-05	43.5	6/27/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-06	26	6/29/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-06	46	6/29/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-07	26	6/29/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-07	46	6/29/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-08	26	6/29/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-08	42.5	6/29/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-09	21	6/29/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-09	41	6/29/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-10	30.5-31	6/22/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-10	46-46.5	6/22/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-11	26-26.5	6/22/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-11	41-41.5	6/22/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-12	20-20.5	6/20/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-12	30.5-31	6/20/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-12	41-41.5	6/20/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05

Notes:
1. All values in milligrams per kilogram (mg/kg)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083675

MKIL206005

TABLE A-1
(Continued)

SUMMARY OF SOIL ANALYSIS - EPA METHOD 8240 COMPOUNDS

Location ID	Sample Depth (ft)	Date Collected	1,1,1-Tri-chloro-ethane	Methylene Chloride	Tetra-chloro-ethene	Tri-chloro-ethene	1,1-Di-chloro-ethene	1,2-Di-chloro-ethene	Cis-1,2-Di-chloro-ethene	Trans-1,2-Dichloro-ethene	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	Benzen
SB-13	25.5-26	6/20/90	<0.05	3.9	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-13	41-41.5	6/20/90	<0.10	29	<0.10	0.6	<0.10	<0.10	NA	NA	<0.10	7	<0.10
SB-14	26-26.5	6/21/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-14	41-41.5	6/21/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-15	26-26.5	6/21/90	<0.05	2.0	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-15	41-41.5	6/21/90	0.14	4.0	1.4	0.91	0.80	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-17A	41	1/25/91	0.1	<0.3	0.2	0.07	0.1	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-19	26	6/26/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-19	41	6/26/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-20	11	7/13/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-20	20.5	7/13/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-20	41	7/13/90	0.09	<0.3	0.2	0.07	0.1	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-21	21	7/05/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-21	31	7/05/90	<0.05	1.1	0.06	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-23	26	7/05/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-23	41	7/05/90	21	30	3.1	0.84	2.6	<0.05	NA	NA	0.1	0.6	<0.05
SB-23A	30.5-31	1/25/91	<0.05	21	0.50	<0.05	0.2	NA	<0.05	<0.05	0.09	0.87	<0.05
SB-23A	128.8-129.	2/04/91	<0.05	<0.3	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-24	1	7/11/90	160	<7.5	33	3.5	<1.2	<1.2	NA	NA	<1.2	<1.2	<1.2
SB-24	21	7/11/90	530	<12.0	630	33	<2.0	<2.0	NA	NA	<2.0	6.4	<2.0
SB-24	41	7/11/90	100	48	58	6	5	<1.0	NA	NA	<1.0	<1.0	<1.0
SB-25	6	7/13/90	0.1	3.5	0.1	<0.10	<0.10	<0.10	NA	NA	0.3	0.2	<0.10
SB-25	21	7/13/90	<0.10	<0.6	<0.10	<0.10	<0.10	<0.10	NA	NA	<0.10	<0.10	<0.10
SB-25	41	7/13/90	<0.15	3.0	0.6	0.5	0.7	0.6	NA	NA	<0.15	0.3	<0.15
SB-26	21	7/16/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-26	26	7/16/90	0.2	3.8	0.07	0.07	<0.05	<0.05	NA	NA	0.1	<0.05	<0.05
SB-26	41	7/16/90	0.4	4.4	0.4	0.3	0.4	0.08	NA	NA	<0.05	<0.05	<0.05
SB-27	21	7/16/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SB-27	31	7/16/90	3.0	23	1	0.5	0.6	0.4	NA	NA	0.2	0.8	<0.12
SB-27	41	7/16/90	0.3	26	0.8	0.4	0.5	<0.20	NA	NA	<0.20	<0.20	<0.20
SB-30	1.5	7/12/90	3500	380	2900	60	<20.0	<20.0	NA	NA	<20.0	32	<20.0

Notes:
1. All values in milligrams per kilogram (mg/kg)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083676

MKIL206006

TABLE A-1
(Continued)

SUMMARY OF SOIL ANALYSIS - EPA METHOD 8240 COMPOUNDS

Location ID	Sample Depth (ft)	Date Collected	Toluene	Ethyl Benzene	Total Xylenes	Acetone	4 Methyl-2-Pentanone (MIBK)	2-Butanone (MEK)	1,1,2,2-Tetrachloroethane	Carbon Tetrachloride	Chlorobenzene
SB-13	25.5-26	6/20/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-13	41-41.5	6/20/90	<0.20	<0.10	<0.10	19	<1.00	9	<0.10	<0.10	<0.10
SB-14	26-26.5	6/21/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-14	41-41.5	6/21/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-15	26-26.5	6/21/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-15	41-41.5	6/21/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-17A	41	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-19	26	6/26/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-19	41	6/26/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-20	11	7/13/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-20	20.5	7/13/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-20	41	7/13/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-21	21	7/05/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-21	31	7/05/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-23	26	7/05/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-23	41	7/05/90	0.63	<0.05	<0.05	<1.0	TR<0.50	TR<1.0	<0.05	<0.05	<0.05
SB-23A	30.5-31	1/25/91	<0.1	<0.05	0.1	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-23A	128.8-129.	2/04/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-24	1	7/11/90	78	<1.2	<1.2	<25.0	<12.5	<25.0	<1.2	<1.2	11
SB-24	21	7/11/90	130	31	160	120	<20.0	65	5.9	82	<2.0
SB-24	41	7/11/90	12	1.8	8.6	<20.0	<10.0	<20.0	<1.0	<1.0	<1.0
SB-25	6	7/13/90	0.1	<0.10	<0.10	19	<1.00	<2.0	<0.10	<0.10	<0.10
SB-25	21	7/13/90	<0.20	<0.10	<0.10	37	<1.00	2.4	<0.10	<0.10	<0.10
SB-25	41	7/13/90	0.3	<0.15	<0.15	3.5	<1.50	<3.0	<0.15	<0.15	<0.15
SB-26	21	7/16/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-26	26	7/16/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-26	41	7/16/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SB-27	21	7/16/90	<0.10	<0.05	<0.05	<1.0	<0.50	1.0	<0.05	<0.05	<0.05
SB-27	31	7/16/90	3.2	<0.12	0.4	<2.5	<1.2	4.6	<0.12	<0.12	<0.12
SB-27	41	7/16/90	1	<0.20	<0.20	<4.0	<2.00	2.2	<0.20	<0.20	<0.20
SB-30	1.5	7/12/90	110	50	90	<400	<200.0	<400	31	550	170

Notes:
1. All values in milligrams per kilogram (mg/kg)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083677

MKIL206007

TABLE A-1
(Continued)

SUMMARY OF SOIL ANALYSIS - EPA METHOD 8240 COMPOUNDS

Location ID	Sample Depth (ft)	Date Collected	1,1,1-Tri-chloro-ethane	Methylene Chloride	Tetra-chloro-ethene	Tri-chloro-ethene	1,1-Di-chloro-ethene	1,2-Di-chloro-ethene	Cis-1,2-Di-chloro-ethene	Trans-1,2-Dichloro-ethene	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	Benzene
SB-30	21	7/12/90	190	120	1000	17	<6.0	<6.0	NA	NA	<6.0	<6.0	<6.0
SB-30	41	7/12/90	3.4	17	7.4	2.6	5.4	<0.10	NA	NA	<0.10	<0.10	<0.10
SB-36	15.0-15.5	1/23/91	<0.05	<0.3	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-36	24.5-25.0	1/23/91	33	<0.3	12	2	<0.05	NA	<0.05	<0.05	<0.05	2	<0.05
SB-36	39.5-40.0	1/23/91	1.4	<0.3	0.87	0.1	0.32	NA	<0.05	<0.05	<0.05	0.07	<0.05
SB-36	45.0-45.5	1/23/91	<0.05	<0.3	1.4	0.2	0.35	NA	<0.05	<0.05	<0.05	0.09	<0.05
SB-37	1.0-1.5	1/25/91	1.6	11	1.5	0.4	0.58	NA	<0.05	<0.05	0.2	0.2	<0.05
SB-37	5.0-5.5	1/25/91	0.3	6.3	5.0	<0.05	<0.05	NA	0.1	<0.05	0.63	0.2	<0.05
SB-37	9.5-10.0	1/25/91	0.5	4.9	0.3	0.1	<0.05	NA	<0.05	<0.05	0.1	0.2	<0.05
SB-37	14.5-15.0	1/25/91	<0.05	2.6	0.1	<0.05	<0.05	NA	<0.05	<0.05	<0.05	0.2	0.07
SB-37	19.5-20.0	1/25/91	0.1	1.8	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	0.1	<0.05
SB-37	24.0-24.5	1/25/91	<0.05	0.66	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-38	5.0-5.5	1/25/91	0.4	0.55	0.93	0.1	<0.05	NA	<0.05	<0.05	0.2	<0.05	<0.05
SB-38	15.0-15.5	1/25/91	0.3	1.8	2.1	0.1	<0.05	NA	<0.05	<0.05	<0.05	0.06	<0.05
SB-38	19.5-20.0	1/25/91	<0.05	<0.3	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-38	24.5-25.0	1/25/91	<0.05	<0.3	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-38	29.5-30.0	1/25/91	1.6	11	1.5	0.4	0.58	NA	<0.05	<0.05	0.2	0.2	<0.05
SB-38	34.5-35.0	1/25/91	1.5	5.7	1.9	0.4	0.77	NA	<0.05	0.63	0.1	0.08	<0.05
SB-38	40.0-40.5	1/25/91	2.2	5.4	1.7	0.4	0.82	NA	<0.05	<0.05	0.2	0.08	<0.05
SB-38	44.0-44.5	1/25/91	0.70	4.3	0.80	0.2	<0.05	NA	<0.05	0.4	0.4	<0.05	<0.05
SB-39	9.5-10.0	1/25/91	0.2	2.0	0.1	<0.05	<0.05	NA	<0.05	<0.05	<0.05	0.1	<0.05
SB-39	5-5.5	1/25/91	0.3	<0.3	0.3	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-40	5.0-5.5	1/25/91	<0.05	<0.3	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-40	9.5-10.0	1/25/91	<0.05	<0.3	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-41	9.5-10.0	1/25/91	<0.05	<0.3	<0.05	<0.05	<0.05	NA	<0.05	<0.05	<0.05	<0.05	<0.05
SB-41	4.5-5.0	1/25/91	0.1	<0.3	<0.05	<0.05	<0.05	NA	0.13	<0.05	<0.05	<0.05	<0.05
SB-42	9.5-10.0	1/25/91	<0.25	<1.5	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.25	<0.25
SB-42	5.0-5.5	1/25/91	<0.25	<1.5	<0.25	<0.25	<0.25	NA	<0.25	<0.25	<0.25	<0.25	<0.25
SS-01	05	7/17/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SS-01	1.0	7/17/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SS-02	0.5	7/18/90	0.08	<0.3	0.71	0.07	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05

Notes:
1. All values in milligrams per kilogram (mg/kg)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

TABLE A-1
(Continued)

SUMMARY OF SOIL ANALYSIS - EPA METHOD 8240 COMPOUNDS

Location ID	Sample Depth (ft)	Date Collected	Toluene	Ethyl Benzene	Total Xylenes	Acetone	4-Methyl-2-Pentanone (MIBK)	2-Butanone (MEK)	1,1,2,2-Tetrachloroethane	Carbon Tetrachloride	Chlorobenzene
SB-30	21	7/12/90	83	15	60	<120	<60.0	<120	<6.0	30	<6.0
SB-30	41	7/12/90	0.3	<0.10	<0.10	<2.0	<1.00	<2.0	<0.10	0.5	<0.10
SB-36	15.0-15.5	1/23/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-36	24.5-25.0	1/23/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-36	39.5-40.0	1/23/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-36	45.0-45.5	1/23/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-37	1.0-1.5	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-37	5.0-5.5	1/25/91	<0.1	<0.05	0.09	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-37	9.5-10.0	1/25/91	0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-37	14.5-15.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-37	19.5-20.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-37	24.0-24.5	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-38	5.0-5.5	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-38	15.0-15.5	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-38	19.5-20.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-38	24.5-25.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-38	29.5-30.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-38	34.5-35.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-38	40.0-40.5	1/25/91	<0.1	<0.05	0.06	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-38	44.0-44.5	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-39	9.5-10.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-39	5-5.5	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-40	5.0-5.5	1/25/91	<0.1	<0.05	<0.05	27	<0.5	4.5	<0.05	<0.05	<0.05
SB-40	9.5-10.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-41	9.5-10.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-41	4.5-5.0	1/25/91	<0.1	<0.05	<0.05	<1	<0.5	<1	<0.05	<0.05	<0.05
SB-42	9.5-10.0	1/25/91	<0.5	<0.25	<0.25	49	<2.5	6.0	<0.25	<0.25	<0.25
SB-42	5.0-5.5	1/25/91	<0.5	<0.25	<0.25	95	<2.5	13	<0.25	<0.25	<0.25
SS-01	05	7/17/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SS-01	1.0	7/17/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05
SS-02	0.5	7/18/90	<0.10	<0.05	<0.05	<1.0	<0.50	<1.0	<0.05	<0.05	<0.05

Notes:
1. All values in milligrams per kilogram (mg/kg)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083679

MKIL206009

TABLE A-1
(Continued)

SUMMARY OF SOIL ANALYSIS - EPA METHOD 8240 COMPOUNDS

Location ID	Sample Depth (ft)	Date Collected	1,1,1-Tri-chloro-ethane	Methylene Chloride	Tetra-chloro-ethene	Tri-chloro-ethene	1,1-Di-chloro-ethene	1,2-Di-chloro-ethene	Cis-1,2-Di-chloro-ethene	Trans-1,2-Dichloro-ethene	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	Benzen
SS-02	1.0	7/18/90	<0.05	<0.3	0.1	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SS-03	0.5	7/18/90	<0.05	<0.3	<0.05	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SS-03	1.0	7/18/90	<0.05	<0.3	1.0	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SS-04	0.5	7/17/90	<0.05	<0.3	1.9	<0.05	<0.05	<0.05	NA	NA	<0.05	<0.05	<0.05
SS-04	1.0	7/17/90	<0.25	<1.5	61	<0.25	<0.25	<0.25	NA	NA	<0.25	<0.25	<0.25

Notes:
1. All values in milligrams per kilogram (mg/kg)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083680

MKIL206010

TABLE A-2

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	1,1,1-Tri-chloro-ethane	Methylene Chloride	Tetra-chloro-ethene	Tri-chloro-ethene	1,1-Di-chloro-ethene	1,2-Di-chloro-ethene	Cis-1,2-Di-chloro-ethene	Trans-1,2-Dichloro-ethene	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	Benzene
MW-01	8/01/90	300	<30	600	590	1100	650	NA	NA	230	7	TR<6
MW-01	10/24/90	260	<50	530	520	790	440	NA	NA	180	<10	<10
MW-01	2/11/91	150	<25	350	360	530	NA	320	<5	93	<5	<5
MW-02	8/01/90	30	<5	220	400	270	80	NA	NA	20	6	<1
MW-02	10/24/90	27	<25	<5	680	67	47	NA	NA	<5	<5	<5
MW-02	2/11/91	37	<25	270	700	360	NA	78	<5	22	<5	<5
MW-03	8/02/90	1700	140	1100	230	1200	230	NA	NA	100	<8	<8
MW-03	10/24/90	2200	<100	1200	400	1700	630	NA	NA	480	<20	29
MW-03	2/11/91	1300	<50	1100	210	1300	NA	280	<10	200	<10	11
SB-04	8/03/90	2700	1400	4100	4300	6200	2500	NA	NA	460	<20	13
SB-04	10/24/90	2000	640	4300	4200	5700	1300	NA	NA	400	<50	120
SB-04	2/11/91	150	<25	410	400	550	NA	110	<5	25	<5	10
SB-07	8/03/90	17000	<250	6700	1100	10000	<50	NA	NA	150	<50	<50
SB-07	10/24/90	3600	<200	3600	760	3300	<40	NA	NA	45	<40	<40
SB-07	2/12/91	6000	<150	3300	680	3600	NA	<30	<30	<30	<30	<30
SB-10	8/02/90	2900	410	2800	830	3600	83	NA	NA	160	<20	<20
SB-10	10/24/90	2400	<125	1600	<25	1800	<25	NA	NA	<25	<25	<25
SB-10	2/11/91	1800	<100	1400	390	1700	NA	<20	<20	85	<20	<20
SB-13	8/02/90	170	700	510	870	630	150	NA	NA	66	53	10
SB-13	10/24/90	16	<10	96	220	62	9	NA	NA	4	4	<2
SB-13	2/11/91	140	<10	300	340	360	NA	40	<2	28	23	4
SB-17	8/02/90	65000	13000	45000	7200	5500	<500	NA	NA	<500	<500	<500
SB-17	10/25/90	25000	45000	19000	5300	6300	1000	NA	NA	<250	600	<250
SB-17	2/13/91	23000	4000	15000	2700	2900	NA	1000	<250	<250	<250	<250
SB-17A	2/12/91	3	<5	7	12	<1	NA	<1	<1	<1	<1	<1
SB-17B	2/12/91	<1	<5	5	33	<1	NA	<1	<1	<1	<1	<1
SB-20	8/02/90	36000	19000	19000	3200	20000	540	NA	NA	200	<500	<500

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083681

MKIL206011

TABLE A-2
(Continued)

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	Toluene	Ethyl Benzene	Total Xylenes	Acetone	4-Methyl-2-Pentanone (MIBK)	2-Butanone (MEK)	Chloroform	Dichlorofluoromethane	Trichlorofluoromethane	1,1,2-Trichloro-1,2,2-Trifluoroethane	1,1,2-Trifluoro-1,1,2-trichloroethane
MW-01	8/01/90	180	<6	13	<120	<60	<120	TR<6	NA	NA	NA	NA
MW-01	10/24/90	<20	<10	<10	<200	<100	<200	<10	NA	NA	NA	NA
MW-01	2/11/91	<10	<5	<5	<100	<50	<100	<5	NA	NA	NA	NA
MW-02	8/01/90	6	<1	<1	<20	<10	<20	2	NA	NA	NA	NA
MW-02	10/24/90	<10	<5	<5	<100	<50	<100	<5	NA	NA	NA	NA
MW-02	2/11/91	<10	<5	<5	<100	<50	<100	<5	NA	NA	NA	NA
MW-03	8/02/90	14	<8	100	210	<80	<160	<8	NA	NA	NA	NA
MW-03	10/24/90	<40	<20	120	<400	<200	<400	<20	NA	NA	NA	NA
MW-03	2/11/91	<20	<10	49	<200	<100	<200	<10	NA	NA	NA	NA
SB-04	8/03/90	93	<20	77	<400	<200	<400	34	NA	NA	NA	NA
SB-04	10/24/90	<100	<50	52	<1000	<500	<1000	<50	NA	NA	NA	NA
SB-04	2/11/91	<10	<5	<5	<100	<50	<100	<5	NA	NA	NA	NA
SB-07	8/03/90	500	<50	<50	<1000	<500	<1000	<50	NA	NA	NA	NA
SB-07	10/24/90	<80	<40	<40	<800	<400	<800	<40	NA	NA	NA	NA
SB-07	2/12/91	<60	<30	<30	<600	<300	<600	<30	NA	NA	NA	NA
SB-10	8/02/90	<40	<20	<20	<400	<200	<400	<20	NA	NA	NA	NA
SB-10	10/24/90	<50	<25	<25	<500	<250	<500	<25	NA	NA	NA	NA
SB-10	2/11/91	<40	<20	<20	<400	<200	<400	<20	NA	NA	NA	NA
SB-13	8/02/90	<20	<10	<10	<200	<100	<200	<10	NA	NA	NA	NA
SB-13	10/24/90	<4	<2	<2	<40	<20	<40	<2	NA	NA	NA	NA
SB-13	2/11/91	<4	<2	<2	<40	<20	<40	<2	NA	NA	NA	NA
SB-17	8/02/90	1000	<500	<500	<10000	<5000	<10000	<500	NA	NA	NA	NA
SB-17	10/25/90	2000	<250	500	<5000	<2500	<5000	<250	NA	NA	NA	NA
SB-17	2/13/91	<500	<250	<250	<5000	<2500	<5000	<250	NA	NA	NA	NA
SB-17A	2/12/91	11	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
SB-17B	2/12/91	3	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
SB-20	8/02/90	<1000	<500	<500	<10000	<5000	<10000	<500	NA	NA	NA	NA

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083682

MKIL206012

TABLE A-2
(Continued)

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	Trichloro-trifluoro-ethane	1,1,2-Tri-chloro-ethane	Aliphatic Hydrocarbon C3	Cyclic Hydrocarbon	Dibromo-chloro-methane	Ethylmethyl-benzene Isomer	Trimethyl-benzene Isomer	Vinyl Chloride
MW-01	8/01/90	NA	NA	NA	NA	<6	NA	NA	<6
MW-01	10/24/90	NA	NA	NA	NA	<10	NA	NA	<10
MW-01	2/11/91	NA	<5	NA	NA	<5	NA	NA	<5
MW-02	8/01/90	NA	NA	NA	NA	<1	NA	NA	<1
MW-02	10/24/90	NA	NA	NA	NA	<5	NA	NA	<5
MW-02	2/11/91	NA	<5	NA	NA	<5	NA	NA	<5
MW-03	8/02/90	NA	NA	NA	NA	<8	NA	NA	<8
MW-03	10/24/90	NA	NA	NA	NA	<20	NA	NA	<20
MW-03	2/11/91	NA	<10	NA	NA	<10	NA	NA	<10
SB-04	8/03/90	NA	NA	NA	NA	<20	NA	NA	<20
SB-04	10/24/90	NA	NA	NA	NA	<50	NA	NA	<50
SB-04	2/11/91	NA	<5	NA	NA	<5	NA	NA	<5
SB-07	8/03/90	NA	NA	NA	NA	<50	NA	NA	<50
SB-07	10/24/90	NA	NA	NA	NA	<40	NA	NA	<40
SB-07	2/12/91	NA	<30	NA	NA	<30	NA	NA	<30
SB-10	8/02/90	NA	NA	NA	NA	<20	NA	NA	<20
SB-10	10/24/90	NA	NA	NA	NA	<25	NA	NA	<25
SB-10	2/11/91	NA	<20	NA	NA	<20	NA	NA	<20
SB-13	8/02/90	NA	NA	NA	NA	12	NA	NA	<10
SB-13	10/24/90	NA	NA	NA	NA	<2	NA	NA	<2
SB-13	2/11/91	NA	<2	NA	NA	<2	NA	NA	<2
SB-17	8/02/90	NA	NA	NA	NA	<500	NA	NA	<500
SB-17	10/25/90	NA	NA	NA	NA	<250	NA	NA	<250
SB-17	2/13/91	NA	<250	NA	NA	<250	NA	NA	<250
SB-17A	2/12/91	NA	<1	NA	NA	<1	NA	NA	<1
SB-17B	2/12/91	NA	<1	NA	NA	<1	NA	NA	<1
SB-20	8/02/90	NA	NA	NA	NA	<500	NA	NA	<500

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083683

MKIL206013

TABLE A-2
(Continued)

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	1,1,1-Tri-chloro-ethane	Methylene Chloride	Tetra-chloro-ethene	Tri-chloro-ethene	1,1-Di-chloro-ethene	1,2-Di-chloro-ethene	Cis-1,2-Di-chloro-ethene	Trans-1,2-Dichloro-ethene	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	Benzene
SB-20	10/25/90	12000	6700	8600	1400	4000	<100	NA	NA	120	150	<100
SB-20	2/13/91	28000	29000	19000	2400	11000	NA	<200	<200	<200	460	<200
SB-23	8/03/90	71000	88000	24000	5800	17000	930	NA	NA	460	<300	<300
SB-23	10/25/90	87000	54000	27000	7100	8200	2500	NA	NA	<1000	<1000	<1000
SB-23	2/14/91	94000	93000	40000	5000	10000	NA	600	<500	<500	1300	<500
SB-23A	2/14/91	12	<5	13	7	2	NA	<1	<1	<1	<1	<1
SB-23B	2/14/91	17	<5	17	67	2	NA	<1	<1	<1	<1	<1
SB-25	8/03/90	2000	72000	7000	4200	9200	1900	NA	NA	740	<200	210
SB-25	10/25/90	1800	25000	5100	4200	7600	1500	NA	NA	<120	160	<120
SB-25	2/13/91	1100	46000	5500	3300	6500	NA	<500	<500	<500	<500	<500
SB-32	8/03/90	5200	<100	3100	4100	5500	780	NA	NA	290	<20	51
SB-32	10/25/90	4600	<125	2600	4100	4200	660	NA	NA	450	<25	56
SB-32	2/12/91	3000	<100	2200	3100	3300	NA	520	<20	250	<20	41
SB-36	2/13/91	40000	17000	13000	1900	14000	NA	<250	<250	<250	<250	<250
SW-01	6/23/90	840	<25	<5	<5	<5	<5	NA	NA	180	<5	<5
SW-02	6/23/90	61	<5	<1	<1	<1	<1	NA	NA	34	<1	<1
TW-01	7/18/90	<1	<5	<1	2	<1	<1	NA	NA	<1	<1	<1
CPT-01	4/09/91	48	<20	150	280	220	NA	160	8	64	<4	<4
CPT-02	4/09/91	610	450	330	220	330	NA	44	<5	88	<5	<5
CPT-03	4/09/91	2400	5000	1500	2200	1900	NA	2700	<50	270	<50	<50
CPT-04	4/09/91	20000	<500	10000	2400	11000	NA	150	<100	730	<100	<100
CPT-06	4/10/91	66	<10	130	200	300	NA	140	<2	81	<2	<2
CPT-07	10/02/91	760	307	460	120	960	NA	290	<10	280	<10	20
CPT-08	10/02/91	4600	8200	13000	2100	3400	NA	<100	<100	400	<100	<100
CPT-09	10/02/91	300	8900	740	200	950	NA	1100	<50	1100	<50	70
CPT-10	9/10/91	5	<10	89	240	56	NA	5	<2	<2	<2	<2
CPT-11	9/10/91	79	<5	70	10	68	NA	3	<1	32	<1	<1

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083684

MKIL206014

TABLE A-2
(Continued)

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	Toluene	Ethyl Benzene	Total Xylenes	Acetone	4-Methyl-2-Pentanone (MIBK)	2-Butanone (MEK)	Chloroform	Dichlorofluoromethane	Trichlorofluoromethane	1,1,2-Trichloro-1,2,2-Trifluoroethane	1,1,2-Trifluoro-1,1,trichloroethane
SB-20	10/25/90	310	<100	<100	<2000	<1000	<2000	<100	NA	NA	NA	NA
SB-20	2/13/91	820	<200	<200	<4000	<2000	<4000	<200	NA	NA	NA	NA
SB-23	8/03/90	1600	440	<300	<6000	<3000	<6000	<300	NA	NA	NA	NA
SB-23	10/25/90	2600	<1000	<1000	<20000	<10000	<20000	<1000	NA	NA	NA	NA
SB-23	2/14/91	2500	<500	<500	<10000	<5000	<10000	<500	NA	NA	NA	NA
SB-23A	2/14/91	10	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
SB-23B	2/14/91	10	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
SB-25	8/03/90	1800	<200	<200	5700	<2000	<4000	<200	NA	NA	NA	NA
SB-25	10/25/90	1600	<120	400	4900	<1200	<2500	<120	NA	NA	NA	NA
SB-25	2/13/91	940	<500	<500	<10000	<5000	<10000	<500	NA	NA	NA	NA
SB-32	8/03/90	110	<20	<20	<400	<200	<400	21	NA	NA	NA	NA
SB-32	10/25/90	<50	<25	<25	<500	<250	<500	<25	NA	NA	NA	NA
SB-32	2/12/91	<40	<20	<20	<400	<200	<400	<20	NA	NA	NA	NA
SB-36	2/13/91	1900	<250	1200	<5000	<2500	<5000	<250	NA	NA	NA	NA
SW-01	6/23/90	<10	<5	<5	<100	<50	<100	<5	NA	NA	NA	NA
SW-02	6/23/90	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
TW-01	7/18/90	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
CPT-01	4/09/91	<8	<4	<4	<80	<40	<80	<4	NA	NA	NA	NA
CPT-02	4/09/91	18	<5	14	<100	<50	<100	<5	NA	NA	NA	NA
CPT-03	4/09/91	210	<50	98	<1000	<500	<1000	<50	NA	NA	NA	NA
CPT-04	4/09/91	<200	<100	<100	<2000	<1000	<2000	<100	NA	NA	NA	NA
CPT-06	4/10/91	<4	<2	<2	<40	<20	<40	<2	NA	28	NA	NA
CPT-07	10/02/91	160	180	370	<200	<100	<200	<10	NA	NA	NA	NA
CPT-08	10/02/91	400	<100	800	<2000	<1000	<2000	<100	NA	NA	NA	NA
CPT-09	10/02/91	2100	300	860	6800	1200	5300	<50	NA	NA	NA	NA
CPT-10	9/10/91	<4	<2	<2	<40	<20	<40	<2	NA	24	NA	NA
CPT-11	9/10/91	<2	<1	<1	<20	<10	<20	<1	NA	<5	NA	NA

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083685

MKIL206015

TABLE A-2
(Continued)

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	Trichloro-trifluoro-ethane	1,1,2-Tri-chloro-ethane	Aliphatic Hydrocarbon C3	Cyclic Hydrocarbon	Dibromo-chloro-methane	Ethylmethyl-benzene Isomer	Trimethyl-benzene Isomer	Vinyl Chloride
SB-20	10/25/90	NA	NA	NA	NA	<100	NA	NA	<100
SB-20	2/13/91	NA	<200	NA	NA	<200	NA	NA	<200
SB-23	8/03/90	NA	NA	NA	NA	<300	NA	NA	<300
SB-23	10/25/90	NA	NA	NA	NA	<1000	NA	NA	<1000
SB-23	2/14/91	NA	<500	NA	NA	<500	NA	NA	<500
SB-23A	2/14/91	NA	<1	NA	NA	<1	NA	NA	<1
SB-23B	2/14/91	NA	<1	NA	NA	<1	NA	NA	<1
SB-25	8/03/90	NA	NA	NA	NA	<200	NA	NA	<200
SB-25	10/25/90	NA	NA	NA	NA	<120	NA	NA	<120
SB-25	2/13/91	NA	<500	NA	NA	<500	NA	NA	<500
SB-32	8/03/90	NA	NA	NA	NA	<20	NA	NA	78
SB-32	10/25/90	NA	NA	NA	NA	<25	NA	NA	<25
SB-32	2/12/91	NA	<20	NA	NA	<20	NA	NA	<20
SB-36	2/13/91	NA	<250	NA	NA	<250	NA	NA	<250
SW-01	6/23/90	NA	NA	NA	NA	<5	NA	NA	<5
SW-02	6/23/90	NA	NA	NA	NA	<1	NA	NA	<1
TW-01	7/18/90	NA	NA	NA	NA	<1	NA	NA	<1
CPT-01	4/09/91	NA	<4	NA	NA	<4	NA	NA	<4
CPT-02	4/09/91	NA	<5	NA	NA	<5	NA	NA	<5
CPT-03	4/09/91	NA	<50	NA	NA	<50	NA	NA	<50
CPT-04	4/09/91	NA	<100	NA	NA	<100	NA	NA	<100
CPT-06	4/10/91	NA	<2	NA	NA	<2	NA	NA	<2
CPT-07	10/02/91	NA	<10	NA	NA	<10	100	200	<10
CPT-08	10/02/91	<5	<100	NA	NA	<100	NA	NA	<100
CPT-09	10/02/91	NA	<50	NA	NA	<50	NA	NA	<50
CPT-10	9/10/91	25	<2	NA	NA	<2	NA	NA	<2
CPT-11	9/10/91	<5	<1	NA	NA	<1	NA	NA	<1

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083686

MKIL206016

TABLE A-2
(Continued)

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	1,1,1-Tri-chloro-ethane	Methylene Chloride	Tetra-chloro-ethene	Tri-chloro-ethene	1,1-Di-chloro-ethene	1,2-Di-chloro-ethene	Cis-1,2-Di-chloro-ethene	Trans-1,2-Dichloro-ethene	1,1-Di-chloro-ethane	1,2-Di-chloro-ethane	Benzene
CPT-12	10/28/91	890	<100	2700	970	3400	NA	990	<20	430	<20	50
CPT-13	10/28/91	88000	52000	36000	11000	38000	NA	4000	<500	1000	900	<500
CPT-14	10/28/91	3300	<120	3000	650	3700	NA	90	<25	100	<25	<25
CPT-15	10/28/91	160	<25	620	130	600	NA	40	<5	40	<5	<5
CPT-16	10/28/91	50	6700	400	200	400	NA	1,900	<50	710	<50	50
CPT-17	10/29/91	5	<5	170	81	53	NA	3	<1	31	<1	<1
CPT-18	10/29/91	<1	<5	170	88	32	NA	3	<1	4	<1	<1
Quality Control Samples - duplicates and blanks												
MW-01	10/24/90	340	<50	710	680	1100	600	NA	NA	240	<10	<10
MW-01	2/11/91	200	<75	480	440	830	NA	400	<15	120	<15	<15
MW-02	8/01/90	27	<5	200	370	210	72	NA	NA	17	5	<1
SB-17	8/02/90	59000	13000	43000	6900	4300	<500	NA	NA	<500	<500	<500
SB-17B	2/12/91	1	<5	4	<1	<1	NA	<1	<1	<1	<1	<1
SB-23	8/03/90	63000	83000	31000	5200	16000	870	NA	NA	450	<300	<300
SB-23	10/25/90	78000	43000	27000	6600	14000	2600	NA	NA	<500	<500	<500
SB-23	2/14/91	110000	100000	44000	5400	11000	NA	500	<500	<500	1000	<500
SB-36	2/13/91	42000	18000	13000	1900	14000	NA	<300	<300	<300	<300	<300
CPT-06	4/10/91	94	<10	160	250	370	NA	160	5	88	<2	<2
CPT-08	10/02/91	4400	8200	12000	2000	3300	NA	<100	<100	400	<100	<100
CPT-10	9/10/91	5	<10	81	210	46	NA	5	<2	<2	<2	<2
CPT-13	10/28/91	62000	50000	38000	11000	50000	NA	3000	<500	900	900	<500
EQUIP	8/01/90	<1	<5	<1	<1	<1	<1	NA	NA	<1	<1	<1
EQUIP	8/02/90	<1	<5	<1	<1	<1	<1	NA	NA	<1	<1	<1
EQUIP	8/03/90	<1	<5	<1	<1	<1	<1	NA	NA	<1	<1	<1
EQUIP	10/24/90	<1	<5	<1	<1	<1	<1	NA	NA	<1	<1	<1
EQUIP	10/25/90	<1	<5	<1	<1	<1	<1	NA	NA	<1	<1	<1

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

TABLE A-2
(Continued)

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	Toluene	Ethyl Benzene	Total Xylenes	Acetone	4-Methyl-2-Pentanone (MIBK)	2-Butanone (MEK)	Chloroform	Dichlorofluoromethane	Trichlorofluoromethane	1,1,2-Trichloro-1,2,2-Trifluoroethane	1,1,2-Trifluoro-1,1,trichloroethane
CPT-12	10/28/91	<40	<20	100	<400	<200	<400	<20	200	100	NA	NA
CPT-13	10/28/91	2000	<500	<500	<10000	<5000	<10000	<500	NA	NA	NA	NA
CPT-14	10/28/91	<50	<25	<25	<500	<250	<500	<25	NA	NA	260	NA
CPT-15	10/28/91	<10	<5	<5	<100	<50	<100	<5	120	40	NA	NA
CPT-16	10/28/91	820	400	650	<1000	740	2,100	<50	NA	NA	NA	NA
CPT-17	10/29/91	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	9
CPT-18	10/29/91	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	50
Quality Control Samples - duplicates and blanks												
MW-01	10/24/90	<20	<10	<10	<200	<100	<200	<10	NA	NA	NA	NA
MW-01	2/11/91	<30	<15	<15	<300	<150	<300	<15	NA	NA	NA	NA
MW-02	8/01/90	5	<1	<1	<20	<10	<20	1	NA	NA	NA	NA
SB-17	8/02/90	1600	<500	<500	<10000	<5000	<10000	<500	NA	NA	NA	NA
SB-17B	2/12/91	2	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
SB-23	8/03/90	1500	400	<300	<6000	<3000	<6000	<300	NA	NA	NA	NA
SB-23	10/25/90	2000	<500	<500	<10000	<5000	<10000	<500	NA	NA	NA	NA
SB-23	2/14/91	3000	<500	620	<10000	<5000	<10000	<500	NA	NA	NA	NA
SB-36	2/13/91	2000	<300	1300	<6000	<3000	<6000	<300	NA	NA	NA	NA
CPT-06	4/10/91	<4	<2	<2	<40	<20	<40	<2	NA	36	NA	NA
CPT-08	10/02/91	300	<100	700	<2000	<1000	<2000	<100	NA	NA	NA	NA
CPT-10	9/10/91	<4	<2	<2	<40	<20	<40	<2	NA	18	NA	NA
CPT-13	10/28/91	2000	<500	<500	<10000	<5000	<10000	<500	NA	NA	NA	NA
EQUIP	8/01/90	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
EQUIP	8/02/90	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
EQUIP	8/03/90	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
EQUIP	10/24/90	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA
EQUIP	10/25/90	<2	<1	<1	<20	<10	<20	<1	NA	NA	NA	NA

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083688

MKIL206018

TABLE A-2
(Continued)

SUMMARY OF GROUNDWATER ANALYSIS - EPA METHOD 624/8240 COMPOUNDS

Location ID	Date Collected	Trichloro-trifluoro-ethane	1,1,2-Tri-chloro-ethane	Aliphatic Hydrocarbon C3	Cyclic Hydrocarbon	Dibromo-chloro-methane	Ethylmethyl-benzene Isomer	Trimethyl-benzene Isomer	Vinyl Chloride
CPT-12	10/28/91	200	<20	NA	NA	<20	NA	NA	<20
CPT-13	10/28/91	NA	<500	NA	NA	<500	NA	NA	<500
CPT-14	10/28/91	NA	<25	NA	NA	<25	NA	NA	<25
CPT-15	10/28/91	120	<5	NA	30	<5	NA	NA	<5
CPT-16	10/28/91	NA	<50	NA	NA	<50	NA	NA	<50
CPT-17	10/29/91	NA	1	700	NA	<1	NA	NA	<1
CPT-18	10/29/91	NA	<1	400	8	<1	NA	NA	<1

Notes:
1. All values in micrograms per liter (ug/L)
2. Compounds shown are those detected at one or more sample locations.
3. See Appendix for laboratory data reports.
4. TR indicates Trace. NA = Not Analyzed.

MK083689

MKIL206019

SURFICIAL SOIL DATA IN AREAS A, B, AND C
(mg/kg)

Mckesson Santa Fe Springs Surficial Soil Data

Soil Boring #	1,1DCA	1,2DCA	MC	PCE	TCE	TCA
SB-24	0.025	0.025	0.15	33	3.5	160
SB-30	0.025	32	380	2900	60	3500
SB-37	0.2	0.2	11	1.5	0.4	1.6
SS-01	0.025	0.025	0.15	0.025	0.025	0.025
SS-01	0.025	0.025	0.15	0.025	0.025	0.025
SS-02	0.025	0.025	0.15	0.71	0.07	0.08
SS-02	0.025	0.025	0.15	0.1	0.025	0.025
SS-03	0.025	0.025	0.15	0.025	0.025	0.025
SS-03	0.025	0.025	0.15	1	0.025	0.025
SS-04	0.025	0.025	0.15	1.9	0.025	0.025
SS-04	0.025	0.025	0.15	61	0.025	0.025
1,1DCA = 1,1-Dichloroethane						
1,2DCA = 1,2-Dichloroethane						
MC = Methylene Chloride						
PCE = Tetrachloroethene						
TCE = Trichloroethene						
TCA = 1,1,1-Trichloroethane						

Mckesson Santa Fe Springs Surficial Soil Data

Soil Boring #	Toluene	Xylenes	1,1DCE	1,2DCE	MEK	Acetone
SB-24	78	0.025	0.025	0.025	0.5	0.5
SB-30	110	90	0.025	0.025	0.5	0.5
SB-37	0.05	0.025	0.58		0.5	0.5
SS-01	0.05	0.025	0.25	0.025	0.5	0.5
SS-01	0.05	0.025	0.25	0.025	0.5	0.5
SS-02	0.05	0.025	0.25	0.025	0.5	0.5
SS-02	0.05	0.025	0.25	0.025	0.5	0.5
SS-03	0.05	0.025	0.25	0.025	0.5	0.5
SS-03	0.05	0.025	0.25	0.025	0.5	0.5
SS-04	0.05	0.025	0.25	0.025	0.5	0.5
SS-04	0.05	0.025	0.25	0.025	0.5	0.5
1,1DCE = 1,1-Dichloroethene						
1,2DCE = 1,2-Dichloroethene						
MEK = Methyl Ethyl Ketone (2-Butanone)						

SUBSURFACE SOIL DATA IN AREAS A, B, AND C
(mg/kg)

Mckesson Santa Fe Springs Subsurface Soil Data

Soil Boring #	1,1DCA	1,2DCA	MC	PCE	TCA	TCE
MW-03	0.025	0.025	0.15	0.025	0.025	0.025
MW-03	0.025	0.025	0.15	0.025	0.025	0.025
SB-02	0.025	0.025	0.15	0.025	0.025	0.025
SB-02	0.025	0.025	0.15	0.08	0.1	0.1
SB-03	0.025	0.025	0.92	0.25	0.16	0.5
SB-03	0.025	0.025	0.15	0.025	0.025	0.26
SB-04	0.025	0.025	0.15	0.025	0.025	0.025
SB-04	0.025	0.025	0.15	0.025	0.025	0.025
SB-05	0.025	0.025	3.3	0.025	0.025	0.025
SB-05	0.025	0.025	0.15	0.025	0.025	0.025
SB-06	0.025	0.025	0.15	0.025	0.025	0.025
SB-06	0.025	0.025	0.15	0.5	0.9	0.07
SB-07	0.025	0.025	0.15	0.05	0.06	0.025
SB-07	0.025	0.025	0.15	0.025	0.025	0.025
SB-08	0.025	0.025	0.15	0.025	0.025	0.025
SB-08	0.025	0.025	0.15	0.08	0.025	0.025
SB-09	0.025	0.025	0.15	0.025	0.025	0.025
SB-09	0.025	0.025	0.15	0.025	0.025	0.025
SB-10	0.025	0.025	0.15	0.7	0.3	0.3
SB-10	0.025	0.025	0.15	0.025	0.025	0.025
SB-11	0.025	0.025	0.15	0.05	0.025	0.025
SB-11	0.025	0.025	0.15	0.025	0.025	0.025
SB-13	0.025	0.025	3.9	0.025	1.6	0.025
SB-13	0.025	7	29	0.025	1.5	0.6
SB-17A	0.025	0.025	0.15	0.2	2.2	0.07
SB-19	0.025	0.025	0.15	0.025	0.7	0.025
SB-19	0.025	0.025	0.15	0.025	0.2	0.025
SB-20	0.025	0.025	0.15	0.025	0.3	0.025
SB-20	0.025	0.025	0.15	0.025	0.025	0.025
SB-20	0.025	0.025	0.15	0.2	0.025	0.07
SB-21	0.025	0.025	0.15	0.025	0.025	0.025
SB-21	0.025	0.025	1.1	0.06	0.1	0.025
SB-23	0.025	0.025	0.15	0.025	0.025	0.025
SB-23A	0.1	0.6	30	3.1	0.025	0.84
SB-23A	0.09	0.87	21	0.5	0.025	0.025
SB-23	0.025	0.025	0.15	0.025	0.025	0.025
SB-24	0.025	6.4	0.15	630	0.025	33
SB-24	0.025	0.025	48	58	0.1	6
SB-25	0.3	0.2	3.5	0.1	0.025	0.025
SB-25	0.025	0.025	0.15	0.025	0.025	0.025
SB-25	0.025	0.3	3	0.6	0.025	0.5
SB-26	0.025	0.025	0.15	0.025	0.025	0.025
SB-26	0.1	0.025	3.8	0.07	0.09	0.07
SB-26	0.025	0.025	4.4	0.4	0.025	0.3
SB-27	0.025	0.025	0.15	0.025	0.025	0.025
SB-27	0.2	0.8	23	1	0.025	0.5
SB-27	0.025	0.025	26	0.8	21	0.4
SB-30	0.025	0.025	120	1000	0.025	17

Mckesson Santa Fe Springs Subsurface Soil Data

Soil Boring #	1,1DCA	1,2DCA	MC	PCE	TCA	TCE
SB-30	0.025	0.025	17	7.4	0.025	2.6
SB-36	0.025	0.025	0.15	0.025	530	0.025
SB-36	0.025	2	0.15	12	100	2
SB-36	0.025	0.07	0.15	0.87	0.1	0.1
SB-36	0.025	0.09	0.15	1.4	0.025	0.2
SB-37	0.63	0.2	6.3	5	0.025	0.025
SB-37	0.1	0.2	4.9	0.3	0.025	0.1
SB-37	0.025	0.2	2.6	0.1	0.2	0.025
SB-37	0.025	0.1	1.8	0.025	0.4	0.025
SB-37	0.025	0.025	0.66	0.025	0.025	0.025
SB-38	0.2	0.025	0.55	0.93	3	0.1
SB-38	0.025	0.06	1.8	2.1	0.3	0.1
SB-38	0.025	0.025	0.15	0.025	190	0.025
SB-38	0.025	0.025	0.15	0.025	3.4	0.025
SB-38	0.2	0.2	11	1.5	0.025	0.4
SB-38	0.1	0.08	5.7	1.9	33	0.4
SB-38	0.2	0.08	5.4	1.7	1.4	0.4
SB-38	0.4	0.025	4.3	0.8	0.025	0.2
SB-39	0.025	0.1	2	0.1	0.3	0.025
SB-39	0.025	0.025	0.15	0.3	0.5	0.025
SB-40	0.025	0.025	0.15	0.025	0.025	0.025
SB-40	0.025	0.025	0.15	0.025	0.1	0.025
SB-41	0.025	0.025	0.15	0.025	0.025	0.025
SB-41	0.025	0.025	0.15	0.025	0.4	0.025
SB-42	0.025	0.025	0.15	0.025	0.3	0.025
SB-42	0.025	0.025	0.15	0.025	0.025	0.025
1,1,DCA = 1,1-Dichloroethane						
1,2DCA = 1,2-Dichloroethane						
MC = Methylene Chloride						
PCE = Tetrachloroethene						
TCA = 1,1,1-Trichloroethane						
TCE = Trichloroethene						

Mckesson Santa Fe Springs Subsurface Soil Data

Soil Boring #	Toluene	Xylenes	1,1DCE	1,2DCE	MEK	Acetone
MW-03	0.05	0.025	0.025	0.025	0.5	0.5
MW-03	0.05	0.025	0.025	0.025	0.5	0.5
SB-02	0.05	0.025	0.025	0.025	0.5	0.5
SB-02	0.05	0.025	0.05	0.025	0.5	0.5
SB-03	0.05	0.025	0.2	0.025	0.5	0.5
SB-03	0.05	0.025	0.025	0.025	0.5	0.5
SB-04	0.05	0.025	0.025	0.025	0.5	0.5
SB-04	0.05	0.025	0.025	0.025	0.5	0.5
SB-05	0.1	0.025	0.025	0.025	0.5	0.5
SB-05	0.05	0.025	0.025	0.025	0.5	0.5
SB-06	0.05	0.025	0.025	0.025	0.5	0.5
SB-06	0.05	0.025	0.2	0.025	0.5	0.5
SB-07	0.05	0.025	0.025	0.025	0.5	0.5
SB-07	0.05	0.025	0.025	0.025	0.5	0.5
SB-08	0.05	0.025	0.025	0.025	0.5	0.5
SB-08	0.05	0.025	0.025	0.025	0.5	0.5
SB-09	0.05	0.025	0.025	0.025	0.5	0.5
SB-09	0.05	0.025	0.025	0.025	0.5	0.5
SB-10	0.05	0.025	0.2	0.025	0.5	0.5
SB-10	0.05	0.025	0.025	0.025	0.5	0.5
SB-11	0.05	0.025	0.025	0.025	0.5	0.5
SB-11	0.05	0.025	0.025	0.025	0.5	0.5
SB-13	0.05	0.025	0.025	0.025	0.5	0.5
SB-13	0.05	0.025	0.025	0.025	9	19
SB-17A	0.05	0.025	0.1		0.5	0.5
SB-19	0.05	0.025	0.025	0.025	0.5	0.5
SB-19	0.05	0.025	0.025	0.025	0.5	0.5
SB-20	0.05	0.025	0.025	0.025	0.5	0.5
SB-20	0.05	0.025	0.025	0.025	0.5	0.5
SB-20	0.05	0.025	0.1	0.025	0.5	0.5
SB-21	0.05	0.025	0.025	0.025	0.5	0.5
SB-21	0.05	0.025	0.025	0.025	0.5	0.5
SB-23	0.63	0.025	0.025	0.025	1	0.5
SB-23	0.05	0.025	2.6		0.5	0.5
SB-23A	0.05	0.1	0.2		0.5	0.5
SB-23A	130	0.025	0.025		65	120
SB-24	12	160	0.025	0.025	0.5	0.5
SB-24	0.1	8.6	5	0.025	0.5	19
SB-25	0.05	0.025	0.025	0.025	2.4	37
SB-25	0.3	0.025	0.025	0.025	0.5	3.5
SB-25	0.05	0.025	0.7	0.6	0.5	0.5
SB-26	0.05	0.025	0.025	0.025	0.5	0.5
SB-26	0.05	0.025	0.025	0.025	0.5	0.5
SB-26	0.05	0.025	0.4	0.08	1	0.5
SB-27	3.2	0.025	0.025	0.025	4.6	0.5
SB-27	1	0.4	0.6	0.4	2.2	0.5
SB-27	83	0.025	0.5	0.025	0.5	0.5
SB-30	0.3	60	0.025	0.025	0.5	0.5

Mckesson Santa Fe Springs Subsurface Soil Data

Soil Boring #	Toluene	Xylenes	1,1DCE	1,2DCE	MEK	Acetone
SB-30	0.05	0.025	5.4	0.025	0.5	0.5
SB-36	0.05	0.025	0.025		0.5	0.5
SB-36	0.05	0.025	0.025		0.5	0.5
SB-36	0.05	0.025	0.32		0.5	0.5
SB-36	0.05	0.025	0.35		0.5	0.5
SB-37	0.1	0.09	0.025		0.5	0.5
SB-37	0.05	0.025	0.025		0.5	0.5
SB-37	0.05	0.025	0.025		0.5	0.5
SB-37	0.05	0.025	0.025		0.5	0.5
SB-37	0.05	0.025	0.025		0.5	0.5
SB-38	0.05	0.025	0.025		0.5	0.5
SB-38	0.05	0.025	0.025		0.5	0.5
SB-38	0.05	0.025	0.025		0.5	0.5
SB-38	0.05	0.025	0.025		0.5	0.5
SB-38	0.05	0.025	0.58		0.5	0.5
SB-38	0.05	0.025	0.77		0.5	0.5
SB-38	0.05	0.06	0.82		0.5	0.5
SB-38	0.05	0.025	0.025		0.5	0.5
SB-39	0.05	0.025	0.025		0.5	0.5
SB-39	0.05	0.025	0.025		0.5	27
SB-40	0.05	0.025	0.025		4.5	0.5
SB-40	0.05	0.025	0.025		0.5	0.5
SB-41	0.05	0.025	0.025		0.5	0.5
SB-41	0.05	0.025	0.025		0.5	49
SB-42	0.05	0.025	0.025		6	95
SB-42	0.05	0.025	0.025		13	0.5
1,1DCE = 1,1-Dichloroethene						
1,2DCE = 1,2-Dichloroethylene						
MEK = Methyl Ethyl Ketone (2-Butanone)						

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APPENDIX B

METHODS FOR PREDICTING CHEMICALS VAPOR EMISSIONS USING THE JURY BEHAVIOR ASSESSMENT MODEL

MK083698

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In order to estimate the vapor emission rates for the 12 chemicals of concern at the Mckesson Facility in Santa Fe Springs, California from soil, the Behavior Assessment Model (BAM) of Jury et al. (1983) was used.

For predicting emission rates a 4.2-year and 30-year time-weighted averages were computed. The BAM solution was numerically integrated in double precision over the indicated time period and then divided by the time period. A Gauss-Legendre quadrature scheme (Stroud, 1966) was used with 104 integration points to assure at least a five digit accurate integration of the BAM equation.

BAM is based on the following assumptions:

- a second-order partial differential equation that describes the fate and transport of a single organic species in a one-dimensional, homogeneous porous medium. Chemical transport is subject to gaseous diffusion, liquid diffusion, liquid advection, evapotranspiration, volatilization, degradation, liquid-solid sorption, and liquid-gaseous partitioning.
- all soil properties are assumed to be uniform and constant throughout the soil column. These include the soil bulk density, moisture content, air content, porosity, liquid water flux (e.g., evaporation), partition coefficients, diffusion coefficients, and organic carbon content.
- the liquid-solid phase partitioning is described by a linear, equilibrium sorption isotherm. It is of the form:

$$Cs = Kd \times Cl$$

Where:

Cs = the sorbed chemical concentration ($mg/kg_{dry\ soil}$)

Cl = the aqueous phase chemical concentration (mg/cm^3)

Kd = the distribution coefficient ($cm^3/kg_{dry\ soil}$).

- the liquid-vapor phase partitioning is described by Henry's Law. It is of the form:

$$Cg = Kh \times Cl$$

Where:

Cg	=	the vapor phase concentration ($mg/cm^3_{soil\ air}$)
Kh	=	the dimensionless Henry's Law constant (cm^3_{liquid}/cm^3_{gas}).

- there is a uniform initial concentration of chemical in the soil (Co; mg/cm^3) at time t = 0 between the surface and depth L (cm). The soil is assumed to be initially uncontaminated below depth L.
- chemical volatilization and water evaporation to the atmosphere is limited by gaseous diffusion through a stagnant air boundary layer above which the chemical has zero vapor concentration and the water vapor is at 50% relative humidity.
- both the soil-gas diffusion coefficient (Dg; cm^3_{gas}/cm-sec) and the soil-liquid diffusion coefficient (Dl; cm^3_{liquid}/cm-sec) include the Millington-Quirk model (Shearer et al., 1973) of tortuosity. This tortuosity factor takes into account the reduced flow area and increased path length of diffusing gas or liquid molecules in partially saturated soil.

In order to predict averaged emission rates with BAM, the following variables need to be estimated:

- Co = the initial solute concentration (mg/cm^3),
- Ve = the effective solute adjective velocity (cm/sec),
- De = the effective diffusion coefficient (cm^2/sec), and
- He = the effective stagnant air boundary coefficient (cm/sec).

The equations describing these variables are given by Jury et al. (1983). The following site-specific soil properties must be estimated:

- Rho = Dry soil bulk density (g/cm^3)
- Pt = Soil porosity (cm^3/cm^3)
- Gw = Gravimetric moisture content (g/g)
- Pw = Volumetric moisture content (cm^3/cm^3)
- Pa = Volumetric air content (cm^3/cm^3)
- Foc = Organic carbon soil fraction (generally assumed to be 1%)

- T = Soil temperature (°C)
- L = Initial contamination depth (cm)
- Rho_{water} = Density of water (1 g/cm^3)
- $Rho_{wv(sat)}$ = Density of saturated water vapor (g/cm^3)
- RH = Relative humidity of stagnant air boundary (generally assumed to be 50%)
- Dg_{air} = Air-gas diffusion coefficient (cm^3/cm-sec)
- Dl_{water} = Water-liquid diffusion coefficient (cm$^3_{liq}$/cm-sec)
- $D_{wv\ air}$ = Binary diffusion coefficient of water in air (cm$^3_{gas}$/cm-sec)
- -Jw = Evaporation rate (cm^3/cm^2-sec)

Although Jury et al. (1983) defines all of the variables needed by BAM, there is one additional equation that must be considered. This equation relates Jury's initial chemical concentration (Co) to that of the measured soil concentration (S).

Most laboratories report soil chemical concentrations (S) as total mass of chemical per mass of wet soil [(mg chem)/(kg wet soil)]. The "wet" term indicates that sample soil weight was determined before the sample was oven dried. This type of laboratory analysis includes the total chemical concentration in the gaseous, liquid and sorbed phases. Jury's term Co is expressed as total chemical concentration per gross volume of soil [(mg chem)/(cm^3 soil)]. The values S and Co are related as follows:

$$Co = [S \times Rho \times (1 + Gw)]/1{,}000$$

Where:

Co = initial concentration of chemical in soil (mg/cm^3)

S = measured soil chemical concentration [(mg chem)/(kg$_{wet\ soil}$)]

Rho = Dry bulk density (g/cm^3)

Gw = gravimetric moisture content (g/g)

1,000 = Conversion Factor; g/kg

TABLE B-1

SOIL PROPERTIES FOR McKESSON SANTA FE SPRINGS SITE USED IN JURY'S BAM VAPOR FLUX MODEL FOR VAPOR EMISSIONS

Parameter (BAM)	Value	Rationale
Dry soil bulk density (Rho/P_b)*	1.58 g/cm^3	HLA, 1991
Soil porosity (Pt)*	0.42 cm^3/cm^3	HLA, 1991
Volumetric water content (Pw)*	0.20 cm^3/cm^3	HLA, 1991
Gravimetric water content (Gw/P_{grav})	0.127 g/g	Calculated
Volumetric air content (Pa)*	0.22 cm^3/cm^3	HLA , 1991
Organic carbon soil fraction (F_{oc})	0.01	Default
Soil temperature (T)	20°C	Default
Thickness of clean soil (X)	0 cm (0 feet)	Default
Initial contaminated depth (L)	0-40 feet	Default
Diffusion coefficient of water vapor through air (Dwv_{air})	0.23 cm^3_{gas}/sec-cm	Jury et al., 1983
Density of water (Rho_{water})	1.0 g/cm^3	Jury et al., 1983
Density of saturated water vapor ($Rho_{wv(sat)}$)	1.73×10^{-3} g/cm^3	Jury et al., 1983
Relative humidity of stagnant air boundary (RH)	0.5 (50%)	Jury et al., 1983
Thickness of stagnant air boundary (d) (cm)	1.23 cm	Calculated
Water-liquid diffusion (Dl_{water})	5.0×10^{-6} cm^3/cm-sec	Jury et al., 1983
Water Flux (Jw)	-8.10×10^{-7} $cm^3/sec\text{-}cm^2$ (10.0 in/yr)	
Evaporation rate (E)	8.10×10^{-7} $cm^3/sec\text{-}cm^2$ (10.0 in/yr)	

* The average value was taken from SB-6 and SB-11 at the Mckesson Santa Fe Springs Site.

TABLE B 2

CHEMICAL PROPERTIES FOR THE McKESSON SANTA FE SPRINGS SITE
USED IN JURY'S BAM VAPOR FLUX MODEL

Parameter	Chemicals of Concern												Rationale
	Acetone	1,1 DCA	1,2 DCA	1,1-DCE	1,2 DCE	2-Butanone (MEK)	Methylene Chloride	PCE	TCE	Toluene	1,1,1-TCA	Xylenes	
Organic Carbon Distribution Coefficient (K_{oc}) (ml/g)	2.0	30	14	65	59	9.0	4.5	364	126	300	152	240	EPA/540/1-86/060
Adsorption Distribution Coefficient (Kd) (ml/g)	0.02	0.30	0.14	0.65	0.59	0.09	0.045	3.64	1.26	3.0	1.52	2.4	Calculated
Henry's Law Constant (atm-m^3_{liq}/mole)	2.06×10^{-5}	4.31×10^{-3}	9.78×10^{-4}	3.40×10^{-2}	6.56×10^{-3}	2.74×10^{-5}	3.19×10^{-3}	2.59×10^{-2}	9.10×10^{-3}	6.37×10^{-3}	1.14×10^{-2}	7.04×10^{-3}	EPA/540/1-86/060
Unitless Henry's (Kh) (cm^3_{liq}/cm^3_{gas})	0.001	0.179	0.041	1.42	0.273	0.001	0.133	1.08	0.379	0.265	0.599	0.293	Calculated
Air-gas Diffusion Coefficient (Dg^{air}) (cm^3_{gas}/sec-cm)	0.12	0.10	0.08	0.08	0.08	0.08	0.10	0.07	0.08	0.09	0.08	0.07	EPA/450/3-87/026
Soil-gas Diffusion Coefficient (Dg) (cm^3_{gas}/cm-sec)	4.39×10^{-3}	3.30×10^{-3}	3.66×10^{-3}	2.93×10^{-3}	2.93×10^{-3}	2.93×10^{-3}	3.66×10^{-3}	2.56×10^{-3}	2.93×10^{-3}	3.30×10^{-3}	2.93×10^{-3}	2.56×10^{-3}	Calculated
Water-liquid Diffusion Coefficient (Dl^{water}) (cm^3_{liq}/cm-sec)	1.10×10^{-5}	5.00×10^{-6}	9.90×10^{-6}	5.00×10^{-6}	5.00×10^{-6}	9.80×10^{-6}	1.20×10^{-5}	1.10×10^{-5}	9.10×10^{-6}	8.60×10^{-6}	8.80×10^{-6}	5.00×10^{-6}	EPA/450/3-87/026
Soil-liquid Diffusion Coefficient (Dl) (cm^3_{liq}/cm-sec)	2.93×10^{-7}	1.33×10^{-7}	2.64×10^{-7}	1.33×10^{-7}	1.33×10^{-7}	2.61×10^{-7}	3.20×10^{-7}	2.93×10^{-7}	2.43×10^{-7}	2.29×10^{-7}	2.35×10^{-7}	1.33×10^{-7}	Calculated
Vapor Partition Coefficient (Rg) (cm^3_{gas}/cm^3)	270.34	3.98	10.57	1.09	4.37	300.28	2.26	5.74	6.00	18.85	4.56	13.84	Calculated
Liquid Partition Coefficient (Rl) (cm^3_{liq}/cm^3)	0.23	0.71	0.43	1.54	1.19	0.34	0.30	6.19	2.27	5.00	2.73	4.06	Calculated

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TABLE B-2

CHEMICAL PROPERTIES FOR THE McKESSON SANTA FE SPRINGS SITE
USED IN JURY'S BAM VAPOR FLUX MODEL

Parameter	Chemicals of Concern												Rationale
	Acetone	1,1-DCA	1,2-DCA	1,1-DCE	1,2-DCE	2-Butanone (MEK)	Methylene Chloride	PCE	TCE	Toluene	1,1,1-TCA	Xylenes	
Effective Solute Adjective Velocity (Ve) (cm/sec)	3.49×10^{-6}	1.14×10^{-6}	1.88×10^{-6}	5.27×10^{-7}	6.79×10^{-7}	2.37×10^{-6}	2.70×10^{-6}	1.31×10^{-7}	3.56×10^{-7}	-1.62×10^{-7}	-2.96×10^{-7}	-2.00×10^{-7}	Calculated
Effective Diffusion Coefficient (De) (cm^2/sec)	8.74×10^{-5}	8.52×10^{-4}	3.85×10^{-4}	2.71×10^{-3}	6.85×10^{-4}	5.78×10^{-5}	1.67×10^{-3}	4.49×10^{-4}	4.95×10^{-4}	1.78×10^{-4}	6.48×10^{-4}	1.89×10^{-4}	Calculated
Effective Stagnant Air Boundary Coefficient (He) (cm/sec)	3.61×10^{-4}	1.84×10^{-2}	7.71×10^{-3}	5.99×10^{-2}	1.49×10^{-2}	2.17×10^{-4}	3.60×10^{-2}	9.93×10^{-3}	1.08×10^{-2}	3.89×10^{-4}	1.43×10^{-2}	4.12×10^{-3}	Calculated
Initial Solute Concentration (Co) (mg/cm^3)	1.75×10^{-2}	1.39×10^{-4}	9.61×10^{-4}	8.90×10^{-5}	1.39×10^{-4}	6.55×10^{-3}	1.60×10^{-2}	9.80×10^{-2}	3.44×10^{-3}	1.30×10^{-2}	4.87×10^{-2}	1.37×10^{-3}	Calculated from 95 UCL Subsurface soil concentration (mg/kg)

Initial solute concentration calculated using the geometric mean subsurface soil concentration (mg/kg).

1,1-DCA: 1,1-Dichloroethane
1,2-DCA: 1,2-Dichloroethane
1,1-DCE: 1,1-Dichloroethene
1,2-DCE: 1,2-Dichloroethene
PCE: Tetrachloroethene
TCE: Trichloroethene
1,1,1-TCA: 1,1,1-Trichloroethane

G:\CHEMRISK\MCKESSON\TABLE2 ARENZ

Example Calculation Using Jury's Model

The following is an example of the computation of vapor flux for acetone using Jury's Behavior Assessment Model.

As stated above, this model requires the estimation of many different chemical and site specific data parameters. One of the most comprehensive sources of chemical data for organics can be found in Exhibit A-1 of the EPA's "Superfund Public Health Evaluation Manual" (USEPA, 1986). Tables B-1 and B-2 present the chemical and site-specific data parameters used for this evaluation.

Jury et al.(1983) gives the following vapor and liquid properties of water.

Diffusion coefficient of liquid through water (Dl_{water})	=	5.00×10^{-6} $cm^3{}_{liq}$/sec-cm
Diffusion coefficient of water vapor through open air (Dwv_{air})	=	0.23 $cm^3{}_{gas}$/sec-cm
Density of water (Rho_{water})	=	1.0 $g/cm^3{}_{liq}$
Density of saturated water vapor $Rho_{wv(sat)}$	=	1.73×10^{-5} $g/cm^3{}_{gas}$

The following soil characteristics were used to predict vapor emissions for site conditions. For this example calculation, the soil parameters used are described below and in table A-2.

Dry bulk density (Rho)	=	1.58 g/cm^3
Total soil porosity (Pt)	=	0.42 cm^3/cm^3
Volumetric water content (Pw) (Pt/2 = Pw)	=	0.22 cm^3/cm^3
Volumetric air content (Pa) (Pt - Pw = Pa)	=	0.20 cm^3/cm^2

Once all of the parameters have been defined, the first step is to calculate the sorption partition coefficient (Kd):

Once all of the parameters have been defined, the first step is to calculate the sorption partition coefficient (Kd):

$$Kd = F_{oc} \times K_{oc}$$

$$= 0.01 \times 2.0 \text{ ml/g}$$

$$= 0.02 \text{ ml/g}$$

In this case, a one percent organic carbon content (F_{oc}) was assumed for the soil. The smaller the carbon content, the higher the vapor concentration. The actual carbon content of soil at most sites is probably over 10 percent.

The second step is to convert the Henry's Law constant to its dimensionless form, using the following expression:

$$K_h = K_{henry}/(Ru \times T)$$

If the soil is assumed to be at 20°C, or 293°K, then Kh for acetone is:

$$Kh = \frac{2.06 \times 10^{-5} \text{ atm-m}^3\text{/mole}}{8.2 \times 10^{-5} \text{ atm-m}^3\text{/mole-K} \times 293°\text{K}}$$

$$= 8.6 \times 10^{-4} \text{ cm}^3_{liq}/\text{cm}^3_{gas}$$

It is important to note that Kh is a dimensionless coefficient, but it is not unitless.

The partition coefficient (Rg) that relates the total soil chemical concentration (Co) to the soil chemical concentration that is in the soil vapor phase is calculated for acetone as:

$$Rg = Pa + [(Pw + Rho \times Kd)/Kh]$$

$$= 0.22 \text{ cm}^3/\text{cm}^3 + [(0.20 \text{ cm}^3/\text{cm}^3 + 1.58 \text{ g/cm}^3 \times 0.02 \text{ ml/g})/8.6 \times 10^{-4} \text{ cm}^3/\text{cm}^3]$$

$$= 270.34 \text{ cm}^3_{gas}/\text{cm}^3$$

The partition coefficient (Rl) that relates the total solute chemical concentration (C_t) to the soil chemical concentration that is in the aqueous phase is calculated for acetone as:

$$
\begin{aligned}
Rl &= (Rho \times Kd) + Pw + (Pa \times Kh) \\
&= (1.58\ g/cm^3 \times 0.02\ ml/g \times (1\ cm^3/1\ ml)) + 0.20\ cm^3/cm^3 + (0.22\ cm^3/cm^3 \times 0.001\ cm^3/cm^3) \\
&= 0.23\ cm^3_{liq}/cm^3
\end{aligned}
$$

The next step in the process is to calculate the diffusion coefficients for gaseous and aqueous transport through soil. Farmer et al. (1972) adjusts the diffusion coefficients with a tortuosity factor to account for the reduced flow area and increased path length of diffusing gas and liquid molecules in soil. The Millington-Quirk model of tortuosity is used. The soil-gas diffusion coefficient (Dg) is estimated by:

$$
\begin{aligned}
Dg &= Dg_{air} \times (Pa^{10/3}/Pt^2) \\
&= 0.12\ cm^3/sec\text{-}cm \times [(0.22\ cm^3/cm^3)^{10/3}]/[(0.42\ cm^3/cm^3)^2] \\
&= 4.39 \times 10^{-3}\ cm^3_{gas}/sec\text{-}cm
\end{aligned}
$$

The soil-liquid diffusion coefficient (Dl) is estimated by:

$$
\begin{aligned}
Dl &= Dl_{water} \times (Pl^{10/3}/Pt^2) \\
&= 1.10 \times 10^{-5}\ cm^3/sec\text{-}cm \times [(0.20\ cm^3/cm^3)^{10/3}]/[(0.42\ cm^3/cm^3)^2] \\
&= 2.93 \times 10^{-7}\ cm^3_{liq}/sec\text{-}cm
\end{aligned}
$$

The effective diffusion coefficient De is defined by Jury et al. (1983) by the expression:

$$
\begin{aligned}
De &= Dg/Rg + Dl/Rl + \alpha\,|Ve| \qquad \alpha = 20\ cm \\
&= \frac{4.39 \times 10^{-3}\ cm^3/sec\text{-}cm}{270.34\ cm^3/cm3} + \frac{2.93 \times 10^{-7}\ cm^3/sec\text{-}cm}{0.23\ cm^3/cm^3} + 20\ cm \times |-3.49 \times 10^{-6} cm/sec| \\
&= 8.74 \times 10^{-5}\ cm^2/sec
\end{aligned}
$$

The thickness of the stagnant air boundary layer (d) lying above the soil surface is defined by Jury et al. (1983) to be inversely proportional to the evaporation rate (E). This thickness can be estimated from the expression:

$$
\begin{aligned}
d &= \frac{Dwv_{air} \times Rho_{wv(sat)} \times (1 - RH)}{2 \times E \times Rho_{water}} \\
&= \frac{0.23\ cm^3/sec\text{-}cm \times 1.73 \times 10^{-5}\ g/cm^3 \times (1 - 0.50)}{2.0 \times 8.10 \times 10^{-7}\ cm^3/sec\text{-}cm^2 \times 1.0\ g/cm^3} \\
&= 1.23\ cm
\end{aligned}
$$

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The effective transport coefficient (He) of gas across the stagnant air boundary layer is defined by Jury et al. (1983) by the expression:

$$He = \frac{Dg_{air}}{Rg \times d}$$

$$= \frac{0.12\ cm^3/sec\text{-}cm}{270.34\ cm^3/cm^3 \times 1.23\ cm}$$

$$= 3.61 \times 10^{-4}\ cm/sec$$

The effective seepage velocity (Ve) of the chemical is defined by Jury et al. (1983) by the expression:

$$Ve = Jw/Rl$$

$$= \frac{-8.10 \times 10^{-7}\ cm^3/sec\text{-}cm^2}{0.23\ cm^3/cm^3}$$

$$= -3.49 \times 10^{-6}\ cm/sec$$

The total solute chemical concentration (C_t), is calculated using the following equation, assuming that the measured subsurface concentration is 9.85 milligrams per kilogram:

$$C_o = Cs \times (1 + Gw) \times Rho / 1000$$
$$= [9.85\ mg/kg \times (1 + 0.127\ g/g) \times 1.58\ g/cm^3\ ] / 1000\ g/kg$$
$$= 1.75 \times 10^{-2}\ mg/cm^3$$

The vapor flux of acetone from subsurface soils can now be estimated using Jury's equation and the above variables and by assuming the atmospheric vapor concentration (Ci) of acetone above the stagnant air boundary is negligible compared to that of the soil solution concentration (C_l) of acetone. For this example, Equation 25 of Jury (see Jury's document, attached) was numerically integrated over a 30 and 4.2 year exposure period using a double precision Gauss-Legendre quadrature scheme (Stroud, 1966) with 104 integration points. This result was then divided by the time period to get the time averaged value of gaseous flux from the soil surface.

$$Js(avg) = \frac{\text{Integral [Js(t)-dt] from t=0,Period}}{\text{Period}}$$

For acetone the 30 year average emission rate from is as follows:

$$Js(30\ yr\ avg) = -2.25 \times 10^{-8}\ mg/cm^2\text{-}sec.$$

MK083708

Mckesson Santa Fe Springs Jury BAM Model

Measured Subsurface Soil Concentrations:

Chemical	Dg air (cm3/cm-sec)	Dl water (cm3/cm-sec)	Koc (ml/g)	Kd (ml/g)	Khenry (atm-m3/mole)	Kh (cm3/cm3)	Dg (cm3/cm-sec)	Dl (cm3/cm-sec)	Rg (cm3/cm3)	Rl (cm3/cm3)	d (cm)	Ve (cm/sec)	De (cm2/sec)	He (cm/sec)
Acetone	0.12	1.10E-05	2	0.02	2.06E-05	0.001	4.39E-03	2.93E-07	270.34	0.23	1.23	-3.49E-06	8.74E-05	3.61E-04
1,1-DCA	0.09	5.00E-06	30	0.3	4.31E-03	0.179	3.30E-03	1.33E-07	3.98	0.71	1.23	-1.14E-06	8.52E-04	1.84E-02
1,2-DCA	0.1	9.90E-06	14	0.14	9.78E-04	0.041	3.66E-03	2.64E-07	10.57	0.43	1.23	-1.88E-06	3.85E-04	7.71E-03
1,1-DCE	0.08	5.00E-06	65	0.65	3.40E-02	1.415	2.93E-03	1.33E-07	1.09	1.54	1.23	-5.27E-07	2.71E-03	5.99E-02
1,2-DCE	0.08	5.00E-06	59	0.59	6.56E-03	0.273	2.93E-03	1.33E-07	4.37	1.19	1.23	-6.79E-07	6.85E-04	1.49E-02
2-Butanone (MEK)	0.08	9.80E-06	9	0.09	2.74E-05	0.001	2.93E-03	2.61E-07	300.28	0.34	1.23	-2.37E-06	5.78E-05	2.17E-04
Methylene Chloride	0.1	1.20E-05	4.5	0.045	3.19E-03	0.133	3.66E-03	3.20E-07	2.26	0.30	1.23	-2.70E-06	1.67E-03	3.60E-02
Tetrachloroethene	0.07	1.10E-05	364	3.64	2.59E-02	1.078	2.56E-03	2.93E-07	5.74	6.19	1.23	-1.31E-07	4.49E-04	9.93E-03
Trichloroethene	0.08	9.10E-06	126	1.26	9.10E-03	0.379	2.93E-03	2.43E-07	6.00	2.27	1.23	-3.56E-07	4.95E-04	1.08E-02
Toluene	0.09	8.60E-06	300	3	6.37E-03	0.265	3.30E-03	2.29E-07	18.85	5.00	1.23	-1.62E-07	1.78E-04	3.89E-03
1,1,1-TCA	0.08	8.80E-06	152	1.52	1.44E-02	0.599	2.93E-03	2.35E-07	4.56	2.73	1.23	-2.96E-07	6.48E-04	1.43E-02
Xylenes	0.07	5.00E-06	240	2.4	7.04E-03	0.293	2.56E-03	1.33E-07	13.84	4.06	1.23	-2.00E-07	1.89E-04	4.12E-03

Ct=RgCg=RlCl=RsCs (1)

Ct =[Cs * (1+ Gw) (Rho)] / 1000 g/kg (2)

Chemical	Cs (mg/kgwet)	Ct (mg/cm3)
Acetone	9.85E+00	1.75E-02
1,1-DCA	7.80E-02	1.39E-04
1,2-DCA	5.40E-01	9.61E-04
1,1-DCE	5.00E-02	8.90E-05
1,2-DCE	7.80E-02	1.39E-04
2-Butanone (MEK)	3.68E+00	6.55E-03
Methylene Chloride	9.00E+00	1.60E-02
Tetrachloroethene	5.51E+01	9.80E-02
Trichloroethene	1.93E+00	3.44E-03
Toluene	7.29E+00	1.30E-02
1,1,1-TCA	2.74E+01	4.87E-02
Xylenes	7.70E+00	1.37E-02

Soil Properties		
Dry Bulk Density (Rho) (g/cm3)	1.58	
Total Porosity (Pt) (cm3/cm3)	0.42	ln(Pa)*3.33
Volumetric Air Content (Pa) (cm3gas/cm3)	0.22	-5.0420453
		ln(Pw)*3.33
Volumetric Water Content (Pw) (cm3liq./cm3)	0.2	-5.3594282
Fraction organic material	0.01	
Net Infiltration (Jw) (cm3/cm2-sec.)	-8.10E-07 (10 in./year)	
Net Evaporation (cm3/cm2-sec.)	8.10E-07	
Relative Humidity (RH)	0.5	
Z1 = 0 feet = feet x 30.48 cm	0	
Z2 = 40 feet = feet x 30.48 cm	1219.2	
Gravimetric Water Content (g/g)	0.127	
Univ. Gas Constant	8.20E-05	
Absolute Temperature	293	
Tp1 (initial time) (sec.)	0	
Tp2 (final time) (sec.)		
Residential (30 years)	9.46E+08	
Industrial (4.2 years)	1.32E+08	

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JURY BEHAVIOR ASSESSMENT MODEL OUTPUT SHEETS

MK083710

MKIL206040

Behavior Assessment Model of Jury

Developed by: Dr. Michael J. Ungs
for both infinite and finite soil columns and for transient and time averaged solutions

Version 2.5

ACETONE 30-YEAR EMISSION RATE

```
Ve    =  -.349000E-05 [cm/sec]
De    =   .874000E-04 [cm**2/sec]
He    =   .361000E-03 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .175000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .624582E-04 [mg/cm**3]
Js    =  -.225474E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.21336E+02	.99843E-07
Integrated surface flux	[mg/cm**2]	-.21330E+02	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0289 %

ACETONE 4.2 YEAR EMISSION RATE

```
Ve    =  -.349000E-05 [cm/sec]
De    =   .874000E-04 [cm**2/sec]
He    =   .361000E-03 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .175000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .178264E-03 [mg/cm**3]
Js    =  -.643532E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.21336E+02	.12840E+02
Integrated surface flux	[mg/cm**2]	-.84946E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0053 %

MK083711

MKIL206041

1,1-DICHLOROETHANE 30-YEAR EMISSION RATE

```
Ve    =  -.114000E-05 [cm/sec]
De    =   .852000E-03 [cm**2/sec]
He    =   .184000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .139000E-03 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .816601E-08 [mg/cm**3]
Js    =  -.150255E-09 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.16947E+00	.27095E-01
Integrated surface flux	[mg/cm**2]	-.14214E+00	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .1373 %

1,1-DICHLOROETHANE 4.2-YEAR EMISSION RATE

```
Ve    =  -.114000E-05 [cm/sec]
De    =   .852000E-03 [cm**2/sec]
He    =   .184000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .139000E-03 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .260788E-07 [mg/cm**3]
Js    =  -.479849E-09 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.16947E+00	.10605E+00
Integrated surface flux	[mg/cm**2]	-.63340E-01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0490 %

MK083712

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1,2-DICHLOROETHANE 30-YEAR EMISSION RATE

Ve = -.188000E-05 [cm/sec]
De = .385000E-03 [cm**2/sec]
He = .771000E-02 [cm/sec]
Mu = .000000E+00 [1/sec]
z1 = .000000E+00 [cm]
z2 = .121920E+04 [cm]
Cto = .961000E-03 [mg/cm**3]
z = .000000E+00 [cm]
Tp1 = .000000E+00 [sec]
Tp2 = .946000E+09 [sec]
Type = 2
Time averaged Ct and Js values are:
Ct = .152150E-06 [mg/cm**3]
Js = -.117308E-08 [mg/(sec*cm**2)]

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.11717E+01	.60855E-01
Integrated surface flux	[mg/cm**2]	-.11097E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0908 %

1,2-DICHLOROETHANE 4.2-YEAR EMISSION RATE

Ve = -.188000E-05 [cm/sec]
De = .385000E-03 [cm**2/sec]
He = .771000E-02 [cm/sec]
Mu = .000000E+00 [1/sec]
z1 = .000000E+00 [cm]
z2 = .121920E+04 [cm]
Cto = .961000E-03 [mg/cm**3]
z = .000000E+00 [cm]
Tp1 = .000000E+00 [sec]
Tp2 = .132000E+09 [sec]
Type = 2
Time averaged Ct and Js values are:
Ct = .380336E-06 [mg/cm**3]
Js = -.293239E-08 [mg/(sec*cm**2)]

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.11717E+01	.78421E+00
Integrated surface flux	[mg/cm**2]	-.38708E+00	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0315 %

MK083713

MKIL206043

1,1-DICHLOROETHENE 30-YEAR EMISSION RATE

```
Ve    =  -.527000E-06 [cm/sec]
De    =   .271000E-02 [cm**2/sec]
He    =   .599000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .609600E+03 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .890000E-04 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .713659E-09 [mg/cm**3]
Js    =  -.427481E-10 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.54254E-01	.13815E-01
Integrated surface flux	[mg/cm**2]	-.40440E-01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0000 %

1,1-DICHLOROETHENE 4.2-YEAR EMISSION RATE

```
Ve    =  -.527000E-06 [cm/sec]
De    =   .271000E-02 [cm**2/sec]
He    =   .599000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .609600E+03 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .890000E-04 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .215901E-08 [mg/cm**3]
Js    =  -.129325E-09 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.54254E-01	.37184E-01
Integrated surface flux	[mg/cm**2]	-.17071E-01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0000 %

MK083714

MKIL206044

1,2-DICHLOROETHENE 30-YEAR EMISSION RATE

```
Ve    =  -.679000E-06 [cm/sec]
De    =   .685000E-03 [cm**2/sec]
He    =   .149000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .139000E-03 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .903326E-08 [mg/cm**3]
Js    =  -.134595E-09 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.16947E+00	.41933E-01
Integrated surface flux	[mg/cm**2]	-.12733E+00	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .1227 %

1,2-DICHLOROETHENE 4.2-YEAR EMISSION RATE

```
Ve    =  -.679000E-06 [cm/sec]
De    =   .685000E-03 [cm**2/sec]
He    =   .149000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .139000E-03 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .272136E-07 [mg/cm**3]
Js    =  -.405483E-09 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.16947E+00	.11587E+00
Integrated surface flux	[mg/cm**2]	-.53524E-01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0436 %

MK083715

MKIL206045

2-BUTANONE (MEK) 30-YEAR EMISSION RATE

```
Ve    =  -.237000E-05 [cm/sec]
De    =   .578000E-04 [cm**2/sec]
He    =   .217000E-03 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .655000E-02 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .388917E-04 [mg/cm**3]
Js    =  -.843950E-08 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.79858E+01	.38619E-03
Integrated surface flux	[mg/cm**2]	-.79838E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0201 %

2-BUTANONE (MEK) 4.2-YEAR EMISSION RATE

```
Ve    =  -.237000E-05 [cm/sec]
De    =   .578000E-04 [cm**2/sec]
He    =   .217000E-03 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .655000E-02 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .770322E-04 [mg/cm**3]
Js    =  -.167160E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.79858E+01	.57790E+01
Integrated surface flux	[mg/cm**2]	-.22065E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0031 %

MK083716

MKIL206046

METHYLENE CHLORIDE 30-YEAR EMISSION RATE

```
Ve    =  -.270000E-05 [cm/sec]
De    =   .167000E-02 [cm**2/sec]
He    =   .360000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .160000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .547744E-06 [mg/cm**3]
Js    =  -.197188E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.19507E+02	.81547E+00
Integrated surface flux	[mg/cm**2]	-.18654E+02	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .1937 %

METHYLENE CHLORIDE 4.2-YEAR EMISSION RATE

```
Ve    =  -.270000E-05 [cm/sec]
De    =   .167000E-02 [cm**2/sec]
He    =   .360000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .160000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .229344E-05 [mg/cm**3]
Js    =  -.825639E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.19507E+02	.85951E+01
Integrated surface flux	[mg/cm**2]	-.10898E+02	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0700 %

MK083717

MKIL206047

TETRACHLOROETHENE 30-YEAR EMISSION RATES

```
Ve    =  -.131000E-06 [cm/sec]
De    =   .449000E-03 [cm**2/sec]
He    =   .993000E-02 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .980000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .728110E-05 [mg/cm**3]
Js    =  -.723013E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.11948E+03	.50967E+02
Integrated surface flux	[mg/cm**2]	-.68397E+02	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0987 %

TETRACHLOROETHENE 4.2-YEAR EMISSION RATE

```
Ve    =  -.131000E-06 [cm/sec]
De    =   .449000E-03 [cm**2/sec]
He    =   .993000E-02 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .980000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .211554E-04 [mg/cm**3]
Js    =  -.210074E-06 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.11948E+03	.91710E+02
Integrated surface flux	[mg/cm**2]	-.27730E+02	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0347 %

MK083718

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TRICHLOROETHENE 30-YEAR EMISSION RATE

```
Ve    =  -.356000E-06 [cm/sec]
De    =   .495000E-03 [cm**2/sec]
He    =   .108000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .344000E-02 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .265420E-06 [mg/cm**3]
Js    =  -.286653E-08 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.41940E+01	.14780E+01
Integrated surface flux	[mg/cm**2]	-.27117E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .1038 %

TRICHLOROETHENE 4.2-YEAR EMISSION RATE

```
Ve    =  -.356000E-06 [cm/sec]
De    =   .495000E-03 [cm**2/sec]
He    =   .108000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .344000E-02 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .753196E-06 [mg/cm**3]
Js    =  -.813452E-08 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.41940E+01	.31188E+01
Integrated surface flux	[mg/cm**2]	-.10738E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0365 %

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TOLUENE 30-YEAR EMISSION RATE

```
Ve     =  -.162000E-06 [cm/sec]
De     =   .178000E-03 [cm**2/sec]
He     =   .389000E-02 [cm/sec]
Mu     =   .000000E+00 [1/sec]
z1     =   .000000E+00 [cm]
z2     =   .121920E+04 [cm]
Cto    =   .130000E-01 [mg/cm**3]
z      =   .000000E+00 [cm]
Tp1    =   .000000E+00 [sec]
Tp2    =   .946000E+09 [sec]
Type   =          2
Time averaged Ct and Js values are:
Ct     =   .187354E-05 [mg/cm**3]
Js     =  -.728806E-08 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.15850E+02	.89455E+01
Integrated surface flux	[mg/cm**2]	-.68945E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0608 %

TOLUENE 4.2-YEAR EMISSION RATE

```
Ve     =  -.162000E-06 [cm/sec]
De     =   .178000E-03 [cm**2/sec]
He     =   .389000E-02 [cm/sec]
Mu     =   .000000E+00 [1/sec]
z1     =   .000000E+00 [cm]
z2     =   .121920E+04 [cm]
Cto    =   .130000E-01 [mg/cm**3]
z      =   .000000E+00 [cm]
Tp1    =   .000000E+00 [sec]
Tp2    =   .132000E+09 [sec]
Type   =          2
Time averaged Ct and Js values are:
Ct     =   .464925E-05 [mg/cm**3]
Js     =  -.180856E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.15850E+02	.13459E+02
Integrated surface flux	[mg/cm**2]	-.23873E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0206 %

MK083720

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1,1,1-TRICHLOROETHANE 30-YEAR EMISSION RATE

```
Ve    =  -.296000E-06 [cm/sec]
De    =   .648000E-03 [cm**2/sec]
He    =   .143000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .487000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .292006E-05 [mg/cm**3]
Js    =  -.417569E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.59375E+02	.19802E+02
Integrated surface flux	[mg/cm**2]	-.39502E+02	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .1193 %

1,1,1-TRICHLOROETHANE 4.2-YEAR EMISSION RATE

```
Ve    =  -.296000E-06 [cm/sec]
De    =   .648000E-03 [cm**2/sec]
He    =   .143000E-01 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .487000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .900326E-05 [mg/cm**3]
Js    =  -.128747E-06 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.59375E+02	.42355E+02
Integrated surface flux	[mg/cm**2]	-.16995E+02	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0424 %

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XYLENES 30-YEAR EMISSION RATE

```
Ve    =  -.200000E-06 [cm/sec]
De    =   .189000E-03 [cm**2/sec]
He    =   .412000E-02 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .137000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .946000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .196881E-05 [mg/cm**3]
Js    =  -.811150E-08 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.94600E+09
Mass in soil column	[mg/cm**2]	.16703E+02	.90191E+01
Integrated surface flux	[mg/cm**2]	-.76735E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0627 %

XYLENES 4.2-YEAR EMISSION RATE

```
Ve    =  -.200000E-06 [cm/sec]
De    =   .189000E-03 [cm**2/sec]
He    =   .412000E-02 [cm/sec]
Mu    =   .000000E+00 [1/sec]
z1    =   .000000E+00 [cm]
z2    =   .121920E+04 [cm]
Cto   =   .137000E-01 [mg/cm**3]
z     =   .000000E+00 [cm]
Tp1   =   .000000E+00 [sec]
Tp2   =   .132000E+09 [sec]
Type  =          2
Time averaged Ct and Js values are:
Ct    =   .482503E-05 [mg/cm**3]
Js    =  -.198791E-07 [mg/(sec*cm**2)]
```

Parameter		At Time Tp1	At Time Tp2
Time	[sec]	.00000E+00	.13200E+09
Mass in soil column	[mg/cm**2]	.16703E+02	.14075E+02
Integrated surface flux	[mg/cm**2]	-.26240E+01	
Integrated bottom flux	[mg/cm**2]	.00000E+00	

A mass balance over this time period shows an error of .0213 %

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Behavior Assessment Model for Trace Organics in Soil: I. Model Description[1]

W. A. JURY, W. F. SPENCER, AND W. J. FARMER[2]

ABSTRACT

A mathematical model is introduced for describing transport and loss of soil-applied organic chemicals. The model assumes linear, equilibrium partitioning between vapor, liquid, and adsorbed chemical phases, net first order degradation, and chemical movement to the atmosphere by volatilization loss through a stagnant air boundary layer at the soil surface. From these assumptions and the assumption of steady state upward or downward water flow, an analytic solution is derived for chemical concentration and volatilization flux.

This model, which is intended to classify and screen organic chemicals for their relative susceptibility to different loss pathways (volatilization, leaching, degradation) in the soil and air, requires knowledge of the organic carbon partition coefficient (K_{oc}), Henry's constant (K_H), and net, first-order degradation rate coefficient or chemical half-life to use on a given chemical.

Illustration of the outputs available with the model is shown for two pesticides, lindane (γ-1,2,3,4,5,6-hexachlorocyclohexane) and 2,4-D [(2,4-dichlorophenoxy)acetic acid], which have widely differing chemical properties. Lindane, with a large K_{oc}, large K_H, and small degradation rate coefficient, is shown to be relatively immobile, persistent, and susceptible to volatilization. 2,4-D, with a small K_{oc}, small K_H, and large degradation rate coefficient, is mobile and degrades rapidly, but is only slightly susceptible to losses by volatilization.

Additional Index Words: pesticide, chemical movement, volatilization, diffusion, leaching.

Jury, W. A., W. F. Spencer, and W. J. Farmer. 1983. Behavior assessment model for trace organics in soil: I. Model description. J. Environ. Qual. 12:558–564.

Beginning with DDT in the late 1960's, several established pesticides with effective weed or insect control were removed from the market because of undesirable environmental characteristics. Unfortunately, these undesirable characteristics (such as excessive mobility, persistence, or volatility) were determined or observed only after the chemical had been widely used. Because a certain amount of mobility and persistence is essential for proper management and performance of a pesticide, its pollution potential can only be minimized subject to its effectiveness for weed or insect control.

For this reason, it is clear that environmental screening tests are needed at the time of development of the chemical when screening for toxicity is being performed. It is equally clear that this screening procedure cannot involve excessive experimentation, because of the massive numbers of chemicals involved. Instead, what it needed is a model that is able to make predictions of behavior of one chemical relative to another from a standard set of easily obtainable chemical benchmark properties.

Ideally, the result of this screening procedure would be a classification of large numbers of chemicals into a smaller number of groups whose members display similar behavior. From these groups could be selected prototypes for more extensive experimentation under natural conditions.

Pesticide simulation models are not new. Lindstrom et al. (1968) proposed a mathematical model for describing leaching of pesticides through soil columns. Oddson et al. (1970) and Davidson and McDougal (1973) reported a theoretical leaching model for use with chemicals whose solid-liquid adsorption was linear, but for which the liquid and solid phases were not in equilibrium. Van Genuchten and coworkers, in a series of papers (Van Genuchten et al., 1974, 1977; Van Genuchten & Wierenga, 1976, 1977), described a model for predicting pesticide movement in soil, including effects of pore bypass and hysteresis in the adsorption isotherm, and validated the model in soil column experiments using 2,4,5-T herbicide. They also investigated the effect of nonequilibrium adsorption. Leistra, in a series of papers (Leistra, 1973, 1978, 1979), has devel-

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oped simulation models for both liquid and vapor phase movement as a function of time for variable boundary conditions. Knisel (1980) has assembled (with the aid of a number of authors) a model (CREAMS) for evaluating the amounts of pesticide in surface runoff.

Volatilization models have also been developed. Mayer et al. (1974) compared five different models, employing various upper-boundary conditions for predicting volatilization of chemicals from soil. Farmer et al. (1980) developed a soil cover model for hexachlorobenzene, which demonstrated the effectiveness of deep placement to prevent volatilization. Jury et al. (1980) proposed and validated a model for predicting volatilization losses of triallate, with and without accompanying soil water evaporation.

The above models, for the most part, were intended to simulate specific circumstances, either of leaching or of volatilization. In this paper, and those to follow, we will propose and apply a general model that includes the effects of volatilization, leaching, and degradation to describe the major loss pathways of soil-applied organic chemicals as a function of specific environmental variables and soil conditions. In this way, the behavior of one chemical relative to another in a standard scenario will reveal the susceptibility of the tested chemicals to various loss or displacement pathways in soil. Thus, the model simulations are not intended to predict a chemical's concentration distribution in a field, but merely to group chemicals according to their behavior in the environmental screening tests. Although the model will be primarily used on pesticides in this series of papers, it is applicable as well to other trace organics that may be of environmental concern. This first paper will describe the model and illustrate its output using the chemical and physical characteristics of lindane (γ-1,2,3,4,5,6-hexachlorocyclohexane) and 2,4-D [(2,4-dichlorophenoxy)acetic acid]. Later papers in this series will develop a classification scheme for the susceptibility of chemicals to leaching, volatilization, or degradation; will examine the experimental evidence in support of the model assumptions and predictions; and will apply the model to screen a large number of organic chemicals.

BENCHMARK PROPERTIES NEEDED TO PREDICT PESTICIDE LOSS FROM SOILS

In this section, we will attempt to define a minimum set of chemical and physical characteristics for a given pesticide, which must be known in order to make a reliable assessment of the extent of loss through volatilization, leaching, and/or degradation in soil. The emphasis will be on developing criteria for determining relative behavior of different pesticides under prototype conditions.

Phase Partitioning Coefficients

A pesticide may reside in either the vapor, liquid, or adsorbed phase, but it is essential to know how a given quantity of applied chemical will partition between these three phases in the soil in order to determine its mobility in soil.

The adsorbed-liquid partitioning is expressed through an adsorption isotherm. At low concentrations, the shape of this isotherm may frequently be approximated by a straight line (Karickhoff et al., 1979; Karickhoff, 1981), giving rise to the simple, linear relationship in Eq. [1].

$$C_S = K_D C_L, \qquad [1]$$

where C_S is adsorbed concentration (g/kg soil), C_L is solution concentration (g/m³ soil solution), and K_D (m³/kg) is the slope of the adsorption isotherm of the distribution coefficient. Since this distribution coefficient (for nonionic pesticides, at least) primarily represents adsorption to organic matter, variability between soils may be reduced to an extent by defining an organic carbon distribution coefficient,

$$K_{oc} = K_D / f_{oc}, \qquad [2]$$

where f_{oc} is the fraction of organic C in the soil. This standardization greatly decreases the coefficient of variability of the adsorption coefficient for a given pesticide in different soils (Hamaker & Thompson, 1972; Rao & Davidson, 1980).

When measured adsorption values are not available, reasonably good correlation has been found between K_{oc} and the octanol-water partition coefficient, K_{ow}, or between K_{oc} and solubility and melting point (Karickhoff, 1981). For example, Rao and Davidson (1980) developed the regression equation (Eq. [3]) using published data for a number of pesticides.

$$\log(K_{oc}/1000) = 1.029 \log(K_{ow}/1000) - 0.18; \quad r^2 = 0.91 \qquad [3]$$

where the factor of 1000 is needed because K is expressed in SI units (m³/kg) and their regression used (mL/g) for the units of K. The limitations of the above partitioning approach are discussed in a recent review by Mingelgrin and Gerstl (1983).

The liquid-vapor partition, as mentioned above, is generally represented through Henry's Law,

$$C_G = K_H C_L, \qquad [4]$$

where C_G is concentration of pesticide in the vapor phase (g/m³ soil air) and K_H is Henry's Law constant, which in this system of units is dimensionless. Because studies have shown (Spencer & Cliath, 1970) that this relationship persists to saturation in many circumstances, the Henry's Law constant may be calculated as the ratio of saturated vapor density C_G^* (g/m³) to pesticide solubility C_L^* (g/m³):

$$K_H = C_G^* / C_L^*. \qquad [5]$$

Degradation Coefficients

Because the degradation rate constant or half-life is a direct assessment of the persistence of the pesticide, it must also be classed as an essential parameter for evaluation. In the vast majority of studies, a net, first-order degradation rate is assumed for all degradative processes in all phases, and the rate constant, μ(per day) is measured by the rate equation

$$M(t) = M(0)\exp(-\mu t), \qquad [6]$$

where $M(t)$ is the quantity of pesticide remaining at time t. The half-life, $T_{1/2}$, is related to the rate constant, μ, by $T_{1/2} = 0.693/\mu$.

Unfortunately, measurements of μ vary enormously between field and laboratory data because "degradation losses" generally include other unmeasured pathways of loss. Furthermore, temperature, water content, and microbial population can influence these processes significantly. Thus, this parameter is both extremely important and extremely difficult to assess. For example, Hamaker (1972) reports a half-life for simazine of 105 d (± 34%), which contrasts with values of 75

* Refers to saturation values.

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d (lab) and 64 d (field) given by Rao and Davidson (1980) and with 55 d (± 63%) given by Nash (1980).

Diffusion Coefficients

Other than mass flow in the soil-water phase, the two dominant transport processes for pesticides in soil are vapor and liquid diffusion. The soil-gas diffusion coefficient, D_G, is usually equated to the air-gas diffusion coefficient, D_G^{air}, multiplied by a tortuosity factor to account for the reduced flow area and increased path length of diffusing gas molecules in soil (Nielsen et al., 1972). This tortuosity factor is a function of volumetric air content, a, and of soil geometry, and has been described using a variety of models (Rose, 1972). One such model that has proven useful for describing pesticide soil diffusion coefficients is the Millington-Quirk model (Shearer et al., 1973; Farmer et al., 1972). With this model, we obtain for the soil-gas diffusion coefficient:

$$D_G = (a^{10/3}/\phi^2)\, D_G^{air}, \qquad \left[\frac{L^3}{L^2 T}\right] \quad [7]$$

where ϕ is the soil porosity.

Because the Millington-Quirk tortuosity formula does not have any calibration constants, the only pesticide property that needs to be measured is the air-gas diffusion coefficient. However, by examining the range of existing values for intermediate molecular weight organic compounds (Boynton & Brattain, 1929), as well as by using the Fuller correlation (Liley & Gambill, 1973), one may show that the air-gas diffusion coefficient of different pesticides varies only slightly at a given temperature. For this reason, we consider that the representative value $D_G^{air} = 0.43$ m²/d from the data of Boynton and Brattain (1929) is adequate for most pesticides and need not be measured in every case. see Shen (1981)

Similarly, the soil liquid diffusion coefficient D_L is set equal to the water-liquid diffusion coefficient D_L^{water} multiplied by the appropriate form of the Millington-Quirk tortuosity model.

$$D_L = (\theta^{10/3}/\phi^2)\, D_L^{water}, \qquad \left[\frac{L^3}{L^2 T}\right] \quad [8]$$

where θ (volumetric water content) = $\phi - a$. Although few, if any, water-liquid diffusion coefficient measurements have been made on pesticides, other similar molecular weight organic compounds seem to differ only slightly in value (Bruins, 1929). From the compilation of Bruins, we chose an average $D_L^{water} = 4.3 \times 10^{-6}$ m²/d as a representative value for all pesticides.

Influence of Hydrodynamic Dispersion

Many modelers of chemical transport in soil include a dispersion term in the flux equation to account for solute spreading due to water velocity variations. At low average water fluxes in uniform soil, this term is relatively unimportant, but it becomes dominant over the diffusion term at high water fluxes or in structured soil where substantial variation in water velocities exists. Because we will be using our model in uniform, idealized scenarios, the influence of spatially variable water velocities on transport is not part of the screening tests, and we will not be including a dispersion coefficient. The relative influence of dispersion on transport should be similar to that of diffusion between different chemicals, unless large structural voids are present.

In summary, among the primary properties discussed above, it is essential to measure the organic C partition coefficient, the saturated vapor density, the solubility, and the degradation half-life for each chemical. As we mentioned above, the two diffusion coefficients may be estimated relatively accurately from known information and need not be measured in each case.

There are a number of soil properties that will influence pesticide movement and loss. However, to a great extent, these properties may be standardized in assessing behavior, and the movement along various pathways of one pesticide relative to another may serve as an index of relative pollution hazard.

THEORY

The screening model introduced below is based on a number of simplifying assumptions. Our purpose in using this model is not to simulate chemical transport in a given field situation, but rather to estimate how and where a pesticide will move under a given set of imposed circumstances, particularly by describing the behavior of one chemical relative to another in an identical setting. In an attempt to be general (but at the same time to allow an analytic solution) we have chosen the following scenario for our pesticide screening model:

1) uniform soil properties consisting of a constant water content, θ; bulk density, ρ_b; porosity, ϕ; liquid water flux, J_w (either upward, downward, or 0); and a constant organic C fraction, f_{oc},
2) linear, equilibrium adsorption isotherm so that Eq. [1] is valid,
3) linear, equilibrium liquid-vapor partition (Henry's Law), Eq. [4],
4) uniform initial incorporation of pesticide at time $t = 0$ between the surface and depth L, and
5) loss of pesticide and water to the atmosphere limited by gaseous diffusion through a stagnant air boundary layer above which the pesticide has zero concentration and the water is at 50% relative humidity.

The general transport theory will be derived below and simplified using these assumptions.

Mass Balance

In a one-dimensional, homogeneous porous medium, the mass conservation equation for a single pesticide species undergoing first-order decay may be written as:

$$\partial C_T/\partial t + \partial J_S/\partial Z + \mu C_T = 0, \qquad [9]$$

where C_T = mass of solute per soil volume (g/m³), J_S = solute mass flow per soil area per time (g/m²/day), μ = net degradation rate (per day), t is time (day), and Z is soil depth (m).

Flux Equation

The mass flux may be written as (ignoring adsorpted-phase transport and hydrodynamic dispersion):

$$J_S = -D_G(\partial C_G/\partial Z) - D_L(\partial C_L/\partial Z) + J_w C_L, \qquad [10]$$

where the first term represents gaseous diffusion, the second term describes liquid diffusion, and the third term describes convection of solute by mass flow of soil solution; D_G and D_L may be related to their values in pure air and water, respectively, through Eq. [7] and [8].

Concentration

Total solute concentration is made up of contributions from each phase, as expressed in Eq. [11].

$$C_T = \rho_b C_S + \theta C_L + a C_G \qquad [11]$$

Equations [9], [10], and [11] may be combined to form a second-order differential equation. However, two independent relations between C_S, C_L, and C_G are needed to produce a complete description of the transport and interaction between

by bulk soil density $\left[\frac{Mass}{L^3}\right]$

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phases. Using the linear, equilibrium approximations in Eq. [1] and [4], however, allows us to rewrite Eq. [9] and [10] in terms of one of the variables alone. Thus, Eq. [11] may be written as:

$$C_T = R_S C_S = R_L C_L = R_G C_G, \qquad [12]$$

where

$$R_S = \varrho_b + \theta/K_D + aK_H/K_D, \qquad [13]$$

$$R_L = \varrho_b K_D + \theta + aK_H, \text{ and} \qquad [14]$$

$$R_G = \varrho_b K_D/K_H + \theta/K_H + a \qquad [15]$$

are the partition coefficients for the solid, liquid, and gaseous phases, respectively, which give the ratio of the total concentration C_T to the concentration in each representative phase.

Equations [12] through [15] allow us to rewrite Eq. [9] and [10] in terms of the total concentration, leaving us with:

$$J_{S_{tot}} = -D_E(\partial C_T/\partial Z) + V_E C_T \text{ and} \qquad [16]$$

$$\partial C_T/\partial T = D_E(\partial^2 C_T/\partial Z^2) - V_E(\partial C_T/\partial Z) - \mu C_T, \qquad [17]$$

where D_E is the effective diffusion coefficient given by

$$D_E = (D_G/R_G) + (D_L/R_L) = (K_H D_G + D_L)/R_L, \qquad [18]$$

and V_E is the effective solute convection velocity given by

$$V_E = J_w/R_L. \qquad [19]$$

We could just as easily have written Eq. [9] and [10] in terms of any one of the three phases rather than the total concentration. The advantage of this form is that it automatically applies when, for example, only liquid flow is present, or only gaseous flow is present, and that it directly predicts total concentrations and losses. As pointed out above, the degradation rate coefficient may actually represent unequal contributions from each phase, weighted by the partition coefficients.

Prototype Screening Simulations

In a typical field situation, some pesticides are applied to a soil layer (surface or incorporated) and are subsequently influenced by leaching, volatilization, water evaporation, or degradation. The extent to which a particular compound is affected by a given process is a useful environmental as well as managerial index for classifying pesticides into categories. As mentioned above, we propose the following scenario as such a screening tool:

1) uniform incorporation of a quantity M (g/m²) of chemical to a depth L (cm) below the surface,
2) volatilization through a stagnant air boundary layer of thickness, d, at the soil surface,
3) convection by a steady water flux $J_w = \pm J$ or 0, and
4) infinite depth of uniform soil below the depth of incorporation.

This scenario is idealized but sufficiently flexible to allow a variety of classifications to be made from a given series of calculations. The initial and boundary conditions appropriate to this scenario follow.

Boundary Conditions

INITIAL CONDITION

$$C_T(Z,0) = C_o \quad \text{if } 0 < Z < L$$
$$C_T(Z,0) = 0 \quad \text{if } Z > L, \qquad [20]$$

where C_o is the uniform initial concentration.

UPPER BOUNDARY CONDITION

$$J_S(0,t) = -hC_G(0,t), \qquad [21]$$

where $h = D_G^{eff}/d$, and is the transport coefficient across the stagnant air boundary layer of thickness d. This transport coefficient is actually a diffusion coefficient divided by a length; $C_G(0,t)$ is the gas concentration at the soil surface below the boundary layer. By assumption, the gas concentration at the top of the boundary layer, a height d above the surface, is zero. Thus, Eq. [21] is Fick's Law for the gas flux across the air layer. We may express Eq. [21] in terms of the total concentration using Eq. [16] and the partition coefficient R_G in Eq. [12].

$$-D_E\,\partial C_T/\partial Z + V_E C_T = -H_E C_T, \qquad \text{at } Z = 0 \qquad [22]$$

where $H_E = h/R_G$.

LOWER BOUNDARY CONDITION

$$C_T(\infty,t) = 0 \qquad [23]$$

Solutions to Equations

If we neglect the possibility of chemical precipitation, we may solve Eq. [17], [20], [22], and [23] analytically to give

$$C_T(Z,t) = \frac{1}{2}C_o \exp(-\mu t)\cdot$$
$$\Big(\{erfc[\frac{(Z-L-V_E t)}{\sqrt{4D_E t}}] - erfc[\frac{(Z-V_E t)}{\sqrt{4D_E t}}]\}$$
$$+ (1 + V_E/H_E)\exp(V_E Z/D_E)\cdot$$
$$\cdot\{erfc[\frac{(Z+L+V_E t)}{\sqrt{4D_E t}}] - erfc[\frac{(Z+V_E t)}{\sqrt{4D_E t}}]\}$$
$$+ (2 + V_E/H_E)\exp\{[H_E(H_E+V_E)t + (H_E+V_E)Z]/D_E\}\cdot$$
$$\cdot\Big[erfc[\frac{(Z+(2H_E+V_E)t)}{\sqrt{4D_E t}}] - \exp(H_E L/D_E)$$
$$erfc[\frac{[Z+L+(2H_E+V_E)t]}{\sqrt{4D_E t}}]\Big]\Big) \qquad [24]$$

Using Eq. [16], [22], and [24], we may write the volatilization flux at the surface as

$$J_{S_{tot}}(0,t) = \frac{1}{2}C_o \exp(-\mu t)\cdot$$
$$\cdot\Big[V_E\{erfc(\frac{V_E t}{\sqrt{4D_E t}}) - erfc[\frac{(L+V_E t)}{\sqrt{4D_E t}}]\}$$
$$+ (2H_E + V_E)\exp[H_E(H_E+V_E)t/D_E]\cdot$$
$$\cdot\{\exp(H_E L/D_E)\,erfc[\frac{(L+(2H_E+V_E)t)}{\sqrt{4D_E t}}]$$
$$- erfc[\frac{(2H_E+V_E)t}{\sqrt{4D_E t}}]\}\Big], \qquad [25]$$

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Table 1—Common properties assumed in calculations with lindane and 2,4-D.

Variable	Property	Value
D_G^{air}	Air diffusion coefficient	0.43 m²/d
D_L^{water}	Water diffusion coefficient	4.3 × 10⁻⁴ m²/d
ϕ	Porosity	0.5
ρ_b	Bulk density	1.350 (kg/m³)
RH	Atmospheric relative humidity	0.5 (50%)
T	Temperature	25°C
f_{oc}	Organic carbon fraction	0.0125, 0.0250
θ	Water content	0.30 (m³/m³)
M	Amount of pesticide applied	0.1 g/m² (1 kg/ha)
L	Depth of incorporation	1, 10 (cm)
E	Water evaporation rate	0, 2.5, 5.0 × 10⁻³ (m/d)
J_w	Leaching rate	5 × 10⁻³ (m/d)

where $erfc(x)$ is the complementary error function. Other expressions may be written down, e.g., pesticide flux at other depths $J_S(Z, t)$, but are omitted here for brevity.

Boundary Layer Model

By assumption, both evaporation rate, E, and pesticide volatilization flux, $J_S(o)$, are limited by diffusion through the stagnant air layer of thickness d above the soil surface. Therefore, since we specify evaporation rate, we must select a consistent boundary layer thickness. To make the appropriate selection, one writes the water and pesticide diffusion equations across the air layer at the soil surface.

Water Vapor Transport

$$E = D_{WV}^{air}[\varrho_{WV}(0) - \varrho_{WV}(d)]/\varrho_{WL}d \qquad [26]$$

Pesticide Vapor Transport

$$J_S = D_G^{air}[C_G(0) - C_G(d)]/d, \qquad [27]$$

where ϱ_{WV} (g/m³) is water vapor density, ϱ_{WL} (g/m3) is liquid water density, and D_{WV}^{air} is the binary diffusion coefficient of water vapor in air (≈ 2 m²/d; Boynton & Brattain, 1929). If we further ssume that ϱ_{WV} is saturated at the surface ($\varrho_{WV}(0) = \varrho_{WV}^*$), that $C_G(d) = 0$, and that our steady state evaporation rate is equal to one-half of a typical evaporation rate (which would be negligible at night), we arrive at the final relation for d:

$$d = D_{WV}^{air}\varrho_{WV}^*(1 - RH)/2E\varrho_{WL}, \qquad [28]$$

where RH = atmospheric relative humidity. Equation [28] was used in all calculations that follow, where upward water flux was nonzero. In calculations where $E = 0$ (i.e., $RH = 1$), d was given a specified value of 4.75 × 10⁻³ m. This value of d is obtained with $E = 2.5 \times 10^{-3}$ m/d (2.5 mm/d), and $RH = 0.5$ in Eq. [28].

ILLUSTRATIVE CALCULATIONS

Table 1 shows the common soil chemical and management properties used in the simulations for lindane and 2,4-D (acid). In later papers, we will examine the influence of variations in several of these parameters, but for the present analysis they will be kept constant at the values given. Table 2 summarizes the benchmark properties of lindane and 2,4-D (acid) obtained from the literature at the standard temperature of 25°C. These values are subject to uncertainties, which will be shown to have an influence on results in a later paper.

The combination of the common and benchmark properties in Tables 1 and 2, the diffusion coefficient definitions (Eq. [7] and [8]), and the effective diffusion coefficient definition (Eq. [13], [14], and [18]) yield the lindane and 2,4-D effective diffusion coefficients, D_E, plotted in Fig. 1 as a function of water content. For lindane, the respective contributions add to a relatively constant diffusion coefficient over much of the range of water content, which implies that the water content effects on diffusive processes should not be significant. This conclusion is consistent with the lindane experimental data for D_E presented by Shearer et al. (1973), which showed very little variation with water content. Their somewhat higher D_E values compared with Fig. 1 could be explained by the low organic matter of the Gila silt loam soil they studied.

The 2,4-D diffusion coefficient, on the other hand, is dominated by liquid diffusion and changes by over three orders of magnitude as a function of water content. The calculated values at saturation are similar to the D_E measurements for 2,4-D of Lindstrom et al. (1968) taken on nine saturated soils.

Figure 2 shows pesticide concentrations remaining at 30 d as a function of depth when the pesticides were subject to 5 mm/d water evaporation, no water evaporation, or 30 d of leaching at 5 mm/d. It is clear from this figure that the high adsorption affinity for lindane keeps it localized near the region where it was incorporated initially, whereas 2,4-D is quite mobile. Furthermore, the lindane curve is only slightly affected by dif-

Table 2—Physical-chemical properties of lindane and 2,4-D at 25°C.

	Lindane			2,4-D		
Property	Value	Reference	Comments	Value	Reference	Comments
Saturated vapor density, C_G^* (g/m³)	10⁻³	Spencer & Cliath, Cliath, 1970	Measured by gas saturation 20–60°C	5 × 10⁻⁶	Goring, 1967	Method not specified
Solubility, C_L^* (g/m³)	7.5	Freed, 1976		900	Herbicide Handbook, 1974	Herbicide Handbook, acid
Organic carbon partition coefficient, K_{oc} (m³/kg)	1.3 ± 16%	Rao & Davidson, 1980	Mean of seven soils	2 × 10⁻⁴ ± 7%	Rao & Davidson, 1980	Mean of nine soils
Degradation coefficient, μ (per day)	2.67 × 10⁻³	Rao & Davidson, 1980	Aerobic lab studies	4.62 × 10⁻³	Rao & Davidson, 1980	Laboratory data
Henry's constant, K_H	1.33 × 10⁻⁶		$K_H = C_G^*/C_L^*$	5.5 × 10⁻⁶		
Half-life, $T_{1/2}$ (days)	260		$T_{1/2} = \ln 2/\mu$	15		

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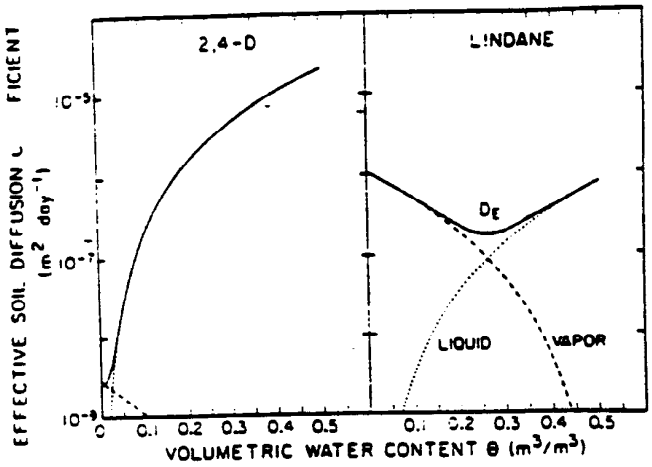

Fig. 1—Effective soil diffusion coefficient calculated for lindane and 2,4-D as a function of water content.

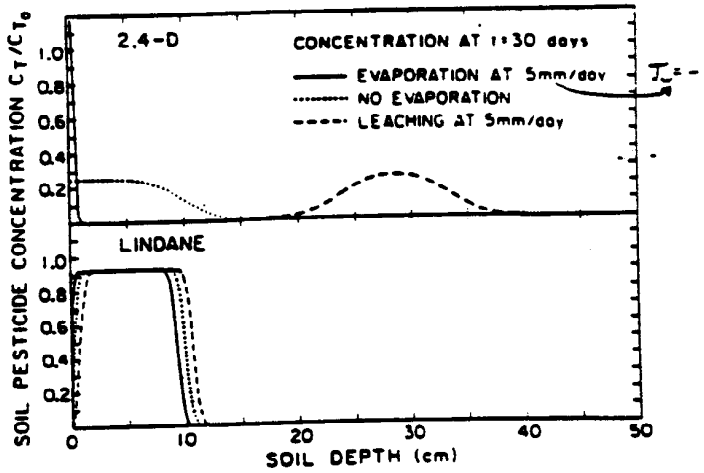

Fig. 2—Calculated lindane and 2,4-D concentrations remaining at 30 d.

fusion and degradation, whereas 2,4-D is significantly depleted by degradation and spread out by diffusion. Figure 3 shows volatilization flux rates given (kg/ha per day) for three cases (volatilization occurring with evaporation rates of 0, 2.5, and 5 mm/d for a soil with f_{oc} = 0.0125). For both chemicals, volatilization can be significantly enhanced by upward water flow, which substantiates the experimental observations of Spencer and Cliath (1973) for lindane in volatilization chambers. This chemical is predicted to have a much more significant volatilization enhancement due to water flow than did triallate in the experiments of Jury et al. (1980). Although the volatilization of 2,4-D is increased significantly with evaporation, it remains quite small compared with lindane.

Table 3 shows the influence of organic C and depth of incorporation on cumulative lindane and 2,4-D volatilization over a 30-d period without water evaporation. Volatilization at two boundary layer thicknesses are given: 5.0 mm and 0.5 mm. The thinner boundary layer corresponds to a well-mixed surface condition (e.g., due to high wind velocity, which causes the pesticides to deplete more rapidly from the surface). As shown in this table, volatilization of lindane, particularly for shallow incorporation, represents a significant loss pathway, whereas for 2,4-D, the loss is negligible. Reduction of boundary layer thickness by a factor of 10 increases lindane volatilization (but not proportionally) indicating that the concentration of lindane at the surface is low (i.e., well-mixed), even at the larger boundary layer thickness.

The influence of water evaporation on volatilization is shown in Table 4 for both chemicals. The values of 2,4-D are higher than in the absence of evaporation, but are still relatively unimportant. Lindane on the other hand could lose up to 68% of the initial amount in 30 d of evaporation-aided volatilization.

Persistence of the chemicals at 30 d is summarized in Table 5 as a percent of initial application. The insensitivity of persistence of 2,4-D to placement, water flow, and soil conditions indicates that degradation is the dominant loss pathway. Persistence of lindane varies significantly with all of these factors, so that volatilization losses could contribute significantly to

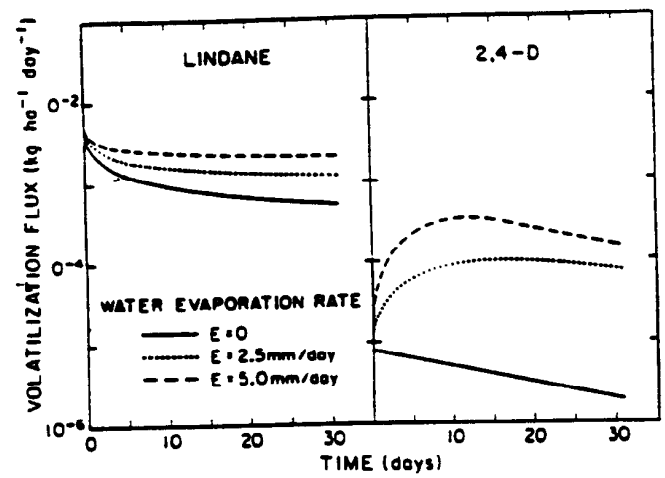

Fig. 3—Calculated lindane and 2,4-D surface volatilization fluxes when water evaporation is occurring.

Table 3—Cumulative volatilization after 30 d, expressed as a percent of the 1 kg/ha amount initially incorporated, when no water evaporation is occurring.

Lindane				2,4-D			
f_{oc} = 0.0125		f_{oc} = 0.0250		f_{oc} = 0.0125		f_{oc} = 0.0250	
d = 5.0 mm	d = 0.5 mm	d = 5.0 mm	d = 0.5 mm	d = 5.0 mm	d = 0.5 mm	d = 5.0 mm	d = 0.5 mm
L = 1 cm							
28.4	32.6	19.1	23.2	0.1	0.7	0.1	0.5
L = 10 cm							
2.9	3.3	1.9	2.3	≈0	0.1	≈0	0.1

errors in the measurement and interpretation of apparent degradation rate calculated from persistence data and Eq. [6].

SUMMARY AND CONCLUSIONS

The calculations above with lindane and 2,4-D illustrate the variety of outputs available with the screening model. The significant differences in behavior between

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Table 4—Cumulative volatilization after 30 d, expressed as a percent of the 1 kg/ha amount initially incorporated, when water evaporation is occurring.

Lindane				2,4-D			
f_{oc} = 0.0125		f_{oc} = 0.0250		f_{oc} = 0.0125		f_{oc} = 0.0250	
E = 2.5 mm/d	E = 5.0 mm/d	E = 2.5 mm/d	E = 5.0 mm/d	E = 2.5 mm/d	E = 5.0 mm/d	E = 2.5 mm/d	E = 5.0 mm/d
			L = 1 cm				
45.9	67.6	27.9	41.3	0.5	0.9	0.3	0.6
			L = 10 cm				
4.7	7.4	2.8	4.2	0.2	0.7	0.1	0.4

Table 5—Persistence of chemicals, expressed as a percent of the 1 kg/ha amount initially incorporated remaining at 30 d, as a function of E, L, and f_{oc}.

Lindane						2,4-D					
f_{oc} = 0.0125			f_{oc} = 0.0250			f_{oc} = 0.0125			f_{oc} = 0.0250		
E = 0	E = 2.5	E = 5.0	E = 0	E = 2.5	E = 5.0	E = 0	E = 2.5	E = 5.0	E = 0	E = 2.5	E = 5.0
mm/day											
					L = 1 cm						
66	49	28	74	66	53	25	25	25	25	25	25
					L = 10 cm						
90	88	85	91	90	89	25	25	25	25	25	25

the two chemicals in identical circumstances show how the model might be used to identify the major loss pathways for a given chemical and to determine the relative mobility, volatility, or persistence of a group of chemicals. In later papers we will illustrate these potential applications in greater detail.

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Behavior Assessment Model for Trace Organics in Soil: II. Chemical Classification and Parameter Sensitivity

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Behavior Assessment Model for Trace Organics in Soil: III. Application of Screening Model

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Behavior Assessment Model for Trace Organics in Soil: IV. Review of Experimental Evidence

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Behavior Assessment Model for Trace Organics in Soil: II. Chemical Classification and Parameter Sensitivity[1]

W. A. JURY, W. J. FARMER, AND W. F. SPENCER[2]

ABSTRACT

In this paper, the organic chemical transport screening model developed in Jury et al. (1983) is simplified by dividing chemicals into volatilization and mobility categories. The volatilization classification is based on whether or not the predominant resistance to volatilization loss lies in the soil or in the boundary layer above the soil surface. This categorization reduces to a condition on the Henry's constant (K_H) and organic C partition coefficient (K_{oc}) when standard values are used to represent soil and chemical parameters. The mobility categories are based on the calculated time to convect or diffuse a given distance through the soil.

Simulations are conducted for chemicals falling into one or another of these volatilization or mobility categories to examine the sensitivity of these processes to variations in water evaporation, water content, organic C fraction, and boundary layer thickness. The dependence of both volatilization flux and leaching flux on these parameters is summarized.

Additional Index Words: chemical movement, diffusion, volatilization, leaching.

Jury, W. A., W. J. Farmer, and W. F. Spencer. 1984. Behavior assessment model for trace organics in soil: II. Chemical classification and parameter sensitivity. J. Environ. Qual. 13:567-572.

In a previous paper (Jury et al., 1983), we introduced a screening model for describing pesticide volatilization, leaching, and degradation in soil. The soil surface boundary consisted of a stagnant boundary layer connecting the soil and air through which pesticide and water vapor must move to reach the atmosphere. Assuming constant water flow and uniform soil properties, we derived an analytical solution, which describes pesticide concentration and flux as a function of chemical, environmental, and soil properties.

In its present form, the theory is too complex to allow a simple analysis to be made of the influence of soil and management properties on chemical behavior. Furthermore, it is not clear to what extent uncertainties in the values of the measured chemical properties will influence the predictions made by the model. Since our proposed use of the model will be as a screening tool to classify pesticides and other trace organics, such knowledge of input parameter sensitivity is essential. In this paper we examine the three major loss pathways: degradation, mobility, and volatilization, and simplify the general theory in such a way as to allow general pesticide classification into specific behavioral groups. Within these groups, we will conduct a sensitivity analysis that will examine the influence of various soil and chemical properties on the loss pathways.

THEORY

Degradation

The processes contributing to biological or chemical degradation of an organic compound in soil are complex, and their functional dependence on such soil and environmental parameters as water content, temperature, organic C, and soil pH are not well understood (Hamaker, 1972). In the absence of such quantitative information, the degradation potential of a given chemical is described with an effective first-order rate constant, μ, or half-life, $T_{1/2}$ (Nash, 1980; Rao & Davidson, 1980). This parameter represents the combined influence of degradation in all phases, and is usually measured by determining the fraction $M(T)/M(0)$ of a given initial quantity of applied chemical $M(0)$ remaining after a time t according to Eq. [1]

$$M(t) = M(0)\exp(-\mu t). \qquad [1]$$

Published measurements of μ differ widely (Hamaker, 1972; Nash, 1980; Rao & Davidson, 1980), not only because of different conditions, but because the degradation process may not best be described as first-order, or because unmeasured volatilization losses and soil measurement errors may interfere with the measurement of degradation losses by Eq. [1]. Nevertheless, the first-order rate coefficient is useful as a relative index of persistence.

In the model of Jury et al. (1983), the soil concentrations and surface volatilization fluxes are proportional to the factor $\exp(-\mu t)$. The uncertainty in μ is likely to be as high as 100% or more (Nash, 1980), which could create a large error in the estimates made for compounds with short half-lives (large μ).

Mobility

CONVECTIVE MOBILITY

In the model of Jury et al. (1983), it was shown that a chemical with a linear, equilibrium partitioning between its vapor, liquid, and adsorbed phases will move with convective velocity

$$V_E = J_W/R_L = J_W/(\varrho_b K_D + \Theta + aK_H). \qquad [2]$$

The ratio of the total concentration to the liquid concentration is R_L, where J_W is water flux, K_D is adsorbed-liquid distribution coefficient, ϱ_b is soil bulk density, K_H is Henry's constant, a is volumetric air content, and Θ is volumetric water content. When the model is used to conduct leaching screening tests, the convective mobility may be classified in a variety of ways. One useful index, in analogy with chromatography, is to define a convection time t_c to move a distance l when a water flux J_W is present (Eq. [3]).

$$t_c = l/V_E = (\varrho_b K_D + \Theta + aK_H)\, l/J_W. \qquad [3]$$

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When adsorption is relatively high (i.e., $K_D > 4 \times 10^{-4}$ (m^3/kg)), the water content Θ and aK_H may be neglected and t_c will be proportional to K_D and ϱ_b. For chemicals such as nonionic pesticides, which primarily adsorb to organic matter, the distribution coefficient K_D may be written as $f_{oc}K_{oc}$, where f_{oc} is organic C fraction and K_{oc} is organic C partition coefficient. In this case,

$$t_c = \varrho_b f_{oc} K_{oc} l / J_w . \qquad [4]$$

This convection time is a useful index of relative mobility and also will approximately describe the movement of a front or of the peak of a narrow pulse of chemical.

DIFFUSIVE MOBILITY

When mass flow by convection is small or negligible, the chemical is able to move through the soil only by liquid or vapor diffusion. In analogy with the convection time, we may define a characteristic diffusion time t_D to move a distance l, which may be written as (Carslaw & Jaeger, 1959).

$$t_D = l^2 / D_E , \qquad [5]$$

where D_E is the effective soil diffusion coefficient (m^2/d), given in Jury et al. (1983) as

$$D_E = \frac{D_G^{air} K_H a^{10/3}/\phi^2 + D_L^{water} \Theta^{10/3}/\phi^2}{\varrho_b K_D + \Theta + aK_H} , \qquad [6]$$

where K_H is Henry's constant, D_G^{air} is gaseous diffusion coefficient in air, D_L^{water} is liquid diffusion coefficient in water, a is air content, and ϕ is porosity. Only those chemicals that move predominantly in the vapor phase will have a relatively small t_D. For these chemicals, the first term in Eq. [6] dominates the second, and Eq. [5] may be written as

$$t_D = (\varrho_b f_{oc} K_{oc} + \Theta + aK_H)\, \phi^2 l^2 / D_G^{air} K_H a^{10/3} . \qquad [7]$$

Unlike the convection time t_c, this index will strongly depend on water or air content.

Volatilization

As described in our previous paper (Jury et al., 1983), the soil and atmosphere are connected by a stagnant air boundary layer through which water vapor and chemical vapor are assumed to move by diffusion. The extent to which this boundary layer limits the volatilization flux may be used as a criterion for classifying pesticides and other volatile organics into general categories, similar to the volatilization groups used to classify chemical losses from water bodies (Smith et al., 1980, 1981). To achieve this, it is convenient to distinguish between processes where no water flow (E) is occurring ($E = 0$) and processes where both volatilization and evaporation are occurring.

CASE 1. NO WATER EVAPORATION $E = 0$

When a chemical is initially uniformly incorporated in the soil at a total concentration C_o (g/m^3), the maximum volatilization flux rate J_1 through the soil surface to the atmosphere that could occur is given by Jury et al. (1980)

$$J_1 = C_o (D_E / \pi t)^{1/2} , \qquad [8]$$

where D_E is given in Eq. [6] and where t is time (days). This flux rate is that which would occur with no boundary layer resistance in the air or equivalently when the surface concentration $C_T(0,t)$ is held at zero for all $t > 0$.

When a boundary layer of thickness d is present, the maximum flux J_{V_1} that can move through the boundary layer occurs when no soil resistance is present and the gas concentration C_G at the soil surface is held at its initial value $C_G(o) = C_o/R_G$

$$J_{V_1} = D_G^{air} C_o / R_G d , \qquad [9]$$

where $R_G = R_L/K_H = (\varrho_b K_D + \Theta + aK_H)/K_H$ is the ratio of the total chemical concentration to the concentration in the vapor phase. Equation [9] assumes that the concentration of the chemical in the free air above the boundary layer is zero.

When a boundary layer is present, it will act to restrict volatilization fluxes only if the maximum flux through the boundary layer J_{V_1} is small compared with the rate at which chemical moves to the soil surface, which we may represent approximately as J_V. Thus, if $J_{V_1} < J_V$, then

$$D_G^{air} C_o / R_G d < C_o (D_E / \pi t)^{1/2} . \qquad [10]$$

By plugging the definitions for R_G and D_E into Eq. [10], we may rewrite the condition expressed there in terms of the soil and chemical parameters in the various terms. To simplify the interpretation, we will use standard values for many of the soil and chemical properties other than the properties that differ greatly for different chemicals. These are summarized in Table 1.

When the soil water content is reasonably high (e.g., $\Theta > 0.2$), then the second term in the numerator of Eq. [6] will dominate the first term under the same circumstances (small K_H) when the inequality in Eq. [10] is valid. Thus, using $D_E = D_L/R_L$, we may rewrite Eq. [10] as

$$K_H^2 / K_{oc} < \frac{D_L^{water} d^2 \Theta^{10/3}}{(D_G^{air})^2 \pi t \phi^2} \varrho_b f_{oc} , \qquad [11]$$

Table 1—Standard values of soil and chemical properties used in simulations.

Parameter	Symbol	Units	Standard value
Porosity	ϕ	m^3/m^3	0.5
Bulk density	ϱ_b	kg/m^3	1350
Organic C fraction	f_{oc}	–	0.0125
Liquid diffusion coefficient	D_L^{water}	m^2/d	4.8×10^{-4}
Air diffusion coefficient	D_G^{air}	m^2/d	4.3×10^{-1}
Water content	Θ	m^3/m^3	0.3

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where it has been assumed in going from Eq. [10] to Eq. [11] that $R_L = \varrho_b K_D = \varrho_b f_{oc} K_{oc}$.

If we plug in the standard values from Table 1, along with $t = 2$ d and $d = 5$ mm from Jury et al. (1983), we obtain a benchmark criterion for a boundary layer influence when volatilization occurs without water evaporation

$$K_H^i/K_D \ll 9 \times 10^{-6}\,(\mathrm{kg/m^3}) \qquad [12]$$

with $f_{oc} = 0.0125$.

CASE 2. WATER EVAPORATION $E \neq 0$

If upward water flow carries an insignificant amount of pesticide compared with upward diffusion, then the analysis is identical to case 1. However, if upward convection is dominant, as it will be if the solution concentration is high, or if evaporation and volatilization both occur for a long time period, then the upward flux of chemical J_V toward the boundary layer is approximately equal to

$$J_V = C_L E = C_o E/R_L, \qquad [13]$$

where C_L is solution concentration. The criterion for a boundary layer restriction on volatilization in this case occurs when $J_V \ll J_{V,}$, or

$$D_G^{air} C_o/R_G d \ll C_o E/R_L. \qquad [14]$$

Further, if we assume, as in Jury et al. (1983), that water evaporation is also regulated by the boundary layer, we may write a water vapor diffusion equation across the boundary layer as

$$E = [D_{wv}^{air} \varrho_{wvs}(1 - \mathrm{RH})/2\varrho_{wL} d \qquad [15]$$

where ϱ_{wL} is liquid water density, ϱ_{wvs} is saturated water vapor density and RH is relative humidity. The factor of 2 is inserted, as explained in Jury et al. (1983), because our model uses a steady-state evaporation flux, whereas normal field evaporation rates are small during the evening hours. When Eq. [15] is plugged into Eq. [14] we obtain

$$K_H \ll [D_{wv}^{air} \varrho_{wvs}(1 - \mathrm{RH})]/2D_G^{air} \varrho_{wL} = 2.5 \times 10^{-5}. \qquad [16]$$

Note that Eq. [12] and [16] are identical for $K_D = 7 \times 10^{-3}$ (m³/kg), which is a value representing moderate adsorption.

Relationship to Chemical Volatilization from Water Bodies

Volatilization of dissolved chemicals from water bodies has been modeled using a linear two-resistance film model (Liss & Slater, 1974), and by a two film model using penetration theory to represent transport from the liquid to the air water interface (Smith et al., 1980, 1981). Irrespective of the model use, however, one concludes that there is substantially less resistance to volatilization from the water body than has been found here (see Eq. [2]) for volatilization from soil. As a result, in water systems the air boundary layer forms a barrier to chemical loss at a much higher value of K_H than that predicted by Eq. [16] for soil systems. For example, the criterion equivalent to Eq. [16] obtained using the approach of Smith et al. (1981) for chemical loss from rivers is

$$K_H \ll 3.8 \times 10^{-1}. \qquad [17]$$

The reason that one obtains such a different answer in water bodies than in soil is that in a soil system upward chemical movement is restricted both by adsorption and by tortuosity effects (increased path length, decreased cross-sectional area) on diffusion compared with water transport. Since resistance to transport to the atmosphere through the stagnant air boundary layer is similar in both cases, the transition point where volatilization loss is regulated by the vapor phase shifts upward by over two orders of magnitude when water is analyzed instead of soil.

Pesticide Volatilization Categories

To simplify subsequent discussion, pesticides whose properties obey the inequalities Eq. [10] or Eq. [16] will be called category III, those whose properties obey the opposite inequality ($\gg$) will be called category I, and those for which Eq. [10] or Eq. [16] represent an equality will be called category II. Table 2 presents hypothetical but representative benchmark properties for pesticides in each of the three categories. For simplicity, each pesticide is given the same K_{oc}, water solubility (C_L^*), and μ, and Henry's constant K_H variations are achieved by varying saturated vapor density, C_G^*. With the above choices, the three pesticides fall unambiguously into different categories by both Eq. [10] and [16].

RESULTS

Mobility Classification

Equation [3] or [4] defines the dependence of the convective mobility time t_c on soil and chemical properties. To illustrate its use we may calculate the time required to move the chemical $l = 10$ cm when water is applied at $J_W = 1.0$ cm/d, for the standard conditions given in Table 1, with the result that $t_c \sim 170\,K_{oc} + 10\,\Theta$ (days). Thus, the chemicals 2,4-D [(2,4-dichlorophenoxy) acetic acid] and lindane (γ-1,2,3,4,5,6-hexachlorocyclo-

Table 2—Hypothetical pesticide benchmark properties and their categorical designation.

Property	Category I	Category II	Category III
Vapor density C_G^* (g/m³)	10^{-1}	10^{-3}	10^{-5}
Solubility C_L^* (g/m³)	40	40	40
K_{oc} (m³/kg)	0.5	0.5	0.5
K_D (m³/kg)	6.3×10^{-1}	6.3×10^{-3}	6.3×10^{-5}
μ (d⁻¹)	0	0	0
K_H	2.5×10^{-3}	2.5×10^{-5}	2.5×10^{-7}
K^i_H/K_{oc}	1.25×10^{-6}	1.25×10^{-8}	1.25×10^{-10}

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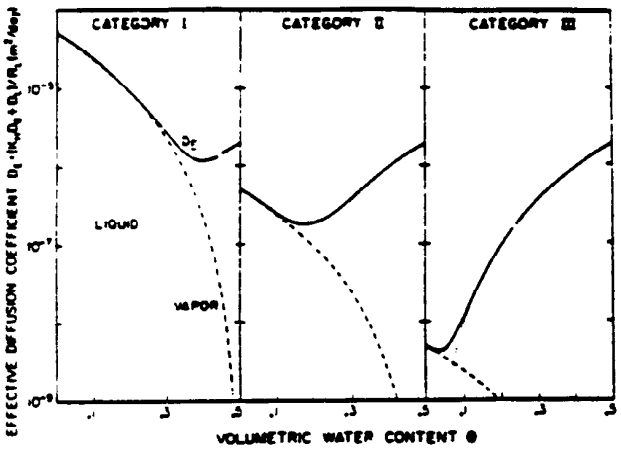

Fig. 1—Effective diffusion coefficients as a function of water content for prototype chemicals representing the three volatilization categories.

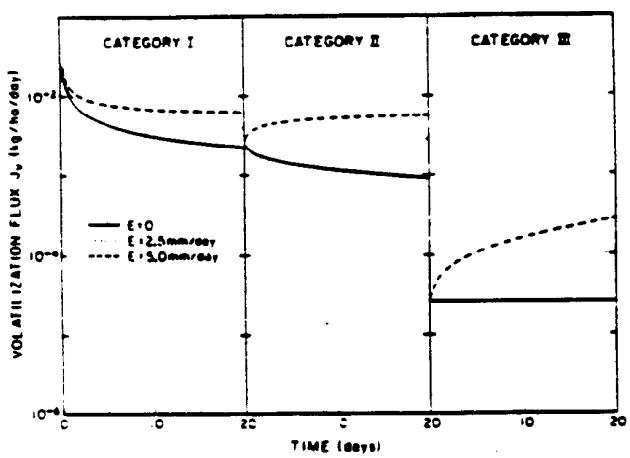

Fig. 2—Volatilization flux rates for the three chemical prototypes for three rates of water evaporation.

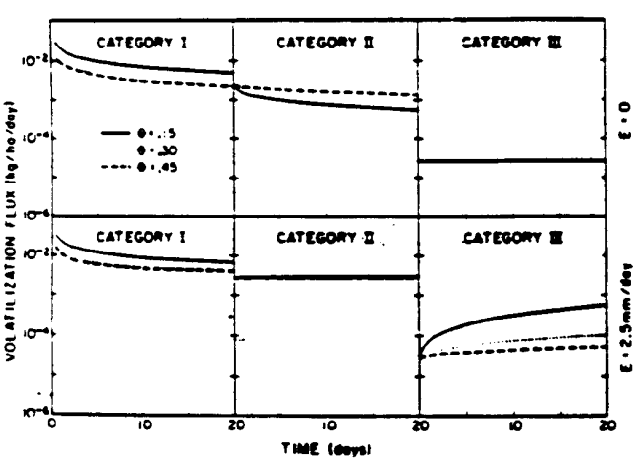

Fig. 3—Effect of changes in water content on volatilization flux rates for the three chemical prototypes. Top curves are for zero evaporation and bottom curves for evaporation of 2.5 mm/d.

hexane), which have K_{oc} = 0.02 and 1.3 m³/kg, respectively (Jury et al., 1983) have convective times of 6.4 and 224 d, respectively. These chemicals would represent highly mobile and relatively immobile compounds in a leaching classification scheme such as that of Helling (1971).

The diffusive mobility as defined by Eq. [7] will be important only for vapor dominated compounds with large K_H and small K_{oc}. To see this, if we require that in dry soil ($a \sim \phi$) the diffusive time to move 10 cm be < 20 d for a soil with properties given in Table 1; Eq. [7] reduces to the condition $K_{oc}/K_H < 20$. This condition is met only for fumigants and other vapor-dominated compounds of low adsorption. The compounds 2,4-D and lindane, for example, have $K_{oc}/K_H = 3.5 \times 10^6$ and 1×10^4, respectively (Jury et al., 1983).

Volatilization Classification

Figure 1 shows a plot of effective diffusion coefficient D_E (Eq. [6]) as a function of volumetric water content for the prototype chemicals (Table 2) chosen to represent the three categories. From this figure it is clear that a category I chemical is dominated by vapor diffusion and a category III chemical is dominated by liquid diffusion over most of the water content range. Category II chemicals are vapor-dominated at low water content and liquid-dominated at high water content.

Figure 2 shows volatilization flux rates vs. time for the three prototype chemicals under three cases of (i) no evaporation, (ii) steady evaporation at 2.5 mm/d, and (iii) steady evaporation at 5.0 mm/d. Again, a clear distinction is apparent between the behavior of category I and category III chemicals. For category I, the volatilization flux shows a characteristic decrease with time in all three cases, whereas the flux rate of the category III chemical tends to increase with time when upward water flow is occurring and to decrease slowly with time when evaporation is not present. The category II volatilization flux decreases with time when no evaporation occurs and increases with time when high evaporation occurs.

Figure 3 shows the influence of changes in water content on volatilization flux rates for the three chemicals for both volatilization without evaporation and volatilization with a water evaporation rate of 2.5 mm/d. The results suggest a very complicated dependence on water content for both cases. For example, category III chemicals show no water content dependence when water is not evaporating, but are strongly water content dependent when evaporation is occurring.

Figure 4 shows the effect of changing organic C fraction f_{oc} on volatilization flux rates. Since decreasing adsorption increases both convective and diffusive transport to the surface, in all cases volatilization increases with decreasing organic C fraction. However, the extent of the dependence seems somewhat stronger in category III than category I.

Figure 5 shows the influence on volatilization of arbitrarily changing the thickness d of the stagnant boundary layer while forcing evaporation to be either 0 or 2.5 mm/d. This arbitrary action has the effect of decoupling water evaporation and boundary layer thickness (Eq. [10]), but could be accomplished in prin-

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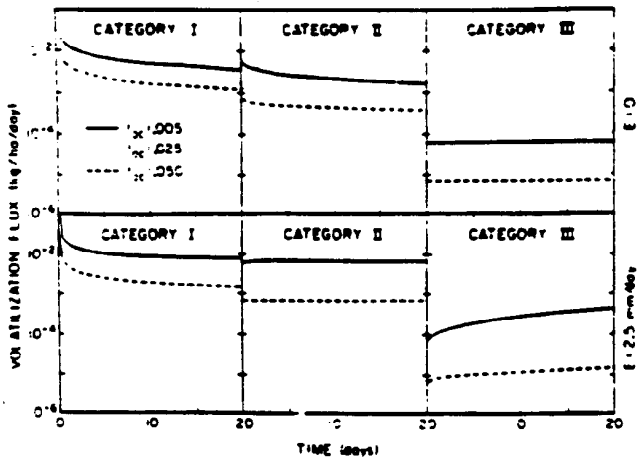

Fig. 4—Effect of changes in organic C fraction on volatilization flux rates for the three chemical prototypes. Top curves are for zero evaporation and bottom curves are for evaporation of 2.5 mm/d.

ciple by adjusting the relative humidity of the air above the boundary layer so as to maintain E = constant. Here it is obvious that the category I chemical has a volatilization rate that is independent of boundary layer thickness in the range $d < 5$ cm and that the category III chemical has a volatilization rate that is inversely proportional to boundary layer thickness over the range $0.05 < d < 5$ cm.

DISCUSSION

Volatilization without Evaporation

Since Eq. [8] and [9] are respectively the maximum rate of chemical movement through the soil to the surface and from the surface to the air, it is worthwhile to compare these fluxes with the actual predicted volatilization rates for the three chemical categories. This is shown in Fig. 6, where the dashed curve gives the boundary layer flux J_V, (Eq. [9]) where $C_G(o)$ is held at its initial value, the dotted curve gives the maximum soil loss rate J_V, (Eq. [8]) and the solid curve gives the actual flux. From this figure it is clear that the category I

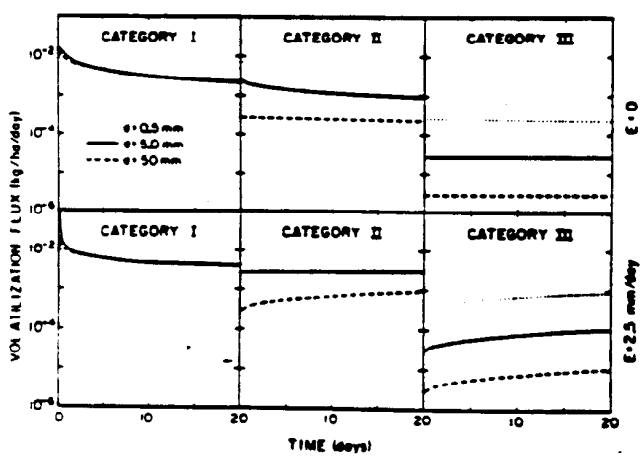

Fig. 5—Effect of changes in diffusion boundary layer thickness on volatilization flux rate for the three chemical prototypes. Top curves are for zero evaporation rate and bottom curves for evaporation of 2.5 mm/d.

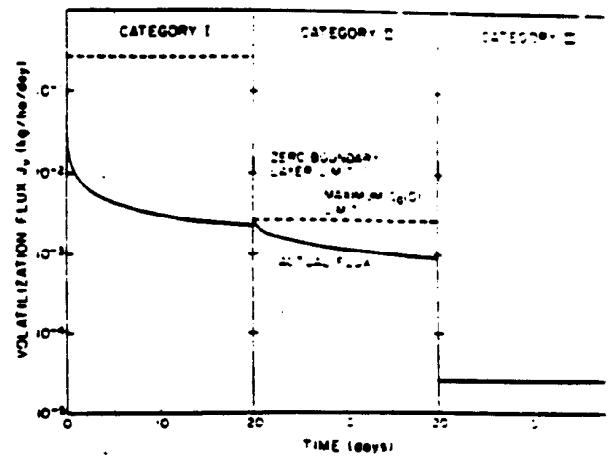

Fig. 6—Calculated volatilization flux rates for the three chemic prototypes when water evaporation is not occurring (solid line along with maximum flux through boundary layer given by Eq. [(dashed lines) and maximum flux possible when no boundary la is present, calculated from Eq. [2] (dotted lines).

chemical behaves as though there is no boundary la resistance [$C_G(o) = 0$] and the category III chemical b haves as though there is no soil resistance [$C_G(o)$ r mains at its initial value]. The category II chemical h properties that create soil and boundary layer resistan of approximately similar size.

Thus, Eq. [8] and [9] may be used to represent t volatilization rates of category I and III chemicals, r spectively, when no water evaporation is present. particular, the functional dependence of t volatilization rate on various soil and chemical para eters may be obtained by plugging in the defining equ tions for D_E and R_G into Eq. [8] and [9], respectively.

Category I Chemicals

$$J_V \propto C_o K_H^{1/2} a^{5/3} K_{oc}^{-1/2} f_{oc}^{-1/2} r^{-1/2} \qquad [1$$

Category III Chemicals

$$J_V \propto C_o K_H K_{oc}^{-1} f_{oc}^{-1} d^{-1} \qquad [1$$

Equations [18] and [19] explain the relevant functio al dependences of the $E = 0$ volatilization curves show in Fig. 1–5. For example, Eq. [19] approximately pr dicts that a category III chemical will have a volatiliz tion rate that has no Θ dependence (Fig. 3), no time c pendence (Fig. 3), will be inversely proportional to J (Fig. 4), and inversely proportional to d (Fig. 5).

Volatilization with Evaporation

The limiting behavior for volatilization with evapor tion is more complex than the evaporation-free case f several reasons. First, both diffusion and convectio may contribute to the movement of chemical toward t soil surface. Therefore, category I chemicals will n have volatilization rates that are equal to the rate which the chemical is moved with water in accordan with Eq. [13], except at large times if the system a proaches a steady-state rate of loss. Second, for boundary-layer limited chemical (category III), upwar

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Behavior Assessment Model for Trace Organics in Soil: III. Application of Screening Model[1]

W. A. JURY, W. F. SPENCER, AND W. J. FARMER

ABSTRACT

The soil chemical screening model developed in Jury et al. (1983) is applied to a set of 35 chemicals for which benchmark properties (organic C partition coefficient, vapor pressure, solubility, half-life) have been obtained. Environmental screening tests are conducted on the chemicals to determine their relative convective mobility, diffusive mobility, volatility, and persistence with the results presented in a series of classifications rating the susceptibility of the chemical to a given loss pathway.

The convective mobility tests estimate the time required for a pulse of chemical to travel a distance of 10 cm through an ideal soil of uniform water content and organic C content while being subjected to a water application rate of 1 cm/day. The diffusive mobility tests determine the time required for a chemical to diffuse 10 cm through the same ideal soil. In the volatilization screening tests, each chemical is applied at a uniform concentration of 1 kg/ha to a standard depth in the soil with uniform properties and is allowed to volatilize through a stagnant air boundary layer during a specified time period in the presence or absence of water evaporation. The resulting volatilization fluxes and cumulative losses for a standard time period are used to categorize the relative susceptibility of the chemical to loss to the atmosphere. The persistence tests are used to determine the amount of chemical left after a specified time period when it is free not only to degrade but also to volatilize.

Additional Index Words: chemical movement, diffusion, volatilization, leaching.

Jury, W. A., W. F. Spencer, and W. J. Farmer. 1984. Behavior assessment model for trace organics in soil: III. Application of screening model. J. Environ. Qual. 13:573-579.

There have been a number of reviews written in recent years in which chemical properties have been assembled for a group of organic compounds for the purpose of characterizing environmental behavior. Helling (1971) and Helling et al. (1971) have used thin-layer chromatography to assess the relative mobility of dissolved chemicals during leaching. Their resulting classification of relative mobility is summarized in terms of R_F values of the chemicals; R_F values denote their relative movement along a thin soil layer. They proposed five categories ranging from highly mobile to immobile. Kenaga and Goring (1980) assembled experimental data from 170 chemicals and found a relationship between water solubility, organic C partition coefficient, and soil bioconcentration factors in animal organisms. Rao and Davidson (1980) published a large list of pesticide organic C and octanol-water partition coefficients as well as half-lives for chemicals and provided a series of categories designating persistence based on the half-lives.

In the first two papers of this series (Jury et al., 1983, 1984a), we proposed a general transport model for describing movement through soil in both the liquid and vapor phases for a chemical that partitions betw liquid, vapor, and adsorbed phases. The model wa veloped in order to analyze scenarios in which a g chemical is incorporated uniformly over a finite d in the soil and is allowed to volatilize with or without presence of water evaporation. In this paper we illustrate the use of the model for screening tests number of pesticides and other chemicals for wh benchmark properties are available. From these resu we will attempt to divide the chemicals into gene groups, based on their susceptibility to various lo pathways in soil.

DESCRIPTION OF CHEMICALS[1]

Table 1 gives the saturated vapor density, C_V aqueous solubility, C_L^*; organic C partition coefficie K_{oc}; Henry's constant, K_H; and half-life, $T_{1/2}$ the 35 chemicals used in our screening tests, togeth with references for the values used. For several the chemicals, we had to calculate K_{oc} from the o tanol water partition coefficient K_{ow} or from t water solubility regression given in Kenaga (1980). Th log-log regression had a $r^2 = 0.79$ when used on the chemicals for which we had both K_{oc} and C_L^* valu Also, for 15 of the chemicals—primarily volatile or with high vapor pressure—we have not been able to o tain a half-life. In these cases we have conducted o screening tests without allowing these compounds to d grade ($T_{1/2} = \infty$). However, the volatilization rate these compounds in soil is high enough that it would n be significantly altered by degradation in the ea stages when our assessments are made.

Figure 1 groups the 35 chemicals in a quadrant wi log of vapor density plotted against log of solubili both expressed in milligrams per liter. The valu plotted correspond to the numbers in Table 1. Al shown are the lines of constant Henry's constant, K they range over almost 11 orders of magnitude in th group of chemicals (from 3.7×10^{-9} for bromacil to 1 $\times 10^{2}$ for *n*-octane). As discussed in Jury et al. (1984 K_H values are a very useful index for classifying vo tilization behavior.

DESCRIPTION OF SCREENING TESTS

The screening tests performed below are designed assess relative convective (liquid) mobility, diffus (primarily as vapor) mobility, susceptibility to loss volatilization, and persistence. The standard conditio are those described in detail by Jury et al. (1983), i. initial chemical application of $M = 1$ kg/ha uniform distributed to depth L (either 1 or 10 cm) with unifor soil properties (porosity, ϕ; bulk density, ρ_b; water co tent, Θ; air content, α; organic C fraction, f_{oc}) a steady water flow, J_W, either upward as evaporatio downward as leaching, or zero.

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[1] See the Appendix for a listing of scientific names of chemicals us in this article.

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Table 1—Benchmark properties used for the chemicals in the screening tests. Reference numbers refer to citation number at end of text.

No.	Chemical	Vapor density	Ref. no.	Solubility	Ref. no.	K_{oc}	Ref. no.	$T_{1/2}$	Ref. no.	Henry's constant
		mg/L		mg/L		m³/kg		days		K_H
1	Atrazine	8.0E−0.6†	5	3.2E+0.1	4	1.6E−01	26	71	26	2.5E−07
2	Benzene	4.0E+02	33	1.8E+03	33	8.3E−0.2	18	∞‡	-	2.2E−01
3	Biphenyl	4.9E−01	33	7.5E+00	33	1.4E+00§	18	∞	-	6.6E−02
4	Bromacil	3.0E−06	34	8.2E+02	36	7.2E−02	26	350	26	3.7E−08
5	Bromobenzene	2.9E+00	33	4.5E+02	33	1.5E−01	18	∞	-	6.2E−03
6	Carbofuran	1.0E−04	2	3.2E+02	1	2.8E−02	26	40	26	3.1E−07
7	Carbon tet.	7.5E+02	33	8.0E+02	33	1.1E−01§	18	∞	-	9.4E−01
8	Chlorobenzene	7.1E+01	33	4.7E+02	33	1.5E−01§	18	∞	-	1.5E−01
9	Chloroform	9.6E+02	33	8.0E+03	33	2.9E−02	§	∞	-	1.2E−01
10	2,4-D	5.0E−06	7	9.0E+02	36	2.0E−02	26	15	26	5.6E−09
11	DDT	6.0E−06	29	3.0E−03	9	2.4E+02	26	3837	10	2.0E−03
12	Diazinon	2.0E−03	4	4.0E+01	18	8.5E−02	26	32	26	5.0E−05
13	Dieldrin	1.0E−04	27	1.5E−01	3	1.2E+01	26	868	23	6.7E−04
14	Diuron	2.0E−06	24	3.7E+01	4	3.8E−01	26	328	26	5.4E−08
15	EPTC	2.2E−01	25	3.7E+02	36	2.8E−01	11	30	23	5.9E−04
16	Ethoprophos	4.8E−03	22	7.5E+02	20	1.2E−01	20	50	20	6.0E−06
17	Ethylene dibr.	1.2E+02	33	3.4E+03	33	4.4E−02	18	∞	-	3.5E−02
18	Lindane	1.0E−03	28	7.5E+02	4	1.3E+00	26	266	26	1.3E−04
19	Mercury	1.5E−02	33	3.0E−0.2	33	4.1E+01	§	∞	-	5.1E−01
20	Methyl bromide	2.0E+04	33	1.3E+04	33	2.2E−02	§	∞	-	1.5E+00
21	Methyl para.	2.5E−04	31	5.7E+01	18	5.1E+00	26	15	26	4.4E−06
22	Monuron	2.0E−06	37	2.6E+02	36	1.8E−01	26	166	10	7.6E−09
23	Napropamide	5.9E−05	36	7.3E+01	36	3.0E−01	6	70	36	7.9E−07
24	Napthalene	1.6E+00	33	3.2E+01	33	1.3E+00	18	∞	-	5.0E−02
25	Nitrobenzene	1.8E+00	33	1.8E+03	33	7.1E−02§	18	∞	-	1.0E−03
26	n-Octane	9.4E+01	33	6.6E−01	33	6.8E+00	§	∞	-	1.4E+02
27	Parathion	1.5E−04	31	2.4E+01	18	1.1E+01	26	18	26	6.1E−06
28	Phenanthrene	2.0E−03	33	1.3E+00	33	2.3E+01	18	∞	-	1.6E−03
29	Phenol	5.7E−01	33	8.2E+04	33	2.7E−02	18	∞	-	7.0E−06
30	Phorate	1.6E−02	32	5.0E+01	18	6.6E−01	26	82	26	3.1E−04
31	Prometryne	2.7E−05	5	4.8E+01	18	6.1E−01	26	60	35	5.6E−07
32	Simazine	1.7E−07	5	5.0E+00	4	1.4E−01	26	75	26	3.4E−08
33	Trialiate	3.2E−03	8	4.0E+00	15	3.6E+00	15	100	36	7.9E−04
34	Trifluralin	2.0E−03	30	3.0E−01	#	7.3E+00	8	132	26	6.7E−03
35	Vinyl chloride	8.7E+03	33	9.0E+01	33	4.0E−01	§	∞	-	9.7E+01

† E−06 = 10^{-6}, etc. ‡ No value available.
§ Calculated from C* formula in Kenaga and Goring (1980).
¶ O. Heiber (1976), Ciba-Geigy Ltd., Basel, Switzerland (unpublished personal communication).
# R. L. Swann, 1982, Dow Chem. Co., Midland, MI (unpublished personal communication).

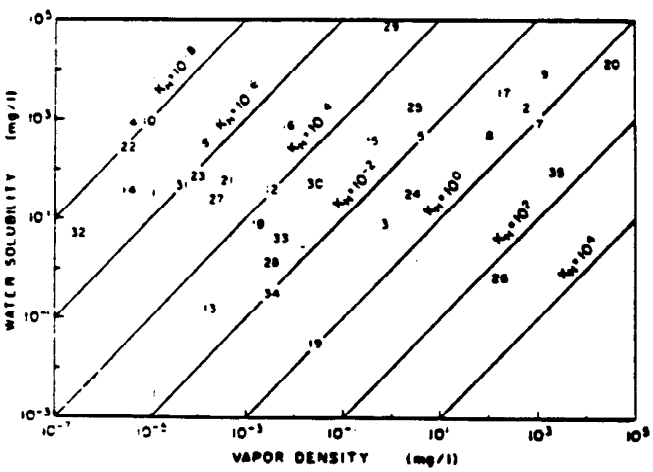

Fig. 1—Vapor density-water solubility plots in milligrams per liter for each of the 35 chemicals. Numbers in the figure correspond to numbers given in Table 1. Solid lines correspond to lines of constant K_H.

Convective Mobility Tests

In order to analyze convective and diffusive mobility in a consistent manner, we will estimate the time required to travel a distance l = 10 cm through the soil by convection and by diffusion, as developed in Jury et al. (1984a). The convective mobility time, t_c, is calculated by assuming piston flow of chemical and instantaneous partitioning between the three phases. The formula, taken from Jury et al. (1984a) is given in Eq. [1]

$$t_c = (\varrho_b f_{oc} K_{oc} + \Theta + aK_H)\, l/J_w. \qquad [1]$$

Diffusive Mobility Tests

The diffusive mobility time, t_D, is small only for vapor-dominated chemicals and is calculated from the formula given in Jury et al. (1984a), summarized here as Eq. [2]

$$t_D = l^2\phi^2(\varrho_b f_{oc} K_{oc} + \Theta + aK_H)/D_G^{air} a^{10/3} K_H, \qquad [2]$$

where a is volumetric air content and D_G^{air} is the binary gaseous diffusion coefficient in free air.

Volatilization Tests

The simulations of volatilization are conducted using the complete model described in Jury et al. (1983), where each chemical is applied at a uniform concentration of 1 kg/ha to a depth L in the soil and is allowed to volatilize through a stagnant air boundary layer during a specified time period in the presence or absence of

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water evaporation. The resulting volatilization fluxes and cumulative losses are used to categorize the relative susceptibility to loss to the atmosphere.

Persistence Tests

For a given chemical, dissipation from the soil occurs both by degradation and volatilization. Since persistence is an essential index for characterizing the effectiveness of the chemical as well as its hazard, a dynamic estimate is needed for persistence, in addition to biochemical half-life values. Persistence, as calculated from the scenarios discussed above, will be summarized in the form of effective half-lives, which include both volatilization and degradation. For a given scenario, this dynamic or volatilization half-life, $T^{V}_{1/2}$, will be calculated as a function of the amount $M(t)$ remaining in the soil after a time t, by solving $M(t) = M(0) \exp(-0.693t/T^{V}_{1/2})$ for $T^{V}_{1/2}$, or

$$T^{V}_{1/2} = -0.693\, t/\ln(M(t)/M(0)), \qquad [3]$$

where $M(0)$ is the initial mass in the soil, ln is the natural logarithm, and 0.693 = ln (2). The rate coefficient μ, discussed in Jury et al. (1983), is defined as $\mu = \ln(2)/T_{1/2}$.

RESULTS

Mobility Tests

Figure 2 shows soil concentrations vs. depth taken at 30 d after leaching at a steady rate J_W = 1 cm/d for three chemicals (DDT, benzene, and bromacil) chosen from Table 1 to represent a range of benchmark properties. These concentrations were calculated with Eq. [24] from Jury et al. (1983). It is clear from this calculation that for two of the chemicals, DDT and bromacil, a simple accounting of the center of mass of the chemical pulse by piston flow would give a good approximation to downward movement by leaching, and Eq. [1] would give a reasonable estimate of the time required to move a given distance by leaching. However, in the case of benzene, movement by vapor diffusion has completely

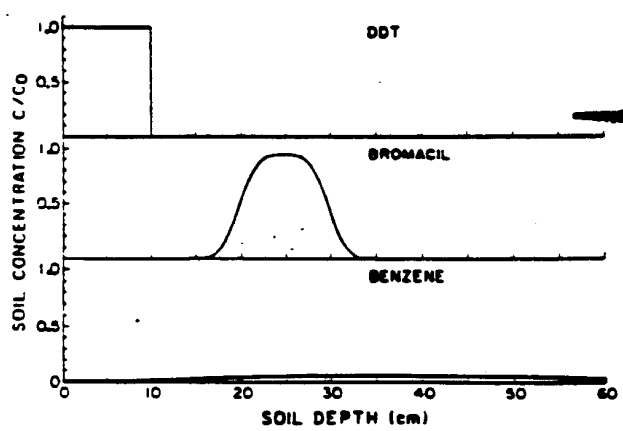

Fig. 2—Pesticide concentration after 30 d of leaching for three representative chemicals using the model of Jury et al. (1983). Standard conditions used are: Θ = 0.3, f_{oc} = 0.0125, J_W = 1 cm/d, L = 10 cm.

dispersed the pulse during the 30 d of leaching an estimate of the location of the center of the pulse but impossible to make. For this reason, it is useful to examine the convective and the diffusive mobili a compound. If the latter is significant, then one n expect behavior such as that seen in Fig. 2 for ben: and hence that purely convective mobility indices, as R_F values (Helling, 1971), are not sufficient t scribe their movement.

Table 2 summarizes convective times t_c and diff times t_D in days calculated from Eq. [1] and [2] spectively, for the case l = 10 cm and J_W = 1 c The classification scheme given next to the conve times corresponds to that given in McCall et al. (1 based on K_{oc} values, where classification 1 repre relatively immobile compounds (K_{oc} > 5 m³/kg) classification 5 represents the most mobile (K_{oc} < m³/kg). This is similar to the mobility classifica based on R_F values given in Helling (1971). Also s in Table 2 are the diffusive times that have been qu tively ranked in a classification scheme where class tion 1 represents insignificant diffusive mobilit > 100 d), classification 2 represents moderate mo (20 < t_D < 100), and classification 3 represents mobility (t_D < 20 d).

By comparing Fig. 2 with Table 2 it is seen that is immobile both in convection (class 1) and diff

Table 2—Convection time t_c and diffusion time t_D (days) to 10 cm (Θ = 0.3, J_W = 1 cm/d, f_{oc} = 0.0125, ρ_b = 1350 kg/ along with mobility classification 1–5 (convection) and 1–3 (diffusion).

No.	Chemical	Convection time	Classification	Diffusion time	C
		days		days	
1	Atrazine	31	3	–†	
2	Benzene	17	4	9	
3	Biphenyl	239	2	450	
4	Bromacil	15	4	–	
5	Bromobenzene	28	4	530	
6	Carbofuran	8	5	–	
7	Carbon tetrachloride	22	4	3	
8	Chlorobenzene	28	4	23	
9	Chloroform	8	5	8	
10	2,4-D	6	5	–	
11	DDT	41 000	1	–	
12	Diazinon	146	2	–	
13	Dieldrin	2 043	1	–	
14	Diuron	68	3	–	
15	EPTC	51	3	–	
16	Ethoprophos	24	4	–	
17	Ethylene dibromide	10	5	37	
18	Lindane	222	2	–	
19	Mercury	6 930	1	–	
20	Methyl bromide	7	5	1	
21	Methyl parathion	864	1	–	
22	Monuron	34	3	–	
23	Napropamide	53	3	–	
24	Napthalene	222	2	550	
25	Nitrobenzene	15	4	–	
26	N-octane	3 156	1	1	
27	Parathion	1 800	1	–	
28	Phenanthrene	3 884	1	–	
29	Phenol	8	5	–	
30	Phorate	114	3	–	
31	Prometryne	107	2	–	
32	Simazine	28	4	–	
33	Triallate	611	1	–	
34	Trifluralin	1 242	1	–	
35	Vinyl chloride	70	3	1	

† t_D > 1000 d.

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(class 1), whereas bromacil is very mobile by convection (class 4) but immobile by diffusion (class 1). For this reason, the pulse of bromacil shown in Fig. 2 moves into the soil but does not significantly change its shape over time. Benzene is also in convection class 4, and by that criterion alone should behave similarly to bromacil. However, benzene has a high diffusive mobility (class 3) and hence penetrates far deeper into the soil than expected based on convection alone. Figure 2 shows how misleading a traditional mobility classification such as the R_F system would be for compounds such as benzene with class 3 diffusive mobility.

Volatilization Tests

Figure 3, 4, and 5 show volatilization fluxes vs. time for each of the 35 compounds for the case of no evaporation (solid curve), evaporation at 2.5 mm/d (dotted curve), and evaporation at 5 mm/d (dashed curve). All of these tests were conducted for standard soil and initial conditions ($M(0)$ = 1 kg/ha, Θ = 0.3, ρ_b = 1350 kg/m^3, f_{oc} = 0.0125, L = 10 cm), and included the stagnant air boundary layer of thickness d through which chemical and water vapor must diffuse to the atmosphere (Jury et al., 1983). The boundary layer thicknesses for the three water evaporation (E) rates, calculated using Eq. [28] of Jury et al. (1983), were d = 4.75 × 10^{-1} m (E = 0 and 2.5 mm/d) and d = 2.38 × 10^{-1} (E = 5 mm/d). Figure 3 contains the so-called volatilization category II and III compounds ($K_H \leq 2.5 \times 10^{-6}$) as discussed in Jury et al. (1983). Fig. 4 contains category I compounds for which evaporation influences volatilization, and Fig. 5 contains category I compounds for which evaporation does not influence volatilization.

When grouped in this way the compounds follow a consistent behavior pattern, with the volatilization flux of category II and III compounds increasing when evaporation is present, decreasing somewhat with time when volatilization occurs without evaporation. Furthermore, for compounds in category I, volatilization flux decreases with time for all cases. The compounds in Fig. 4 and 5 may be distinguished by whether or not evaporation-aided volatilization is increased significantly relative to volatilization without evaporation.

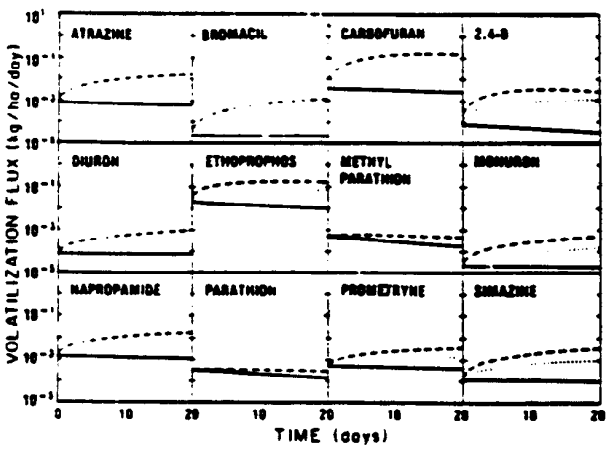

Fig. 3—Volatilization flux vs. time for chemicals used in the screening test. Standard conditions used are: f_{oc} = 0.0125; Θ = 0.3; L = 10 cm: E = 0 (solid curve), E = 2.5 mm/d (dotted curve), and E = 5.0 mm/d (dashed curve).

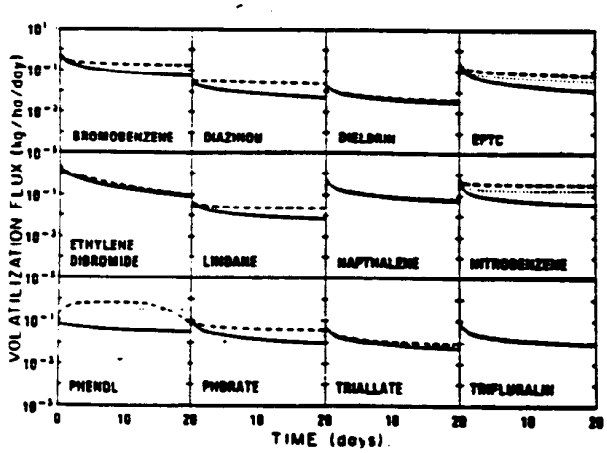

Fig. 4—Volatilization flux vs. time for chemicals used in the screening test. Standard conditions used are: f_{oc} = 0.0125; Θ = 0.3; L = 10 cm: and E = 0 (solid curve), E = 2.5 mm/d (dotted curve), and E = 5.0 mm/d (dashed curve).

Persistence Tests

Table 3 gives the mass remaining at 30 d expressed as a percent of the mass initially present for the low volatility compounds, subject to either E = 0 or E = 5 mm/d and for shallow (L = 1 cm) or deep (L = 10 cm) incorporation. These results were calculated by integrating Eq. [25] of Jury et al. (1983) and thus include degradation as well as volatilization losses. Table 4 presents percent mass remaining after only 1 d of volatilization for the high volatility compounds in Table 1 for the case of E = 0 and L = 1 and 10-cm depths of incorporation. Also shown in this table are effective volatilization half-lives, $T^V_{1/2}$, calculated using Eq. [3] for t = 1 d. As noted in Table 1, these compounds were assigned infinite degradation half-lives; thus, the $T^V_{1/2}$ values in Table 4 are only for volatilization. Finally, Table 5 calculates effective volatilization half-lives for all of the 35 compounds without evaporation using Eq. [3] and the values given in Table 3 and 4 for E = 0 and

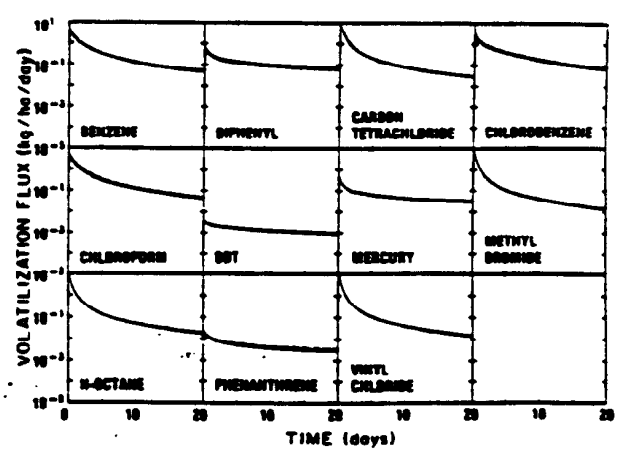

Fig. 5—Volatilization flux vs. time for chemicals used in the screening test. Standard conditions used are: f_{oc} = 0.0125; Θ = 0.3; L × 10 cm: E = 0 (solid curve), E = 2.5 mm/d (dotted curve), and E = 5.0 mm/d (dashed curve).

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Table 3—Percent mass remaining in soil after 30 d of volatilization for low volatility compounds as a function of E (mm/day) and L (cm) along with effective volatilization half-lives (day) calculated from Eq. [3]. (θ) = 0.3, $M(0)$ = 1 kg/ha, f_{oc} = 0.0125).

	L = 1 cm				L = 10 cm			
	E = 0.0		E = 5.0		E = 0.0		E = 5.0	
Chemical	σ_r	$T^V_{1/2}$	σ_r	$T^V_{1/2}$	σ_r	$T^V_{1/2}$	σ_r	$T^V_{1/2}$
Atrazine	73.6	68	54.6	34	74.7	71	68.8	56
Bromacil	94.3	354	93.3	300	94.3	354	93.8	325
Carbofuran	56.6	37	11.6	10	59.3	40	17.9	12
2,4-D	25.4	15	24.6	15	25.5	15	24.8	15
DDT	95.9	497	95.3	432	99.1	2300	99.0	2069
Diazinon	37.4	21	8.6	8	51.1	31	47.1	28
Dieldrin	85.2	130	80.6	96	96.4	567	95.9	497
Diuron	93.8	330	91.9	246	93.9	330	93.6	314
EPTC	17.9	12	1.9	5	45.9	27	34.7	20
Ethoprophos	45.4	26	0.6	4	63.5	46	27.6	16
Lindane	66.5	49	27.9	16	89.8	193	85.4	132
Methyl parathion	25.2	15	24.1	15	25.4	15	25.3	15
Monuron	88.3	167	87.7	158	88.4	169	88.2	166
Napropamide	72.0	63	43.5	25	74.3	70	68.3	55
Parathion	31.7	18	31.1	18	32.0	18	31.9	18
Phenanthrene	88.5	171	86.5	143	98.9	1799	98.6	1526
Phorate	42.1	24	7.3	8	74.0	69	66.6	51
Prometryne	70.1	59	60.4	41	70.9	60	69.7	58
Simazine	75.9	75	72.2	64	76.0	76	74.8	72
Triallate	60.4	41	48.4	29	79.3	90	78.1	84
Trifluralin	51.7	32	46.6	27	82.1	105	81.5	102

L = 10. Table 5 presents a persistence classification scheme ranging from 1 (very persistent) to 5 (very short-lived).

DISCUSSION

Mobility Tests

For compounds that move primarily in the liquid phase, the organic C partition coefficient, K_{oc}, appears to be a useful benchmark property for characterizing susceptibility to leaching. However, for volatile compounds such as fumigants, which have a substantial activity in the vapor phase, movement by vapor diffusion may be significant compared with convective transport. For this reason, it is recommended to use both convective and diffusive criteria for assessing mobility, since, as shown in Fig. 2, convective mobility is not a sufficient criteria for determining movement of benzene or other compounds of high K_H and low K_{oc}. On the other hand, for the high volatility compounds with substantial vapor mobility, dissipation to the atmosphere will be extremely rapid except in those cases where continuous downward movement or a soil cover prevents escape through the soil surface.

Volatility Tests

The similar volatilization behavior of the compounds in category II or III shown in Fig. 3 is consistent with the generalizations given by Jury et al. (1984a). The only compounds in this group for which volatilization decreases with time are those in category-II whose biochemical half-lives (parathion, methyl parathion) are short enough to cause substantial disappearance of the compound during the 20 d of simulation. For the rest of the compounds, the dependence of volatilization on evaporation of water is substantial and leads to increases in volatilization flux of up to 2 orders of mag-

Table 4—Percent mass remaining in soil and effecti volatilization half-life (days) after 1 d of volatilization without water evaporation (θ) = 0.3, $M(0)$ = 1 kg/ha, f_{oc} = 0.0125) for high volatility compounds.

	Percent remaining		Half-life $T^V_{1/2}$	
Chemical	L = 1 cm	L = 10 cm	L = 1 cm	L = 10
Benzene	8.7	63.0	0.3	1.6
Biphenyl	50.4	94.6	1.0	12.6
Bromobenzene	52.6	94.5	1.1	13.4
Carbon tetrachloride	4.9	44.0	0.2	0.8
Chlorobenzene	13.5	76.6	0.3	12.6
Chloroform	8.1	61.6	0.3	1.4
Ethylene dibromide	16.8	81.4	0.4	3.4
Mercury	72.4	97.3	2.1	24.7
Methyl bromide	2.6	24.4	0.2	0.5
Naphthalene	54.2	95.2	1.1	14.0
Nitrobenzene	65.4	96.5	1.6	19.4
N-octane	3.2	29.9	0.2	0.6
Phenol	67.6	96.8	1.6	20.5
Vinyl chloride	2.5	24.2	0.2	0.5

Table 5—Persistence classes defined in terms of effectiv half-life $T^{V}_{1/2}$ (days) under standard conditions of deep placement (L = 10 cm, θ = 0.3, E = 0).

Herbicide	$T^V_{1/2}$	Herbicide	T
	days		
Class 1. Highly persistent $T^V_{1/2} > 100$			
Bromacil	354	Lindane	
DDT	2300	Monuron	
Dieldrin	567	Phenanthrene	1
Diuron	330	Trifluralin	
Class 2. Moderately persistent $30 < T^V_{1/2} < 100$			
Atrazine	71	Phorate	
Carbofuran	40	Prometryne	
Diazinon	31	Simazine	
Ethoprophos	46	Triallate	
Napropamide	70		
Class 3. Moderately short-lived $15 < T^V_{1/2} < 30$			
2,4-D	15	Nitrobenzene	
EPTC	27	Parathion	
Methyl parathion	15	Phenol	
Mercury	25		
Class 4. Short-lived $5 < T^V_{1/2} < 15$			
Biphenyl	13	Chlorobenzene	
Bromobenzene	13	Napthalene	
Class 5. Very short-lived $T^V_{1/2} < 5$			
Benzene	1.6	Ethylene dibromide	
Carbon tetrachloride	0.8	Methyl bromide	
Chloroform	1.4	N-octane	
		Vinyl chloride	

nitude at the end of 20 d compared with evaporati free volatilization.

The category I compounds shown in Fig. 4 and 5 behave consistently and differ only in the extent of pendence on evaporation. As discussed in Jury et (1984a), enhancement of volatilization flux by evap tion depends primarily on the relative importance of ward movement to the soil surface by convection vapor diffusion to the atmosphere at the soil surf Thus, those compounds in Fig. 5 with large K_{oc} (i large t_c) (biphenyl, DDT, mercury, n-octane, phenanthrene) will have a small convective flux tow the surface and hence little effect of evaporation pesticide loss. However, the rest of the compound Fig. 5 that show little effect of evaporation on vola zation have small K_{oc}'s. These remaining compou have very high volatilization fluxes, which are do

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nated by diffusive loss. Furthermore, the extent of upward convection is controlled by the rapid decrease in initial pulse size by vapor diffusion, since all of the remaining compounds in Fig. 5 have high diffusive mobility (Table 2). It is instructive in this regard to compare the volatilization flux vs. time graphs for chloroform (Fig. 5) and nitrobenzene (Fig. 4). Under evaporation-free conditions, the chloroform volatilization flux is much larger than that of nitrobenzene, except for long time periods. For evaporation-aided volatilization, however, the nitrobenzene flux exceeds that of chloroform after about 4 d when $E = 5.0$ mm/d. The compounds have two major differences. Nitrobenzene has negligible vapor diffusion (vapor mobility class 1), whereas chloroform has high (class 3) vapor diffusive mobility. Thus, the nitrobenzene pulse will approximately retain its initial shape during volatilization, so that the liquid concentration moving to the surface by convection is high. Chloroform, on the other hand, will diffuse downward and the pulse will decrease in size much as benzene did during leaching in Fig. 2. As a consequence, the equilibrium liquid concentration moving to the surface by convection is smaller than that of nitrobenzene, even though their liquid partition coefficients, $R_L = C_T/C_L$, where C_T is total concentration and C_L is solution concentration, are similar. Hence, evaporation does not enhance the volatilization of compounds like chloroform.

Persistence Tests

Tables 3 to 5 demonstrate that volatility can greatly affect the persistence of many of the compounds screened. In fact, Table 5 suggests that many of the degradation coefficient measurements made in the field have probably been influenced by volatilization losses and hence are not a good index of biochemical activity. For persistence class 1 compounds, shallow placement greatly influences effective half-life and persistence. For example, lindane was calculated to have an effective volatilization half-live of $T^{V}_{1/2} = 49$ d with 1-cm placement and 193 d with 10-cm placement ($E = 0$). Furthermore, these effective volatilization half-lives are greatly reduced (to 16 and 132 d, respectively) when water evaporation is present. Our benchmark degradation half-life for lindane (Table 1), based on laboratory measurements with volatilization suppressed, is 266 d. For shallow placement, the degradation loss pathway is insignificant compared with volatilization. On the other hand, monuron, which does not volatilize significantly, has essentially the same effective half-life ($T^{V}_{1/2} = 266$) under all conditions except when $E = 5$ mm/d and $L = 1$ cm, when it reduces somewhat to 158 d.

On the basis of information given in Tables 3 and 4, it is possible to group the 35 compounds into qualitative persistence classes. This is done in Table 5, for the standard condition of $L = 10$ cm, $f_{oc} = 0.0125$, $E = 0$, $\Theta = 0.3$. In all cases, the results of these tests are a function of the standard conditions assumed. If the tests were repeated under different organic C fractions, different water contents, etc., somewhat different conclusions might be drawn. However, the analysis of Jury et al. (1984a) was intended to discern the underlying functional dependence of volatilization category I and category III compounds on these standard conditions so that repeated screening tests need not be run in all cases. Thus, for example, using Table 3 of Jury et al. (1984a), one would predict for volatilization flux an inverse dependence on organic C fraction for category III compounds (J_V proportional to f_{oc}^{-1}) and an inverse square root dependence for category I compounds (J_V proportional to $f_{oc}^{-1/2}$) when volatilization occurs without evaporation. Under these conditions, one would also expect no water content dependence for volatilization of category III compounds.

SUMMARY AND CONCLUSIONS

Using the model of Jury et al. (1983), we have performed tests on the 35 chosen chemicals to determine relative convective and diffusive mobility, susceptibility to volatilization at the soil surface, and general persistence in soil as a function of depth of incorporation. The results have been presented in a series of relative categories for susceptibility to loss through the various pathways. This information might be useful in a specific application by considering several different classifications simultaneously, such as convective mobility and persistence to determine whether the chemical will persist long enough to be a hazard to underlying groundwater in an area where leaching is prevalent. Furthermore, information on relative volatility as a function of depth of incorporation is useful for placement design. Finally, if a substantial amount of experimental information is available about the behavior of one compound under natural conditions, this information could serve to represent a group of compounds that have been classified as similar using the screening model. In this manner, the ideal scenarios represented in our model could be linked to the nonideal properties of the real world environment through experimental data.

However, it must be emphasized that this is not a simulation model. The purpose of the series of papers is to present a simple procedure for determining the relative behavior of chemicals under prototype conditions. In the final paper in this series, Jury et al. (1984b), we will review the experimental literature to substantiate the general model assumptions used in the paper and will demonstrate where predicted behavior is manifested and certain trends seen under natural conditions.

APPENDIX

Scientific names of chemicals used in this article.

Common or trade name	Chemical name
Atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine
Bromacil	5-bromo-3-*sec*-butyl-6-methyluracil
Carbofuran	2,3-dihydro-2,2-dimethyl-7-benzofuranylmethylcarbamate
Chloroform	trichloromethane
2,4-D	(2,4-dichlorophenoxy) acetic acid
DDT	1,1,1-trichloro-2,2-bis(*p*-chlorophenyl) ethane

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Diazinon	*O,O*-diethyl-*O*-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate
Dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a, octahydro-1,4-*endo-exo*-5,8-dimethanonaphthalene
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea
EPTA	*S*-ethyl dipropylthiocarbamate
Ethoprophos	*O*-Ethyl *s,s*-dipropyl phosphorodithioate
Lindane	γ-1,2,3,4,5,6-hexachlorocyclohexane
Methyl parathion	*O,O*-dimethyl *O*-(*p*-nitrophenyl) phosphorodithioate
Monuron	3-(*p*-chlorophenyl)-1,1-dimethylurea
Napropamide	2-(*a*-naphthoxy)-*N,N*-diethylpropionamide
Parathion	*O,O*-diethyl *O*-(*p*-nitrophenyl) phosphorodithioate
Phorate	*O,O*-diethyl *s*-[(ethylthio) methyl] phosphorodithioate
Prometryne	2,4-bis(isopropylamino)-6-methylthio-*s*-triazine
Simazine	2-chloro-4,6-bis (ethylamino)-*s*-triazine
Triallate	*S*-(2,3,3-trichloroally)diisopropylthiocarbamate
Trifluralin	α,α,α-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine

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Behavior Assessment Model for Trace Organics in Soil: IV. Review of Experimental Evidence[1]

W. A. JURY, W. F. SPENCER, AND W. J. FARMER[2]

ABSTRACT

Experimental evidence supporting the environmental screening model of Jury et al. (1983) is reviewed and discussed. For several laboratory studies of volatilization, initial and boundary conditions matched those used in our model and simulations were run. In all cases, good agreement was found between predicted and measured volatilization losses, with and without accompanying water evaporation. When five chemicals of widely differing volatility were exposed to identical experimental conditions, the model correctly predicted the relative loss behavior observed.

The convective mobility predictions of the model were shown to be consistent with several laboratory studies of compound leaching, as long as the water flow rate was slow enough (< 0.01 cm/s) to ensure equilibrium between the solution and adsorbed phases.

The Millington and Quirk tortuosity model used in our representation of the soil diffusion coefficient was found to give a good prediction of the water content dependence of the effective diffusion coefficient observed in several studies. The thickness of the stagnant boundary layer predicted from our similarity assumption was shown to be consistent with the apparent thickness inferred from several laboratory and field measurements of volatilization.

Additional Index Words: chemical movement, diffusion, volatilization, leaching.

Jury, W. A., W. F. Spencer, and W. J. Farmer. 1984. Behavior assessment model for trace organics in soil: IV. Review of experimental evidence. J. Environ. Qual. 13:580–586.

In a previous series of papers (Jury et al., 1983, 1984a,b) we introduced a model for screening large numbers of chemicals for their relative volatility, mobility, and persistence in the soil environment. The model is intended to be used with standard conditions in an ideal soil environment in order to assess the relative behavior of chemicals exposed to those identical soil and environmental conditions, rather than to be used for simulation of a given transport process. The model is constructed so as to require only knowledge of the Henry's constant, K_H, organic C partition coefficient, K_{oc}, and degradation half-life, $T_{1/2}$, for a given chemical, which would enable an assessment of potential environmental risk to be made on large numbers of new chemicals at the time of their development—provided that these benchmark properties could be measured or estimated.

The philosophy of the model, as explained in earlier papers in this series, is to group chemicals together into similar mobility, persistence, or volatility categories, enabling chemicals for which substantial in situ experimental information is available to serve as a representative for a large number of chemicals that have been classified as similar by the screening model.

The purpose of this paper is to provide experimental verification of the model by comparing its output with data from the literature. The experimental evidence reviewed in this paper to verify the model and its assumptions is of three types. First, there are a limited number of laboratory studies conducted under conditions that closely match the ideal scenario represented in the model. For these cases, exact simulation is possible. Second, a limited number of experiments have been conducted in which groups of chemicals are simultaneously studied under identical conditions. For these cases, the screening model will produce a rank ordering of the chemicals that can be compared with the experimental results. Third, there are a number of assumptions in our screening model that have been tested experimentally and will also be discussed in this paper.

VOLATILIZATION STUDIES[3]

In 1980, Jury et al. published the results of a laboratory chamber experiment measuring volatilization of triallate from two soils, a San Joaquin sandy loam (Abruptic Durixeralfs) (1.2% organic matter) and a Flanagan silt loam (Aquic Argiudolls) (5% organic matter), together with a successful model simulation of volatilization with and without water evaporation. The triallate model, which assumed zero concentration at the soil surface and infinite depth of incorporation of chemical, makes surface volatilization predictions that are virtually identical to those of our screening model for a compound like triallate with a large Henry's constant, K_H, and high adsorption because volatilization of such compounds is not restricted by the stagnant boundary layer (Jury et al., 1984a).

In a similar chamber experiment, Spencer and Cliath (1973) studied volatilization of dieldrin and lindane from Gila silt loam (Typic Torrifluvents) (0.6% organic matter). Figure 1 shows their experimental results together with the simulations of the screening model. The soil and chemical parameters used in the model calculation, given in Table 1, were taken from the article by Spencer and Cliath (1973). In these simulations, the boundary layer thickness, d, was estimated from the water evaporation rate, as discussed in Jury et al. (1983) (see their Eq. [28]), and the effective soil diffusion coefficient, D_E, was calculated using the Millington and Quirk model formulation, which is part of our screening model (Jury et al., 1983) (see their Eq. [18]). No calibrations were made using the data.

In a soil column volatilization experiment, Yang (1978) studied volatilization and degradation of parathion in two soils— a Panoche clay loam (Typic Torriorthents) (0.9% organic matter) and a Hanford sandy loam (Typic Xerorthents) (2.5% organic matter)—over a 6-d period. This compound, which degrades quite rapidly in soil, also has a relatively low Henry's constant and thus has a smaller volatilization flux than dieldrin or lindane under equivalent conditions. As discussed in

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[3] See the Appendix for a listing of scientific names of chemicals used in this article.

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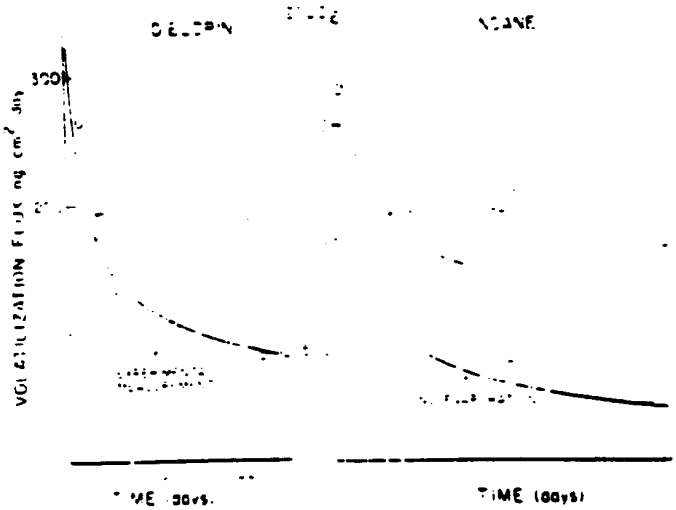

Fig. 1—Measured volatilization fluxes (data points) taken from Spencer and Cliath (1973) compared with predicted fluxes (solid lines) obtained using the screening model.

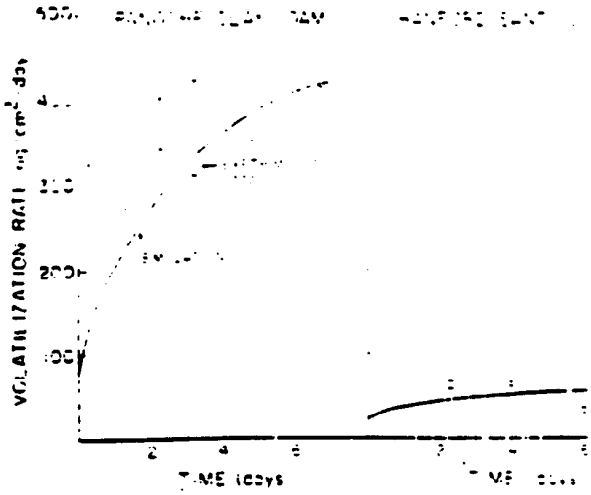

Fig. 2—Measured volatilization fluxes (vertical lines) taken Yang (1978) compared with predicted fluxes (solid lines) obt using the screening model. The vertical lines represent the s between six replicates.

Jury et al. (1984a), a compound such as parathion should have a noticeably enhanced volatilization flux in the presence of water evaporation. Figure 2 shows the experimental results of Yang (1978) together with the simulation of the screening model for conditions given in Table 1.

Burkhard and Guth (1981) reported results of a 24-h volatilization experiment for five different compounds of low Henry's constant on two different soils, a Collombey sand (2.2% organic matter) and a Les Evouettes silt loam (3.6% organic matter). Measured volatilization rates for these five compounds, subjected to identical conditions, differed by orders of magnitude. In the experiment, they maintained a saturated air atmosphere above the volatilization chamber so that no water evaporation occurred, and they exchanged the soil air above the soil surface only once every 36 s, so that stagnant conditions prevailed. Our model represents stagnancy with a boundary layer above the soil surface, which in the absence of water evaporation must be estimated by calibration. Using the conditions specified in the experiment by Burkhard and Guth (given for diazinon in Table 1), we varied the thickness, d, for our boundary layer for diazinon in the experiment on Collombey sand until a reasonable agreement was tained between measured and calculated volatiliza over the 24-h period. This occurred with d = 0.75 This same boundary layer thickness was subseque used for all other chemicals and in both soils. Result the simulation and experimental measurements given in Table 2. It should be noted that the agreen between their measurements and our calculations is c siderably better than the agreement they achieved u a simple partitioning model.

Farmer et al. (1972) measured volatilization of eldrin, lindane, and DDT over 7 d in shallow, 0.5 trays. The volatilization fluxes were high becaus shallow incorporation, but the surface was exposed very slow air flow rate, which exchanged the chan air every 30 s. The simulation was run for the condit given in Table 1 using a boundary layer thickness of cm, which was obtained by calibration with the linc flux, to represent the stagnant surface. The adsorl liquid distribution coefficient, K_D, of DDT was culated from the measured K_D of dieldrin and their values given in Jury et al. (1984b). Results of the si lation, expressed as a percent of applied chemical, shown in Table 3.

Table 1—Experimental conditions used in simulations.

Chemical	Soil	Type	K_H	K_D	$T_{1/2}$	C_{To}†	L	Θ	T	E	d	Ref.
				m³/kg × 10³	days	g/m³	cm		°C	cm/day	cm	
Dieldrin	Gila	Silt loam	1.3 × 10⁻¹	125	868	14	10	0.27	30	0.26	1.2	3
Lindane	Gila	Silt loam	2.6 × 10⁻⁴	2.2	266	14	10	0.23	30	0.13	1.2	3
Parathion	Panoche	Clay loam	3.0 × 10⁻⁶	4.0	10	36	13	0.15	20	0.3	1.0	3
Parathion	Hanford	Sandy loam	3.0 × 10⁻⁶	13.5	10	34	13	0.15	20	0.3	1.0	3
Diazinon	Collombey	Sand	3.0 × 10⁻⁷	5.6	50	60	0.9	0.12	20	0	0.75	4
Dieldrin	Commerce	Silty clay	3.3 × 10⁻⁴	250	868	14	1	0.3	20	0	0.5	3
Dieldrin	Commerce	Silty clay	3.3 × 10⁻⁴	250	868	14	1	0.5	20	0	332	3
Dieldrin	Gila	Silt loam	1.3 × 10⁻¹	125	868	7.5	0.5	0.1	30	0	1.5	7
Lindane	Gila	Silt loam	2.7 × 10⁻⁴	2.2	266	7.5	0.5	0.1	30	0	1.5	7
DDT	Gila	Silt loam	4.2 × 10⁻¹	2500	3837	7.5	0.5	0.1	30	0	1.5	7
Dimethoate			~0	0.29	-	-	-	-	25	-	-	10
Triallate	San Joaquin	Sandy loam	7.9 × 10⁻⁴	32	∞	12.1	10	0.28	25	0.60	0.4	15

† C_{To} = initial total concentration.
‡ Equivalent vapor thickness of 10 cm water barrier (see Eq. [1]).

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Table 2—Twenty-four-hour average volatilization fluxes measured in experiment in Burkhard and Guth (1981).

Chemical	K_D	Volatilization (g m⁻² × 10⁴)					
		Collombey sand Organic matter = 2.2%			Les Evouettes silt loam Organic matter = 3.6%		
		K_D	Measured	Calculated	K_D	Measured	Calculated
		(m³ kg) × 10⁴			(m³ kg) × 10⁴		
Diazinon	3.0 × 10[illegible]	5.6	1224	1329	11.7	348	703
Isazophos	3.6 × 10[illegible]	1.25	616	754	2.25	194	456
Metolachlor	3.7 × 10[illegible]	1.54	106	76	3.18	36	38
Methidathion	6.8 × 10[illegible]	2.35	20	10	3.89	6.7	5.9
Metalaxyl	4.4 × 10[illegible]	0.43	8.4	1.5	0.87	2.9	1.5

Indirect Evidence

Many studies reported in the literature either did not provide enough information for direct simulation or had conditions that differed from those of our model. In these cases, only qualitative comparisons were made. In a comparative volatilization study, Kearney et al. (1964) examined the relative volatilization of different *s*-triazine compounds, and found that the volatilization of atrazine > prometryne > simazine. This corresponds to the relative volatilization rank ordering of these three compounds based on our screening model (Jury et al., 1984b).

Willis et al. (1972) conducted field experiments on dieldrin in saturated and moist soil over a 150-d period on a Commerce silty clay loam soil (Aeric Fluvaquents). The moist plot was sprinkler-irrigated to maintain soil-water potential between 0.33 and 1 bar, which we approximated as 60% of saturated water content. The model predicted that 21.5 and 3.0% of the dieldrin should have volatilized during the 150-d period, compared with 18 and 2% measured losses for the moist and flooded conditions, respectively. The K_D of dieldrin was calculated from K_{oc} and the equivalent vapor thickness, d_v, of the water barrier of thickness d_L was calculated from Eq. [1].

$$D_L^{water}/d_L = K_H D_G^{air}/d_v \text{ or } d_v = K_H D_G^{air}\, d_L/D_L^{water}, \quad [1]$$

where D_L^{water} is the liquid diffusion coefficient in water and D_G^{air} is the vapor diffusion coefficient in air.

In a comparative study, Caro et al. (1976) examined volatilization of dieldrin and carbofuran under field and laboratory conditions. The dieldrin volatilization flux was found to continually decrease with time, whereas the carbofuran volatilization flux remained relatively constant. In one experiment, when no water was evaporating, the volatilization of dieldrin greatly exceeded that of carbofuran, whereas in the other experiment where the soil surface dried and water was evaporating, they had comparable volatilization rates. These observations are consistent with the predicted behavior of a category I compound (dieldrin), and a category III compound (carbofuran) under identical situations as discussed in Jury et al. (1984b).

Table 3—Cumulative volatilization after 7 d expressed as a percent of initially incorporated chemical, from the experiment of Farmer et al. (1972).

Chemical	Measured	Simulated
Lindane	63	66
Dieldrin	40	27
DDT	9	7

Cliath and Spencer (1971) studied persistence of field-applied dieldrin and lindane over a 2-yr period. They observed effective half-lives, including volatilization, of between 3 and 5 yr for dieldrin and between 240 and 300 d for lindane. These figures are consistent with the persistence categories we defined for these two compounds in Jury et al. (1984b).

Boundary Layer Model

An important feature of our screening model is the assumption that a stagnant air boundary layer exists above the soil surface through which organic chemical vapor and water vapor must move by molecular diffusion. The thickness of this boundary layer is a complicated function of wind speed, fetch, and surface roughness, which we do not attempt to model. Rather, we assume a constant thickness of the boundary layer, which is calculated from measured water evaporation rates and assuming an analogy between water vapor movement and pesticide vapor movement. Thus, as shown in Jury et al. (1983), an evaporation rate of 2.5 mm/d into an atmosphere of 50% relative humidity and a temperature of 25°C implies a stagnant boundary layer thickness of approximately 5 mm. Since no direct measurements can be made of this boundary layer thickness, experimental tests of the model must be made in an indirect manner.

In several laboratory and field studies, the volatilization flux, J_V, and the chemical vapor concentration C_G^{air} at a height near the soil surface were measured for experiments where pesticide had been applied at concentrations sufficient to saturate the soil vapor density or where the initial vapor concentration was known (Spencer & Cliath, 1973; Jury et al., 1980; Glotfelty, 1981). For these experiments, the boundary layer thickness, d, may be estimated by Eq. [2]

$$d = D_G^{air}(C_G^* - C_G^{air})/J_V) \quad [2]$$

where * denotes saturation, provided that C_G^{air} is measured above the boundary layer.

Table 4 presents a summary of a number of different experiments conducted in the field and the laboratory in which the boundary layer thickness, using Eq. [2], was calculated from fluxes measured immediately after application. For several cases in the laboratory, a water evaporation rate was also measured, which allowed us to calculate the boundary layer thickness directly using our model (see Eq. [28] of Jury et al., 1983). As shown in Table 4, all of the boundary layer thicknesses calculated from the volatilization data are consistent with the thicknesses that we use in our model. Furthermore, a correlation was obtained between predicted boundary layer thickness (Eq. [2]) and the boundary layer thickness calculated from measured water evaporation and water vapor density difference. Since the boundary layer model is an idealization, no better agreement than this could be expected.

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Table 4—Boundary layer thickness calculated from various laboratory and field experiments.

Compound	Experiment	d Measured	Evaporation	$d(E)$†	Ref. no.	Comments
		cm	cm/day	cm		
Trifluralin	Field	0.84	–	–	9	Measurements taken at 0900 h
Heptachlor	Field	1.3	–	–	9	Wind speed 2.0-2.7 m/s
Dacthal	Field	0.68	–	–	9	(0.2-2.0 m)
Chlordane	Field	0.88	–	–	9	
	Average	0.93				
Trifluralin	Field	0.16	–	–	9	Measurements taken at 1200 h
Lindane	Field	0.13	–	–	9	Wind speed 3.8-5.6 m/s
	Average	0.15				(0.34-2.5 m)
Triallate	Lab	0.37	0.63	0.38	15	50% Relative humidity
Triallate	Lab	0.21	0.60	0.26	15	
	Average	0.28				
Trifluralin	Lab	0.39	–	–	31	100% Relative humidity
Lindane	Lab	0.12	0.27	0.55	30	50-100% Cycled relative humid
Dieldrin	Lab	0.78	0.25	1.2	30	50% Relative humidity

† Calculated from water evaporation rate.

Effective Diffusion Coefficient

Our model assumes equilibrium partitioning between liquid, vapor, and adsorbed phases and assumes that the variation in diffusion coefficient with water content or air content may be described by the model of Millington and Quirk (1961) as shown in Eq. [3].

$$D_E = (D_G^{air} K_H a^{10/3} - D_L^{water} \Theta^{10/3})/\phi^2 R_L, \qquad [3]$$

where a = volumetric air content; Θ = volumetric water content; ϕ = porosity; R_L = liquid partition coefficient = C_T/C_L, where C_T = total concentration and C_L = solution concentration. The liquid partition coefficient, R_L, is approximately equal to $\varrho_b K_D + \Theta$, where ϱ_b = soil bulk density (Jury et al., 1983).

There have been few measurements made of effective diffusion coefficients for organic compounds over large ranges of water content. One such study, however, is the experiment reported in Shearer et al. (1973) in which the effective diffusion coefficient of lindane was measured over a range of water contents from near air dry to saturation on Gila silt loam. The measured values of lindane diffusion coefficient, together with the model calculation using Eq. [3], are shown in Fig. 3, using the appropriate parameters for lindane and Gila silt loam taken from their article (see Table 1). Also shown in Fig. 3 are the measured and predicted diffusion coefficients for dimethoate as measured in the experiment of Graham-Bryce (1969) for the parameters given in Table 1. The good agreement found for each of these compounds of widely differing characteristics using the same model supports the use of the Millington and Quirk model. Additional verification for this model was obtained by Farmer et al. (1980), who found a good agreement between measured and calculated diffusion coefficients for hexachlorobenzene (HCB) over a large range of soil air contents.

In addition to the Millington-Quirk method of representing tortuosity, our model assumes a common value for the air-gas diffusion coefficient, D_G^{air} = 4320 cm²/d, and liquid-water diffusion coefficient, D_L^{water} = 0.432 cm²/d, for all organic chemicals in the intermediate molecular weight range. The justification for this assumption was reviewed in Jury et al. (1983) and was also discussed in Letey and Farmer (1973). In our 19[illegible] article, we alluded to the common values found in t[illegible] numerous measurements of gas diffusion coefficient r[illegible]ported in the article of Boynton and Brattain (1929) a[illegible] of liquid diffusion coefficient reported in the article [illegible] Bruins (1929). From these two sources, we calculat[illegible] the average values given above.

It should be noted that the volatilization simulatio[illegible] discussed above all use the Millington and Quirk form[illegible]lation and the common parameter assumptions. Th[illegible] the good agreement found for the case discussed abo[illegible] is additional verification of the effective diffusion co[illegible]ficient model.

LEACHING STUDIES

The leaching behavior of compounds in our screeni[illegible] model is described with the same simple distribution c[illegible]efficient model assumption used over the years by ma[illegible] other authors [see reviews by Bailey & White (197[illegible] Karickhoff et al. (1971), Rao & Davidson (1980), Gre[illegible] et al. (1980)]. For example, we showed that the time r[illegible]

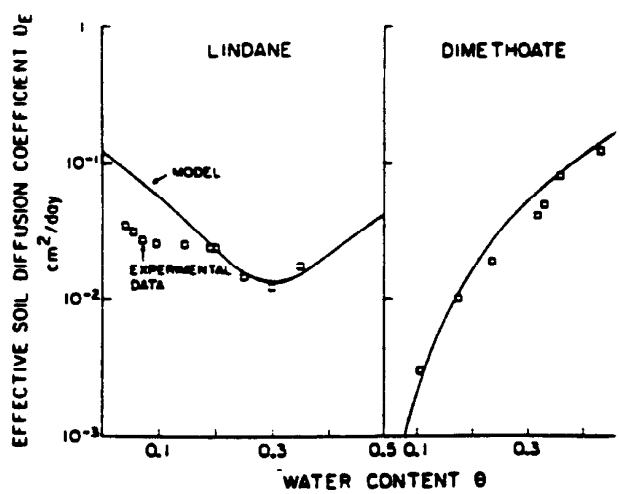

Fig. 3—Measured effective diffusion coefficients for lindane tak[illegible] from Shearer et al. (1973), and for dimethoate taken from Graha[illegible] Bryce (1969), compared with the diffusion model (solid lines) us[illegible] in our screening model.

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quired to leach an adsorbed compound a given distance under continuous leaching was proportional to the distribution coefficient, K_D (Jury et al., 1983). The distribution coefficient model, which assumes linear, equilibrium partitioning between solution and adsorbed chemical phases, has had extensive testing under laboratory conditions with slowly percolating solutions. King and McCarty (1968) obtained distribution coefficients by batch equilibrium and then conducted extensive leaching tests on columns of 4, 15, and 90 cm. Using a total of four soils and six pesticides, they obtained good agreement between predicted and measured effluent concentrations for a chromatography model (formally similar to our own) when degradation was taken into account using a first-order rate constant. Our model would produce equivalent results to theirs when applied on the same data.

Huggenberger et al. (1972, 1973) studied leaching of lindane, diuron, and atrazine in three soils. They measured distribution coefficients in separate experiments and then studied vertical infiltration of pesticide at a constant water rate into dry soil. Although they had difficulty simulating the shape of the breakthrough curves, they achieved a good agreement between observed depth of leaching and predicted depth of leaching using the measured distribution coefficient. Our model would produce equivalent results on the same data.

Weber and Whitacre (1982) conducted 30 d of leaching on bromacil, buthidazole, atrazine, prometone, and diuron and observed leaching distances that were inversely proportional to the organic C coefficient, K_{oc}. Swartzenbach and Westall (1981) conducted leaching studies on 11 polar organic compounds and found that leaching predicted by the batch equilibrium distribution coefficient agreed with the leaching behavior observed in the columns at low flow rates. They found that nonequilibrium effects began to appear at water velocities of 0.01 cm/s or greater. These rates greatly exceed typical velocities found in the field except under infiltration conditions.

McCall et al. (1980) found an inverse relation between distance leached and organic C partition coefficients for nine different compounds. As we discussed in Jury et al. (1984a), our model predicts an inverse relation between leaching distance and distribution coefficient (or K_{oc}), unless the compound is only slightly adsorbed.

DISCUSSION

Volatilization

The experimental evidence reviewed above offers strong support for the volatilization part of the screening model. In cases where the experiments were conducted under similar conditions to those assumed in the model, a simulation produced good agreement with observation. In cases where a number of compounds of widely differing properties were studied, the model predicted a rank ordering that agreed with the observed order. Significantly, all compounds studied behaved in a manner consistent with the volatilization category predictions made in our earlier paper (Jury et al., 1984a), in which we grouped large numbers of compounds depending on whether the Henry's constant K_H was significantly greater (category I) or less (category III) than $K_H \approx 10^{-7}$. For example, parathion (category II) in Fig. 2 increases its volatilization rate with time when evaporation is occurring, but dieldrin and lindane (category I) in Fig. 1 decrease with time.

The field studies reviewed above offer indirect support for the volatilization calculations made in our model. In the experiments of Glotfelty (1981), the apparent thickness of the boundary layer inferred from using Eq. [2] with the field measurements was consistent with the thickness calculated from an analogy with water evaporation fluxes to the atmosphere. Furthermore, the boundary layer thickness appeared to decrease as windspeed increased (Table 4). Since—as shown in Mayer et al. (1974)—the thickness assumed for the boundary layer has a critical influence on model calculations, the direct and indirect evidence given in Table 4 to support our method of selecting this thickness is encouraging.

The volatilization flux is strongly influenced by the effective diffusion coefficient, which for the Millington and Quirk (1961) model used in our calculations is a nonlinear function of air or water content. Although this model is empirical, the evidence presented here (Fig. 3 and Farmer et al., 1980) supports its use in homogeneous laboratory soil systems when hydrodynamic dispersion is small. In addition, recent evidence (Sallam et al., 1984) suggests that the Millington and Quirk model may be useful for representing vapor diffusion, even at extremely low air contents.

There are influences on volatilization that are not taken into account in our model. When the soil surface layer dries out sufficiently, adsorption of chemical to the mineral or organic surfaces increases significantly and volatilization rates decrease (Spencer et al., 1969). However, there is experimental evidence, both in the laboratory (Spencer et al., 1969) and in the field (Harper et al., 1976), that this increased adsorption over a wetting and drying cycle is similar to what would have occurred if the soil had not dried.

The experimental studies of Burkhard and Guth (1981) (Table 2) are significant in that they are among the few volatilization experiments conducted on category III (small $K_H < 10^{-9}$) compounds, which we predicted to have completely different properties than category I ($K_H > 10^{-5}$) compounds (Jury et al., 1984a). There was reasonably good agreement obtained between our model calculations and their measurements, especially considering that the range of volatilization rates was over two orders of magnitude. We would recommend further study of compounds in this category because our model predicts that under certain conditions (high water evaporation, high concentrations) they would volatilize significantly (Jury et al., 1984a).

Leaching

The leaching behavior of adsorbed compounds is reasonably well described by the linear, equilibrium adsorption model used in our calculations for compounds tested in homogeneous laboratory columns at low flow rates. The studies reviewed here all fall into that cate-

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gory. Since our model is based on the same assumptions as other earlier work on mobility, the general mobility criteria used by McCall et al. (1980) and others are equivalent to our own. The use of a distribution coefficient does have limitations, however, which are reviewed in Mingelgrin and Gerstl (1983).

Little quantitative information is available about leaching of adsorbed chemicals under field conditions, where soil structure may result in incomplete exposure of adsorbing surfaces to the chemical in solution during transport. It is hoped that the *relative mobility* of different compounds under field conditions will be similar to that predicted from laboratory studies. This would allow field calibrations to be run on a few representative chemicals from each group rather than on all compounds.

SUMMARY AND CONCLUSIONS

The screening model developed in Jury et al. (1983, 1984a,b) has been tested on published experimental data on volatilization, leaching, and persistence where comparisons could be made. The reasonable agreement found in these comparisons offers encouragement for the use of the model to classify and group chemicals into similar loss pathway categories.

We firmly believe that in situ experiments offer the only reliable method for determining the loss pathways of a chemical, particularly under field conditions. However, the expense and time required for such experiments, and the large number of chemicals in need of testing, make it likely that models will play a significant role in such assessments. Our series of papers has developed a number of relationships between the benchmark properties of a chemical and its relative susceptibility to loss, which should be extensively tested in situ prior to use of the model. The evidence offered above in support of the model's predictions is the first step in this testing.

APPENDIX

Scientific names of chemicals used in this article.

Common or trade name	Chemical name
Atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine
Bromacil	5-bromo-3-*sec*-butyl-6-methyluracil
Buthidazole	3,5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2yl-1 hydroxy-1-methyl-1-imidazolidinone
Carbofuran	2,3-dihydro-2,2-dimethyl-7-benzofuranylmethylcarbamate
Chlordane	1,2,4,5,6,7,8,8-Octachlor-2,3,3a,4,7,7a-hexahydro-4,7-methanoindane
Dacthal	Dimethyl tetrachloroterephthalate
DDT	1,1,1-trichloro-2,2-bis(*p*-chlorophenyl) ethane
Diazinon	*O,O*-diethyl-*O*-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate
Dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy,1,4,4a,5,6,7,8,8a,octahydro-1,4-*endo*-*exo*-5,8-dimethanonaphthalene
Dimethoate	*O,O*-Dimethyl S-(*N*-methylcarbamoy methyl) phosphorodithioate
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylu
Heptachlor	1,4,5,6,7,8,8-Heptachloro-3*a*,4,6,6*a*-tetrahydro-4,7-methanoindene
Isazophos	O-(5-chloro-1-{methylethyl}-1H 1,2, triazol-3-yl) O,O-diethyl phosphor thioate
Lindane	γ-1,2,3,4,5,6-hexachlorocyclohexanc
Metalaxyl	*N*-(2,6-Dimethylphenyl)-*N*-(methoxy acetyl)-alanine methyl ester
Methidathion	*O,O*-dimethyl phosphorodithioate, S ester with 4-(mercaptomethyl)-2-methoxy Δ^2-1,3,4-thiadiazolin-5-o
Metolachlor	2-chloro-*N*-(2-ethyl-6-methylphenyl) (2-methoxy-1-methylethyl) acetam
Parathion	*O,O*-diethyl *O*-(*p*-nitrophenyl) phosphorodithioate
Prometone	2,4-bis(isopropylamino)-6-methoxy-triazine
Prometryne	2,4-bis(isopropylamino)-6-methylthi triazine
Simazine	2-chloro-4,6-bis (ethylamino)-*s*-triaz
Triallate	*S*-(2,3,3-trichloroally)diisopropylthi carbamate
Trifluralin	*a,a,a*-trifluoro-2,6-dinitro-*N,N*-dipropyl-*p*-toluidine

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APPENDIX C

BOX MODEL INPUT PARAMETERS AND RESULTS

The box model is based on a mass balance expression that assumes that the soil-gas flux is instantly mixed with the air flowing through a theoretical box. The equation(s) used to determine exposure point air concentrations for two scenarios (residential and occupational) are presented below. The attachments following this appendix provide the spreadsheets used to calculate the air concentrations.

Calculation of Exposure Point Air Concentrations

The following assumptions and equation were used to calculate vapor concentrations:

Box Parameters:

Emitting Area	=	1.44×10^8 cm^2
Area of site	=	1.9589×10^5 ft^2 (calculated from map)
Cross-section Length	=	sq. root of 1.9591×10^5 ft^2 = 4.426×10^2 ft (0.3048 m/1 ft) = 134.9 m

Equation:

$$C_{air} = (F \times A) / (\mu \times h \times w)$$

Where:

C_{air}	=	Total air concentration (mg/m^3)
F	=	Emission rate estimated by Jury BAM model (mg/cm^2-sec)
μ	=	Conservative wind speed (2 m/sec; a calm wind speed)
h	=	Height of exposure box (2 m - breathing zone)
A	=	Emitting area of the site (cm^2)
w	=	Width of exposure box (m)

<u>Example Calculation: Acetone Air Concentration</u>

$$C_{air} = (F \times A) / (\mu \times h \times w)$$

Where:

C_{air}	=	Total air concentration (mg/m^3)
F	=	Emission rate estimated by Jury BAM (2.25×10^{-8} mg/cm^2-sec)
μ	=	Conservative wind speed (2 m/sec)
h	=	Height of exposure box (2 m - breathing zone)
A	=	Emitting area of the site (1.44×10^8 cm^2)
w	=	Width of exposure box (134.90 m)

Therefore:

$$C_{air} = (2.25 \times 10^{-8} \text{ mg/cm}^2\text{-sec} \times 1.44 \times 10^8 \text{ m} / (2 \text{ m/sec.} \times 2 \text{ m} \times 134.9 \text{ m})$$
$$= 6.00 \times 10^{-3} \text{ mg/m}^3$$

The following attachments provide the calculations for the exposure point concentrations used in this assessment to estimate chronic noncarcinogenic and carcinogenic health effects.

BOX MODEL RESULTS USING EMISSION RATES FROM THE JURY BEHAVIOR ASSESSMENT MODEL

Mckesson Santa Fe Springs Box Model for Jury BAM 30-year and 4.2-year Emission Rates:

30-year

Chemical	Flux (mg/cm2-sec)	Area Emitting / (cm2)	Wind Speed (m/sec.)	Height (m)	Width (m)	Cair (mg/m3)
Acetone	2.25E-08	1.44E+08	2	2	134.90	6.00E-03
1,1-DCA	1.50E-10	1.44E+08	2	2	134.90	4.00E-05
1,2-DCA	1.17E-09	1.44E+08	2	2	134.90	3.12E-04
1,1-DCE	4.27E-11	1.44E+08	2	2	134.90	1.14E-05
1,2-DCE	1.35E-10	1.44E+08	2	2	134.90	3.59E-05
2-Butanone (MEK)	8.44E-09	1.44E+08	2	2	134.90	2.25E-03
Methylene Chloride	1.97E-08	1.44E+08	2	2	134.90	5.26E-03
Tetrachloroethene	7.23E-08	1.44E+08	2	2	134.90	1.93E-02
Trichloroethene	2.87E-09	1.44E+08	2	2	134.90	7.65E-04
Toluene	7.29E-09	1.44E+08	2	2	134.90	1.94E-03
1,1,1-TCA	4.17E-08	1.44E+08	2	2	134.90	1.11E-02
Xylenes	8.11E-09	1.44E+08	2	2	134.90	2.16E-03

4.2-year

Chemical	Flux (mg/cm2-sec)	Area Emitting / (cm2)	Wind Speed (m/sec.)	Height (m)	Width (m)	Cair (mg/m3)
Acetone	6.43E-08	1.44E+08	2	2	134.90	1.72E-02
1,1-DCA	4.79E-10	1.44E+08	2	2	134.90	1.28E-04
1,2-DCA	2.93E-09	1.44E+08	2	2	134.90	7.82E-04
1,1-DCE	1.29E-10	1.44E+08	2	2	134.90	3.44E-05
1,2-DCE	4.05E-10	1.44E+08	2	2	134.90	1.08E-04
2-Butanone (MEK)	1.67E-08	1.44E+08	2	2	134.90	4.46E-03
Methylene Chloride	8.26E-08	1.44E+08	2	2	134.90	2.20E-02
Tetrachloroethene	2.10E-07	1.44E+08	2	2	134.90	5.60E-02
Trichloroethene	8.13E-09	1.44E+08	2	2	134.90	2.17E-03
Toluene	1.80E-08	1.44E+08	2	2	134.90	4.80E-03
1,1,1-TCA	1.29E-07	1.44E+08	2	2	134.90	3.44E-02
Xylenes	1.99E-08	1.44E+08	2	2	134.90	5.31E-03

APPENDIX D

DOSE CALCULATIONS AND HEALTH RISK ESTIMATES

Future Onsite Worker

Inhalation of Vapors

Carcinogenic Effects:

Chemical	C * (mg/m3)	IR * (m3/hr.)	ET * (hours/day)	EF * (days/year)	ED * (years)	1 / (million)	BW * (kg)	AT * (days)	LADD * (mg/kg-day)	SF * (mg/kg-day)-1	Cancer Risk
1,2-Dichloroethane	7.82E-04	1.25	8	250	4.2	1	70	25550	4.59E-06	9.1E-02	4.18E-07
1,1-Dichloroethene	3.44E-05	1.25	8	250	4.2	1	70	25550	2.02E-07	1.2E+00	2.42E-07
Methylene Chloride	2.20E-02	1.25	8	250	4.2	1	70	25550	1.29E-04	1.6E-03	2.07E-07
Tetrachloroethene	5.60E-02	1.25	8	250	4.2	1	70	25550	3.29E-04	1.8E-03	5.92E-07
Trichloroethene	2.17E-03	1.25	8	250	4.2	1	70	25550	1.27E-05	1.7E-02	2.17E-07
										Total Cancer Risk	2E-06

Noncarcinogenic Effects:

Chemical	C * (mg/m3)	IR * (m3/hr.)	ET * (hours/day)	EF * (days/year)	ED * (years)	1 / (million)	BW * (kg)	AT * (days)	ADD / (mg/kg-day)	RfD = (mg/kg-day)	Hazard Index
Acetone	1.72E-02	1.25	8	250	4.2	1	70	1533	1.68E-03	ND	ND
1,1-Dichloroethane	1.28E-04	1.25	8	250	4.2	1	70	1533	1.25E-05	1.0E-01	1.25E-04
1,2-Dichloroethane	7.82E-04	1.25	8	250	4.2	1	70	1533	7.65E-05	2.7E-02	2.83E-03
1,1-Dichloroethene	3.44E-05	1.25	8	250	4.2	1	70	1533	3.37E-06	ND	ND
1,2-Dichloroethene	1.08E-04	1.25	8	250	4.2	1	70	1533	1.06E-05	ND	ND
2-Butanone (MEK)	4.46E-03	1.25	8	250	4.2	1	70	1533	4.36E-04	9.00E-02	4.85E-03
Methylene Chloride	2.20E-02	1.25	8	250	4.2	1	70	1533	2.15E-03	8.60E-01	2.50E-03
Tetrachloroethene	5.60E-02	1.25	8	250	4.2	1	70	1533	5.48E-03	1.00E-02	5.48E-01
Trichloroethene	2.17E-03	1.25	8	250	4.2	1	70	1533	2.12E-04	1.80E-01	1.18E-03
Toluene	4.80E-03	1.25	8	250	4.2	1	70	1533	4.70E-04	5.70E-01	8.24E-04
1,1,1-Trichloroethane	3.44E-02	1.25	8	250	4.2	1	70	1533	3.37E-03	3.00E-01	1.12E-02
Xylenes	5.31E-03	1.25	8	250	4.2	1	70	1533	5.20E-04	8.57E-02	6.06E-03
										Total Hazard Index	6E-01

c

Concentrations calculated using the Jury and Box models.

ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

Total Occupational Cancer Risk = 8E-06

Total Occupational Hazard Index = 8E-01

MK083756

MKIL206086

Future Onsite Worker

Dermal Contact With Soil

Carcinogenic Effects:

Chemical	C c *	SA *	AF *	B *	EF *	ED *	CF /	BW *	AT *	LADD *	SF *	Cancer Risk
	(mg chem./kg soil)	(cm2)	(mg/cm2-day)	(unitless)	(days/year)	(years)	(kg/mg)	(kg)	(days)	(mg/kg-day)	(mg/kg-day)-1	
1,2-Dichloroethane	9.42E+00	3900	0.5	0.1	250	4.2	1E-06	70	25550	1.08E-06	9.1E-02	9.81E-08
1,2-Dichloroethene	3.40E-01	3900	0.5	0.1	250	4.2	1E-06	70	25550	3.89E-08	6.0E-01	2.34E-08
Methylene Chloride	1.12E+02	3900	0.5	0.1	250	4.2	1E-06	70	25550	1.29E-05	7.5E-03	9.65E-08
Tetrachloroethene	8.58E+02	3900	0.5	0.1	250	4.2	1E-06	70	25550	9.83E-05	5.1E-02	5.01E-06
Trichloroethene	1.79E+01	3900	0.5	0.1	250	4.2	1E-06	70	25550	2.05E-06	1.1E-02	2.26E-08
											Total Cancer Risk	5E-06

Noncarcinogenic Effects:

Chemical	C c *	SA *	AF *	B *	EF *	ED *	CF /	BW *	AT *	ADD /	RfD *	Hazard Index
	(mg chem./kg soil)	(cm2)	(mg/cm2-day)	(unitless)	(days/year)	(years)	(kg/mg)	(kg)	(days)	(mg/kg-day)	(mg/kg-day)	
Acetone	5.00E-01	3900	0.5	0.1	250	4.2	1E-06	70	1533	9.54E-07	1.0E-01	9.54E-06
1,1-Dichloroethane	7.60E-02	3900	0.5	0.1	250	4.2	1E-06	70	1533	1.45E-07	1.0E-01	1.45E-06
1,2-Dichloroethane	9.42E+00	3900	0.5	0.1	250	4.2	1E-06	70	1533	1.80E-05	2.7E-02	6.66E-04
1,1-Dichloroethene	3.40E-01	3900	0.5	0.1	250	4.2	1E-06	70	1533	6.49E-07	9.0E-03	7.21E-05
1,2-Dichloroethene	2.50E-02	3900	0.5	0.1	250	4.2	1E-06	70	1533	4.77E-08	ND	ND
2-Butanone (MEK)	5.00E-01	3900	0.5	0.1	250	4.2	1E-06	70	1533	9.54E-07	5.0E-02	1.91E-05
Methylene Chloride	1.12E+02	3900	0.5	0.1	250	4.2	1E-06	70	1533	2.15E-04	6.0E-02	3.58E-03
Tetrachloroethene	8.58E+02	3900	0.5	0.1	250	4.2	1E-06	70	1533	1.64E-03	1.0E-02	1.64E-01
Trichloroethene	1.79E+01	3900	0.5	0.1	250	4.2	1E-06	70	1533	3.42E-05	1.8E-01	1.90E-04
Toluene	4.31E+01	3900	0.5	0.1	250	4.2	1E-06	70	1533	8.23E-05	2.0E-01	4.11E-04
1,1,1-Trichloroethane	1.04E+03	3900	0.5	0.1	250	4.2	1E-06	70	1533	1.98E-03	9.0E-02	2.20E-02
Xylenes	2.64E+01	3900	0.5	0.1	250	4.2	1E-06	70	1533	5.04E-05	2.0E+00	2.52E-05
											Total Hazard Index	2E-01

c

Representative concentrations are the 95th percent upper confidence limit of the arithmetic mean concentrations of surficial site soil samples (sample depth less than 2 feet).
ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

MK083757

MKIL206087

Future Onsite Worker

Ingestion of Soil

Carcinogenic Effects:

Chemical	C (mg chem./kg soil)	* IR (mg soil/day)	* CF (kg/mg)	* EF (days/year)	* ED (years)	* B (unitless)	/ BW (kg)	* AT (days)	= LADD (mg/kg-day)	* SF (mg/kg-day)-1	= Cancer Risk
1,2-Dichloroethane	9.42E+00	50	1E-06	250	4.2	1	70	25550	2.77E-07	9.1E-02	2.52E-08
1,1-Dichloroethene	3.40E-01	50	1E-06	250	4.2	1	70	25550	9.98E-09	6.0E-01	5.99E-09
Methylene Chloride	1.12E+02	50	1E-06	250	4.2	1	70	25550	3.30E-06	7.5E-03	2.48E-08
Tetrachloroethene	8.58E+02	50	1E-06	250	4.2	1	70	25550	2.52E-05	5.1E-02	1.28E-06
Trichloroethene	1.79E+01	50	1E-06	250	4.2	1	70	25550	5.26E-07	1.1E-02	5.79E-09
										Total Cancer Risk	1E-06

Noncarcinogenic Effects:

Chemical	C [a] (mg chem./kg soil)	* IR (mg soil/day)	* CF (kg/mg)	* EF (days/year)	* ED (years)	* B (unitless)	/ BW (kg)	* AT (days)	= ADD (mg/kg-day)	/ RfD (mg/kg-day)	= Hazard Index
Acetone	5.00E-01	50	1E-06	250	4.2	1	70	1533	2.45E-07	1.0E-01	2.45E-06
1,1-Dichloroethane	7.60E-02	50	1E-06	250	4.2	1	70	1533	3.72E-08	1.0E-01	3.72E-07
1,2-Dichloroethane	9.42E+00	50	1E-06	250	4.2	1	70	1533	4.61E-06	2.7E-02	1.71E-04
1,1-Dichloroethene	3.40E-01	50	1E-06	250	4.2	1	70	1533	1.66E-07	9.0E-03	1.85E-05
1,2-Dichloroethene	2.50E-02	50	1E-06	250	4.2	1	70	1533	1.22E-08	ND	ND
2-Butanone (MEK)	5.00E-01	50	1E-06	250	4.2	1	70	1533	2.45E-07	5.0E-02	4.89E-06
Methylene Chloride	1.12E+02	50	1E-06	250	4.2	1	70	1533	5.50E-05	6.0E-02	9.17E-04
Tetrachloroethene	8.58E+02	50	1E-06	250	4.2	1	70	1533	4.20E-04	1.0E-02	4.20E-02
Trichloroethene	1.79E+01	50	1E-06	250	4.2	1	70	1533	8.77E-06	1.8E-01	4.87E-05
Toluene	4.31E+01	50	1E-06	250	4.2	1	70	1533	2.11E-05	2.0E-01	1.05E-04
1,1,1-Trichloroethane	1.04E+03	50	1E-06	250	4.2	1	70	1533	5.09E-04	9.0E-02	5.65E-03
Xylenes	2.64E+01	50	1E-06	250	4.2	1	70	1533	1.29E-05	2.0E+00	6.47E-06
										Total Hazard Index	5E-02

[a] Representative concentrations are the 95th percent upper confidence limit of the arithmetic mean concentrations of surficial site soil samples (sample depth less than 2 feet).

ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

MK083758

MKIL206088

Future Onsite Resident (Adult)

Inhalation of Vapors

Carcinogenic Effects:

Chemical	C (mg/m3)	* IR (m3/hr)	* ET (hrs/day)	* EF (days/yrs)	* ED (years)	* B (unitless)	/ BW (kg)	* AT (days)	= LADD (mg/kg-day)
1,2-Dichloroethane	3.12E-04	0.83	24	350	24	1	70	25550	2.92E-05
1,1-Dichloroethane	1.14E-05	0.83	24	350	24	1	70	25550	1.07E-06
Methylene Chloride	5.26E-03	0.83	24	350	24	1	70	25550	4.92E-04
Tetrachloroethene	1.93E-02	0.83	24	350	24	1	70	25550	1.81E-03
Trichloroethene	7.65E-04	0.83	24	350	24	1	70	25550	7.16E-05

Noncarcinogenic Effects:

Chemical	C (mg/m3)	* IR (m3/hr)	* ET (hrs/day)	* EF (days/yrs)	* ED (years)	* B (unitless)	/ BW (kg)	* AT (days)	= ADD (mg/kg-day)	/ RfD (mg/kg-day)	= Hazard Index
Acetone	6.00E-03	0.83	24	350	24	1	70	8760	1.64E-03	ND	ND
1,1-Dichloroethane	4.00E-05	0.83	24	350	24	1	70	8760	1.09E-05	1.0E-01	1.09E-04
1,2-Dichloroethane	3.12E-04	0.83	24	350	24	1	70	8760	8.51E-05	2.7E-02	3.15E-03
1,1-Dichloroethane	1.14E-05	0.83	24	350	24	1	70	8760	3.11E-06	ND	ND
1,2-Dichloroethane	3.59E-05	0.83	24	350	24	1	70	8760	9.80E-06	ND	ND
2-Butanone (MEK)	2.25E-03	0.83	24	350	24	1	70	8760	6.14E-04	9.00E-02	6.82E-03
Methylene Chloride	5.26E-03	0.83	24	350	24	1	70	8760	1.44E-03	8.60E-01	1.67E-03
Tetrachloroethene	1.93E-02	0.83	24	350	24	1	70	8760	5.27E-03	1.00E-02	5.27E-01
Trichloroethene	7.65E-04	0.83	24	350	24	1	70	8760	2.09E-04	1.80E-01	1.16E-03
Toluene	1.94E-03	0.83	24	350	24	1	70	8760	5.29E-04	5.70E-01	9.29E-04
1,1,1-Trichloroethane	1.11E-02	0.83	24	350	24	1	70	8760	3.03E-03	3.00E-01	1.01E-02
Xylenes	2.16E-03	0.83	24	350	24	1	70	8760	5.89E-04	8.57E-02	6.88E-03
										Total Hazard Index	6E-01

Chemical	Total LADD	* SF	= Cancer Risk
1,2 Dichloroethane	4.7E-05	9.1E-02	4.30E-06
1,1-Dichloroethane	1.7E-06	1.2E+00	2.07E-06
Methylene Chloride	8.0E-04	1.6E-03	1.27E-06
Tetrachloroethene	2.9E-03	1.8E-03	5.26E-06
Trichloroethene	1.2E-04	1.7E-02	1.97E-06
Total Residential Inhalation Cancer Risk			1E-05

c

Representative concentrations predicted by Jury and Box Models.

ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

Total Residential (Adult and Child 0-6 years) Cancer Risk = 2E-05

MK083759

MKIL206089

Future Onsite Resident (0-6 years of age)

Inhalation of Vapors

Carcinogenic Effects:

Chemical	C c (mg/m3)	* IR (m3/hr.)	* ET (hrs/day)	* EF (days/year)	* ED (years)	* B (unitless)	/ BW (kg)	* AT (days)	= LADD (mg/kg-day)
1,2-Dichloroethane	3.12E-04	0.44	24	350	6	1	15	25550	1.81E-05
1,1-Dichloroethene	1.14E-05	0.44	24	350	6	1	15	25550	6.60E-07
Methylene Chloride	5.26E-03	0.44	24	350	6	1	15	25550	3.04E-04
Tetrachloroethene	1.93E-02	0.44	24	350	6	1	15	25550	1.12E-03
Trichloroethene	7.65E-04	0.44	24	350	6	1	15	25550	4.43E-05

Noncarcinogenic Effects:

Chemical	C c (mg/m3)	* IR (m3/hr.)	* ET (hrs/day)	* EF (days/year)	* ED (years)	* B (unitless)	/ BW (kg)	* AT (days)	= ADD (mg/kg-day)	/ RfD (mg/kg-day)	= Hazard Index
Acetone	6.00E-03	0.44	24	350	6	1	15	2190	4.05E-03	ND	ND
1,1-Dichloroethane	4.00E-05	0.44	24	350	6	1	15	2190	2.70E-05	1.0E-01	2.70E-04
1,2-Dichloroethane	3.12E-04	0.44	24	350	6	1	15	2190	2.11E-04	2.7E-02	7.80E-03
1,1-Dichloroethene	1.14E-05	0.44	24	350	6	1	15	2190	7.70E-06	ND	ND
1,2-Dichloroethene	3.59E-05	0.44	24	350	6	1	15	2190	2.42E-05	ND	ND
2-Butanone (MEK)	2.25E-03	0.44	24	350	6	1	15	2190	1.52E-03	9.00E-02	1.69E-02
Methylene Chloride	5.26E-03	0.44	24	350	6	1	15	2190	3.55E-03	8.60E-01	4.13E-03
Tetrachloroethene	1.93E-02	0.44	24	350	6	1	15	2190	1.30E-02	1.00E-02	1.30E+00
Trichloroethene	7.65E-04	0.44	24	350	6	1	15	2190	5.16E-04	1.80E-01	2.87E-03
Toluene	1.94E-03	0.44	24	350	6	1	15	2190	1.31E-03	5.70E-01	2.30E-03
1,1,1-Trichloroethane	1.11E-02	0.44	24	350	6	1	15	2190	7.49E-03	3.00E-01	2.50E-02
Xylenes	2.16E-03	0.44	24	350	6	1	15	2190	1.46E-03	8.57E-02	1.70E-02
										Total Hazard Index	1E+00

c

Representative concentrations predicted by Jury and Box Models.

ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

Note: Inhalation rate determined by averaging the infant resting (L/min.) with a six year old mean light activity (L/min.) and converting to m3/day.

MK083760

MKIL206090

Future Onsite Resident (Adult)

Dermal Contact With Soil

Carcinogenic Effects:

Chemical	C * (mg chem./kg soil)	SA * (cm2)	AF * (mg/cm2-day)	B * (unitless)	EF * (days/year)	ED * (years)	CF / (kg/mg)	BW * (kg)	AT * (days)	LADD (mg/kg-day)
1,2-Dichloroethane	5.00E-03	3900	0.5	0.1	350	24	1E-06	70	25550	4.58E-09
1,1-Dichloroethane	2.30E-02	3900	0.5	0.1	350	24	1E-06	70	25550	2.11E-08
Methylene Chloride	2.00E-03	3900	0.5	0.1	350	24	1E-06	70	25550	1.83E-09
Tetrachloroethene	4.65E-06	3900	0.5	0.1	350	24	1E-06	70	25550	4.26E-12
Trichloroethene	1.89E+00	3900	0.5	0.1	350	24	1E-06	70	25550	1.73E-06

Noncarcinogenic Effects:

Chemical	C * (mg chem./kg soil)	SA * (cm2)	AF * (mg/cm2-day)	B * (unitless)	EF * (days/year)	ED * (years)	CF / (kg/mg)	BW * (kg)	AT * (days)	ADD / (mg/kg-day)	RfD = (mg/kg-day)	Hazard Index
Acetone	1.76E-17	3900	0.5	0.1	350	24	1E-06	70	8760	4.70E-23	1.0E-01	4.70E-22
1,1-Dichloroethane	5.00E-03	3900	0.5	0.1	350	24	1E-06	70	8760	1.34E-08	1.0E-01	1.34E-07
1,2-Dichloroethane	4.08E-01	3900	0.5	0.1	350	24	1E-06	70	8760	1.09E-06	2.7E-02	4.04E-05
1,1-Dichloroethene	2.30E-02	3900	0.5	0.1	350	24	1E-06	70	8760	6.14E-08	9.0E-03	6.83E-06
1,2-Dichloroethene	1.00E-03	3900	0.5	0.1	350	24	1E-06	70	8760	2.67E-09	ND	ND
2-Butanone (MEK)	1.76E-17	3900	0.5	0.1	350	24	1E-06	70	8760	4.70E-23	5.0E-02	9.40E-22
Methylene Chloride	2.00E-03	3900	0.5	0.1	350	24	1E-06	70	8760	5.34E-09	6.0E-02	8.90E-08
Tetrachloroethene	4.65E-06	3900	0.5	0.1	350	24	1E-06	70	8760	1.24E-11	1.0E-02	1.24E-09
Trichloroethene	1.89E+00	3900	0.5	0.1	350	24	1E-06	70	8760	5.05E-06	1.8E-01	2.80E-05
Toluene	7.19E-05	3900	0.5	0.1	350	24	1E-06	70	8760	1.92E-10	2.0E-01	9.60E-10
1,1,1-Trichloroethane	8.03E+01	3900	0.5	0.1	350	24	1E-06	70	8760	2.14E-04	9.0E-02	2.38E-03
Xylenes	5.00E-04	3900	0.5	0.1	350	24	1E-06	70	8760	1.34E-09	2.0E+00	6.68E-10
											Total Hazard Index	2E-03

Chemical	Total LADD *	SF =	Cancer Risk
1,2-Dichloroethane	1.74E-07	9.1E-02	1.59E-08
1,1-Dichloroethene	3.06E-08	6.0E-01	1.84E-08
Methylene Chloride	2.66E-09	7.5E-03	2.00E-11
Tetrachloroethene	3.79E-05	5.1E-02	1.94E-06
Trichloroethene	2.52E-06	1.1E-02	2.77E-08
Total Residential Dermal Contact Cancer Risk			2E-06

c

Representative concentrations are the 95th percent upper confidence limit of the arithmetic mean concentrations of surficial site soil samples (sample depth less than 2 feet).
ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

MK083761

MKIL206091

Future Onsite Resident (0-6 years of age)

Dermal Contact With Soil

Carcinogenic Effects:

Chemical	C e * (mg chem/kg soil)	* SA (cm2)	* AF (mg/cm2-day)	* B (unitless)	* EF (days/year)	* ED (years)	* CF (kg/mg)	/ BW (kg)	* AT (days)	& LADD (mg/kg-day)
1,2-Dichloroethane	4.08E-01	1520	0.5	0.1	350	6	1E-06	15	25550	1.70E-07
1,1-Dichloroethene	2.30E-02	1520	0.5	0.1	350	6	1E-06	15	25550	9.58E-09
Methylene Chloride	2.00E-03	1520	0.5	0.1	350	6	1E-06	15	25550	8.33E-10
Tetrachloroethene	9.11E+01	1520	0.5	0.1	350	6	1E-06	15	25550	3.79E-05
Trichloroethene	1.89E+00	1520	0.5	0.1	350	6	1E-06	15	25550	7.87E-07

Noncarcinogenic Effects:

Chemical	C e * (mg chem/kg soil)	* SA (cm2)	* AF (mg/cm2-day)	* B (unitless)	* EF (days/year)	* ED (years)	* CF (kg/mg)	/ BW (kg)	* AT (days)	* ADD (mg/kg-day)	/ RfD (mg/kg-day)	& Hazard Index
Acetone	1.76E-17	1520	0.5	0.1	350	6	1E-06	15	2190	8.55E-23	1.0E-01	8.55E-22
1,1-Dichloroethane	5.00E-03	1520	0.5	0.1	350	6	1E-06	15	2190	2.43E-08	1.0E-01	2.43E-07
1,2-Dichloroethane	4.08E-01	1520	0.5	0.1	350	6	1E-06	15	2190	1.98E-06	2.7E-02	7.34E-05
1,1-Dichloroethene	2.30E-02	1520	0.5	0.1	350	6	1E-06	15	2190	1.12E-07	9.0E-03	1.24E-05
1,2-Dichloroethene	1.00E-03	1520	0.5	0.1	350	6	1E-06	15	2190	4.86E-09	ND	ND
2-Butanone (MEK)	1.76E-17	1520	0.5	0.1	350	6	1E-06	15	2190	8.55E-23	5.0E-02	1.71E-21
Methylene Chloride	2.00E-03	1520	0.5	0.1	350	6	1E-06	15	2190	9.72E-09	6.0E-02	1.62E-07
Tetrachloroethene	9.11E+01	1520	0.5	0.1	350	6	1E-06	15	2190	4.43E-04	1.0E-02	4.43E-02
Trichloroethene	1.89E+00	1520	0.5	0.1	350	6	1E-06	15	2190	9.18E-06	1.8E-01	5.10E-05
Toluene	7.19E-05	1520	0.5	0.1	350	6	1E-06	15	2190	3.49E-10	2.0E-01	1.75E-09
1,1,1-Trichloroethane	8.03E+01	1520	0.5	0.1	350	6	1E-06	15	2190	3.90E-04	9.0E-02	4.33E-03
Xylenes	5.00E-04	1520	0.5	0.1	350	6	1E-06	15	2190	2.43E-09	2.0E+00	1.21E-09
											Total Hazard Index	5E-02

e

Representative concentrations are the 95th percent upper confidence limit of the arithmetic mean concentrations of surficial site soils samples (sample depth less than 2 feet).

ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

MK083762

MKIL206092

Future Onsite Resident (Adult)

Ingestion of Soil

Carcinogenic Effects:

Chemical	C c *	IR *	CF *	EF *	ED *	B /	BW *	AT =	LADD
	(mg chem./kg soil)	(mg soil/day)	(kg/mg)	(days/year)	(years)	(unitless)	(kg)	(days)	(mg/kg-day)
1,2-Dichloroethane	5.00E-03	100	1E-06	350	24	1	70	25550	2.35E-09
1,1-Dichloroethene	2.30E-02	100	1E-06	350	24	1	70	25550	1.08E-08
Methylene Chloride	2.00E-03	100	1E-06	350	24	1	70	25550	9.39E-10
Tetrachloroethene	4.65E-06	100	1E-06	350	24	1	70	25550	2.18E-12
Trichloroethene	1.89E+00	100	1E-06	350	24	1	70	25550	8.88E-07

Noncarcinogenic Effects:

Chemical	C c *	IR *	CF *	EF *	ED *	B /	BW *	AT =	ADD /	RfD =	Hazard Index
	(mg chem./kg soil)	(mg soil/day)	(kg/mg)	(days/year)	(years)	(unitless)	(kg)	(days)	(mg/kg-day)	(mg/kg-day)	
Acetone	1.76E-17	100	1E-06	350	24	1	70	8760	2.41E-23	1.0E-01	2.41E-22
1,1-Dichloroethane	5.00E-03	100	1E-06	350	24	1	70	8760	6.85E-09	1.0E-01	6.85E-08
1,2-Dichloroethane	4.08E-01	100	1E-06	350	24	1	70	8760	5.59E-07	2.7E-02	2.07E-05
1,1-Dichloroethene	2.30E-02	100	1E-06	350	24	1	70	8760	3.15E-08	9.0E-03	3.50E-06
1,2-Dichloroethene	1.00E-03	100	1E-06	350	24	1	70	8760	1.37E-09	ND	ND
2-Butanone (MEK)	1.76E-17	100	1E-06	350	24	1	70	8760	2.41E-23	5.0E-02	4.82E-22
Methylene Chloride	2.00E-03	100	1E-06	350	24	1	70	8760	2.74E-09	6.0E-02	4.57E-08
Tetrachloroethene	4.65E-06	100	1E-06	350	24	1	70	8760	6.37E-12	1.0E-02	6.37E-10
Trichloroethene	1.89E+00	100	1E-06	350	24	1	70	8760	2.59E-06	1.8E-01	1.44E-05
Toluene	7.19E-05	100	1E-06	350	24	1	70	8760	9.85E-11	2.0E-01	4.92E-10
1,1,1-Trichloroethane	8.03E+01	100	1E-06	350	24	1	70	8760	1.10E-04	9.0E-02	1.22E-03
Xylenes	5.00E-04	100	1E-06	350	24	1	70	8760	6.85E-10	2.0E+00	3.42E-10
										Total Hazard Index	1E-03

Chemical	Total LADD *	SF =	Cancer Risk
1,2-Dichloroethane	4.49E-07	9.1E-02	4.09E-08
1,1-Dichloroethene	3.60E-08	6.0E-01	2.16E-08
Methylene Chloride	3.13E-09	7.5E-03	2.35E-11
Tetrachloroethene	9.98E-05	5.1E-02	5.09E-06
Trichloroethene	2.96E-06	1.1E-02	3.25E-08
Total Residential Soil Ingestion Cancer Risk			5E-06

c

Representative concentrations are the 95th percent upper confidence limit of the arithmetic mean concentration of surficial soil samples (sample depth less than 2 feet).

ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

MK083763

MKIL206093

Future Onsite Resident (0-6 years of age)

Ingestion of Soil

Carcinogenic Effects:

Chemical	C e (mg chem./kg soil)	* IR (mg soil/day)	* CF (kg/mg)	* EF (days/year)	* ED (years)	* B f (unitless)	* BW (kg)	* AT (days)	= LADD (mg/kg-day)
1,2-Dichloroethane	4.08E-01	200	1E-06	350	6	1	15	25550	4.47E-07
1,1-Dichloroethene	2.30E-02	200	1E-06	350	6	1	15	25550	2.52E-08
Methylene Chloride	2.00E-03	200	1E-06	350	6	1	15	25550	2.19E-09
Tetrachloroethene	9.11E+01	200	1E-06	350	6	1	15	25550	9.98E-05
Trichloroethene	1.89E+00	200	1E-06	350	6	1	15	25550	2.07E-06

Noncarcinogenic Effects:

Chemical	C e (mg chem./kg soil)	* IR (mg soil/day)	* CF (kg/mg)	* EF (days/year)	* ED (years)	* B f (unitless)	* BW (kg)	* AT (days)	= ADD (mg/kg-day)	/ RfD g (mg/kg-day)	= Hazard Index
Acetone	1.76E-17	200	1E-06	350	6	1	15	2190	2.25E-22	1.0E-01	2.25E-21
1,1-Dichloroethane	5.00E-03	200	1E-06	350	6	1	15	2190	6.39E-08	1.0E-01	6.39E-07
1,2-Dichloroethane	4.08E-01	200	1E-06	350	6	1	15	2190	5.22E-06	2.7E-02	1.93E-04
1,1-Dichloroethene	2.30E-02	200	1E-06	350	6	1	15	2190	2.94E-07	9.0E-03	3.27E-05
1,2-Dichloroethene	1.00E-03	200	1E-06	350	6	1	15	2190	1.28E-08	ND	ND
2-Butanone (MEK)	1.76E-17	200	1E-06	350	6	1	15	2190	2.25E-22	5.0E-02	4.50E-21
Methylene Chloride	2.00E-03	200	1E-06	350	6	1	15	2190	2.56E-08	6.0E-02	4.26E-07
Tetrachloroethene	9.11E+01	200	1E-06	350	6	1	15	2190	1.16E-03	1.0E-02	1.16E-01
Trichloroethene	1.89E+00	200	1E-06	350	6	1	15	2190	2.42E-05	1.8E-01	1.34E-04
Toluene	7.19E-05	200	1E-06	350	6	1	15	2190	9.19E-10	2.0E-01	4.60E-09
1,1,1-Trichloroethane	8.03E+01	200	1E-06	350	6	1	15	2190	1.03E-03	9.0E-02	1.14E-02
Xylenes	5.00E-04	200	1E-06	350	6	1	15	2190	6.39E-09	2.0E+00	3.20E-09
										Total Hazard Index	1E-01

e

Representative concentrations are the 95th percent upper confidence limit of the arithmetic mean concentrations of surficial site soil samples (sample depth less than 2 feet).

ND- Not determined. There are no toxicity values available through Cal-EPA list, IRIS, HEAST, or CAPCOA.

MK083764

MKIL206094

Existing Off-Site and Future Onsite Resident (Adult)

Incidental Ingestion of Groundwater

Carcinogenic:

Chemical	C (mg/L)	* IR (L/day)	* EF (days/year)	* ED (years)	/ BW (kg)	* AT (days)	= LADD (mg/kg-day)
1,1,2-Trichloroethane	1.00E-03	0.05	52	24	70	25550	3.49E-08
1,1-Dichloroethene	5.00E+01	0.05	52	24	70	25550	1.74E-03
1,2-Dichloroethane	2.00E+01	0.05	52	24	70	25550	6.98E-04
Benzene	2.10E-01	0.05	52	24	70	25550	7.33E-06
Chloroform	3.40E-02	0.05	52	24	70	25550	1.19E-06
Dibromochloromethane	1.20E-02	0.05	52	24	70	25550	4.19E-07
Methylene Chloride	1.00E+02	0.05	52	24	70	25550	3.49E-03
Tetrachloroethene	4.50E+01	0.05	52	24	70	25550	1.57E-03
Trichloroethene	1.10E+01	0.05	52	24	70	25550	3.84E-04
Vinyl Chloride	7.80E-02	0.05	52	24	70	25550	2.72E-06

Noncarcinogenic:

Chemical	C (mg/L)	* IR (L/day)	* EF (days/year)	* ED (years)	/ BW (kg)	* AT (days)	= LADD (mg/kg-day)	/ RfD (mg/kg-day)	= Hazard Index
1,1,1-Trichloroethane	8.80E+01	0.05	52	24	70	8760	8.95E-03	9.00E-02	9.95E-02
1,1,2-Trichloroethane	1.00E-03	0.05	52	24	70	8760	1.02E-07	4.00E-03	2.54E-05
1,1-Dichloroethene	5.00E+01	0.05	52	24	70	8760	5.09E-03	9.00E-03	5.65E-01
1,2-Dichloroethane	2.00E+01	0.05	52	24	70	8760	2.04E-03	2.70E-02	7.54E-02
2-Butanone (MEK)	2.10E+00	0.05	52	24	70	8760	2.14E-04	5.00E-02	4.27E-03
Acetone	5.70E+00	0.05	52	24	70	8760	5.80E-04	1.00E-01	5.80E-03
Benzene	2.10E-01	0.05	52	24	70	8760	2.14E-05	2.00E-02	1.07E-03
Chloroform	3.40E-02	0.05	52	24	70	8760	3.46E-06	1.00E-02	3.46E-04
Cis-1,2-Dichloroethene	4.00E+00	0.05	52	24	70	8760	4.07E-04	1.00E-02	4.07E-02
Dibromochloromethane	1.20E-02	0.05	52	24	70	8760	1.22E-06	2.00E-02	6.11E-05
Ethylbenzene	4.40E-01	0.05	52	24	70	8760	4.48E-05	1.00E-01	4.48E-04
Manganese	9.00E-05	0.05	52	24	70	8760	9.16E-09	1.00E-01	9.16E-08
Methylene Chloride	1.00E+02	0.05	52	24	70	8760	1.02E-02	1.00E-02	1.02E+00
Tetrachloroethene	4.50E+01	0.05	52	24	70	8760	4.58E-03	1.00E-02	4.58E-01
Toluene	3.00E+00	0.05	52	24	70	8760	3.05E-04	2.00E-01	1.53E-03
Trans-1,2-Dichloroethene	8.00E-03	0.05	52	24	70	8760	8.14E-07	2.00E-02	4.07E-05
Trichloroethene	1.10E+01	0.05	52	24	70	8760	1.12E-03	1.80E-01	6.22E-03
Trichlorofluoromethane	3.60E-02	0.05	52	24	70	8760	3.66E-06	3.00E-01	1.22E-05
Vinyl Chloride	7.80E-02	0.05	52	24	70	8760	7.94E-06	ND	ND
Xylenes	1.30E+00	0.05	52	24	70	8760	1.32E-04	2.00E+00	6.61E-05
Zinc	2.62E+00	0.05	52	24	70	8760	2.67E-04	2.00E-01	1.33E-03
								Total Adult Hazard Index	2E+00

Chemical	Total LADD * (mg/kg-day)	SF (mg/kg-day)-1	= Cancer Risk
1,1,2-Trichloroethane	7.56E-08	5.70E-02	4E-09
1,1-Dichloroethene	3.78E-03	6.00E-01	2E-03
1,2-Dichloroethane	1.51E-03	9.10E-02	1E-04
Benzene	1.59E-05	2.90E-02	5E-07
Chloroform	2.57E-06	6.10E-03	2E-08
Dibromochloromethane	9.07E-07	8.40E-02	8E-08
Methylene Chloride	7.56E-03	7.50E-03	6E-05
Tetrachloroethene	3.40E-03	5.10E-02	2E-04
Trichloroethene	8.32E-04	1.10E-02	9E-06
Vinyl Chloride	5.90E-06	1.90E+00	1E-05
Total Residential Ingestion Cancer Risk			3E-03

MK083765

MKIL206095

Existing Off-Site and Future Onsite Resident (Child 0-6 years old)

Incidental Ingestion of Groundwater

Carcinogenic:

Chemical	C (mg/L)	* IR (L/day)	* EF (days/year)	* ED (years)	/ BW (kg)	* AT (days)	= LADD (mg/kg-day)
1,1,2-Trichloroethane	1.00E-03	0.05	52	6	15	25550	4.07E-08
1,1-Dichloroethane	5.00E+01	0.05	52	6	15	25550	2.04E-03
1,2-Dichloroethane	2.00E+01	0.05	52	6	15	25550	8.14E-04
Benzene	2.10E-01	0.05	52	6	15	25550	8.55E-06
Chloroform	3.40E-02	0.05	52	6	15	25550	1.38E-06
Dibromochloromethane	1.20E-02	0.05	52	6	15	25550	4.88E-07
Methylene Chloride	1.00E+02	0.05	52	6	15	25550	4.07E-03
Tetrachloroethene	4.50E+01	0.05	52	6	15	25550	1.83E-03
Trichloroethene	1.10E+01	0.05	52	6	15	25550	4.48E-04
Vinyl Chloride	7.80E-02	0.05	52	6	15	25550	3.17E-06

Noncarcinogenic:

Chemical	C (mg/L)	* IR (L/day)	* EF (days/year)	* ED (years)	/ BW (kg)	* AT (days)	= LADD (mg/kg-day)	/ RfD (mg/kg-day)	= Hazard Index
1,1,1-Trichloroethane	8.80E+01	0.05	52	6	15	2190	4.18E-02	9.00E-02	4.64E-01
1,1,2-Trichloroethane	1.00E-03	0.05	52	6	15	2190	4.75E-07	4.00E-03	1.19E-04
1,1-Dichloroethane	5.00E+01	0.05	52	6	15	2190	2.37E-02	9.00E-03	2.64E+00
1,2-Dichloroethane	2.00E+01	0.05	52	6	15	2190	9.50E-03	2.70E-02	3.52E-01
2-Butanone (MEK)	2.10E+00	0.05	52	6	15	2190	9.97E-04	5.00E-02	1.99E-02
Acetone	5.70E+00	0.05	52	6	15	2190	2.71E-03	1.00E-01	2.71E-02
Benzene	2.10E-01	0.05	52	6	15	2190	9.97E-05	2.00E-02	4.99E-03
Chloroform	3.40E-02	0.05	52	6	15	2190	1.61E-05	1.00E-02	1.61E-03
Cis-1,2-Dichloroethene	4.00E+00	0.05	52	6	15	2190	1.90E-03	1.00E-02	1.90E-01
Dibromochloromethane	1.20E-02	0.05	52	6	15	2190	5.70E-06	2.00E-02	2.85E-04
Ethylbenzene	4.40E-01	0.05	52	6	15	2190	2.09E-04	1.00E-01	2.09E-03
Manganese	9.00E-05	0.05	52	6	15	2190	4.27E-08	1.00E-01	4.27E-07
Methylene Chloride	1.00E+02	0.05	52	6	15	2190	4.75E-02	1.00E-02	4.75E+00
Tetrachloroethene	4.50E+01	0.05	52	6	15	2190	2.14E-02	1.00E-02	2.14E+00
Toluene	3.00E+00	0.05	52	6	15	2190	1.42E-03	2.00E-01	7.12E-03
Trans-1,2-Dichloroethene	8.00E-03	0.05	52	6	15	2190	3.80E-06	2.00E-02	1.90E-04
Trichloroethene	1.10E+01	0.05	52	6	15	2190	5.22E-03	1.80E-01	2.90E-02
Trichlorofluoromethane	3.60E-02	0.05	52	6	15	2190	1.71E-05	3.00E-01	5.70E-05
Vinyl Chloride	7.80E-02	0.05	52	6	15	2190	3.70E-05	ND	ND
Xylenes	1.30E+00	0.05	52	6	15	2190	6.17E-04	2.00E+00	3.09E-04
Zinc	2.62E+00	0.05	52	6	15	2190	1.24E-03	2.00E-01	6.22E-03
								Total Child Hazard Index	1E+01

MK083766

MKIL206096

Existing Off-Site and Future Onsite Resident (Adult)

Incidental Dermal Contact With Groundwater

Carcinogenic:

Chemical	C (mg/L)	* SA (cm2)	* PC (cm2/hr)	* ET (hr/day)	* EF (days/year)	* ED (years)	* CF / (L/cm3)	BW (kg)	* AT (days)	* LADD (mg/kg-day)
1,1,2-Trichloroethane	1.00E-03	3900	8.40E-04	1	52	24	1.00E-03	70	25550	2.29E-09
1,1-Dichloroethene	5.00E+01	3900	8.40E-04	1	52	24	1.00E-03	70	25550	1.14E-04
1,2-Dichloroethane	2.00E+01	3900	8.40E-04	1	52	24	1.00E-03	70	25550	4.57E-05
Benzene	2.10E-01	3900	8.40E-04	1	52	24	1.00E-03	70	25550	4.80E-07
Chloroform	3.40E-02	3900	8.40E-04	1	52	24	1.00E-03	70	25550	7.77E-08
Dibromochloromethane	1.20E-02	3900	8.40E-04	1	52	24	1.00E-03	70	25550	2.74E-08
Methylene Chloride	1.00E+02	3900	8.40E-04	1	52	24	1.00E-03	70	25550	2.29E-04
Tetrachloroethene	4.50E+01	3900	8.40E-04	1	52	24	1.00E-03	70	25550	1.03E-04
Trichloroethene	1.10E+01	3900	8.40E-04	1	52	24	1.00E-03	70	25550	2.51E-05
Vinyl Chloride	7.80E-02	3900	8.40E-04	1	52	24	1.00E-03	70	25550	1.78E-07

Noncarcinogenic:

Chemical	C (mg/L)	* SA (cm2)	* PC (cm2/hr)	* ET (hr/day)	* EF (days/year)	* ED (years)	* CF / (L/cm3)	BW (kg)	* AT (days)	* LADD / (mg/kg-day)	RfD (mg/kg-day)	* Hazard Index
1,1,1-Trichloroethane	8.80E+01	3900	8.40E-04	1	52	24	1.00E-03	70	8760	5.87E-04	9.00E-02	6.52E-03
1,1,2-Trichloroethane	1.00E-03	3900	8.40E-04	1	52	24	1.00E-03	70	8760	6.67E-09	4.00E-03	1.67E-06
1,1-Dichloroethene	5.00E+01	3900	8.40E-04	1	52	24	1.00E-03	70	8760	3.33E-04	9.00E-03	3.70E-02
1,2-Dichloroethane	2.00E+01	3900	8.40E-04	1	52	24	1.00E-03	70	8760	1.33E-04	2.70E-02	4.94E-03
2-Butanone (MEK)	2.10E+00	3900	8.40E-04	1	52	24	1.00E-03	70	8760	1.40E-05	5.00E-02	2.80E-04
Acetone	5.70E+00	3900	8.40E-04	1	52	24	1.00E-03	70	8760	3.80E-05	1.00E-01	3.80E-04
Benzene	2.10E-01	3900	8.40E-04	1	52	24	1.00E-03	70	8760	1.40E-06	2.00E-02	7.00E-05
Chloroform	3.40E-02	3900	8.40E-04	1	52	24	1.00E-03	70	8760	2.27E-07	1.00E-02	2.27E-05
Cis-1,2-Dichloroethene	4.00E+00	3900	8.40E-04	1	52	24	1.00E-03	70	8760	2.67E-05	1.00E-02	2.67E-03
Dibromochloromethane	1.20E-02	3900	8.40E-04	1	52	24	1.00E-03	70	8760	8.00E-08	2.00E-02	4.00E-06
Ethylbenzene	4.40E-01	3900	8.40E-04	1	52	24	1.00E-03	70	8760	2.93E-06	1.00E-01	2.93E-05
Manganese	9.00E-05	3900	8.40E-04	1	52	24	1.00E-03	70	8760	6.00E-10	1.00E-01	6.00E-09
Methylene Chloride	1.00E+02	3900	8.40E-04	1	52	24	1.00E-03	70	8760	6.67E-04	1.00E-02	6.67E-02
Tetrachloroethene	4.50E+01	3900	8.40E-04	1	52	24	1.00E-03	70	8760	3.00E-04	1.00E-02	3.00E-02
Toluene	3.00E+00	3900	8.40E-04	1	52	24	1.00E-03	70	8760	2.00E-05	2.00E-01	1.00E-04
Trans-1,2-Dichloroethene	8.00E-03	3900	8.40E-04	1	52	24	1.00E-03	70	8760	5.33E-08	2.00E-02	2.67E-06
Trichloroethene	1.10E+01	3900	8.40E-04	1	52	24	1.00E-03	70	8760	7.33E-05	1.00E-01	4.07E-04
Trichlorofluoromethane	3.60E-02	3900	8.40E-04	1	52	24	1.00E-03	70	8760	2.40E-07	3.00E-01	8.00E-07
Vinyl Chloride	7.80E-02	3900	8.40E-04	1	52	24	1.00E-03	70	8760	5.20E-07	ND	ND
Xylenes	1.30E+00	3900	8.40E-04	1	52	24	1.00E-03	70	8760	8.67E-06	2.00E+00	4.33E-06
Zinc	2.62E+00	3900	8.40E-04	1	52	24	1.00E-03	70	8760	1.75E-05	2.00E-01	8.73E-05
											Total Adult Hazard Index	1E-01

Chemical	Total LADD (mg/kg-day)	* SF (mg/kg-day)-1	* Cancer Risk
1,1,2-Trichloroethane	3.33E-09	5.70E-02	2E-10
1,1-Dichloroethylene	1.66E-04	6.00E-01	1E-04
1,2-Dichloroethane	6.65E-05	9.10E-02	6E-06
Benzene	6.98E-07	2.90E-02	2E-08
Chloroform	1.13E-07	6.10E-03	7E-10
Dibromochloromethane	3.99E-08	8.40E-02	3E-09
Methylene Chloride	3.33E-04	7.50E-03	2E-06
Tetrachloroethene	1.50E-04	5.10E-02	8E-06
Trichloroethene	3.66E-05	1.10E-02	4E-07
Vinyl Chloride	2.59E-07	1.90E+00	5E-07
Total Residential Dermal Contact Cancer Risk			1E-04

MK083767

MKIL206097

Existing Off-Site and Future Onsite Resident (Child 0-6 years old)

Incidental Dermal Contact With Groundwater

Carcinogenic:

Chemical	C (mg/L)	* SA (cm2)	* PC (cm2/hr)	* ET (hr/day)	* EF (day/year)	* ED (years)	* CF (L/cm3)	/ BW (kg)	* AT (days)	* LADD (mg/kg-day)
1,1,2-Trichloroethane	1.00E-03	1520	8.40E-04	1	52	6	1.00E-03	15	25550	1.04E-09
1,1-Dichloroethane	5.00E+01	1520	8.40E-04	1	52	6	1.00E-03	15	25550	5.20E-05
1,2-Dichloroethane	2.00E+01	1520	8.40E-04	1	52	6	1.00E-03	15	25550	2.08E-05
Benzene	2.10E-01	1520	8.40E-04	1	52	6	1.00E-03	15	25550	2.18E-07
Chloroform	3.40E-02	1520	8.40E-04	1	52	6	1.00E-03	15	25550	3.53E-08
Dibromochloromethane	1.20E-02	1520	8.40E-04	1	52	6	1.00E-03	15	25550	1.25E-08
Methylene Chloride	1.00E+02	1520	8.40E-04	1	52	6	1.00E-03	15	25550	1.04E-04
Tetrachloroethene	4.50E+01	1520	8.40E-04	1	52	6	1.00E-03	15	25550	4.68E-05
Trichloroethene	1.10E+01	1520	8.40E-04	1	52	6	1.00E-03	15	25550	1.14E-05
Vinyl Chloride	7.80E-02	1520	8.40E-04	1	52	6	1.00E-03	15	25550	8.11E-08

Noncarcinogenic:

Chemical	C (mg/L)	* SA (cm2)	* PC (cm2/hr)	* ET (hr/day)	* EF (day/year)	* ED (years)	* CF (L/cm3)	/ BW (kg)	* AT (days)	= LADD (mg/kg-day)	/ RfD (mg/kg-day)	= Hazard Index
1,1,1-Trichloroethane	8.80E+01	1520	8.40E-04	1	52	6	1.00E-03	15	2190	1.07E-03	9.00E-02	1.19E-02
1,1,2-Trichloroethane	1.00E-03	1520	8.40E-04	1	52	6	1.00E-03	15	2190	1.21E-08	4.00E-03	3.03E-06
1,1-Dichloroethane	5.00E+01	1520	8.40E-04	1	52	6	1.00E-03	15	2190	6.06E-04	9.00E-03	6.74E-02
1,2-Dichloroethane	2.00E+01	1520	8.40E-04	1	52	6	1.00E-03	15	2190	2.43E-04	2.70E-02	8.98E-03
2-Butanone (MEK)	2.10E+00	1520	8.40E-04	1	52	6	1.00E-03	15	2190	2.55E-05	5.00E-02	5.09E-04
Acetone	5.70E+00	1520	8.40E-04	1	52	6	1.00E-03	15	2190	6.91E-05	1.00E-01	6.91E-04
Benzene	2.10E-01	1520	8.40E-04	1	52	6	1.00E-03	15	2190	2.55E-06	2.00E-02	1.27E-04
Chloroform	3.40E-02	1520	8.40E-04	1	52	6	1.00E-03	15	2190	4.12E-07	1.00E-02	4.12E-05
Cis-1,2-Dichloroethene	4.00E+00	1520	8.40E-04	1	52	6	1.00E-03	15	2190	4.85E-05	1.00E-02	4.85E-03
Dibromochloromethane	1.20E-02	1520	8.40E-04	1	52	6	1.00E-03	15	2190	1.46E-07	2.00E-02	7.28E-06
Ethylbenzene	4.40E-01	1520	8.40E-04	1	52	6	1.00E-03	15	2190	5.34E-06	1.00E-01	5.34E-05
Manganese	9.00E-05	1520	8.40E-04	1	52	6	1.00E-03	15	2190	1.09E-09	1.00E-01	1.09E-08
Methylene Chloride	1.00E+02	1520	8.40E-04	1	52	6	1.00E-03	15	2190	1.21E-03	1.00E-02	1.21E-01
Tetrachloroethene	4.50E+01	1520	8.40E-04	1	52	6	1.00E-03	15	2190	5.46E-04	1.00E-02	5.46E-02
Toluene	3.00E+00	1520	8.40E-04	1	52	6	1.00E-03	15	2190	3.64E-05	2.00E-01	1.82E-04
Trans-1,2-Dichloroethene	8.00E-03	1520	8.40E-04	1	52	6	1.00E-03	15	2190	9.70E-08	2.00E-02	4.85E-06
Trichloroethene	1.10E+01	1520	8.40E-04	1	52	6	1.00E-03	15	2190	1.33E-04	1.00E-01	7.41E-04
Trichlorofluoromethane	3.60E-02	1520	8.40E-04	1	52	6	1.00E-03	15	2190	4.37E-07	3.00E-01	1.46E-06
Vinyl Chloride	7.80E-02	1520	8.40E-04	1	52	6	1.00E-03	15	2190	9.46E-07	ND	ND
Xylenes	1.30E+00	1520	8.40E-04	1	52	6	1.00E-03	15	2190	1.58E-05	2.00E+00	7.88E-06
Zinc	2.62E+00	1520	8.40E-04	1	52	6	1.00E-03	15	2190	3.18E-05	2.00E-01	1.59E-04
											Total Child Hazard Index	3E-01

MK083768

MKIL206098

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC initial	C final
Acetone	1.92E-02	36.09375	1	36.09375	-0.69314718	1.06E-16
	1.92E-02	36.09375	2	72.1875	-36.7088972	4.71E-48
	1.92E-02	36.09375	3	108.28125	-108.974397	4.44E-95
	1.92E-02	36.09375	4	144.375	-217.255647	8.83E-158
	1.92E-02	36.09375	5	180.46875	-217.255647	1.86E-173
	1.92E-02	36.09375	6	216.5625	-397.724397	1.65E-267
	1.92E-02	36.09375	7	252.65625	-614.286897	0.00E+00
	1.92E-02	36.09375	8	288.75	#NUM!	#NUM!
	1.92E-02	36.09375	9	324.84375	#NUM!	#NUM!
	1.92E-02	36.09375	10	360.9375	#NUM!	#NUM!
	1.92E-02	36.09375	11	397.03125	#NUM!	#NUM!
	1.92E-02	36.09375	12	433.125	#NUM!	#NUM!
	1.92E-02	36.09375	13	469.21875	#NUM!	#NUM!
	1.92E-02	36.09375	14	505.3125	#NUM!	#NUM!
	1.92E-02	36.09375	15	541.40625	#NUM!	#NUM!
	1.92E-02	36.09375	16	577.5	#NUM!	#NUM!
	1.92E-02	36.09375	17	613.59375	#NUM!	#NUM!
	1.92E-02	36.09375	18	649.6875	#NUM!	#NUM!
	1.92E-02	36.09375	19	685.78125	#NUM!	#NUM!
	1.92E-02	36.09375	20	721.875	#NUM!	#NUM!
	1.92E-02	36.09375	21	757.96875	#NUM!	#NUM!
	1.92E-02	36.09375	22	794.0625	#NUM!	#NUM!
	1.92E-02	36.09375	23	830.15625	#NUM!	#NUM!
	1.92E-02	36.09375	24	866.25	#NUM!	#NUM!
	1.92E-02	36.09375	25	902.34375	#NUM!	#NUM!
	1.92E-02	36.09375	26	938.4375	#NUM!	#NUM!
	1.92E-02	36.09375	27	974.53125	#NUM!	#NUM!
	1.92E-02	36.09375	28	1010.625	#NUM!	#NUM!
	1.92E-02	36.09375	29	1046.7188	#NUM!	#NUM!
	1.92E-02	36.09375	30	1082.8125	#NUM!	#NUM!
	1.92E-02	36.09375	31	1118.9063	#NUM!	#NUM!
	1.92E-02	36.09375	32	1155	#NUM!	#NUM!
	1.92E-02	36.09375	33	1191.0938	#NUM!	#NUM!
	1.92E-02	36.09375	34	1227.1875	#NUM!	#NUM!
	1.92E-02	36.09375	35	1263.2813	#NUM!	#NUM!
	1.92E-02	36.09375	36	1299.375	#NUM!	#NUM!
	1.92E-02	36.09375	37	1335.4688	#NUM!	#NUM!
	1.92E-02	36.09375	38	1371.5625	#NUM!	#NUM!
	1.92E-02	36.09375	39	1407.6563	#NUM!	#NUM!
	1.92E-02	36.09375	40	1443.75	#NUM!	#NUM!
	1.92E-02	36.09375	41	1479.8438	#NUM!	#NUM!
	1.92E-02	36.09375	42	1515.9375	#NUM!	#NUM!
	1.92E-02	36.09375	43	1552.0313	#NUM!	#NUM!
	1.92E-02	36.09375	44	1588.125	#NUM!	#NUM!
	1.92E-02	36.09375	45	1624.2188	#NUM!	#NUM!
	1.92E-02	36.09375	46	1660.3125	#NUM!	#NUM!
	1.92E-02	36.09375	47	1696.4063	#NUM!	#NUM!
	1.92E-02	36.09375	48	1732.5	#NUM!	#NUM!
	1.92E-02	36.09375	49	1768.5938	#NUM!	#NUM!
	1.92E-02	36.09375	50	1804.6875	#NUM!	#NUM!
	1.92E-02	36.09375	51	1840.7813	#NUM!	#NUM!
	1.92E-02	36.09375	52	1876.875	#NUM!	#NUM!
	1.92E-02	36.09375	53	1912.9688	#NUM!	#NUM!
	1.92E-02	36.09375	54	1949.0625	#NUM!	#NUM!
	1.92E-02	36.09375	55	1985.1563	#NUM!	#NUM!
	1.92E-02	36.09375	56	2021.25	#NUM!	#NUM!
	1.92E-02	36.09375	57	2057.3438	#NUM!	#NUM!
	1.92E-02	36.09375	58	2093.4375	#NUM!	#NUM!
	1.92E-02	36.09375	59	2129.5313	#NUM!	#NUM!
	1.92E-02	36.09375	60	2165.625	#NUM!	#NUM!
	1.92E-02	36.09375	61	2201.7188	#NUM!	#NUM!
	1.92E-02	36.09375	62	2237.8125	#NUM!	#NUM!
	1.92E-02	36.09375	63	2273.9063	#NUM!	#NUM!
	1.92E-02	36.09375	64	2310	#NUM!	#NUM!
	1.92E-02	36.09375	65	2346.0938	#NUM!	#NUM!
	1.92E-02	36.09375	66	2382.1875	#NUM!	#NUM!
	1.92E-02	36.09375	67	2418.2813	#NUM!	#NUM!
	1.92E-02	36.09375	68	2454.375	#NUM!	#NUM!
	1.92E-02	36.09375	69	2490.4688	#NUM!	#NUM!
	1.92E-02	36.09375	70	2526.5625	#NUM!	#NUM!
	1.92E-02	36.09375	70	2526.5625	#NUM!	#NUM!

Concentration	
1.76E-17	Average (child)
Will Use Same	Average (adult)

MK083769

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (init)	C final
1,1-Dichloroethane	4.22E-01	1.642180095	1	1.6421801	-2.57702194	1.47E-02
	4.22E-01	1.642180095	2	3.2843602	-4.21920203	5.51E-04
	4.22E-01	1.642180095	3	4.9265403	-7.55556222	4.00E-06
	4.22E-01	1.642180095	4	6.5687204	-12.43501025	5.61E-09
	4.22E-01	1.642180095	5	8.2109005	4.00840834	1.50E-02
	4.22E-01	1.642180095	6	9.8530806	-4.20249514	7.87E-07
	4.22E-01	1.642180095	7	11.495261	-14.0555757	8.01E-12
	4.22E-01	1.642180095	8	13.137441	-25.5508364	1.58E-17
	4.22E-01	1.642180095	9	14.779621	-38.6882771	6.01E-24
	4.22E-01	1.642180095	10	16.421801	-53.447898	4.44E-31
	4.22E-01	1.642180095	11	18.063981	-69.8896809	6.34E-39
	4.22E-01	1.642180095	12	19.706161	-87.95348	1.75E-47
	4.22E-01	1.642180095	13	21.348341	-107.659841	9.39E-57
	4.22E-01	1.642180095	14	22.990521	-129.008182	9.72E-67
	4.22E-01	1.642180095	15	24.632701	-151.998704	1.95E-77
	4.22E-01	1.642180095	16	26.274882	-176.631405	7.57E-89
	4.22E-01	1.642180095	17	27.917062	-176.631405	1.46E-89
	4.22E-01	1.642180095	18	29.559242	-204.548467	2.13E-102
	4.22E-01	1.642180095	19	31.201422	-234.107708	5.99E-116
	4.22E-01	1.642180095	20	32.843602	-265.30913	3.27E-130
	4.22E-01	1.642180095	21	34.485782	-298.152732	3.44E-145
	4.22E-01	1.642180095	22	36.127962	-332.638514	7.05E-161
	4.22E-01	1.642180095	23	37.770142	-368.766476	2.78E-177
	4.22E-01	1.642180095	24	39.412322	-406.536618	2.12E-194
	4.22E-01	1.642180095	25	41.054502	-445.948941	3.14E-212
	4.22E-01	1.642180095	26	42.696682	-487.003443	9.00E-231
	4.22E-01	1.642180095	27	44.338863	-529.700125	4.99E-250
	4.22E-01	1.642180095	28	45.981043	-574.038988	5.35E-270
	4.22E-01	1.642180095	29	47.623223	-620.020031	1.11E-290
	4.22E-01	1.642180095	30	49.265403	-667.643253	0.00E+00
	4.22E-01	1.642180095	31	50.907583	#NUM!	#NUM!
	4.22E-01	1.642180095	32	52.549763	#NUM!	#NUM!
	4.22E-01	1.642180095	33	54.191943	#NUM!	#NUM!
	4.22E-01	1.642180095	34	55.834123	#NUM!	#NUM!
	4.22E-01	1.642180095	35	57.476303	#NUM!	#NUM!
	4.22E-01	1.642180095	36	59.118483	#NUM!	#NUM!
	4.22E-01	1.642180095	37	60.760664	#NUM!	#NUM!
	4.22E-01	1.642180095	38	62.402844	#NUM!	#NUM!
	4.22E-01	1.642180095	39	64.045024	#NUM!	#NUM!
	4.22E-01	1.642180095	40	65.687204	#NUM!	#NUM!
	4.22E-01	1.642180095	41	67.329384	#NUM!	#NUM!
	4.22E-01	1.642180095	42	68.971564	#NUM!	#NUM!
	4.22E-01	1.642180095	43	70.613744	#NUM!	#NUM!
	4.22E-01	1.642180095	44	72.255924	#NUM!	#NUM!
	4.22E-01	1.642180095	45	73.898104	#NUM!	#NUM!
	4.22E-01	1.642180095	46	75.540284	#NUM!	#NUM!
	4.22E-01	1.642180095	47	77.182464	#NUM!	#NUM!
	4.22E-01	1.642180095	48	78.824645	#NUM!	#NUM!
	4.22E-01	1.642180095	49	80.466825	#NUM!	#NUM!
	4.22E-01	1.642180095	50	82.109005	#NUM!	#NUM!
	4.22E-01	1.642180095	51	83.751185	#NUM!	#NUM!
	4.22E-01	1.642180095	52	85.393365	#NUM!	#NUM!
	4.22E-01	1.642180095	53	87.035545	#NUM!	#NUM!
	4.22E-01	1.642180095	54	88.677725	#NUM!	#NUM!
	4.22E-01	1.642180095	55	90.319905	#NUM!	#NUM!
	4.22E-01	1.642180095	56	91.962085	#NUM!	#NUM!
	4.22E-01	1.642180095	57	93.604265	#NUM!	#NUM!
	4.22E-01	1.642180095	58	95.246445	#NUM!	#NUM!
	4.22E-01	1.642180095	59	96.888626	#NUM!	#NUM!
	4.22E-01	1.642180095	60	98.530806	#NUM!	#NUM!
	4.22E-01	1.642180095	61	100.17299	#NUM!	#NUM!
	4.22E-01	1.642180095	62	101.81517	#NUM!	#NUM!
	4.22E-01	1.642180095	63	103.45735	#NUM!	#NUM!
	4.22E-01	1.642180095	64	105.09953	#NUM!	#NUM!
	4.22E-01	1.642180095	65	106.74171	#NUM!	#NUM!
	4.22E-01	1.642180095	66	108.38389	#NUM!	#NUM!
	4.22E-01	1.642180095	67	110.02607	#NUM!	#NUM!
	4.22E-01	1.642180095	68	111.66825	#NUM!	#NUM!
	4.22E-01	1.642180095	69	113.31043	#NUM!	#NUM!
	4.22E-01	1.642180095	70	114.95261	#NUM!	#NUM!
	4.22E-01	1.642180095	70	114.95261	#NUM!	#NUM!

Concentration	
0.00503742	Average (child)
Will Use Same	Average (adult)

MK083770

MKIL206100

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (initial)	C (final)
1,2-Dichloroethane	4.93E-01	1.405679513	1	1.4056795	2.24283509	2.31E+00
	4.93E-01	1.405679513	2	2.811359	0.83715558	1.39E-01
	4.93E-01	1.405679513	3	4.2170385	-1.97420345	2.05E-03
	4.93E-01	1.405679513	4	5.6227181	-6.19124199	7.40E-06
	4.93E-01	1.405679513	5	7.0283976	-11.81396	6.56E-09
	4.93E-01	1.405679513	6	8.4340771	-18.8423576	1.43E-12
	4.93E-01	1.405679513	7	9.8397566	-27.2764347	7.60E-17
	4.93E-01	1.405679513	8	11.245436	-37.1161913	9.95E-22
	4.93E-01	1.405679513	9	12.651116	-48.3616274	3.18E-27
	4.93E-01	1.405679513	10	14.056795	-61.012743	2.50E-33
	4.93E-01	1.405679513	11	15.462475	-75.0885381	4.81E-40
	4.93E-01	1.405679513	12	16.868154	-90.5320128	2.27E-47
	4.93E-01	1.405679513	13	18.273834	-107.400167	2.63E-55
	4.93E-01	1.405679513	14	19.679513	-125.674001	7.48E-64
	4.93E-01	1.405679513	15	21.085193	-145.353514	5.21E-73
	4.93E-01	1.405679513	16	22.490872	-166.438706	8.89E-83
	4.93E-01	1.405679513	17	23.896552	-166.438706	2.18E-83
	4.93E-01	1.405679513	18	25.302231	-190.335258	2.24E-94
	4.93E-01	1.405679513	19	26.707911	-215.637489	5.63E-106
	4.93E-01	1.405679513	20	28.11359	-242.3454	3.48E-118
	4.93E-01	1.405679513	21	29.51927	-270.45899	5.26E-131
	4.93E-01	1.405679513	22	30.924949	-299.97826	1.95E-144
	4.93E-01	1.405679513	23	32.330629	-330.90321	1.78E-158
	4.93E-01	1.405679513	24	33.736308	-363.233838	3.96E-173
	4.93E-01	1.405679513	25	35.141988	-396.970147	2.17E-188
	4.93E-01	1.405679513	26	36.547667	-432.112134	2.91E-204
	4.93E-01	1.405679513	27	37.953347	-468.659802	9.57E-221
	4.93E-01	1.405679513	28	39.359026	-506.613149	7.71E-238
	4.93E-01	1.405679513	29	40.764706	-545.972175	1.53E-255
	4.93E-01	1.405679513	30	42.170385	-586.736881	7.40E-274
	4.93E-01	1.405679513	31	43.576065	-628.907266	8.79E-293
	4.93E-01	1.405679513	32	44.981744	-672.483331	0.00E+00
	4.93E-01	1.405679513	33	46.387424	#NUM!	#NUM!
	4.93E-01	1.405679513	34	47.793103	#NUM!	#NUM!
	4.93E-01	1.405679513	35	49.198783	#NUM!	#NUM!
	4.93E-01	1.405679513	36	50.604462	#NUM!	#NUM!
	4.93E-01	1.405679513	37	52.010142	#NUM!	#NUM!
	4.93E-01	1.405679513	38	53.415822	#NUM!	#NUM!
	4.93E-01	1.405679513	39	54.821501	#NUM!	#NUM!
	4.93E-01	1.405679513	40	56.227181	#NUM!	#NUM!
	4.93E-01	1.405679513	41	57.63286	#NUM!	#NUM!
	4.93E-01	1.405679513	42	59.03854	#NUM!	#NUM!
	4.93E-01	1.405679513	43	60.444219	#NUM!	#NUM!
	4.93E-01	1.405679513	44	61.849899	#NUM!	#NUM!
	4.93E-01	1.405679513	45	63.255578	#NUM!	#NUM!
	4.93E-01	1.405679513	46	64.661258	#NUM!	#NUM!
	4.93E-01	1.405679513	47	66.066937	#NUM!	#NUM!
	4.93E-01	1.405679513	48	67.472617	#NUM!	#NUM!
	4.93E-01	1.405679513	49	68.878296	#NUM!	#NUM!
	4.93E-01	1.405679513	50	70.283976	#NUM!	#NUM!
	4.93E-01	1.405679513	51	71.689655	#NUM!	#NUM!
	4.93E-01	1.405679513	52	73.095335	#NUM!	#NUM!
	4.93E-01	1.405679513	53	74.501014	#NUM!	#NUM!
	4.93E-01	1.405679513	54	75.906694	#NUM!	#NUM!
	4.93E-01	1.405679513	55	77.312373	#NUM!	#NUM!
	4.93E-01	1.405679513	56	78.718053	#NUM!	#NUM!
	4.93E-01	1.405679513	57	80.123732	#NUM!	#NUM!
	4.93E-01	1.405679513	58	81.529412	#NUM!	#NUM!
	4.93E-01	1.405679513	59	82.935091	#NUM!	#NUM!
	4.93E-01	1.405679513	60	84.340771	#NUM!	#NUM!
	4.93E-01	1.405679513	61	85.74645	#NUM!	#NUM!
	4.93E-01	1.405679513	62	87.15213	#NUM!	#NUM!
	4.93E-01	1.405679513	63	88.557809	#NUM!	#NUM!
	4.93E-01	1.405679513	64	89.963489	#NUM!	#NUM!
	4.93E-01	1.405679513	65	91.369168	#NUM!	#NUM!
	4.93E-01	1.405679513	66	92.774848	#NUM!	#NUM!
	4.93E-01	1.405679513	67	94.180527	#NUM!	#NUM!
	4.93E-01	1.405679513	68	95.586207	#NUM!	#NUM!
	4.93E-01	1.405679513	69	96.991886	#NUM!	#NUM!
	4.93E-01	1.405679513	70	98.397566	#NUM!	#NUM!
	4.93E-01	1.405679513	70	98.397566	#NUM!	#NUM!

Concentration	
0.40845236	Average (child)
Will use same	Average (adult)

MK083771

MKIL206101

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC initial	C final
1,1-Dichloroethane	4.93E-01	1.405679513	1	1.4056795	-1.07880966	8.34E-02
	4.93E-01	1.405679513	2	2.811359	-2.48448917	5.01E-03
	4.93E-01	1.405679513	3	4.2170385	-5.2958482	7.39E-05
	4.93E-01	1.405679513	4	5.6227181	-9.51288674	2.67E-07
	4.93E-01	1.405679513	5	7.0283976	4.00840534	4.88E-02
	4.93E-01	1.405679513	6	8.4340771	-3.01999223	1.08E-05
	4.93E-01	1.405679513	7	9.8397566	-11.4540893	5.65E-10
	4.93E-01	1.405679513	8	11.245436	-21.2958259	7.39E-15
	4.93E-01	1.405679513	9	12.651116	-32.539262	2.57E-20
	4.93E-01	1.405679513	10	14.056795	-45.1908776	1.84E-26
	4.93E-01	1.405679513	11	15.462475	-59.3471728	3.38E-33
	4.93E-01	1.405679513	12	16.868154	-74.7086474	1.88E-40
	4.93E-01	1.405679513	13	18.273834	-91.5778016	1.94E-48
	4.93E-01	1.405679513	14	19.679513	-109.851635	5.54E-57
	4.93E-01	1.405679513	15	21.085193	-129.531148	3.87E-66
	4.93E-01	1.405679513	16	22.490872	-150.616341	6.61E-76
	4.93E-01	1.405679513	17	23.896552	-150.616341	1.62E-76
	4.93E-01	1.405679513	18	25.302231	-174.512893	1.46E-87
	4.93E-01	1.405679513	19	26.707911	-199.815124	4.19E-99
	4.93E-01	1.405679513	20	28.11359	-226.529035	2.58E-111
	4.93E-01	1.405679513	21	29.51927	-254.636625	3.91E-124
	4.93E-01	1.405679513	22	30.924949	-284.155895	1.45E-137
	4.93E-01	1.405679513	23	32.330629	-315.080844	1.32E-151
	4.93E-01	1.405679513	24	33.736308	-347.411473	2.95E-166
	4.93E-01	1.405679513	25	35.141988	-381.147781	1.61E-181
	4.93E-01	1.405679513	26	36.547667	-416.289769	2.16E-197
	4.93E-01	1.405679513	27	37.953347	-452.837436	7.12E-214
	4.93E-01	1.405679513	28	39.359026	-490.790783	5.74E-231
	4.93E-01	1.405679513	29	40.764706	-530.14981	1.13E-248
	4.93E-01	1.405679513	30	42.170385	-570.914516	5.90E-267
	4.93E-01	1.405679513	31	43.576065	-613.084901	6.34E-286
	4.93E-01	1.405679513	32	44.981744	-656.660966	1.91E-305
	4.93E-01	1.405679513	33	46.387424	-701.64271	0.00E+00
	4.93E-01	1.405679513	34	47.793103	#NUM!	#NUM!
	4.93E-01	1.405679513	35	49.198783	#NUM!	#NUM!
	4.93E-01	1.405679513	36	50.604462	#NUM!	#NUM!
	4.93E-01	1.405679513	37	52.010142	#NUM!	#NUM!
	4.93E-01	1.405679513	38	53.415822	#NUM!	#NUM!
	4.93E-01	1.405679513	39	54.821501	#NUM!	#NUM!
	4.93E-01	1.405679513	40	56.227181	#NUM!	#NUM!
	4.93E-01	1.405679513	41	57.63286	#NUM!	#NUM!
	4.93E-01	1.405679513	42	59.03854	#NUM!	#NUM!
	4.93E-01	1.405679513	43	60.444219	#NUM!	#NUM!
	4.93E-01	1.405679513	44	61.849899	#NUM!	#NUM!
	4.93E-01	1.405679513	45	63.255578	#NUM!	#NUM!
	4.93E-01	1.405679513	46	64.661258	#NUM!	#NUM!
	4.93E-01	1.405679513	47	66.066937	#NUM!	#NUM!
	4.93E-01	1.405679513	48	67.472617	#NUM!	#NUM!
	4.93E-01	1.405679513	49	68.878296	#NUM!	#NUM!
	4.93E-01	1.405679513	50	70.283976	#NUM!	#NUM!
	4.93E-01	1.405679513	51	71.689655	#NUM!	#NUM!
	4.93E-01	1.405679513	52	73.095335	#NUM!	#NUM!
	4.93E-01	1.405679513	53	74.501014	#NUM!	#NUM!
	4.93E-01	1.405679513	54	75.906694	#NUM!	#NUM!
	4.93E-01	1.405679513	55	77.312373	#NUM!	#NUM!
	4.93E-01	1.405679513	56	78.718053	#NUM!	#NUM!
	4.93E-01	1.405679513	57	80.123732	#NUM!	#NUM!
	4.93E-01	1.405679513	58	81.529412	#NUM!	#NUM!
	4.93E-01	1.405679513	59	82.935091	#NUM!	#NUM!
	4.93E-01	1.405679513	60	84.340771	#NUM!	#NUM!
	4.93E-01	1.405679513	61	85.74645	#NUM!	#NUM!
	4.93E-01	1.405679513	62	87.15213	#NUM!	#NUM!
	4.93E-01	1.405679513	63	88.557809	#NUM!	#NUM!
	4.93E-01	1.405679513	64	89.963489	#NUM!	#NUM!
	4.93E-01	1.405679513	65	91.369168	#NUM!	#NUM!
	4.93E-01	1.405679513	66	92.774848	#NUM!	#NUM!
	4.93E-01	1.405679513	67	94.180527	#NUM!	#NUM!
	4.93E-01	1.405679513	68	95.586207	#NUM!	#NUM!
	4.93E-01	1.405679513	69	96.991886	#NUM!	#NUM!
	4.93E-01	1.405679513	70	98.397566	#NUM!	#NUM!
	4.93E-01	1.405679513	70	98.397566	#NUM!	#NUM!

Concentration	
0.02287781	Average (child)
Will Use Same	Average (adult)

MK083772

MKIL206102

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (initial	C final
1,2-Dichloroethane	4.93E-01	1.405679513	1	1.4056795	-3.48887945	6.13E-03
	4.93E-01	1.405679513	2	2.811359	-5.09455897	3.69E-04
	4.93E-01	1.405679513	3	4.2170385	-7.90591799	5.43E-06
	4.93E-01	1.405679513	4	5.6227181	-12.1220565	1.94E-08
	4.93E-01	1.405679513	5	7.0283976	-17.7436746	1.74E-11
	4.93E-01	1.405679513	6	8.4340771	-24.7740722	3.78E-15
	4.93E-01	1.405679513	7	9.8397566	-33.2081492	2.02E-19
	4.93E-01	1.405679513	8	11.245436	-43.0679058	2.63E-24
	4.93E-01	1.405679513	9	12.651116	-54.2933419	8.44E-30
	4.93E-01	1.405679513	10	14.056795	-66.9444575	6.63E-36
	4.93E-01	1.405679513	11	15.462475	-81.0012527	1.28E-42
	4.93E-01	1.405679513	12	16.868154	-96.4637273	6.03E-50
	4.93E-01	1.405679513	13	18.273834	-113.331881	6.99E-58
	4.93E-01	1.405679513	14	19.679513	-131.605715	1.98E-66
	4.93E-01	1.405679513	15	21.085193	-151.285228	1.38E-75
	4.93E-01	1.405679513	16	22.490872	-172.370421	2.34E-85
	4.93E-01	1.405679513	17	23.896552	-172.370421	5.79E-96
	4.93E-01	1.405679513	18	25.302231	-196.266973	5.94E-97
	4.93E-01	1.405679513	19	26.707911	-221.569204	1.49E-108
	4.93E-01	1.405679513	20	28.11359	-248.277115	9.23E-121
	4.93E-01	1.405679513	21	29.51927	-276.390705	1.40E-133
	4.93E-01	1.405679513	22	30.924949	-305.909975	5.18E-147
	4.93E-01	1.405679513	23	32.330629	-336.834924	4.71E-161
	4.93E-01	1.405679513	24	33.736308	-369.165553	1.05E-175
	4.93E-01	1.405679513	25	35.141988	-402.901861	5.75E-191
	4.93E-01	1.405679513	26	36.547667	-438.043849	7.72E-207
	4.93E-01	1.405679513	27	37.953347	-474.591516	2.54E-223
	4.93E-01	1.405679513	28	39.359026	-512.544863	2.05E-240
	4.93E-01	1.405679513	29	40.764706	-551.90389	4.05E-258
	4.93E-01	1.405679513	30	42.170385	-592.668595	1.96E-276
	4.93E-01	1.405679513	31	43.576065	-634.838981	2.33E-295
	4.93E-01	1.405679513	32	44.981744	-678.415046	0.00E+00
	4.93E-01	1.405679513	33	46.387424	#NUM!	#NUM!
	4.93E-01	1.405679513	34	47.793103	#NUM!	#NUM!
	4.93E-01	1.405679513	35	49.198783	#NUM!	#NUM!
	4.93E-01	1.405679513	36	50.604462	#NUM!	#NUM!
	4.93E-01	1.405679513	37	52.010142	#NUM!	#NUM!
	4.93E-01	1.405679513	38	53.415822	#NUM!	#NUM!
	4.93E-01	1.405679513	39	54.821501	#NUM!	#NUM!
	4.93E-01	1.405679513	40	56.227181	#NUM!	#NUM!
	4.93E-01	1.405679513	41	57.63286	#NUM!	#NUM!
	4.93E-01	1.405679513	42	59.03854	#NUM!	#NUM!
	4.93E-01	1.405679513	43	60.444219	#NUM!	#NUM!
	4.93E-01	1.405679513	44	61.849899	#NUM!	#NUM!
	4.93E-01	1.405679513	45	63.255578	#NUM!	#NUM!
	4.93E-01	1.405679513	46	64.661258	#NUM!	#NUM!
	4.93E-01	1.405679513	47	66.066937	#NUM!	#NUM!
	4.93E-01	1.405679513	48	67.472617	#NUM!	#NUM!
	4.93E-01	1.405679513	49	68.878296	#NUM!	#NUM!
	4.93E-01	1.405679513	50	70.283976	#NUM!	#NUM!
	4.93E-01	1.405679513	51	71.689655	#NUM!	#NUM!
	4.93E-01	1.405679513	52	73.095335	#NUM!	#NUM!
	4.93E-01	1.405679513	53	74.501014	#NUM!	#NUM!
	4.93E-01	1.405679513	54	75.906694	#NUM!	#NUM!
	4.93E-01	1.405679513	55	77.312373	#NUM!	#NUM!
	4.93E-01	1.405679513	56	78.718053	#NUM!	#NUM!
	4.93E-01	1.405679513	57	80.123732	#NUM!	#NUM!
	4.93E-01	1.405679513	58	81.529412	#NUM!	#NUM!
	4.93E-01	1.405679513	59	82.935091	#NUM!	#NUM!
	4.93E-01	1.405679513	60	84.340771	#NUM!	#NUM!
	4.93E-01	1.405679513	61	85.74645	#NUM!	#NUM!
	4.93E-01	1.405679513	62	87.15213	#NUM!	#NUM!
	4.93E-01	1.405679513	63	88.557809	#NUM!	#NUM!
	4.93E-01	1.405679513	64	89.963489	#NUM!	#NUM!
	4.93E-01	1.405679513	65	91.369168	#NUM!	#NUM!
	4.93E-01	1.405679513	66	92.774848	#NUM!	#NUM!
	4.93E-01	1.405679513	67	94.180527	#NUM!	#NUM!
	4.93E-01	1.405679513	68	95.586207	#NUM!	#NUM!
	4.93E-01	1.405679513	69	96.991886	#NUM!	#NUM!
	4.93E-01	1.405679513	70	98.397566	#NUM!	#NUM!
	4.93E-01	1.405679513	70	98.397566	#NUM!	#NUM!

Concentration	
0.001084	Average (child)
#NUM!	Average (adult)

MK083773

MKIL206103

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (initial	C final
2-Butanone (MEK)	1.92E-02	36.09375	1	36.09375	-0.69314718	1.08E-16
	1.92E-02	36.09375	2	72.1875	-36.7969972	4.71E-48
	1.92E-02	36.09375	3	108.28125	-108.974397	4.44E-95
	1.92E-02	36.09375	4	144.375	-217.255647	8.83E-158
	1.92E-02	36.09375	5	180.46875	-361.430647	3.71E-236
	1.92E-02	36.09375	6	216.5625	-542.099397	0.00E+00
	1.92E-02	36.09375	7	252.65625	#NUM!	#NUM!
	1.92E-02	36.09375	8	288.75	#NUM!	#NUM!
	1.92E-02	36.09375	9	324.84375	#NUM!	#NUM!
	1.92E-02	36.09375	10	360.9375	#NUM!	#NUM!
	1.92E-02	36.09375	11	397.03125	#NUM!	#NUM!
	1.92E-02	36.09375	12	433.125	#NUM!	#NUM!
	1.92E-02	36.09375	13	469.21875	#NUM!	#NUM!
	1.92E-02	36.09375	14	505.3125	#NUM!	#NUM!
	1.92E-02	36.09375	15	541.40625	#NUM!	#NUM!
	1.92E-02	36.09375	16	577.5	#NUM!	#NUM!
	1.92E-02	36.09375	17	613.59375	#NUM!	#NUM!
	1.92E-02	36.09375	18	649.6875	#NUM!	#NUM!
	1.92E-02	36.09375	19	685.78125	#NUM!	#NUM!
	1.92E-02	36.09375	20	721.875	#NUM!	#NUM!
	1.92E-02	36.09375	21	757.96875	#NUM!	#NUM!
	1.92E-02	36.09375	22	794.0625	#NUM!	#NUM!
	1.92E-02	36.09375	23	830.15625	#NUM!	#NUM!
	1.92E-02	36.09375	24	866.25	#NUM!	#NUM!
	1.92E-02	36.09375	25	902.34375	#NUM!	#NUM!
	1.92E-02	36.09375	26	938.4375	#NUM!	#NUM!
	1.92E-02	36.09375	27	974.53125	#NUM!	#NUM!
	1.92E-02	36.09375	28	1010.625	#NUM!	#NUM!
	1.92E-02	36.09375	29	1046.7188	#NUM!	#NUM!
	1.92E-02	36.09375	30	1082.8125	#NUM!	#NUM!
	1.92E-02	36.09375	31	1118.9063	#NUM!	#NUM!
	1.92E-02	36.09375	32	1155	#NUM!	#NUM!
	1.92E-02	36.09375	33	1191.0938	#NUM!	#NUM!
	1.92E-02	36.09375	34	1227.1875	#NUM!	#NUM!
	1.92E-02	36.09375	35	1263.2813	#NUM!	#NUM!
	1.92E-02	36.09375	36	1299.375	#NUM!	#NUM!
	1.92E-02	36.09375	37	1335.4688	#NUM!	#NUM!
	1.92E-02	36.09375	38	1371.5625	#NUM!	#NUM!
	1.92E-02	36.09375	39	1407.6563	#NUM!	#NUM!
	1.92E-02	36.09375	40	1443.75	#NUM!	#NUM!
	1.92E-02	36.09375	41	1479.8438	#NUM!	#NUM!
	1.92E-02	36.09375	42	1515.9375	#NUM!	#NUM!
	1.92E-02	36.09375	43	1552.0313	#NUM!	#NUM!
	1.92E-02	36.09375	44	1588.125	#NUM!	#NUM!
	1.92E-02	36.09375	45	1624.2188	#NUM!	#NUM!
	1.92E-02	36.09375	46	1660.3125	#NUM!	#NUM!
	1.92E-02	36.09375	47	1696.4063	#NUM!	#NUM!
	1.92E-02	36.09375	48	1732.5	#NUM!	#NUM!
	1.92E-02	36.09375	49	1768.5938	#NUM!	#NUM!
	1.92E-02	36.09375	50	1804.6875	#NUM!	#NUM!
	1.92E-02	36.09375	51	1840.7813	#NUM!	#NUM!
	1.92E-02	36.09375	52	1876.875	#NUM!	#NUM!
	1.92E-02	36.09375	53	1912.9688	#NUM!	#NUM!
	1.92E-02	36.09375	54	1949.0625	#NUM!	#NUM!
	1.92E-02	36.09375	55	1985.1563	#NUM!	#NUM!
	1.92E-02	36.09375	56	2021.25	#NUM!	#NUM!
	1.92E-02	36.09375	57	2057.3438	#NUM!	#NUM!
	1.92E-02	36.09375	58	2093.4375	#NUM!	#NUM!
	1.92E-02	36.09375	59	2129.5313	#NUM!	#NUM!
	1.92E-02	36.09375	60	2165.625	#NUM!	#NUM!
	1.92E-02	36.09375	61	2201.7188	#NUM!	#NUM!
	1.92E-02	36.09375	62	2237.8125	#NUM!	#NUM!
	1.92E-02	36.09375	63	2273.9063	#NUM!	#NUM!
	1.92E-02	36.09375	64	2310	#NUM!	#NUM!
	1.92E-02	36.09375	65	2346.0938	#NUM!	#NUM!
	1.92E-02	36.09375	66	2382.1875	#NUM!	#NUM!
	1.92E-02	36.09375	67	2418.2813	#NUM!	#NUM!
	1.92E-02	36.09375	68	2454.375	#NUM!	#NUM!
	1.92E-02	36.09375	69	2490.4688	#NUM!	#NUM!
	1.92E-02	36.09375	70	2526.5625	#NUM!	#NUM!
	1.92E-02	36.09375	70	2526.5625	#NUM!	#NUM!

Concentration	
1.76E-17	Average (child)
#NUM!	Average (adult)

MK083774

MKIL206104

Mckeesen Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	tr	LnC (initial)	C (final)
Methylene Chloride	7.70E-02	9	1	9	4.72233081	1.30E-02
	7.70E-02	9	2	18	-4.27764019	2.11E-10
	7.70E-02	9	3	27	-22.2776692	3.97E-22
	7.70E-02	9	4	36	-49.2776692	9.21E-36
	7.70E-02	9	5	45	-85.2776692	2.64E-57
	7.70E-02	9	6	54	-130.27764	9.32E-81
	7.70E-02	9	7	63	-184.27764	4.08E-108
	7.70E-02	9	8	72	-247.27764	2.19E-139
	7.70E-02	9	9	81	-319.27764	1.45E-174
	7.70E-02	9	10	90	-400.27764	1.19E-213
	7.70E-02	9	11	99	-490.27764	1.28E-256
	7.70E-02	9	12	108	-589.27764	1.50E-303
	7.70E-02	9	13	117	-697.27764	0.00E+00
	7.70E-02	9	14	126	#NUM!	#NUM!
	7.70E-02	9	15	135	#NUM!	#NUM!
	7.70E-02	9	16	144	#NUM!	#NUM!
	7.70E-02	9	17	153	#NUM!	#NUM!
	7.70E-02	9	18	162	#NUM!	#NUM!
	7.70E-02	9	19	171	#NUM!	#NUM!
	7.70E-02	9	20	180	#NUM!	#NUM!
	7.70E-02	9	21	189	#NUM!	#NUM!
	7.70E-02	9	22	198	#NUM!	#NUM!
	7.70E-02	9	23	207	#NUM!	#NUM!
	7.70E-02	9	24	216	#NUM!	#NUM!
	7.70E-02	9	25	225	#NUM!	#NUM!
	7.70E-02	9	26	234	#NUM!	#NUM!
	7.70E-02	9	27	243	#NUM!	#NUM!
	7.70E-02	9	28	252	#NUM!	#NUM!
	7.70E-02	9	29	261	#NUM!	#NUM!
	7.70E-02	9	30	270	#NUM!	#NUM!
	7.70E-02	9	31	279	#NUM!	#NUM!
	7.70E-02	9	32	288	#NUM!	#NUM!
	7.70E-02	9	33	297	#NUM!	#NUM!
	7.70E-02	9	34	306	#NUM!	#NUM!
	7.70E-02	9	35	315	#NUM!	#NUM!
	7.70E-02	9	36	324	#NUM!	#NUM!
	7.70E-02	9	37	333	#NUM!	#NUM!
	7.70E-02	9	38	342	#NUM!	#NUM!
	7.70E-02	9	39	351	#NUM!	#NUM!
	7.70E-02	9	40	360	#NUM!	#NUM!
	7.70E-02	9	41	369	#NUM!	#NUM!
	7.70E-02	9	42	378	#NUM!	#NUM!
	7.70E-02	9	43	387	#NUM!	#NUM!
	7.70E-02	9	44	396	#NUM!	#NUM!
	7.70E-02	9	45	405	#NUM!	#NUM!
	7.70E-02	9	46	414	#NUM!	#NUM!
	7.70E-02	9	47	423	#NUM!	#NUM!
	7.70E-02	9	48	432	#NUM!	#NUM!
	7.70E-02	9	49	441	#NUM!	#NUM!
	7.70E-02	9	50	450	#NUM!	#NUM!
	7.70E-02	9	51	459	#NUM!	#NUM!
	7.70E-02	9	52	468	#NUM!	#NUM!
	7.70E-02	9	53	477	#NUM!	#NUM!
	7.70E-02	9	54	486	#NUM!	#NUM!
	7.70E-02	9	55	495	#NUM!	#NUM!
	7.70E-02	9	56	504	#NUM!	#NUM!
	7.70E-02	9	57	513	#NUM!	#NUM!
	7.70E-02	9	58	522	#NUM!	#NUM!
	7.70E-02	9	59	531	#NUM!	#NUM!
	7.70E-02	9	60	540	#NUM!	#NUM!
	7.70E-02	9	61	549	#NUM!	#NUM!
	7.70E-02	9	62	558	#NUM!	#NUM!
	7.70E-02	9	63	567	#NUM!	#NUM!
	7.70E-02	9	64	576	#NUM!	#NUM!
	7.70E-02	9	65	585	#NUM!	#NUM!
	7.70E-02	9	66	594	#NUM!	#NUM!
	7.70E-02	9	67	603	#NUM!	#NUM!
	7.70E-02	9	68	612	#NUM!	#NUM!
	7.70E-02	9	69	621	#NUM!	#NUM!
	7.70E-02	9	70	630	#NUM!	#NUM!
	7.70E-02	9	70	630	#NUM!	#NUM!

Concentration	
0.00231249	Average (child)
#NUM!	Average (adult)

MK083775

MKIL206105

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (initial	C final
PCE	9.90E-01	0.7	1	0.7	6.75494204	4.26E+02
	9.90E-01	0.7	2	1.4	6.05494204	1.05E+02
	9.90E-01	0.7	3	2.1	4.65494204	1.29E+01
	9.90E-01	0.7	4	2.8	2.55494204	7.83E-01
	9.90E-01	0.7	5	3.5	4.00840534	1.66E+00
	9.90E-01	0.7	6	4.2	0.50840534	2.49E-02
	9.90E-01	0.7	7	4.9	-3.49159466	1.86E-04
	9.90E-01	0.7	8	5.6	-8.59159466	6.87E-07
	9.90E-01	0.7	9	6.3	-14.1915947	1.26E-09
	9.90E-01	0.7	10	7	-20.4915947	1.15E-12
	9.90E-01	0.7	11	7.7	-27.4915947	5.21E-16
	9.90E-01	0.7	12	8.4	-35.1915947	1.17E-19
	9.90E-01	0.7	13	9.1	-43.5915947	1.31E-23
	9.90E-01	0.7	14	9.8	-52.6915947	7.25E-28
	9.90E-01	0.7	15	10.5	-62.4915947	2.00E-32
	9.90E-01	0.7	16	11.2	-72.9915947	2.73E-37
	9.90E-01	0.7	17	11.9	-72.9915947	1.34E-37
	9.90E-01	0.7	18	12.6	-84.8915947	4.57E-43
	9.90E-01	0.7	19	13.3	-97.4915947	7.65E-49
	9.90E-01	0.7	20	14	-110.791595	6.34E-55
	9.90E-01	0.7	21	14.7	-124.791595	2.63E-61
	9.90E-01	0.7	22	15.4	-139.491595	5.59E-68
	9.90E-01	0.7	23	16.1	-154.891595	5.49E-75
	9.90E-01	0.7	24	16.8	-170.991595	2.77E-82
	9.90E-01	0.7	25	17.5	-187.791595	6.97E-90
	9.90E-01	0.7	26	18.2	-205.291595	8.68E-98
	9.90E-01	0.7	27	18.9	-223.491595	5.38E-106
	9.90E-01	0.7	28	19.6	-242.391595	1.65E-114
	9.90E-01	0.7	29	20.3	-261.991595	2.53E-123
	9.90E-01	0.7	30	21	-282.291595	1.91E-132
	9.90E-01	0.7	31	21.7	-303.291595	7.21E-142
	9.90E-01	0.7	32	22.4	-324.991595	1.35E-151
	9.90E-01	0.7	33	23.1	-347.391595	1.25E-161
	9.90E-01	0.7	34	23.8	-370.491595	5.77E-172
	9.90E-01	0.7	35	24.5	-394.291595	1.52E-182
	9.90E-01	0.7	36	25.2	-418.791595	1.50E-193
	9.90E-01	0.7	37	25.9	-443.991595	8.49E-205
	9.90E-01	0.7	38	26.6	-469.891595	2.38E-216
	9.90E-01	0.7	39	27.3	-496.491595	3.31E-228
	9.90E-01	0.7	40	28	-523.791595	2.28E-240
	9.90E-01	0.7	41	28.7	-551.791595	7.87E-253
	9.90E-01	0.7	42	29.4	-580.491595	1.34E-265
	9.90E-01	0.7	43	30.1	-609.891595	1.14E-278
	9.90E-01	0.7	44	30.8	-639.991595	4.77E-292
	9.90E-01	0.7	45	31.5	-670.791595	9.97E-306
	9.90E-01	0.7	46	32.2	-702.291595	0.00E+00
	9.90E-01	0.7	47	32.9	#NUM!	#NUM!
	9.90E-01	0.7	48	33.6	#NUM!	#NUM!
	9.90E-01	0.7	49	34.3	#NUM!	#NUM!
	9.90E-01	0.7	50	35	#NUM!	#NUM!
	9.90E-01	0.7	51	35.7	#NUM!	#NUM!
	9.90E-01	0.7	52	36.4	#NUM!	#NUM!
	9.90E-01	0.7	53	37.1	#NUM!	#NUM!
	9.90E-01	0.7	54	37.8	#NUM!	#NUM!
	9.90E-01	0.7	55	38.5	#NUM!	#NUM!
	9.90E-01	0.7	56	39.2	#NUM!	#NUM!
	9.90E-01	0.7	57	39.9	#NUM!	#NUM!
	9.90E-01	0.7	58	40.6	#NUM!	#NUM!
	9.90E-01	0.7	59	41.3	#NUM!	#NUM!
	9.90E-01	0.7	60	42	#NUM!	#NUM!
	9.90E-01	0.7	61	42.7	#NUM!	#NUM!
	9.90E-01	0.7	62	43.4	#NUM!	#NUM!
	9.90E-01	0.7	63	44.1	#NUM!	#NUM!
	9.90E-01	0.7	64	44.8	#NUM!	#NUM!
	9.90E-01	0.7	65	45.5	#NUM!	#NUM!
	9.90E-01	0.7	66	46.2	#NUM!	#NUM!
	9.90E-01	0.7	67	46.9	#NUM!	#NUM!
	9.90E-01	0.7	68	47.6	#NUM!	#NUM!
	9.90E-01	0.7	69	48.3	#NUM!	#NUM!
	9.90E-01	0.7	70	49	#NUM!	#NUM!
	9.90E-01	0.7	70	49	#NUM!	#NUM!

Concentration	
91.1098852	Average (child)
4.6587E-06	Average (adult)

MK083776

MKIL206106

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (initial	C final
1,1,1-Trichloroethane	7.50E-01	0.924	1	0.924	6.94438928	4.13E+02
	7.50E-01	0.924	2	1.848	6.02238928	6.50E+01
	7.50E-01	0.924	3	2.772	4.17438928	4.06E+00
	7.50E-01	0.924	4	3.696	1.40238928	1.01E-01
	7.50E-01	0.924	5	4.62	-2.29361072	9.94E-04
	7.50E-01	0.924	6	5.544	-6.91361072	3.89E-06
	7.50E-01	0.924	7	6.468	-12.4576107	6.04E-09
	7.50E-01	0.924	8	7.392	-18.9256107	3.72E-12
	7.50E-01	0.924	9	8.316	-26.3176107	9.10E-16
	7.50E-01	0.924	10	9.24	-34.6336107	8.83E-20
	7.50E-01	0.924	11	10.164	-43.8736107	3.40E-24
	7.50E-01	0.924	12	11.088	-54.0376107	5.20E-29
	7.50E-01	0.924	13	12.012	-65.1256107	3.16E-34
	7.50E-01	0.924	14	12.936	-77.1376107	7.61E-40
	7.50E-01	0.924	15	13.86	-90.0736107	7.28E-46
	7.50E-01	0.924	16	14.784	-103.93611	2.76E-52
	7.50E-01	0.924	17	15.708	-103.93611	1.10E-52
	7.50E-01	0.924	18	16.632	-119.641611	6.56E-60
	7.50E-01	0.924	19	17.556	-136.273611	1.56E-67
	7.50E-01	0.924	20	18.48	-153.828611	1.67E-75
	7.50E-01	0.924	21	19.404	-172.303611	5.49E-84
	7.50E-01	0.924	22	20.328	-191.713611	8.16E-93
	7.50E-01	0.924	23	21.252	-212.041611	4.81E-102
	7.50E-01	0.924	24	22.176	-233.283611	1.12E-111
	7.50E-01	0.924	25	23.1	-255.448611	1.04E-121
	7.50E-01	0.924	26	24.024	-278.548611	3.85E-132
	7.50E-01	0.924	27	24.948	-302.593611	5.63E-143
	7.50E-01	0.924	28	25.872	-327.541611	3.27E-154
	7.50E-01	0.924	29	26.796	-353.413611	7.53E-166
	7.50E-01	0.924	30	27.72	-380.208611	6.89E-178
	7.50E-01	0.924	31	28.644	-407.928611	2.30E-190
	7.50E-01	0.924	32	29.568	-436.573611	3.61E-203
	7.50E-01	0.924	33	30.492	-466.141611	2.06E-216
	7.50E-01	0.924	34	31.416	-496.633611	4.69E-230
	7.50E-01	0.924	35	32.34	-528.049611	4.23E-244
	7.50E-01	0.924	36	33.264	-560.389611	1.51E-258
	7.50E-01	0.924	37	34.188	-593.653611	2.15E-273
	7.50E-01	0.924	38	35.112	-627.841611	1.21E-288
	7.50E-01	0.924	39	36.036	-662.953611	2.71E-304
	7.50E-01	0.924	40	36.96	-698.989611	0.00E+00
	7.50E-01	0.924	41	37.884	#NUM!	#NUM!
	7.50E-01	0.924	42	38.808	#NUM!	#NUM!
	7.50E-01	0.924	43	39.732	#NUM!	#NUM!
	7.50E-01	0.924	44	40.656	#NUM!	#NUM!
	7.50E-01	0.924	45	41.58	#NUM!	#NUM!
	7.50E-01	0.924	46	42.504	#NUM!	#NUM!
	7.50E-01	0.924	47	43.428	#NUM!	#NUM!
	7.50E-01	0.924	48	44.352	#NUM!	#NUM!
	7.50E-01	0.924	49	45.276	#NUM!	#NUM!
	7.50E-01	0.924	50	46.2	#NUM!	#NUM!
	7.50E-01	0.924	51	47.124	#NUM!	#NUM!
	7.50E-01	0.924	52	48.048	#NUM!	#NUM!
	7.50E-01	0.924	53	48.972	#NUM!	#NUM!
	7.50E-01	0.924	54	49.896	#NUM!	#NUM!
	7.50E-01	0.924	55	50.82	#NUM!	#NUM!
	7.50E-01	0.924	56	51.744	#NUM!	#NUM!
	7.50E-01	0.924	57	52.668	#NUM!	#NUM!
	7.50E-01	0.924	58	53.592	#NUM!	#NUM!
	7.50E-01	0.924	59	54.516	#NUM!	#NUM!
	7.50E-01	0.924	60	55.44	#NUM!	#NUM!
	7.50E-01	0.924	61	56.364	#NUM!	#NUM!
	7.50E-01	0.924	62	57.288	#NUM!	#NUM!
	7.50E-01	0.924	63	58.212	#NUM!	#NUM!
	7.50E-01	0.924	64	59.136	#NUM!	#NUM!
	7.50E-01	0.924	65	60.06	#NUM!	#NUM!
	7.50E-01	0.924	66	60.984	#NUM!	#NUM!
	7.50E-01	0.924	67	61.908	#NUM!	#NUM!
	7.50E-01	0.924	68	62.832	#NUM!	#NUM!
	7.50E-01	0.924	69	63.756	#NUM!	#NUM!
	7.50E-01	0.924	70	64.68	#NUM!	#NUM!
	7.50E-01	0.924	70	64.68	#NUM!	#NUM!

Concentration	
80.2883466	Average (child)
#NUM!	Average (adult)

MK083777

MKIL206107

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (initial)	C final
Xylenes	7.70E-02	9	1	9	3.27449973	3.26E-03
	7.70E-02	9	2	18	-5.72550027	4.97E-11
	7.70E-02	9	3	27	-23.7255003	9.34E-23
	7.70E-02	9	4	36	-50.7255003	2.17E-38
	7.70E-02	9	5	45	-86.7255003	6.30E-58
	7.70E-02	9	6	54	-131.7255	2.19E-81
	7.70E-02	9	7	63	-185.7255	9.55E-109
	7.70E-02	9	8	72	-248.7255	5.14E-140
	7.70E-02	9	9	81	-320.7255	3.41E-175
	7.70E-02	9	10	90	-401.7255	2.79E-214
	7.70E-02	9	11	99	-491.7255	2.83E-257
	7.70E-02	9	12	108	-590.7255	3.53E-304
	7.70E-02	9	13	117	-698.7255	0.00E+00
	7.70E-02	9	14	126	#NUM!	#NUM!
	7.70E-02	9	15	135	#NUM!	#NUM!
	7.70E-02	9	16	144	#NUM!	#NUM!
	7.70E-02	9	17	153	#NUM!	#NUM!
	7.70E-02	9	18	162	#NUM!	#NUM!
	7.70E-02	9	19	171	#NUM!	#NUM!
	7.70E-02	9	20	180	#NUM!	#NUM!
	7.70E-02	9	21	189	#NUM!	#NUM!
	7.70E-02	9	22	198	#NUM!	#NUM!
	7.70E-02	9	23	207	#NUM!	#NUM!
	7.70E-02	9	24	216	#NUM!	#NUM!
	7.70E-02	9	25	225	#NUM!	#NUM!
	7.70E-02	9	26	234	#NUM!	#NUM!
	7.70E-02	9	27	243	#NUM!	#NUM!
	7.70E-02	9	28	252	#NUM!	#NUM!
	7.70E-02	9	29	261	#NUM!	#NUM!
	7.70E-02	9	30	270	#NUM!	#NUM!
	7.70E-02	9	31	279	#NUM!	#NUM!
	7.70E-02	9	32	288	#NUM!	#NUM!
	7.70E-02	9	33	297	#NUM!	#NUM!
	7.70E-02	9	34	306	#NUM!	#NUM!
	7.70E-02	9	35	315	#NUM!	#NUM!
	7.70E-02	9	36	324	#NUM!	#NUM!
	7.70E-02	9	37	333	#NUM!	#NUM!
	7.70E-02	9	38	342	#NUM!	#NUM!
	7.70E-02	9	39	351	#NUM!	#NUM!
	7.70E-02	9	40	360	#NUM!	#NUM!
	7.70E-02	9	41	369	#NUM!	#NUM!
	7.70E-02	9	42	378	#NUM!	#NUM!
	7.70E-02	9	43	387	#NUM!	#NUM!
	7.70E-02	9	44	396	#NUM!	#NUM!
	7.70E-02	9	45	405	#NUM!	#NUM!
	7.70E-02	9	46	414	#NUM!	#NUM!
	7.70E-02	9	47	423	#NUM!	#NUM!
	7.70E-02	9	48	432	#NUM!	#NUM!
	7.70E-02	9	49	441	#NUM!	#NUM!
	7.70E-02	9	50	450	#NUM!	#NUM!
	7.70E-02	9	51	459	#NUM!	#NUM!
	7.70E-02	9	52	468	#NUM!	#NUM!
	7.70E-02	9	53	477	#NUM!	#NUM!
	7.70E-02	9	54	486	#NUM!	#NUM!
	7.70E-02	9	55	495	#NUM!	#NUM!
	7.70E-02	9	56	504	#NUM!	#NUM!
	7.70E-02	9	57	513	#NUM!	#NUM!
	7.70E-02	9	58	522	#NUM!	#NUM!
	7.70E-02	9	59	531	#NUM!	#NUM!
	7.70E-02	9	60	540	#NUM!	#NUM!
	7.70E-02	9	61	549	#NUM!	#NUM!
	7.70E-02	9	62	558	#NUM!	#NUM!
	7.70E-02	9	63	567	#NUM!	#NUM!
	7.70E-02	9	64	576	#NUM!	#NUM!
	7.70E-02	9	65	585	#NUM!	#NUM!
	7.70E-02	9	66	594	#NUM!	#NUM!
	7.70E-02	9	67	603	#NUM!	#NUM!
	7.70E-02	9	68	612	#NUM!	#NUM!
	7.70E-02	9	69	621	#NUM!	#NUM!
	7.70E-02	9	70	630	#NUM!	#NUM!
	7.70E-02	9	70	630	#NUM!	#NUM!

Concentration	
0.00054362	Average (child)
#NUM!	Average (adult)

MK083778

MKIL206108

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (mg/kg)	C (mg/kg)
Trichloroethane	9.90E-01	0.7	1	0.7	2.18591741	8.90E+00
	9.90E-01	0.7	2	1.4	2.18591741	2.19E+00
	9.90E-01	0.7	3	2.1	0.78591741	2.69E-01
	9.90E-01	0.7	4	2.8	-1.31408259	1.63E-02
	9.90E-01	0.7	5	3.5	-4.31408259	4.93E-04
	9.90E-01	0.7	6	4.2	-7.61408259	7.40E-06
	9.90E-01	0.7	7	4.9	-11.8140826	5.51E-08
	9.90E-01	0.7	8	5.6	-16.7140826	2.04E-10
	9.90E-01	0.7	9	6.3	-22.3140826	3.74E-13
	9.90E-01	0.7	10	7	-28.6140826	3.41E-16
	9.90E-01	0.7	11	7.7	-35.6140826	1.55E-19
	9.90E-01	0.7	12	8.4	-43.3140826	3.47E-23
	9.90E-01	0.7	13	9.1	-51.7140826	3.88E-27
	9.90E-01	0.7	14	9.8	-60.8140826	2.13E-31
	9.90E-01	0.7	15	10.5	-70.6140826	5.92E-36
	9.90E-01	0.7	16	11.2	-81.1140826	8.10E-41
	9.90E-01	0.7	17	11.9	-81.1140826	4.02E-41
	9.90E-01	0.7	18	12.6	-93.0140826	1.36E-46
	9.90E-01	0.7	19	13.3	-105.614083	2.27E-52
	9.90E-01	0.7	20	14	-118.914083	1.89E-58
	9.90E-01	0.7	21	14.7	-132.914083	7.90E-65
	9.90E-01	0.7	22	15.4	-147.614083	1.60E-71
	9.90E-01	0.7	23	16.1	-163.014083	1.63E-78
	9.90E-01	0.7	24	16.8	-179.114083	8.23E-86
	9.90E-01	0.7	25	17.5	-195.914083	2.07E-93
	9.90E-01	0.7	26	18.2	-213.414083	2.38E-101
	9.90E-01	0.7	27	18.9	-231.614083	1.60E-109
	9.90E-01	0.7	28	19.6	-250.514083	4.91E-118
	9.90E-01	0.7	29	20.3	-270.114083	7.49E-127
	9.90E-01	0.7	30	21	-290.414083	5.68E-136
	9.90E-01	0.7	31	21.7	-311.414083	2.14E-145
	9.90E-01	0.7	32	22.4	-333.114083	4.00E-155
	9.90E-01	0.7	33	23.1	-355.514083	3.72E-165
	9.90E-01	0.7	34	23.8	-378.614083	1.71E-175
	9.90E-01	0.7	35	24.5	-402.414083	3.92E-186
	9.90E-01	0.7	36	25.2	-426.914083	4.46E-197
	9.90E-01	0.7	37	25.9	-452.114083	2.52E-208
	9.90E-01	0.7	38	26.6	-478.014083	7.06E-220
	9.90E-01	0.7	39	27.3	-504.614083	9.83E-232
	9.90E-01	0.7	40	28	-531.914083	6.80E-244
	9.90E-01	0.7	41	28.7	-559.914083	2.33E-256
	9.90E-01	0.7	42	29.4	-588.614083	3.98E-269
	9.90E-01	0.7	43	30.1	-618.014083	3.37E-282
	9.90E-01	0.7	44	30.8	-648.114083	1.42E-295
	9.90E-01	0.7	45	31.5	-678.914083	0.00E+00
	9.90E-01	0.7	46	32.2	#NUM!	#NUM!
	9.90E-01	0.7	47	32.9	#NUM!	#NUM!
	9.90E-01	0.7	48	33.6	#NUM!	#NUM!
	9.90E-01	0.7	49	34.3	#NUM!	#NUM!
	9.90E-01	0.7	50	35	#NUM!	#NUM!
	9.90E-01	0.7	51	35.7	#NUM!	#NUM!
	9.90E-01	0.7	52	36.4	#NUM!	#NUM!
	9.90E-01	0.7	53	37.1	#NUM!	#NUM!
	9.90E-01	0.7	54	37.8	#NUM!	#NUM!
	9.90E-01	0.7	55	38.5	#NUM!	#NUM!
	9.90E-01	0.7	56	39.2	#NUM!	#NUM!
	9.90E-01	0.7	57	39.9	#NUM!	#NUM!
	9.90E-01	0.7	58	40.6	#NUM!	#NUM!
	9.90E-01	0.7	59	41.3	#NUM!	#NUM!
	9.90E-01	0.7	60	42	#NUM!	#NUM!
	9.90E-01	0.7	61	42.7	#NUM!	#NUM!
	9.90E-01	0.7	62	43.4	#NUM!	#NUM!
	9.90E-01	0.7	63	44.1	#NUM!	#NUM!
	9.90E-01	0.7	64	44.8	#NUM!	#NUM!
	9.90E-01	0.7	65	45.5	#NUM!	#NUM!
	9.90E-01	0.7	66	46.2	#NUM!	#NUM!
	9.90E-01	0.7	67	46.9	#NUM!	#NUM!
	9.90E-01	0.7	68	47.6	#NUM!	#NUM!
	9.90E-01	0.7	69	48.3	#NUM!	#NUM!
	9.90E-01	0.7	70	49	#NUM!	#NUM!
	9.90E-01	0.7	70	49	#NUM!	#NUM!

Concentration	
1.89644506	Average (child)
#NUM!	Average (adult)

MK083779

MKIL206109

Mckesson Representative Surficial Soil Concentrations for the Soil Ingestion/Dermal Contact Pathway

Chemical	Half-life in soil	k	t (years)	kt	LnC (initial	C final
Toluene	6.02E-02	11.51162791	1	11.51162	3.76390693	4.32E-04
	6.02E-02	11.51162791	2	23.023256	-7.74764098	4.35E-14
	6.02E-02	11.51162791	3	34.534884	-30.7708948	4.35E-29
	6.02E-02	11.51162791	4	46.046512	-65.3057805	4.37E-49
	6.02E-02	11.51162791	5	57.55814	-111.352292	4.40E-74
	6.02E-02	11.51162791	6	69.069767	-168.910432	4.43E-104
	6.02E-02	11.51162791	7	80.581395	-237.980199	4.47E-139
	6.02E-02	11.51162791	8	92.093023	-318.561594	4.52E-179
	6.02E-02	11.51162791	9	103.60465	-410.654618	4.57E-224
	6.02E-02	11.51162791	10	115.11628	-514.259289	4.63E-274
	6.02E-02	11.51162791	11	126.62791	-628.375548	0.00E+00
	6.02E-02	11.51162791	12	138.13953	#NUM!	#NUM!
	6.02E-02	11.51162791	13	149.65116	#NUM!	#NUM!
	6.02E-02	11.51162791	14	161.16279	#NUM!	#NUM!
	6.02E-02	11.51162791	15	172.67442	#NUM!	#NUM!
	6.02E-02	11.51162791	16	184.18605	#NUM!	#NUM!
	6.02E-02	11.51162791	17	195.69767	#NUM!	#NUM!
	6.02E-02	11.51162791	18	207.2093	#NUM!	#NUM!
	6.02E-02	11.51162791	19	218.72093	#NUM!	#NUM!
	6.02E-02	11.51162791	20	230.23256	#NUM!	#NUM!
	6.02E-02	11.51162791	21	241.74419	#NUM!	#NUM!
	6.02E-02	11.51162791	22	253.25581	#NUM!	#NUM!
	6.02E-02	11.51162791	23	264.76744	#NUM!	#NUM!
	6.02E-02	11.51162791	24	276.27907	#NUM!	#NUM!
	6.02E-02	11.51162791	25	287.7907	#NUM!	#NUM!
	6.02E-02	11.51162791	26	299.30233	#NUM!	#NUM!
	6.02E-02	11.51162791	27	310.81395	#NUM!	#NUM!
	6.02E-02	11.51162791	28	322.32558	#NUM!	#NUM!
	6.02E-02	11.51162791	29	333.83721	#NUM!	#NUM!
	6.02E-02	11.51162791	30	345.34884	#NUM!	#NUM!
	6.02E-02	11.51162791	31	356.86047	#NUM!	#NUM!
	6.02E-02	11.51162791	32	368.37209	#NUM!	#NUM!
	6.02E-02	11.51162791	33	379.88372	#NUM!	#NUM!
	6.02E-02	11.51162791	34	391.39535	#NUM!	#NUM!
	6.02E-02	11.51162791	35	402.90698	#NUM!	#NUM!
	6.02E-02	11.51162791	36	414.4186	#NUM!	#NUM!
	6.02E-02	11.51162791	37	425.93023	#NUM!	#NUM!
	6.02E-02	11.51162791	38	437.44186	#NUM!	#NUM!
	6.02E-02	11.51162791	39	448.95349	#NUM!	#NUM!
	6.02E-02	11.51162791	40	460.46512	#NUM!	#NUM!
	6.02E-02	11.51162791	41	471.97674	#NUM!	#NUM!
	6.02E-02	11.51162791	42	483.48837	#NUM!	#NUM!
	6.02E-02	11.51162791	43	495	#NUM!	#NUM!
	6.02E-02	11.51162791	44	506.51163	#NUM!	#NUM!
	6.02E-02	11.51162791	45	518.02326	#NUM!	#NUM!
	6.02E-02	11.51162791	46	529.53488	#NUM!	#NUM!
	6.02E-02	11.51162791	47	541.04651	#NUM!	#NUM!
	6.02E-02	11.51162791	48	552.55814	#NUM!	#NUM!
	6.02E-02	11.51162791	49	564.06977	#NUM!	#NUM!
	6.02E-02	11.51162791	50	575.5814	#NUM!	#NUM!
	6.02E-02	11.51162791	51	587.09302	#NUM!	#NUM!
	6.02E-02	11.51162791	52	598.60465	#NUM!	#NUM!
	6.02E-02	11.51162791	53	610.11628	#NUM!	#NUM!
	6.02E-02	11.51162791	54	621.62791	#NUM!	#NUM!
	6.02E-02	11.51162791	55	633.13953	#NUM!	#NUM!
	6.02E-02	11.51162791	56	644.65116	#NUM!	#NUM!
	6.02E-02	11.51162791	57	656.16279	#NUM!	#NUM!
	6.02E-02	11.51162791	58	667.67442	#NUM!	#NUM!
	6.02E-02	11.51162791	59	679.18605	#NUM!	#NUM!
	6.02E-02	11.51162791	60	690.69767	#NUM!	#NUM!
	6.02E-02	11.51162791	61	702.2093	#NUM!	#NUM!
	6.02E-02	11.51162791	62	713.72093	#NUM!	#NUM!
	6.02E-02	11.51162791	63	725.23256	#NUM!	#NUM!
	6.02E-02	11.51162791	64	736.74419	#NUM!	#NUM!
	6.02E-02	11.51162791	65	748.25581	#NUM!	#NUM!
	6.02E-02	11.51162791	66	759.76744	#NUM!	#NUM!
	6.02E-02	11.51162791	67	771.27907	#NUM!	#NUM!
	6.02E-02	11.51162791	68	782.7907	#NUM!	#NUM!
	6.02E-02	11.51162791	69	794.30233	#NUM!	#NUM!
	6.02E-02	11.51162791	70	805.81395	#NUM!	#NUM!
	6.02E-02	11.51162791	70	805.81395	#NUM!	#NUM!

Concentration	
7.19E-05	Average (child)
#NUM!	Average (adult)

MK083780

MKIL206110

APPENDIX E

SUMMARY STATISTICS FOR MCKESSON UNCERTAINTY ANALYSIS

APPENDIX E

SUMMARY STATISTICS FOR MCKESSON UNCERTAINTY ANALYSIS

Simulation Statistics
Date: 1/10/92 at 13:41
Iterations: 3000
Simulations: 1

	Adult Inhalation Hazard Index	Child Inhalation Hazard Index	Inhalation Cancer Risk	Child Soil Ingestion Hazard Index
Minimum=	5.969E-05	0.0001433	8.255E-09	5.796E-07
Maximum=	17.21228	86.064575	0.0003836	0.2960678
Mean=	0.0481031	0.1462157	1.694E-06	0.0169128
Std Deviation=	0.4046	1.7492431	1.041E-05	0.0553292
Variance=	0.1637011	3.0598516	1.083E-10	0.0030613
Skewness=	30.887387	41.768086	31.379119	3.4632557
Kurtosis=	1178.111	1974.0187	1103.9225	14.049154
Percentile Values				
5Perc=	0.0005447	0.0014819	6.304E-08	9.531E-07
10Perc=	0.0008932	0.0025157	9.635E-08	1.322E-06
15Perc=	0.0012572	0.0035624	1.336E-07	1.68E-06
20Perc=	0.0016872	0.0050407	1.68E-07	2.037E-06
25Perc=	0.0021976	0.0064622	2.064E-07	2.383E-06
30Perc=	0.0027651	0.008034	2.563E-07	4.586E-06
35Perc=	0.0034045	0.0101861	3.091E-07	9.26E-06
40Perc=	0.0041904	0.0123872	3.719E-07	3.257E-05
45Perc=	0.0052665	0.0151714	4.365E-07	4.587E-05
50Perc=	0.0065015	0.0187988	5.228E-07	5.98E-05
55Perc=	0.0081154	0.0233706	6.184E-07	7.186E-05
60Perc=	0.0103055	0.0291282	7.499E-07	8.934E-05
65Perc=	0.0128459	0.0363765	8.735E-07	0.0001111
70Perc=	0.0161257	0.0460658	1.067E-06	0.0001449
75Perc=	0.0216458	0.0598021	1.282E-06	0.0013401
80Perc=	0.0285145	0.079068	1.579E-06	0.0023204
85Perc=	0.04175	0.1116529	2.084E-06	0.0033017
90Perc=	0.0657748	0.1753567	3.091E-06	0.0056441
95Perc=	0.1314518	0.3787186	5.369E-06	0.1678662

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