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Mansour Zakikhani, Mark S. Dortch, Jeffrey A. Gerald

Environmental Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Melanie S. Hawkins

U.S. Army Center for Health Promotion and Preventive Medicine
5158 Blackhawk Road
Aberdeen Proving Ground, Maryland 21010-5403

Final report

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Aberdeen Proving Ground, MD 21010-5401

ABSTRACT: This study was conducted to evaluate potential human and ecological health risks associated with emission of pyrotechnic chemical constituents during future training exercises at the Massachusetts Military Reservation. Air dispersion modeling was used to determine air concentrations and deposition rates for emissions. Annual average and spatially averaged air concentrations and deposition rates were used to perform the risk assessments. The Army Risk Assessment Modeling System (ARAMS) was used to conduct the human health risk assessment, which evaluated a site visitor or trespasser exposed to air and soil using air concentrations and deposition rates from the air dispersion modeling. ARAMS was also used to evaluate the time for deposited compounds to reach groundwater and the peak concentration upon contact with the water table. This study completed the evaluation of the remaining 195 chemicals following the first part of the study that was conducted in 2003 for 24 chemicals and reported in Zakikhani et al. (2004). Of all 219 chemicals, only Cr(VI), with an incremental cancer risk of 2.4×10^{-6}, posed a potential concern for human health with the maximum exposure and effect through the air inhalation pathway/route. However, lack of input toxicological data for most of the 219 chemicals limited the scope of the analysis for human health risk. None of the compounds are suspected to cause a groundwater problem. Computed soil concentrations were compared to soil screening toxicity benchmarks for the ecological risk assessment for the purpose of retaining or eliminating chemicals from the assessment. Toluene and hexachlorobenzene exceeded the soil toxicity benchmarks as reported in "Risk-Characterization for Future Training Scenarios at the Massachusetts Military Reservation (MMR)," ERDC/EL TR-04-2, by Zakikhani et al. (2004). However, because of the slight exceedence and its nonbioaccumulating properties, toluene is not considered to be a chemical of potential concern. Although hexachlorobenzene exceeded the toxicity benchmark, uncertainties and conservative assumptions associated with the modeled soil concentrations and conservative soil benchmarks should be recognized. Two other chemicals, m-xylene and p-xylene, exceeded the low-effect toxicity benchmarks, but not the moderate-effect benchmarks. Aluminum exceeded the screening-level soil benchmark; however, it did not exceed the background 95 percent upper tolerance limit. The initial soil concentration for barium exceeded the low-effect screening-level benchmark slightly. However, the modeled (initial and final) soil concentrations fell within the range of background soil concentrations for barium. Additionally, the conservative approach that was used for emissions and transport overestimated the impacts. More realistic emission durations could be used and would reduce conservatism. The assumption of no degradation overestimated exposure concentrations. However, obtaining degradation rates is highly problematic when so many chemicals are involved, rates are often site specific, and available data on such rates are very limited.

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Preface

This report describes the application of models and risk assessment methods to evaluate potential human and ecological health risks associated with future training activities at the Massachusetts Military Reservation (MMR). Drs. Mansour Zakikhani and Mark S. Dortch and Mr. Jeffrey A. Gerald, Water Quality and Contaminant Modeling Branch (WQCMB), Environmental Processes and Engineering Division (EPED), Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, conducted the portion of the study that used the Army Risk Assessment Modeling System (ARAMS) for the groundwater assessment and human risk assessment. Mr. Stafford Coakley, U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM), conducted the air dispersion modeling as reported in Zakikhani et al. (2004), and Ms. Melanie Hawkins, CHPPM, conducted the screening-level ecological risk assessment.

Drs. Zakikhani and Dortch prepared the main body of this report dealing with the ARAMS application; Ms. Hawkins prepared Appendix A on Ecological Assessment. This material was located in the appendix for convenience during report preparation and does not in any way suggest that these components were not paramount to the entire study effort.

The U.S. Army Environmental Center (USAEC), Aberdeen Proving Ground, MD, funded this study. Mr. Michael Dette was the USAEC point of contact. The ARAMS application was conducted under the general supervision of Dr. Barry Bunch, Chief, WQCMB, and Dr. Richard E. Price, Chief, EPED. The ecological assessment was conducted under the general supervision of Mr. Dennis Druck, CHPPM.

Drs. Judy C. Pennington and Dennis L. Brandon, EL, reviewed the report. Dr. Edwin A. Theriot was Director of EL.

A the time of publication of this report, COL James R. Rowan, EN, was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction

Background

This study was conducted at the request of the U.S. Army Environmental Center (USAEC) to complete the risk evaluation of the remaining 195 chemicals following the first part of the study that was conducted in 2003 for 24 chemicals and reported by Zakikhani et al (2004). The USAEC provided the list of chemicals evaluated during this study. The analyses entailed application of the Army Risk Assessment Modeling System (ARAMS) for screening-level groundwater modeling and human health risk assessment at the Massachusetts Military Reservation (MMR) for future training conditions. Zakikhani et al (2004) describes the training conditions and detailed site and modeling information. Additionally, a screening level ecological risk assessment was conducted by the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) separately from the ARAMS application (Appendix A).

Results from the application of the ISCST3 air dispersion and deposition model were used to drive these analyses, just as in the initial study (Zakikhani et al. 2004). The CHPPM air modeling results, which had been previously provided to The U.S. Army Engineer Research and Development Center (ERDC), were used as boundary conditions for the ARAMS modeling. Procedures for the ARAMS modeling followed the same approach described in Zakikhani et al. (2004). As in the previous study, analyses were done to determine the potential for compounds generated during military training to migrate to groundwater and to determine the potential health risk to on-site visitors or trespassers. Also, results from the ARAMS modeling were used to drive the screening level ecological risk assessment conducted by CHPPM.

Objective

The overall objective of this study was to assess potential human and ecological health impacts/risks associated with exposure to compounds projected to be released during future training scenarios at MMR. An additional objective was to determine which compounds could pose the greatest potential hazard to groundwater. To more fully accomplish the latter objective, vadose zone simulations were included to assess the time for migration to groundwater and chemical concentration at point of penetration from the vadose zone.

Scope of Work

The staff at CHPPM conducted atmospheric transport and deposition modeling to predict air concentrations and land deposition rates of chemicals as a result of future training scenarios at the Camp Edwards area of MMR. The air modeling approach and results are described in Zakikhani et al. (2004). Results of the air simulations were provided by CHPPM to ERDC for use as boundary conditions of the ARAMS modeling. ARAMS version 1.2 (Dortch and Gerald 2004) was used to conduct the human health impacts assessment and the subsurface fate/transport modeling. Average soil concentrations computed by ARAMS were utilized in the screening level ecological risk assessment conducted by CHPPM (Appendix A). The scope of this study was to address the additional 195 chemicals that were not addressed in the initial study (Zakikhani et al. 2004). Results from the initial study are also included in this report.

2 Site Description

MMR, a military training facility, is located on the upper western portion of Cape Cod, immediately south of the Cape Cod Canal in Barnstable County, Massachusetts.

Portions of MMR have been used for military purposes since 1911. Since 1935, the base has been used for Army training and maneuvers, military aircraft operations, maintenance, and support. The northern portion of the MMR, known as Camp Edwards, is used for training National Guard and law enforcement personnel from the New England area. This portion is approximately 15,000 acres with an Impact Area of 2,200 acres at its center. The Impact Area (Figure 1) was used as a target for artillery and mortar firing and considered here as the study site for the future training scenario risk evaluations.

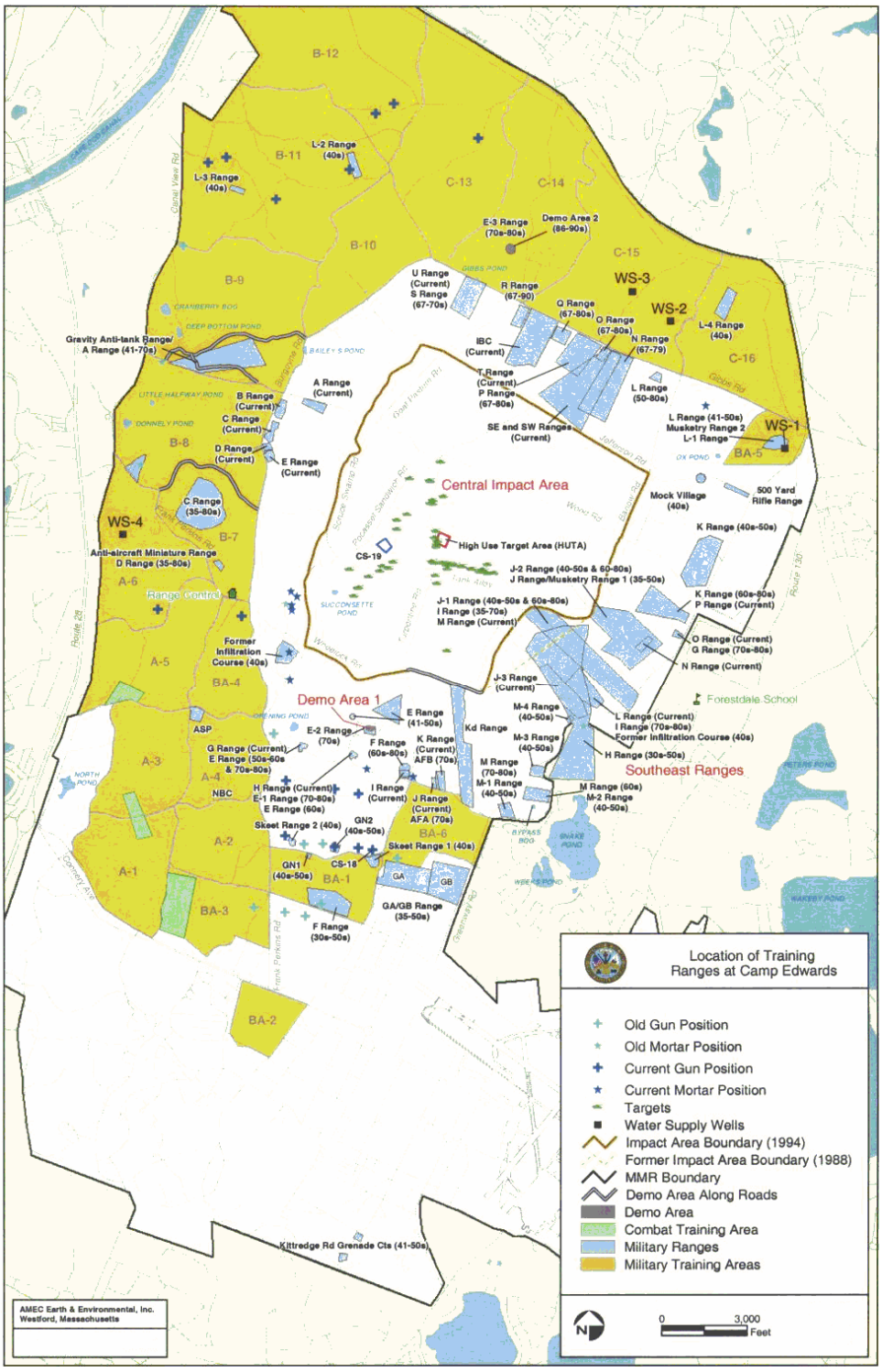

Figure 1. Map of MMR and impact area

3 Modeling Approach

ARAMS (*http://el.erdc.usace.army.mil/arams/*) is based on the widely accepted risk paradigm, where exposure and effects assessments are integrated to characterize risk. ARAMS version 1.2 (Dortch and Gerald 2004) includes screening-level models for contaminant fate/transport. Screening-level models are those that can be conducted rather quickly with limited data at low cost using conservative assumptions, whereas comprehensive assessments require more time, cost, and data, but should provide more definitive information. Later versions of ARAMS will feature more comprehensive fate/transport and exposure models.

The ARAMS modeling provided the following components for this study:

a. Modeling to predict potential human health risk from air and soil exposure associated with a site visitor entering the MMR.

b. Modeling of subsurface fate/transport processes to predict the movement of chemicals through the vadose zone to quantify the time required for these chemicals to migrate from the soil surface to the groundwater table and the chemical concentration at the water table.

The module linkage framework of ARAMS is the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES) (*http://mepas.pnl.gov/FRAMESV1/index.html*). FRAMES serves as an object-oriented, digital, conceptual site model where objects are used to denote different pathways and stages of analysis. Objects or icons represent the primary exposure media of air, land or soil, surface water, vadose zone, and groundwater. Similarly, there are objects representing the sources of contamination, the exposure pathways, uptake, and health impact assessment. The Multimedia Environmental Pollutant Assessment System (MEPAS) is integrated into ARAMS/FRAMES and provides a variety of models for risk assessment. MEPAS provides much of the screening-level fate/transport modeling needed for ARAMS, including models for describing sources of contamination and fate/transport in air, streams, vadose zone, and groundwater. Additionally, MEPAS includes models for exposure pathways to humans, human receptor intake routes, and human health impacts. The MEPAS fate/transport models are typically simplified (e.g., reduced spatial dimensions) mathematical models with analytical solutions.

Modeling Scenarios and Methods

The air dispersion modeling reported in Zakikhani et al. (2004) provided average (temporally and spatially) air concentrations and deposition rates needed as input conditions for ARAMS. Two ARAMS/FRAMES independent modeling scenarios, one for human health impacts and one for subsurface fate/transport through the vadose zone, were conducted and evaluated. Each scenario and its associated modules/models are described briefly below. For more details, the reader should refer to Zakikhani et al. (2004).

Human health analysis

This section describes the exposure pathways and models for conducting the human health analysis. The Human Exposure Pathways Module was used to describe the pathways from media to receptor, and the MEPAS Human Receptor Intake Module was used to compute intake doses for the receptor. Human Health Impacts Module along with toxicity benchmarks were used to compute incremental carcinogenic risks and noncarcinogenic hazard indices (HI).

Human exposure pathways module

Future training can result in chemicals potentially moving from air to soil through deposition. Thus, air and soil are the exposure media. The MMR human receptor consisted of an adult individual moving around or within the site as a visitor or trespasser. It was assumed that the receptor used no domestic water from wells potentially contaminated by the site. The receptor also did not recreate in site surface waters or consume any fish and wildlife from the site, although it is possible to consider all of these exposure pathways with ARAMS. Also, it was assumed that this site does not produce any agricultural products. Therefore, the exposure pathways and routes were air inhalation, soil dermal contact, incidental soil ingestion, and inhalation of suspended soil. These pathway/routes were specified in the Human Exposure Module. Parameters dealing with exposure, soil leaching, and soil resuspension must also be specified. Since this module accepts depositional fluxes and computes soil concentrations, surficial soil properties must also be specified. All parameters required for this module and the modeled scenario and the values used are listed in Table 1. Site data were used to set as many parameters as possible, such as soil bulk density, while others (e.g., soil thickness for leaching) were assumed. In addition to leaching as a loss pathway in the soil, it is possible for chemicals to degrade or decay in the soil. The ARAMS chemical databases contain decay values in soil for some chemicals estimated from volatilization, however, for his study, we assumed a conservative approach of no-decay (i.e., large values for half-life parameters) to provide a worse case exposure scenario.

Table 1
Exposure Module Parameters

Parameter	Value
Exposure duration	30 years
Time to start exposure	0
Maximum time for reporting results	[1]
Number of time points for reporting results	[2]
Surficial soil thickness receiving deposition	7.6 cm
Bulk density for surficial soil receiving deposition	1.6 g/cm^3
X and Y coordinates of exposure site	[3]
Soil leach option	Calculated from infiltration, soil properties, and K_d
Surficial soil sorption distribution coefficient for leaching	[4]
Surficial soil thickness for leaching	7.6 cm
Surficial soil moisture content fraction for leaching	0.3
Surficial soil bulk density for leaching	1.6 g/cm^3
Total infiltration rate for leaching	76.2 cm/yr
Atmospheric resuspension factor for soil	1 x 10^{-7} m^{-1}

[1] Variable and depended on chemical characteristics. Models were run until a maximum exposure concentration was reached.
[2] Depended on maximum time for reporting results, but enough detail to determine maximum exposure concentration.
[3] Not required.
[4] Depended on chemical-specific properties (see Chapter 4).

Receptor module

User input parameters for the Receptor Module are: individual's body weight (set at 70 kg); exposure duration set at 30 years; age at the start and end of the exposure duration (ages must be input but are not presently used except to distinguish output for different receptor age groups); air and soil inhalation parameters (Table 2); and soil ingestion and dermal contact parameters (Table 3). Values for the parameters in Tables 2 and 3 were agreed upon in collaboration with the CHPPM. The area of exposure skin (3,300 cm^2) and the soil adherence factor (0.2 mg cm-2) for an outdoor worker were used and obtained from USEPA (2001a). The annual frequency factors for exposure were based on 50 days and 2 hr per day over 365 days per year, which is:

$$\frac{50}{365} \times \frac{2}{24} = 0.0114$$

Table 2
Air and Soil Inhalation Parameters

Parameter	Value
Inhalation rate for contaminated air	20 m^3/day
Inhalation rate for resuspended contaminated soil	20 m^3/day
Annual frequency factor (fraction of year) for contaminated air inhalation[1]	0.0114
Annual frequency factor (fraction of year) for resuspended soil inhalation[1]	0.0114

[1] Based upon 50 days per year for 2 hours per day

Table 3
Soil Ingestion and Dermal Contact Parameters

Parameter	Value
Skin thickness (not required unless water contact is considered)	0.001 cm
Exposed skin area	3300 cm^2
Soil adherence factor	0.2 mg/cm^2
Soil dermal contact frequency	1 event/day
Annual dermal contact frequency factor (fraction of year)[1]	0.0114
Soil ingestion rate	0.1 g/day
Annual soil ingestion frequency factor (fraction of year)[1]	0.0114

[1] Based upon 50 visits per year for 2 hours per day

In addition to these parameters, the gastrointestinal (GI) absorption fraction and absorption fraction for soil are required and are provided via the constituent physicochemical properties database as discussed in Chapter 4.

Health impacts module

Output from the Receptor Module (doses) is used with either the cancer slope factors (for carcinogens) or the reference doses (for non-carcinogens) to determine the incremental lifetime cancer risk or the hazard index, respectively. Cancer risk is determined by multiplying dose by the cancer slope factor, and hazard index is obtained by dividing the dose by the reference dose. Both metrics apply to an individual, and cancer risk represents lifetime risks, whereas hazard index is averaged over the exposure duration. For the models in ARAMS, exposure concentrations and resulting health impacts can vary over time. A sliding time-average of exposure concentrations and dose are computed over the exposure duration for HI and over 70 years for cancer risk. Although a constant air concentration and depositional flux over time were used in these analyses, the results are time varying since the soil concentrations can change over time as a result of chemical buildup and loss from leaching. Soil chemical concentrations eventually reached a steady-state for constant deposition. Highly adsorptive chemicals required a longer time to reach steady-state.

Subsurface Fate/Transport

For the subsurface fate/transport modeling, the source zone was idealized as a unit area of 1 m × 1 m, and the MEPAS 4.1 Vadose Zone and Aquifer models were used. The User Defined Object with the WFF (Water Flux File) Vadose Zone Module was used to prescribe the boundary conditions for water and chemical fluxes (m^3/yr and g/yr, respectively) moving from the surficial soil horizon into the top of the vadose zone. These flux rates were obtained by taking the infiltration rate (76.2 cm/yr) and air deposition rates (g m^{-2} yr^{-1}) for each chemical obtained from the CHPPM air modeling and multiplying by the unit source area of 1.0 m^2. Output flux (mass/time) from the Vadose Zone model fed into the MEPAS Aquifer model, which was used to obtain concentrations in the

aquifer. A Human Exposure Pathways Module was linked to the Aquifer module to capture concentration versus time at the aquifer exposure location, which was specified as 1.0 m downstream from the point of vadose zone interception and at the top of the water table. This location was chosen to obtain maximum (worst case) aquifer concentrations. The concentration time series yielded the time for the contamination to reach the water table and the maximum concentration, which was the main information of interest for screening chemicals of potential concern. The aquifer exposure location could have been placed farther downstream anywhere in the aquifer to yield concentrations at other desired locations had this been an objective of the study. Input parameters for the subsurface modeling are described in Chapter 4.

4 Input Data

Hydrogeologic Data

Several parameters from the site hydrogeologic characterization data were needed for the simulations. Some of these data were obtained from a site characterization report prepared by AMEC, Earth & Environmental, Inc. (AMEC 2001) and some from the web site on the MMR project (*www.mmr.org*). This section describes the data that were required for the site modeling.

Dispersion

A large-scale tracer test in sand and gravel of Cape Cod, MA, indicated longitudinal, transverse, and vertical dispersivities of 96 cm, 1.8 cm, and 0.15 cm, respectively (Garabedian et al. 1991). These data were included in the ARAMS/FRAMES simulations along with other inputs as indicated in Table 4.

Sorption partitioning

The chemicals evaluated in this study are listed in Table 5. The partition coefficient, K_d (L/kg), for each organic chemical was calculated using K_{ow}, f_{oc}, and the equation defined by Karickhoff et al. (1979)

$$K_d = 0.63\ f_{oc} K_{ow} \quad (1)$$

where

K_{ow} = octanol to water partitioning coefficient, L/kg

f_{oc} = fraction of organic carbon of the soil

Barber et al. (1988) measured the organic carbon content of MMR aquifer materials and used $f_{oc} = 0.001$ in their transport calculations; therefore f_{oc} of 0.001 was used here as well as for K_d calculation. The MEPAS vadose zone and groundwater models (Buck et al. 1995), requires the percentage of organic matter (f_{om}) for use in soil composition. The relationship between f_{oc} (fraction) and f_{om} (percent) is given as:

$$f_{oc} = f_{om} / 172.4 \quad (2)$$

Table 4
Input Parameters for Subsurface Pathway

Parameter	Value
Source (flow data)	
Natural recharge rate	0.762 m yr^{-1}
Vadose Zone (hydrogeologic data)	
Thickness	27 m (90 ft)
Soil Composition	Sandy Clay Loam[1]
Percentage of organic matter	0.1724
Saturated hydraulic conductivity	3337.56 myr^{-1}
Dry bulk density	1.6 g cm^{-3}
Total porosity	39.8 percent
Saturated Zone (hydrogeologic data)	
Thickness	24 m (80 ft)
Soil Composition	Sandy Clay Loam[1]
Percentage of organic matter	0.1724
Dry bulk density	1.6 g cm^{-3}
Total porosity	39.8 percent
Effective porosity	30 percent
Darcy velocity	100 cm day^{-1}
Horizontal dispersivity	0.96 m
Lateral dispersivity	0.018 m
Vertical dispersivity	0.0015 m

[1] Soil composition available in Multimedia Environmental Pollutant Assessment System (MEPAS) model that is closest to the site soil composition.

Table 5 provides the K_d values for all the chemicals evaluated in this study. The K_{ow} values for organic chemicals used in Equation 1 were obtained from either the ARAMS/FRAMES constituent database or the Estimations Programs Interface EPI suite software (USEPA 2000). For inorganic chemicals, the sorption coefficient is highly site-specific and usually dependent on soil composition, cation exchange capacity, water pH, and other factors. Therefore, if site data become available, the K_d value should be adjusted accordingly. For this study, K_d values for inorganic chemicals were obtained from Strenge et al. (1989).

Decay Rates

The MEPAS human exposure pathways model provides the exposure concentrations for soil dermal contact, soil incidental ingestion, and inhalation of air and suspended soil. The soil concentrations computed by the human exposure pathways model can change with time as a result of deposition, leaching, and decay. Soil and chemical loss due to wind and water erosion are not considered. A conservative assessment approach was adopted in which decay (i.e., degradation) was not considered. Furthermore, information on degradation rates for these chemicals in the natural environment is generally not available.

Table 5
Adsorption Coefficient of the Chemicals

ID	Chemical	CAS No. [1]	K_d (L/kg^{-1})	Reference[2]
1	1,1,2,2-Tetrachloroethane	79-34-5	0.155	ARAMS/FRAMES
2	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	0.911	ARAMS/FRAMES
3	1,1,2-Trichloroethane	79-00-5	0.050	ARAMS/FRAMES
4	1,1-Dichloro-2-propanone	513-88-2	0.001	EPI Software
5	1,1-Dichloroethane	75-34-3	0.040	ARAMS/FRAMES
6	1,2,3-Trichloropropane	96-18-4	0.120	ARAMS/FRAMES
7	1,2,4-Trichlorobenzene	120-82-1	6.600	ARAMS/FRAMES
8	1,2-Dichloro-2-methylpropane	594-37-6	0.320	EPI Software
9	1,2-Dichloro-3-methylbenzene	32768-54-0	5.750	EPI Software
10	1,2-Dichlorobenzene	95-50-1	1.700	ARAMS/FRAMES
11	1,2-Dichlorobutane	616-21-7	0.350	EPI Software
12	1,2-Dichloroethane	107-06-2	0.020	ARAMS/FRAMES
13	1,2-Dichloropropane	78-87-5	0.060	ARAMS/FRAMES
14	1,3,5-Trimethylbenzene	108-67-8	1.660	ARAMS/FRAMES
15	1,3-Butadiene	106-99-0	0.060	ARAMS/FRAMES
16	1,3-Dichlorobenzene	541-73-1	2.135	ARAMS/FRAMES
17	1,4-Dichlorobenzene	106-46-7	1.740	ARAMS/FRAMES
18	1-Acetoxyacetone	592-20-1	4.00E-04	EPI Software
19	1-Bromo-2-chloroethane	107-04-0	0.052	EPI Software
20	1-Butanol	71-36-3	0.005	ARAMS/FRAMES
21	1-Butene	106-98-9	0.160	EPI Software
22	1-Chloro-2-methylbenzene	95-49-8	1.660	ARAMS/FRAMES
23	1-Chloro-3-methylbenzene	108-41-8	1.200	EPI Software
24	1-Chloro-4-ethylbenzene	622-98-0	3.000	EPI Software
25	1-Chlorobutane	109-69-3	0.280	ARAMS/FRAMES
26	1-Hexene	592-41-6	1.550	EPI Software
27	1-Hydroxy-2-propanone	116-09-6	1.00E-04	EPI Software
28	1-Penten-3-one	1629-58-9	0.005	EPI Software
29	1-Pentene	109-67-1	0.288	EPI Software
30	2,2,4-Trimethylhexane	16747-26-5	24.000	EPI Software
31	2,2,4-Trimethylpentane	540-84-1	7.750	EPI Software
32	2,2-Dimethylbutane	75-83-2	4.160	EPI Software
33	2,2-Dimethylpropane	463-82-1	0.812	EPI Software
34	2,3,4-Trimethylpentane	565-75-3	7.070	EPI Software
35	2,3-Butanedione	431-03-8	2.88E-05	EPI Software
36	2,3-Dihydro-1-methyl-1H-indene	767-58-8	4.780	EPI Software
37	2,3-Dimethylbutane	79-29-8	1.660	EPI Software
38	2,3-Dimethylhexane	584-94-1	8.300	EPI Software
39	2,3-Dimethylpentane	565-59-3	2.687	EPI Software

(Sheet 1 of 5)

[1] CAS Number = Chemical Abstract Service Number.
[2] References for K_{ow} values for organic and K_d for Inorganic chemicals, PNNL = Strenge , D. L., S. R. Peterson , and Sager (1989).

Table 5 (Continued)

ID	Chemical	CAS No.	K_d (L/kg^{-1})	Reference
40	2,3-Pentanedione	600-14-6	8.90E-05	EPI Software
41	2,4-Dimethylhexane	589-43-5	8.300	EPI Software
42	2,4-Dimethylpentane	108-08-7	2.700	EPI Software
43	2,5-Dimethylfuran	625-86-5	0.109	EPI Software
44	2,5-Dimethylhexane	592-13-2	8.310	EPI Software
45	2-Bromo-1-chloropropane	3017-95-6	0.140	EPI Software
46	2-Butoxyethanol	111-76-2	0.004	ARAMS/FRAMES
47	2-Furaldehyde	98-01-1	0.002	ARAMS/FRAMES
48	2-Heptanone	110-43-0	0.060	EPI Software
49	2-Hexanone	591-78-6	0.015	ARAMS/FRAMES
50	2-Methyl-1-butene	563-46-2	0.331	EPI Software
51	2-Methyl-1-pentene	763-29-1	1.022	EPI Software
52	2-Methyl-2-butene	513-35-9	0.295	EPI Software
53	2-Methyl-2-pentene	625-27-4	0.850	EPI Software
54	2-Methylfuran	534-22-5	0.045	EPI Software
55	2-Methylheptane	592-27-8	9.985	EPI Software
56	2-Methylhexane	591-76-4	3.230	EPI Software
57	2-Methylnaphthalene	91-57-6	4.560	ARAMS/FRAMES
58	2-Methylpentane	107-83-5	1.020	EPI Software
59	2-Methylthiophene	554-14-3	0.135	EPI Software
60	2-Nitrophenol	88-75-5	0.039	EPI Software
61	2-Octanone	111-13-7	0.148	EPI Software
62	2-Pentanone	107-87-9	0.005	EPI Software
63	2-Propanol	67-63-0	7.00E-4	ARAMS/FRAMES
64	2-Thiophenecarboxaldehyde	98-03-3	6.60E-03	EPI Software
65	3-Ethylhexane	619-99-8	9.985	EPI Software
66	3-Heptanone	106-35-4	0.038	EPI Software
67	3-Methyl-1-butene	563-45-1	0.245	EPI Software
68	3-Methyl-2-butanone	563-80-4	0.004	EPI Software
69	3-Methylfuran	930-27-8	0.050	EPI Software
70	3-Methylhexane	589-34-4	3.230	EPI Software
71	3-Methylpentane	96-14-0	2.500	EPI Software
72	3-Methylphenol	108-39-4	0.060	ARAMS/FRAMES
73	3-Methylthiophene	616-44-4	0.140	EPI Software
74	3-Pentanone	96-22-0	0.006	EPI Software
75	4-Methyl-1-pentene	691-37-2	0.757	EPI Software
76	4-Methyl-2-pentanone	108-10-1	0.013	ARAMS/FRAMES
77	4-Methylbenzonitrile	104-85-8	0.077	EPI Software
78	4-Methylphenol	106-44-5	0.050	ARAMS/FRAMES
79	5-Methyl-2-furaldehyde	620-02-0	0.003	EPI Software
80	6-Methyl-2-heptanone	928-68-7	0.090	EPI Software
81	6-Methyl-5-hepten-2-one	110-93-0	0.070	EPI Software

(Sheet 2 of 5)

Table 5 (Continued)

ID	Chemical	CAS No.	K_d (L/kg^{-1})	Reference
82	Acenaphthylene	208-96-8	5.500	ARAMS/FRAMES
83	Acetaldehyde	75-07-0	3.0E-04	ARAMS/FRAMES
84	Acetic Acid	64-19-7	4.0E-04	EPI Software
85	Acetone	67-64-1	4.0E-04	ARAMS/FRAMES
86	Acetonitrile	75-05-8	3.0E-04	ARAMS/FRAMES
87	Acetophenone	98-86-2	0.0240	ARAMS/FRAMES
88	Acetylene	74-86-2	1.5E-03	EPI Software
89	Acrolein	107-02-8	6.0E-04	ARAMS/FRAMES
90	Acrylonitrile	107-13-1	0.001	ARAMS/FRAMES
91	Aluminum	7429-90-5	3.53E+04	PNNL
92	Antimony	7440-36-0	6.00E+00	PNNL
93	Barium	7440-39-3	2.80E+03	PNNL
94	Benzofuran	271-89-6	0.290	EPI Software
95	Benzoic acid	65-85-0	0.050	ARAMS/FRAMES
96	Benzonitrile	100-47-0	0.023	EPI Software
97	Benzyl alcohol	100-51-6	0.008	ARAMS/FRAMES
98	Beryllium	7440-41-7	1.40E+03	PNNL
99	bis(2-Ethylhexyl)phthalate	117-81-7	2.51E+04	ARAMS/FRAMES
100	Butanal	123-72-8	0.005	EPI Software
101	Butyl Acetate	123-86-4	0.040	EPI Software
102	Butylbenzylphthalate	85-68-7	33.800	ARAMS/FRAMES
103	Carbon Dioxide	124-38-9	0.004	EPI Software
104	Carbonyl Sulfide	463-58-1	2.95E-05	EPI Software
105	Chlorobenzene	108-90-7	0.440	ARAMS/FRAMES
106	Chloroethene	75-01-4	0.026	ARAMS/FRAMES
107	cis 1,3-Dichloro-1-propene	10061-01-5	0.072	EPI Software
108	cis-2-Butene	590-18-1	0.135	EPI Software
109	cis-2-Hexene	7688-21-3	0.740	EPI Software
110	cis-2-Pentene	627-20-3	0.240	EPI Software
111	Cobalt	7440-48-4	8.81E+00	PNNL
112	Copper	7440-50-8	9.22E+01	PNNL
113	Cyclohexane	110-82-7	1.740	EPI Software
114	Cyclohexanone	108-94-1	0.004	ARAMS/FRAMES
115	Cyclopentane	287-92-3	0.630	EPI Software
116	Cyclopentanone	120-92-3	0.003	EPI Software
117	Cyclopentene	142-29-0	0.186	EPI Software
118	Decanal	112-31-2	3.630	EPI Software
119	Dichloroacetonitrile	3018-12-0	0.001	EPI Software
120	Dichlorodifluoromethane	75-71-8	0.092	ARAMS/FRAMES
121	Diethylphthalate	84-66-2	0.166	ARAMS/FRAMES
122	Dimethyldisulfide	624-92-0	0.037	EPI Software
123	Di-n-butylphthalate	84-74-2	19.900	ARAMS/FRAMES

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Table 5 (Continued)

ID	Chemical	CAS No.	K_d (L/kg^{-1})	Reference
124	d-Limonene	5989-27-5	23.4	EPI Software
125	Ethane	74-84-0	0.040	EPI Software
126	Ethanol	64-17-5	3.0E-04	EPI Software
127	Ethylchloride	75-00-3	0.017	ARAMS/FRAMES
128	Ethylene	74-85-1	0.008	EPI Software
129	Fluorene	86-73-7	9.540	ARAMS/FRAMES
130	Heptanal	111-71-7	0.123	EPI Software
131	Hexachlorobutadiene	87-68-3	38.000	ARAMS/FRAMES
132	Hexachlorocyclopentadiene	77-47-4	69.100	ARAMS/FRAMES
133	Hexachloroethane	67-72-1	8.700	ARAMS/FRAMES
134	Hexachloropropene	1888-71-7	15.100	EPI Software
135	Hexanal	66-25-1	0.040	EPI Software
136	Indane	496-11-7	0.950	EPI Software
137	Isobutane	75-28-5	0.360	EPI Software
138	Isobutene	115-11-7	0.140	EPI Software
139	Isopentane	78-78-4	0.330	EPI Software
140	Isoprene	78-79-5	0.165	EPI Software
141	Isopropylbenzene	98-82-8	2.900	ARAMS/FRAMES
142	Isothiocyanatomethane	556-61-6	0.005	EPI Software
143	Magnesium	7439-95-4	1.40E+03	PNNL
144	Manganese	7439-96-5	2.53E+01	PNNL
145	Mercury	7439-97-6	5.80E+02	PNNL
146	Methacrolein	78-85-3	0.003	EPI Software
147	Methylbromide	74-83-9	0.010	ARAMS/FRAMES
148	Methylchloroform	71-55-6	0.190	ARAMS/FRAMES
149	Methylcyclohexane	108-87-2	2.570	ARAMS/FRAMES
150	Methylcyclopentane	96-37-7	1.480	ARAMS/FRAMES
151	Methylnitrite	624-91-9	0.005	EPI Software
152	m-Ethyltoluene	620-14-4	6.020	EPI Software
153	Methyl-vinyl Ketone	78-94-4	1.60E-03	EPI Software
154	MTBE	1634-04-4	0.005	ARAMS/FRAMES
155	m-Xylene	108-38-3	0.998	ARAMS/FRAMES
156	n-Butane	106-97-8	0.490	EPI Software
157	n-Decane	124-18-5	64.500	EPI Software
158	n-Heptane	142-82-5	28.800	ARAMS/FRAMES
159	n-Hexane	110-54-3	5.000	ARAMS/FRAMES
160	Nickel	7440-02-0	5.86E+01	PNNL
161	Nitromethane	75-52-5	3.0E-04	EPI Software
162	n-Nonane	111-84-2	36.300	EPI Software
163	n-Octane	111-65-9	95.400	EPI Software
164	Nonanal	124-19-6	1.170	EPI Software
165	n-Pentane	109-66-0	1.550	EPI Software

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Table 5 (Concluded)

ID	Chemical	CAS No.	K_d (L/kg^{-1})	Reference
166	n-Propylbenzene	103-65-1	3.090	EPI Software
167	Octanal	124-13-0	0.380	EPI Software
168	o-Ethyltoluene	611-14-3	2.130	EPI Software
169	o-Xylene	95-47-6	0.830	EPI Software
170	Pentachloro-1-propene	1600-37-9	1.770	EPI Software
171	Pentanal	110-62-3	0.013	EPI Software
172	p-Ethyltoluene	622-96-8	2.690	EPI Software
173	Phenol	108-95-2	0.018	ARAMS/FRAMES
174	Phenylacetylene	536-74-3	0.210	EPI Software
175	Propanal	123-38-6	0.002	EPI Software
176	Propane	74-98-6	0.144	EPI Software
177	Propanenitrile	107-12-0	9.0E-04	EPI Software
178	Propene	115-07-1	0.040	EPI Software
179	p-Xylene	106-42-3	9.0E-01	ARAMS/FRAMES
180	sec-Butylbenzene	135-98-8	23.400	EPI Software
181	Selenium	7782-49-2	1.49E+01	PNNL
182	Silver	7440-22-4	4.00E+00	PNNL
183	Styrene	100-42-5	0.561	ARAMS/FRAMES
184	Tetrahydrofuran	109-99-9	0.002	EPI Software
185	Thiophene	110-02-1	0.040	EPI Software
186	trans 1,3-Dichloro-1-propene	10061-02-6	2.5E-03	EPI Software
187	trans-2-Butenal	123-73-9	2.5E-03	EPI Software
188	trans-2-Butene	624-64-6	0.130	EPI Software
189	trans-2-Hexene	4050-45-7	0.740	EPI Software
190	trans-2-Pentene	646-04-8	0.240	EPI Software
191	trans-3-Penten-2-one	3102-33-8	0.004	EPI Software
192	Trichloroacetonitrile	545-06-2	0.077	EPI Software
193	Trichloromonofluoromethane	75-69-4	0.213	ARAMS/FRAMES
194	Vinylidene chloride	75-35-4	0.084	ARAMS/FRAMES
195	Zinc	7440-66-6	9.39E+02	PNNL

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Toxicological and Exposure Data

The human risk calculations require input of toxicological data. Human toxicological benchmarks are not available for most of the chemical compounds evaluated in this study. A data search utilized on-line databases, including the Risk Assessment Information System (RAIS, *http://risk.lsd.ornl.gov/*), EPA Integrated Risk Information System (IRIS, *http://www.epa.gov/iriswebp/iris/*), and International Toxicity Estimates for Risk (ITER, *http://iter.ctcnet.net/*) databases. The required input data for the carcinogenic risk calculation are different from those for the non-carcinogenic hazards calculations. Non-carcinogenic reference dose/concentrations for HI calculation were available for 59 of the chemicals, while cancer slope factors/unit risk for the carcinogenic risk

calculations were available for only 13 chemicals. The MEPAS health impacts model uses the oral reference dose and oral cancer slope factor along with the gastrointestinal (GI) absorption fraction to calculate dermal toxicological values per USEPA guidance (USEPA 1992). Dermal reference dose is obtained by multiplying the oral reference dose by the GI absorption fraction. The dermal cancer slope factor is obtained by dividing the oral slope by the GI absorption fraction. The GI absorption fractions shown in Table 6 were used for these calculations in MEPAS. The soil chemical-specific dermal absorption fraction is also required. The values for GI absorption fraction and dermal absorption fraction shown in Table 6 were obtained from the RAIS database.

Boundary Loading Conditions

The CHPPM provided the air concentrations and deposition rates used as input to ARAMS/FRAMES. The data set consisted of location-specific data and spatially averaged data. Other variables provided included: P_c, the average annual particulate concentration in air (μg m^{-3}); P_{dd}, the average annual deposition rate resulting from dry deposition/gravitational settling of particulates (g m^{-2} yr^{-1}); P_{wd}, the average annual deposition rate resulting from wet deposition (rain and snow) of particulates (g m^2 yr^{-1}); V_c, the average annual vapor concentration in air (μg m^{-3}); V_{wd}, the average annual deposition rate of vapors due to rain and snow (g m^2 yr^{-1}); *VF*, the vapor fraction of each chemical; and *PF*, particle fraction of each chemical.

The selected chemicals can be in gas, particle, or both forms. The load data were kept constant throughout the simulation. Total (wet and dry) deposition rates were used. Figure 2 shows, as an example, the input screen of the User-Defined ATO Air Module of ARAMS/FRAMES for acenaphthylene. In Figure 2, P1 Total is the total particulate deposition rate, and AC Gas and AC P1 are the air concentrations for gas and particulate phases, respectively. Tables 7, 8, and 9 provide the complete list of air concentration and deposition data used in this study. The annual average air concentration and deposition rates were spatially averaged over the entire study site and used to drive the analyses in this report. The details of the air modeling and resulting loading conditions for the ARAMS modeling are described by Zakikhani et al. (2004).

The deposition rates and air concentrations were held constant for 100 years, then they were set to zero after year 100. A total simulation time of 100 years was used for assessing human health impacts. For the subsurface transport modeling, the vadose zone and aquifer models were run until vadose zone fluxes and aquifer concentrations peaked and came back down to near 0.0, but with a maximum simulation time of 10,000 years.

Table 6
Toxicity Values used in the Analysis

ID	Chemical	CAS Number	Absorption Faction, Dermal	GI Absorption Fraction	Inhalation Chronic RfD mg/kg-day	Oral Chronic RfD mg/kg-day	Inhalation Slope Factor $mg/kg\text{-}day^{-1}$	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$
1	1,1,2,2-Tetrachloroethane	79-34-5	1.00E-02	7.00E-01	NA	6.00E-02	2.03E-01	2.00E-01
2	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	1.00E-02	8.00E-01	8.57	3.00E+01	NA	NA
3	1,1,2-Trichloroethane	79-00-5	1.00E-02	8.10E-01	NA	4.00E-03	5.60E-02	5.70E-02
4	1,1-Dichloro-2-propanone	513-88-2	NA	NA	NA	NA	NA	NA
5	1,1-Dichloroethane	75-34-3	1.00E-02	1.00E+00	0.143	1.00E-01	NA	NA
6	1,2,3-Trichloropropane	96-18-4	1.00E-02	8.00E-01	NA	6.00E-03	NA	7.00E+00
7	1,2,4-Trichlorobenzene	120-82-1	1.00E-02	9.70E-01	0.00114	1.00E-02	NA	NA
8	1,2-Dichloro-2-methylpropane	594-37-6	NA	NA	NA	NA	NA	NA
9	1,2-Dichloro-3-methylbenzene	32768-54-0	NA	NA	NA	NA	NA	NA
10	1,2-Dichlorobenzene	95-50-1	1.00E-02	8.00E-01	5.71E-02	9.00E-02	NA	NA
11	1,2-Dichlorobutane	616-21-7	NA	NA	NA	NA	NA	NA
12	1,2-Dichloroethane	107-06-2	1.00E-02	1.00E+00	NA	NA	9.10E-02	9.10E-02
13	1,2-Dichloropropane	78-87-5	1.00E-02	7.40E-01	1.14E-03	NA	NA	6.80E-02
14	1,3,5-Trimethylbenzene	108-67-8	1.00E-02	8.00E-01	0.00171	5.00E-02	NA	NA
15	1,3-Butadiene	106-99-0	1.00E-02	8.00E-01	0.000571	NA	1.05E-01	NA
16	1,3-Dichlorobenzene	541-73-1	1.00E-02	8.00E-01	NA	NA	NA	NA
17	1,4-Dichlorobenzene	106-46-7	1.00E-02	9.00E-01	2.29E-01	NA	NA	2.40E-02
18	1-Acetoxyacetone	592-20-1	NA	NA	NA	NA	NA	NA
19	1-Bromo-2-chloroethane	107-04-0	NA	NA	NA	NA	NA	NA
20	1-Butanol	71-36-3	1.00E-02	5.00E-01	NA	1.00E-01	NA	NA
21	1-Butene	106-98-9	NA	NA	NA	NA	NA	NA
22	1-Chloro-2-methylbenzene	95-49-8	1.00E-02	8.00E-01	NA	2.00E-02	NA	NA
23	1-Chloro-3-methylbenzene	108-41-8	NA	NA	NA	NA	NA	NA
24	1-Chloro-4-ethylbenzene	622-98-0	NA	NA	NA	NA	NA	NA
25	1-Chlorobutane	109-69-3	1.00E-02	8.00E-01	NA	4.00E-01	NA	NA
26	1-Hexene	592-41-6	NA	NA	NA	NA	NA	NA
27	1-Hydroxy-2-propanone	116-09-6	NA	NA	NA	NA	NA	NA

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Table 6 (Continued)

ID	Chemical	CAS Number	Absorption Faction, Dermal	GI Absorption Fraction	Inhalation Chronic RfD mg/kg-day	Oral Chronic RfD mg/kg-day	Inhalation Slope Factor mg/kg-day^{-1}	Oral Slope Factor (mg/kg-day)$^{-1}$
28	1-Penten-3-one	1629-58-9	NA	NA	NA	NA	NA	NA
29	1-Pentene	109-67-1	NA	NA	NA	NA	NA	NA
30	2,2,4-Trimethylhexane	16747-26-5	NA	NA	NA	NA	NA	NA
31	2,2,4-Trimethylpentane	540-84-1	NA	NA	NA	NA	NA	NA
32	2,2-Dimethylbutane	75-83-2	NA	NA	NA	NA	NA	NA
33	2,2-Dimethylpropane	463-82-1	NA	NA	NA	NA	NA	NA
34	2,3,4-Trimethylpentane	565-75-3	NA	NA	NA	NA	NA	NA
35	2,3-Butanedione	431-03-8	NA	NA	NA	NA	NA	NA
36	2,3-Dihydro-1-methyl-1H-indene	767-58-8	NA	NA	NA	NA	NA	NA
37	2,3-Dimethylbutane	79-29-8	NA	NA	NA	NA	NA	NA
38	2,3-Dimethylhexane	584-94-1	NA	NA	NA	NA	NA	NA
39	2,3-Dimethylpentane	565-59-3	NA	NA	NA	NA	NA	NA
40	2,3-Pentanedione	600-14-6	NA	NA	NA	NA	NA	NA
41	2,4-Dimethylhexane	589-43-5	NA	NA	NA	NA	NA	NA
42	2,4-Dimethylpentane	108-08-7	NA	NA	NA	NA	NA	NA
43	2,5-Dimethylfuran	625-86-5	NA	NA	NA	NA	NA	NA
44	2,5-Dimethylhexane	592-13-2	NA	NA	NA	NA	NA	NA
45	2-Bromo-1-chloropropane	3017-95-6	NA	NA	NA	NA	NA	NA
46	2-Butoxyethanol	111-76-2	1.00E-02	5.00E-01	3.71	5.00E-01	NA	NA
47	2-Furaldehyde	98-01-1	1.00E-02	5.00E-01	0.0143	3.00E-03	NA	NA
48	2-Heptanone	110-43-0	NA	NA	NA	NA	NA	NA
49	2-Hexanone	591-78-6	1.00E-02	6.60E-01	NA	NA	NA	NA
50	2-Methyl-1-butene	563-46-2	NA	NA	NA	NA	NA	NA
51	2-Methyl-1-pentene	763-29-1	NA	NA	NA	NA	NA	NA
52	2-Methyl-2-butene	513-35-9	NA	NA	NA	NA	NA	NA
53	2-Methyl-2-pentene	625-27-4	NA	NA	NA	NA	NA	NA
54	2-Methylfuran	534-22-5	NA	NA	NA	NA	NA	NA
55	2-Methylheptane	592-27-8	NA	NA	NA	NA	NA	NA

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Table 6 (Continued)

ID	Chemical	CAS Number	Absorption Faction, Dermal	GI Absorption Fraction	Inhalation Chronic RfD mg/kg-day	Oral Chronic RfD mg/kg-day	Inhalation Slope Factor $mg/kg\text{-}day^{-1}$	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$
56	2-Methylhexane	591-76-4	NA	NA	NA	NA	NA	NA
57	2-Methylnaphthalene	91-57-6	1.00E-02	8.00E-01	NA	NA	NA	NA
58	2-Methylpentane	107-83-5	NA	NA	NA	NA	NA	NA
59	2-Methylthiophene	554-14-3	NA	NA	NA	NA	NA	NA
60	2-Nitrophenol	88-75-5	NA	NA	NA	NA	NA	NA
61	2-Octanone	111-13-7	NA	NA	NA	NA	NA	NA
62	2-Pentanone	107-87-9	NA	NA	NA	NA	NA	NA
63	2-Propanol	67-63-0	1.00E-02	1.00E+00	NA	NA	NA	NA
64	2-Thiophenecarboxaldehyde	98-03-3	NA	NA	NA	NA	NA	NA
65	3-Ethylhexane	619-99-8	NA	NA	NA	NA	NA	NA
66	3-Heptanone	106-35-4	NA	NA	NA	NA	NA	NA
67	3-Methyl-1-butene	563-45-1	NA	NA	NA	NA	NA	NA
68	3-Methyl-2-butanone	563-80-4	NA	NA	NA	NA	NA	NA
69	3-Methylfuran	930-27-8	NA	NA	NA	NA	NA	NA
70	3-Methylhexane	589-34-4	NA	NA	NA	NA	NA	NA
71	3-Methylpentane	96-14-0	NA	NA	NA	NA	NA	NA
72	3-Methylphenol	108-39-4	1.00E-02	5.00E-01	NA	5.00E-02	NA	NA
73	3-Methylthiophene	616-44-4	NA	NA	NA	NA	NA	NA
74	3-Pentanone	96-22-0	NA	NA	NA	NA	NA	NA
75	4-Methyl-1-pentene	691-37-2	NA	NA	NA	NA	NA	NA
76	4-Methyl-2-pentanone	108-10-1	1.00E-02	8.00E-01	0.857	8.00E-02	NA	NA
77	4-Methylbenzonitrile	104-85-8	NA	NA	NA	NA	NA	NA
78	4-Methylphenol	106-44-5	1.00E-02	6.50E-01	NA	5.00E-03	NA	NA
79	5-Methyl-2-furaldehyde	620-02-0	NA	NA	NA	NA	NA	NA
80	6-Methyl-2-heptanone	928-68-7	NA	NA	NA	NA	NA	NA
81	6-Methyl-5-hepten-2-one	110-93-0	NA	NA	NA	NA	NA	NA
82	Acenaphthylene	208-96-8	1.00E-02	3.10E-01	NA	NA	NA	NA
83	Acetaldehyde	75-07-0	1.00E-02	8.00E-01	2.57E-03	NA	7.70E-03	NA

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Table 6 (Continued)

ID	Chemical	CAS Number	Absorption Faction, Dermal	GI Absorption Fraction	Inhalation Chronic RfD mg/kg-day	Oral Chronic RfD mg/kg-day	Inhalation Slope Factor $mg/kg\text{-}day^{-1}$	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$
84	Acetic Acid	64-19-7	NA	NA	NA	NA	NA	NA
85	Acetone	67-64-1	1.00E-02	8.30E-01	NA	9.00E-01	NA	NA
86	Acetonitrile	75-05-8	1.00E-02	8.00E-01	1.71E-02	6.00E-03	NA	NA
87	Acetophenone	98-86-2	1.00E-02	8.00E-01	5.71E-06	1.00E-01	NA	NA
88	Acetylene	74-86-2	NA	NA	NA	NA	NA	NA
89	Acrolein	107-02-8	1.00E-02	8.00E-01	5.71E-06	5.00E-04	NA	NA
90	Acrylonitrile	107-13-1	1.00E-02	8.00E-01	5.71E-04	1.00E-03b	2.38E-01	5.40E-01
91	Aluminum	7429-90-5	1.00E-03	1.00E-01	0.00143	1.00E+00	NA	NA
92	Antimony	7440-36-0	1.00E-03	2.00E-02	NA	4.00E-04	NA	NA
93	Barium	7440-39-3	1.00E-03	7.00E-02	1.43E-04	7.00E-02	NA	NA
94	Benzofuran	271-89-6	NA	NA	NA	NA	NA	NA
95	Benzoic acid	65-85-0	1.00E-02	1.00E+00	NA	4.00E+00	NA	NA
96	Benzonitrile	100-47-0	NA	NA	NA	NA	NA	NA
97	Benzyl alcohol	100-51-6	1.00E-02	6.60E-01	NA	3.00E-01	NA	NA
98	Beryllium	7440-41-7	1.00E-03	1.00E-02	5.71E-06	2.00E-03	8.40E+00	4.30E+00
99	bis(2-Ethylhexyl)phthalate	117-81-7	1.00E-02	1.90E-01	NA	2.00E-02	NA	1.40E-02
100	Butanal	123-72-8	NA	NA	NA	NA	NA	NA
101	Butyl Acetate	123-86-4	NA	NA	NA	NA	NA	NA
102	Butylbenzylphthalate	85-68-7	1.00E-02	6.10E-01	NA	2.00E-01	NA	NA
103	Carbon Dioxide	124-38-9	NA	NA	NA	NA	NA	NA
104	Carbonyl Sulfide	463-58-1	NA	NA	NA	NA	NA	NA
105	Chlorobenzene	108-90-7	1.00E-02	3.10E-01	0.00571	2.00E-02	NA	NA
106	Chloroethene	75-01-4	1.00E-02	1.00E+00	0.0286	3.00E-03	3.08E-02	1.40E+00
107	cis 1,3-Dichloro-1-propene	10061-01-5	NA	NA	NA	NA	NA	NA
108	cis-2-Butene	590-18-1	NA	NA	NA	NA	NA	NA
109	cis-2-Hexene	7688-21-3	NA	NA	NA	NA	NA	NA
110	cis-2-Pentene	627-20-3	NA	NA	NA	NA	NA	NA
111	Cobalt	7440-48-4	1.00E-03	8.00E-01	5.71E-06	2.00E-02	9.80E+00	NA

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Table 6 (Continued)

ID	Chemical	CAS Number	Absorption Faction, Dermal	GI Absorption Fraction	Inhalation Chronic RfD mg/kg-day	Oral Chronic RfD mg/kg-day	Inhalation Slope Factor $mg/kg\text{-}day^{-1}$	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$
112	Copper	7440-50-8	1.00E-03	3.00E-01	NA	4.00E-02	NA	NA
113	Cyclohexane	110-82-7	NA	NA	1.71E+00	NA	NA	NA
114	Cyclohexanone	108-94-1	1.00E-02	8.00E-01	NA	5.00E+00	NA	NA
115	Cyclopentane	287-92-3	NA	NA	NA	NA	NA	NA
116	Cyclopentanone	120-92-3	NA	NA	NA	NA	NA	NA
117	Cyclopentene	142-29-0	NA	NA	NA	NA	NA	NA
118	Decanal	112-31-2	NA	NA	NA	NA	NA	NA
119	Dichloroacetonitrile	3018-12-0	NA	NA	NA	NA	NA	NA
120	Dichlorodifluoromethane	75-71-8	1.00E-02	2.30E-01	0.0571	2.00E-01	NA	NA
121	Diethylphthalate	84-66-2	1.00E-02	9.00E-01	NA	8.00E-01	NA	NA
122	Dimethyldisulfide	624-92-0	NA	NA	NA	NA	NA	NA
123	Di-n-butylphthalate	84-74-2	1.00E-02	1.00E+00	NA	1.00E-01	NA	NA
124	d-Limonene	5989-27-5	NA	NA	NA	NA	NA	NA
125	Ethane	74-84-0	NA	NA	NA	NA	NA	NA
126	Ethanol	64-17-5	NA	NA	NA	NA	NA	NA
127	Ethylchloride	75-00-3	1.00E-02	8.00E-01	2.86E+00	NA	NA	NA
128	Ethylene	74-85-1	NA	NA	NA	NA	NA	NA
129	Fluorene	86-73-7	1.00E-02	5.00E-01	NA	4.00E-02	NA	NA
130	Heptanal	111-71-7	NA	NA	NA	NA	NA	NA
131	Hexachlorobutadiene	87-68-3	1.00E-02	5.00E-01	NA	2.00E-04	7.70E-02	7.80E-02
132	Hexachlorocyclopentadiene	77-47-4	1.00E-02	5.00E-01	5.71e-005	6.00E-03	NA	NA
133	Hexachloroethane	67-72-1	1.00E-02	5.00E-01	NA	1.00E-03	1.40E-02	1.40E-02
134	Hexachloropropene	1888-71-7	NA	NA	NA	NA	NA	NA
135	Hexanal	66-25-1	NA	NA	NA	NA	NA	NA
136	Indane	496-11-7	NA	NA	NA	NA	NA	NA
137	Isobutane	75-28-5	NA	NA	NA	NA	NA	NA
138	Isobutene	115-11-7	NA	NA	NA	NA	NA	NA
139	Isopentane	78-78-4	NA	NA	NA	NA	NA	NA

(Sheet 5 of 7)

Table 6 (Continued)

ID	Chemical	CAS Number	Absorption Faction, Dermal	GI Absorption Fraction	Inhalation Chronic RfD mg/kg-day	Oral Chronic RfD mg/kg-day	Inhalation Slope Factor mg/kg-day^{-1}	Oral Slope Factor (mg/kg-day)$^{-1}$
140	Isoprene	78-79-5	NA	NA	NA	NA	NA	NA
141	Isopropylbenzene	98-82-8	1.00E-02	8.00E-01	0.114	1.00E-01	NA	NA
142	Isothiocyanatomethane	556-61-6	NA	NA	NA	NA	NA	NA
143	Magnesium	7439-95-4	1.00E-03	2.00E-01	NA	NA	NA	NA
144	Manganese	7439-96-5	1.00E-03	4.00E-02	1.43e-005	4.60E-02	NA	NA
145	Mercury	7439-97-6	1.00E-03	7.00E-02	NA	3.00E-04	NA	NA
146	Methacrolein	78-85-3	NA	NA	NA	NA	NA	NA
147	Methylbromide	74-83-9	1.00E-02	8.00E-01	0.00143	1.40E-03	NA	NA
148	Methylchloroform	71-55-6	1.00E-02	9.00E-01	0.629	2.00E-01	NA	NA
149	Methylcyclohexane	108-87-2	1.00E-02	8.00E-01	0.857	NA	NA	NA
150	Methylcyclopentane	96-37-7	1.00E-02	8.00E-01	NA	NA	NA	NA
151	Methylnitrite	624-91-9	NA	NA	NA	NA	NA	NA
152	m-Ethyltoluene	620-14-4	NA	NA	NA	NA	NA	NA
153	Methyl-vinyl Ketone	78-94-4	NA	NA	NA	NA	NA	NA
154	MTBE	1634-04-4	1.00E-02	8.00E-01	0.857	NA	NA	NA
155	m-Xylene	108-38-3	1.00E-02	8.00E-01	NA	2.00E+00	NA	NA
156	n-Butane	106-97-8	NA	NA	NA	NA	NA	NA
157	n-Decane	124-18-5	NA	NA	NA	NA	NA	NA
158	n-Heptane	142-82-5	1.00E-02	8.00E-01	NA	NA	NA	NA
159	n-Hexane	110-54-3	1.00E-02	8.00E-01	0.0571	6.00E-02	NA	NA
160	Nickel	7440-02-0	1.00E-03	2.70E-01	NA	2.00E-02	NA	NA
161	Nitromethane	75-52-5	NA	NA	NA	NA	NA	NA
162	n-Nonane	111-84-2	NA	NA	NA	NA	NA	NA
163	n-Octane	111-65-9	NA	NA	NA	NA	NA	NA
164	Nonanal	124-19-6	NA	NA	NA	NA	NA	NA
165	n-Pentane	109-66-0	NA	NA	NA	NA	NA	NA
166	n-Propylbenzene	103-65-1	NA	NA	NA	NA	NA	NA
167	Octanal	124-13-0	NA	NA	NA	NA	NA	NA

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Table 6 (Concluded)

ID	Chemical	CAS Number	Absorption Faction, Dermal	GI Absorption Fraction	Inhalation Chronic RfD mg/kg-day	Oral Chronic RfD mg/kg-day	Inhalation Slope Factor $mg/kg\text{-}day^{-1}$	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$
168	o-Ethyltoluene	611-14-3	NA	NA	NA	NA	NA	NA
169	o-Xylene	95-47-6	1.00E-02	8.00E-01	NA	2.00E+00	NA	NA
170	Pentachloro-1-propene	1600-37-9	NA	NA	NA	NA	NA	NA
171	Pentanal	110-62-3	NA	NA	NA	NA	NA	NA
172	p-Ethyltoluene	622-96-8	NA	NA	NA	NA	NA	NA
173	Phenol	108-95-2	1.00E-02	9.00E-01	NA	3.00E-01	NA	NA
174	Phenylacetylene	536-74-3	NA	NA	NA	NA	NA	NA
175	Propanal	123-38-6	NA	NA	NA	NA	NA	NA
176	Propane	74-98-6	NA	NA	NA	NA	NA	NA
177	Propanenitrile	107-12-0	NA	NA	NA	NA	NA	NA
178	Propene	115-07-1	NA	NA	NA	NA	NA	NA
179	p-Xylene	106-42-3	1.00E-02	8.00E-01	NA	NA	NA	NA
180	sec-Butylbenzene	135-98-8	NA	NA	NA	NA	NA	NA
181	Selenium	7782-49-2	1.00E-03	4.40E-01	NA	5.00E-03	NA	NA
182	Silver	7440-22-4	1.00E-03	1.80E-01	NA	5.00E-03	NA	NA
183	Styrene	100-42-5	1.00E-02	8.00E-01	2.86E-01	2.00E-01	NA	NA
184	Tetrahydrofuran	109-99-9	NA	NA	NA	NA	NA	NA
185	Thiophene	110-02-1	NA	NA	NA	NA	NA	NA
186	trans 1,3-Dichloro-1-propene	10061-02-6	NA	NA	NA	NA	NA	NA
187	trans-2-Butenal	123-73-9	1.00E-02	5.00E-01	NA	NA	NA	1.90E+00
188	trans-2-Butene	624-64-6	NA	NA	NA	NA	NA	NA
189	trans-2-Hexene	4050-45-7	NA	NA	NA	NA	NA	NA
190	trans-2-Pentene	646-04-8	NA	NA	NA	NA	NA	NA
191	trans-3-Penten-2-one	3102-33-8	NA	NA	NA	NA	NA	NA
192	Trichloroacetonitrile	545-06-2	NA	NA	NA	NA	NA	NA
193	Trichloromonofluoromethane	75-69-4	1.00E-02	2.30E-01	2.00E-01	3.00E-01	NA	NA
194	Vinylidene chloride	75-35-4	1.00E-02	1.00E+00	0.0571	5.00E-02	1.75E-01	6.00E-01
195	Zinc	7440-66-6	1.00E-03	2.00E-01	NA	3.00E-01	NA	NA

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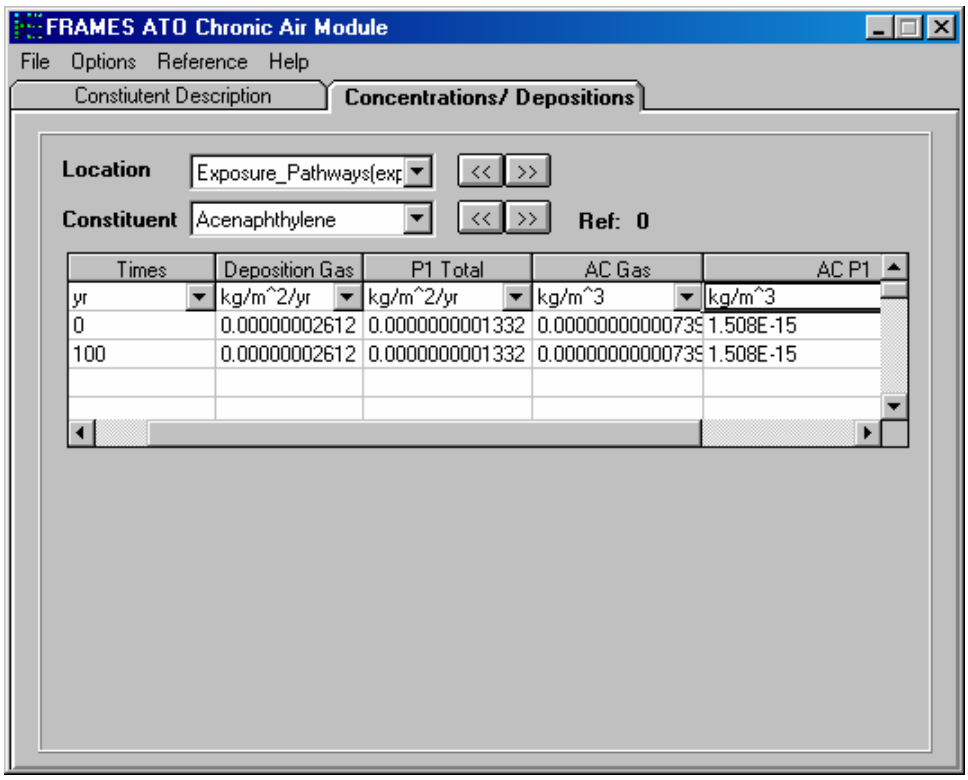

Figure 2. Input load data for Acenaphthylene

Table 7
Input Load Data, Gases

Chemical	CAS Number	Deposition Rate Gas, kg m^{-2} yr^{-1}	Air Concentration Gas, kg m^{-3}
1,1,2,2-Tetrachloroethane	79-34-5	1.44E-10	4.07E-14
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	1.42E-09	4.02E-13
1,1,2-Trichloroethane	79-00-5	3.93E-10	1.11E-13
1,1-Dichloro-2-propanone	513-88-2	1.45E-09	4.09E-13
1,1-Dichloroethane	75-34-3	1.67E-10	4.72E-14
1,2,3-Trichloropropane	96-18-4	1.22E-09	3.44E-13
1,2,4-Trichlorobenzene	120-82-1	1.05E-10	2.97E-14
1,2,4-Trimethylbenzene	95-63-6	2.98E-05	8.44E-09
1,2-Dichloro-2-methylpropane	594-37-6	7.94E-09	2.25E-12
1,2-Dichloro-3-methylbenzene	32768-54-0	1.24E-09	3.52E-13
1,2-Dichlorobenzene	95-50-1	1.66E-09	4.69E-13
1,2-Dichlorobutane	616-21-7	4.90E-10	1.39E-13
1,2-Dichloroethane	107-06-2	8.61E-09	2.44E-12
1,2-Dichloropropane	78-87-5	1.11E-09	3.14E-13
1,3,5-Trimethylbenzene	108-67-8	1.54E-05	4.35E-09
1,3-Butadiene	106-99-0	8.53E-07	2.41E-10
1,3-Dichlorobenzene	541-73-1	9.80E-10	2.77E-13

(Sheet 1 of 5)

Table 7 (Continued)

Chemical	CAS Number	Deposition Rate Gas, kg m^{-2} yr^{-1}	Air Concentration Gas, kg m^{-3}
1,4-Dichlorobenzene	106-46-7	2.73E-10	7.73E-14
1-Acetoxyacetone	592-20-1	1.93E-08	5.45E-12
1-Bromo-2-chloroethane	107-04-0	1.94E-09	5.49E-13
1-Butanol	71-36-3	3.23E-10	9.13E-14
1-Butene	106-98-9	1.02E-07	2.89E-11
1-Chloro-2-methylbenzene	95-49-8	3.17E-08	8.96E-12
1-Chloro-3-methylbenzene	108-41-8	2.61E-09	7.37E-13
1-Chloro-4-ethylbenzene	622-98-0	3.93E-10	1.11E-13
1-Chlorobutane	109-69-3	6.11E-10	1.73E-13
1-Hexene	592-41-6	1.82E-08	5.15E-12
1-Hydroxy-2-propanone	116-09-6	2.42E-08	6.85E-12
1-Penten-3-one	1629-58-9	4.25E-09	1.20E-12
1-Pentene	109-67-1	3.63E-08	1.03E-11
2,2,4-Trimethylhexane	16747-26-5	7.03E-08	1.99E-11
2,2,4-Trimethylpentane	540-84-1	6.42E-07	1.82E-10
2,2-Dimethylbutane	75-83-2	3.29E-07	9.31E-11
2,2-Dimethylpropane	463-82-1	3.40E-09	9.63E-13
2,3,4-Trimethylpentane	565-75-3	1.11E-07	3.15E-11
2,3-Butanedione	431-03-8	3.52E-08	9.96E-12
2,3-Dihydro-1-methyl-1H-indene	767-58-8	2.05E-06	5.79E-10
2,3-Dimethylbutane	79-29-8	7.33E-07	2.07E-10
2,3-Dimethylhexane	584-94-1	1.95E-07	5.52E-11
2,3-Dimethylpentane	565-59-3	7.04E-07	1.99E-10
2,3-Pentanedione	600-14-6	1.09E-08	3.10E-12
2,4-Dimethylhexane	589-43-5	3.93E-07	1.11E-10
2,4-Dimethylpentane	108-08-7	4.31E-07	1.22E-10
2,5-Dimethylfuran	625-86-5	5.01E-09	1.42E-12
2,5-Dimethylhexane	592-13-2	3.38E-07	9.56E-11
2-Bromo-1-chloropropane	3017-95-6	2.47E-09	6.99E-13
2-Butoxyethanol	111-76-2	0.00E+00	0.00E+00
2-Furaldehyde	98-01-1	3.87E-08	1.09E-11
2-Heptanone	110-43-0	9.39E-11	2.66E-14
2-Hexanone	591-78-6	1.06E-09	2.99E-13
2-Methyl-1-butene	563-46-2	5.22E-08	1.48E-11
2-Methyl-1-pentene	763-29-1	3.18E-08	9.01E-12
2-Methyl-2-butene	513-35-9	2.04E-08	5.77E-12
2-Methyl-2-pentene	625-27-4	2.04E-08	5.77E-12
2-Methylfuran	534-22-5	5.43E-09	1.54E-12
2-Methylheptane	592-27-8	1.07E-06	3.03E-10
2-Methylhexane	591-76-4	2.34E-06	6.62E-10
2-Methylnaphthalene	91-57-6	5.46E-07	1.55E-10
2-Methylpentane	107-83-5	3.75E-06	1.06E-09

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Table 7 (Continued)

Chemical	CAS Number	Deposition Rate Gas, kg m^{-2} yr^{-1}	Air Concentration Gas, kg m^{-3}
2-Methylthiophene	554-14-3	9.06E-10	2.56E-13
2-Nitrophenol	88-75-5	6.09E-09	1.72E-12
2-Octanone	111-13-7	2.56E-11	7.23E-15
2-Pentanone	107-87-9	1.83E-08	5.18E-12
2-Propanol	67-63-0	4.08E-09	1.15E-12
2-Thiophenecarboxaldehyde	98-03-3	1.63E-09	4.61E-13
3-Ethylhexane	619-99-8	5.56E-10	1.57E-13
3-Heptanone	106-35-4	2.71E-09	7.66E-13
3-Methyl-1-butene	563-45-1	1.81E-08	5.13E-12
3-Methyl-2-butanone	563-80-4	1.65E-09	4.68E-13
3-Methylfuran	930-27-8	1.81E-09	5.12E-13
3-Methylhexane	589-34-4	2.54E-06	7.19E-10
3-Methylpentane	96-14-0	2.64E-06	7.48E-10
3-Methylphenol	108-39-4	2.41E-08	6.83E-12
3-Methylthiophene	616-44-4	8.39E-10	2.37E-13
3-Pentanone	96-22-0	1.90E-09	5.38E-13
4-Methyl-1-pentene	691-37-2	1.36E-08	3.85E-12
4-Methyl-2-pentanone	108-10-1	3.17E-10	8.98E-14
4-Methylbenzonitrile	104-85-8	2.77E-09	7.83E-13
4-Methylphenol	106-44-5	2.41E-08	6.83E-12
5-Methyl-2-furaldehyde	620-02-0	1.26E-08	3.58E-12
6-Methyl-2-heptanone	928-68-7	9.78E-11	2.77E-14
6-Methyl-5-hepten-2-one	110-93-0	6.15E-12	1.74E-15
Acetaldehyde	75-07-0	1.11E-07	3.13E-11
Acetic Acid	64-19-7	8.88E-07	2.51E-10
Acetone	67-64-1	6.75E-07	1.91E-10
Acetonitrile	75-05-8	9.02E-09	2.55E-12
Acetophenone	98-86-2	1.15E-08	3.26E-12
Acetylene	74-86-2	7.86E-07	2.22E-10
Acrolein	107-02-8	3.43E-07	9.72E-11
Acrylonitrile	107-13-1	1.20E-08	3.40E-12
Benzofuran	271-89-6	5.13E-09	1.45E-12
Benzoic acid	65-85-0	1.59E-09	4.50E-13
Benzonitrile	100-47-0	1.44E-08	4.06E-12
Benzyl alcohol	100-51-6	2.65E-08	7.50E-12
bis(2-Ethylhexyl)phthalate	117-81-7	3.56E-08	1.01E-11
Butanal	123-72-8	7.71E-09	2.18E-12
Butyl Acetate	123-86-4	3.16E-09	8.93E-13
Carbon Dioxide	124-38-9	4.66E-03	1.32E-06
Carbonyl Sulfide	463-58-1	1.00E-07	2.84E-11
Chlorobenzene	108-90-7	2.18E-09	6.17E-13
Chloroethene	75-01-4	1.86E-09	5.27E-13

(Sheet 3 of 5)

Table 7 (Continued)

Chemical	CAS Number	Deposition Rate Gas, kg m^{-2} yr^{-1}	Air Concentration Gas, kg m^{-3}
cis 1,3-Dichloro-1-propene	10061-01-5	1.95E-09	5.52E-13
cis-2-Butene	590-18-1	2.27E-08	6.41E-12
cis-2-Hexene	7688-21-3	1.36E-08	3.85E-12
cis-2-Pentene	627-20-3	1.81E-08	5.13E-12
Cyclohexane	110-82-7	1.93E-06	5.47E-10
Cyclohexanone	108-94-1	3.71E-10	1.05E-13
Cyclopentane	278-92-3	3.09E-07	8.74E-11
Cyclopentanone	120-92-3	3.19E-09	9.03E-13
Cyclopentene	142-29-0	1.59E-08	4.49E-12
Decanal	112-31-2	7.88E-07	2.23E-10
Dichloroacetonitrile	3018-12-0	3.81E-10	1.08E-13
Dichlorodifluoromethane	75-71-8	4.38E-08	1.24E-11
Diethylphthalate	84-66-2	5.19E-09	1.47E-12
Dimethyldisulfide	624-92-0	2.84E-09	8.02E-13
Di-n-butylphthalate	84-74-2	5.70E-08	1.61E-11
d-Limonene	5989-27-5	0.00E+00	0.00E+00
Ethane	74-84-0	3.83E-08	1.08E-11
Ethanol	64-17-5	1.48E-09	4.19E-13
Ethylchloride	75-00-3	2.14E-10	6.06E-14
Ethylene	74-85-1	9.13E-07	2.58E-10
Heptanal	111-71-7	2.40E-07	6.80E-11
Hexachlorobutadiene	87-68-3	3.57E-08	1.01E-11
Hexachlorocyclopentadiene	77-47-4	2.61E-08	7.38E-12
Hexachloroethane	67-72-1	1.24E-08	3.50E-12
Hexachloropropene	1888-71-7	2.48E-08	7.02E-12
Hexanal	66-25-1	4.13E-09	1.17E-12
Indane	496-11-7	6.66E-06	1.88E-09
Isobutane	75-28-5	1.29E-07	3.66E-11
Isobutene	115-11-7	2.65E-07	7.51E-11
Isopentane	78-78-4	3.68E-06	1.04E-09
Isoprene	78-79-5	8.89E-09	2.52E-12
Isopropylbenzene	98-82-8	9.07E-08	2.57E-11
Isothiocyanatomethane	556-61-6	2.05E-09	5.81E-13
Methacrolein	78-85-3	7.31E-09	2.07E-12
Methylbromide	74-83-9	1.47E-09	4.17E-13
Methylchloroform	71-55-6	2.56E-10	7.24E-14
Methylcyclohexane	108-87-2	3.39E-06	9.59E-10
Methylcyclopentane	96-37-7	1.61E-06	4.56E-10
Methylnitrite	624-91-9	1.61E-06	4.57E-10
m-Ethyltoluene	620-14-4	9.46E-07	2.68E-10
Methyl-vinyl Ketone	78-94-4	1.18E-08	3.33E-12
MTBE	1634-04-4	4.14E-05	1.17E-08

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Table 7 (Concluded)

Chemical	CAS Number	Deposition Rate Gas, kg m^{-2} yr^{-1}	Air Concentration Gas, kg m^{-3}
m-Xylene	108-38-3	7.19E-05	2.04E-08
n-Butane	106-97-8	6.87E-07	1.94E-10
n-Decane	124-18-5	7.49E-08	2.12E-11
n-Heptane	142-82-5	3.32E-06	9.39E-10
n-Hexane	110-54-3	4.43E-06	1.25E-09
Nitromethane	75-52-5	2.30E-07	6.50E-11
n-Nonane	111-84-2	2.81E-07	7.96E-11
n-Octane	111-65-9	1.22E-06	3.45E-10
Nonanal	124-19-6	8.83E-07	2.50E-10
n-Pentane	109-66-0	3.76E-06	1.06E-09
n-Propylbenzene	103-65-1	5.17E-07	1.46E-10
Octanal	124-13-0	6.53E-07	1.85E-10
o-Ethyltoluene	611-14-3	6.08E-07	1.72E-10
o-Xylene	95-47-6	4.51E-05	1.28E-08
Pentachloro-1-propene	1600-37-9	1.30E-09	3.67E-13
Pentanal	110-62-3	1.89E-09	5.36E-13
p-Ethyltoluene	622-96-8	1.58E-05	4.47E-09
Phenol	108-95-2	1.18E-10	3.34E-14
Phenylacetylene	536-74-3	1.27E-08	3.59E-12
Propanal	123-38-6	1.48E-08	4.18E-12
Propane	74-98-6	1.18E-08	3.35E-12
Propanenitrile	107-12-0	1.54E-09	4.35E-13
Propene	115-07-1	4.17E-07	1.18E-10
p-Xylene	106-42-3	7.19E-05	2.04E-08
sec-Butylbenzene	135-98-8	3.14E-06	8.88E-10
Styrene	100-42-5	5.61E-07	1.59E-10
Tetrahydrofuran	109-99-9	4.05E-09	1.15E-12
Thiophene	110-02-1	1.61E-08	4.54E-12
trans 1,3-Dichloro-1-propene	10061-02-6	3.93E-10	1.11E-13
trans-2-Butenal	123-73-9	9.15E-09	2.59E-12
trans-2-Butene	624-64-6	7.25E-08	2.05E-11
trans-2-Hexene	4050-45-7	2.49E-08	7.06E-12
trans-2-Pentene	646-04-8	3.40E-08	9.62E-12
trans-3-Penten-2-one	3102-33-8	2.71E-09	7.66E-13
Trichloroacetonitrile	545-06-2	3.09E-10	8.75E-14
Trichloromonofluoromethane	75-69-4	4.12E-09	1.17E-12
Vinylidene chloride	75-35-4	1.35E-09	3.82E-13

(Sheet 5 of 5)

Table 8
Input Load Data of Chemicals in Particle and Gas Form

Chemical	CAS Number	Deposition Rate Gas kg m^{-2} yr^{-1}	Air Concentration Gas kg m^{-3}	Deposition Rate, Particle kg m^{-2} yr^{-1}	Air Concentration Particle kg m^{-3}
Acenaphthylene	208-96-8	2.61E-08	7.39E-12	1.33E-10	1.51E-15
Butylbenzylphthalate	85-68-7	4.11E-08	1.16E-11	2.34E-08	2.65E-13
Fluorene	86-73-7	5.13E-09	1.45E-12	2.49E-12	2.82E-17
Magnesium	7439-95-4	2.01E-05	5.69E-09	9.47E-03	1.07E-07

Table 9
Input Load Data of Inorganic Chemicals in Particle Form

Chemical	CAS Number	Total Deposition Rate, kg m^{-2} yr^{-1}	Air Concentration Particle, kg m^{-3}
Aluminum	7429-90-5	8.37E-03	9.48E-08
Antimony	7440-36-0	3.73E-04	4.22E-09
Barium	7440-39-3	1.45E-03	1.64E-08
Beryllium	7440-41-7	2.08E-08	2.35E-13
Cobalt	7440-48-4	4.08E-07	4.61E-12
Copper	7440-50-8	3.21E-05	3.63E-10
Manganese	7439-96-5	1.61E-05	1.82E-10
Mercury	7439-97-6	8.56E-09	9.69E-14
Nickel	7440-02-0	9.32E-07	1.06E-11
Selenium	7782-49-2	9.46E-08	1.07E-12
Silver	7440-22-4	1.58E-08	1.79E-13
Zinc	7440-66-6	1.34E-05	1.52E-10

5 Human Health Risks and Groundwater Concentrations

This study required a significant amount of data discovery (especially for toxicological data), which were not readily available. Data search included the Risk Assessment Information System (RAIS), EPA Integrated Risk Information System (IRIS), and International Toxicity Estimates for Risk (ITER) databases. Although the lack of input data prevented us from quantifying potential risks for most of the chemicals on the list, Table 10, however, provides important information about carcinogenicity assessment (qualitative risk) for each chemical of concern according to the USEPA laboratory studies. The table includes two columns, Risk (incremental cancer incidence) and HI (hazard index for non-carcinogenic chemicals). In these columns, (*yes*) means data were available, (*no*) means data were not available, and (*yes*-) means part of the data were available (such as inhalation benchmark was available but ingestion benchmark was not).

Human health risk for the chemicals having toxicological data was evaluated in terms of cancer and non-cancer effects. Incremental cancer risks were estimated as a probability, or chance, that a person would develop cancer over his or her lifetime as a result of exposure to the chemicals at the site. For example, a risk of one in one million means that if one million people were exposed to the contamination at MMR for 30 years, at most, one additional case of cancer would be expected to occur over a person's lifetime as a result of their exposure. Non-cancer hazard potential (hazard index, HI) is presented as a ratio of the predicted exposure compared to a safe level. Aggregate exposures yielding an HI less than 1.0 will likely not result in adverse non-cancer health effects. However, an HI value greater than 1.0 does not necessarily suggest a likelihood of adverse effects. Furthermore, the HI cannot be translated into a probability that adverse effects will occur and is not likely to be proportional to risk. For example, a respiratory HI greater than 1.0 can be best described as indicating that a potential may exist for adverse irritation to the respiratory system. The non-carcinogenic and carcinogenic risks were estimated according to the route of exposure, i.e., dermal, inhalation, and ingestion.

Table 10
Availability of Toxicological Benchmark Input Data for Noncarcinogenic HI and Carcinogenic Risk Calculations

Chemical	CAS Number	HI[1]	Risk[1]	Carcinogenicity Assessment[2]
1,1,2,2-Tetrachloroethane	79-34-5	yes-	yes	C
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	yes	no	NR
1,1,2-Trichloroethane	79-00-5	yes-	yes	C
1,1-Dichloro-2-propanone	513-88-2	no	no	NR
1,1-Dichloroethane	75-34-3	yes	no	C
1,2,3-Trichloropropane	96-18-4	yes-	yes-	NR
1,2,4-Trichlorobenzene	120-82-1	yes	no	D
1,2-Dichloro-2-methylpropane	594-37-6	no	no	NR
1,2-Dichloro-3-methylbenzene	32768-54-0	no	no	NR
1,2-Dichlorobenzene	95-50-1	yes	no	D
1,2-Dichlorobutane	616-21-7	no	no	NR
1,2-Dichloroethane	107-06-2	yes-	yes	B2
1,2-Dichloropropane	78-87-5	yes-	yes-	NA
1,3,5-Trimethylbenzene	108-67-8	yes	no	NR
1,3-Butadiene	106-99-0	yes-	yes-	NA
1,3-Dichlorobenzene	541-73-1	yes-	no	D
1,4-Dichlorobenzene	106-46-7	yes-	yes-	NA
1-Acetoxyacetone	592-20-1	no	no	NA
1-Bromo-2-chloroethane	107-04-0	no	no	NA
1-Butanol	71-36-3	yes-	no	D
1-Butene	106-98-9	no	no	NA
1-Chloro-2-methylbenzene	95-49-8	yes-	no	NA
1-Chloro-3-methylbenzene	108-41-8	no	no	NR
1-Chloro-4-ethylbenzene	622-98-0	no	no	NR
1-Chlorobutane	109-69-3	yes-	no	D
1-Hexene	592-41-6	no	no	NR
1-Hydroxy-2-propanone	116-09-6	no	no	NR
1-Penten-3-one	1629-58-9	no	no	NR
1-Pentene	109-67-1	no	no	NR
2,2,4-Trimethylhexane	16747-26-5	no	no	NR
2,2,4-Trimethylpentane	540-84-1	no	no	NA
2,2-Dimethylbutane	75-83-2	no	no	NR
2,2-Dimethylpropane	463-82-1	no	no	NR
2,3,4-Trimethylpentane	565-75-3	no	no	NR
2,3-Butanedione	431-03-8	no	no	NR
2,3-Dihydro-1-methyl-1H-indene	767-58-8	no	no	NR
2,3-Dimethylbutane	79-29-8	no	no	NR
2,3-Dimethylhexane	584-94-1	no	no	NR
2,3-Dimethylpentane	565-59-3	no	no	NR
2,3-Pentanedione	600-14-6	no	no	NR
2,4-Dimethylhexane	589-43-5	no	no	NR
2,4-Dimethylpentane	108-08-7	no	no	NR

(Sheet 1 of 4)

[1] (yes) means data were available; (no) means data were not available; (yes-) means part of the data were available (such as inhalation benchmark was available, but ingestion benchmark was not).

[2] A = (Human carcinogen); B1 = (Probable human carcinogen - based on limited evidence of carcinogenicity in humans); B2 = Possible human carcinogen-based on sufficient evidence of carcinogenicity in animals; C = possible human carcinogen; D =Not classifiable as to human carcinogenicity; E = (Evidence of non-carcinogenicity for humans); NA = Not assessed under the IRIS program; NR = Not in IRIS.

Table 10 (Continued)

Chemical	CAS Number	HI	Risk	Carcinogenicity Assessment
2,5-Dimethylfuran	625-86-5	no	no	NR
2,5-Dimethylhexane	592-13-2	no	no	NR
2-Bromo-1-chloropropane	3017-95-6	no	no	NR
2-Butoxyethanol	111-76-2	no	no	C
2-Furaldehyde	98-01-1	yes	no	NA
2-Heptanone	110-43-0	no	no	NR
2-Hexanone	591-78-6	no	no	NR
2-Methyl-1-butene	563-46-2	no	no	NR
2-Methyl-1-pentene	763-29-1	no	no	NR
2-Methyl-2-butene	513-35-9	no	no	NR
2-Methyl-2-pentene	625-27-4	no	no	NR
2-Methylfuran	534-22-5	no	no	NR
2-Methylheptane	592-27-8	no	no	NR
2-Methylhexane	591-76-4	no	no	NR
2-Methylnaphthalene	91-57-6	no	no	NA
2-Methylpentane	107-83-5	no	no	NR
2-Methylthiophene	554-14-3	no	no	NR
2-Nitrophenol	88-75-5	no	no	NR
2-Octanone	111-13-7	no	no	NR
2-Pentanone	107-87-9	no	no	NR
2-Propanol	67-63-0	no	no	NR
2-Thiophenecarboxaldehyde	98-03-3	no	no	NA
3-Ethylhexane	619-99-8	no	no	NR
3-Heptanone	106-35-4	no	no	NR
3-Methyl-1-butene	563-45-1	no	no	NR
3-Methyl-2-butanone	563-80-4	no	no	NR
3-Methylfuran	930-27-8	no	no	NR
3-Methylhexane	589-34-4	no	no	NR
3-Methylpentane	96-14-0	no	no	NR
3-Methylphenol	108-39-4	yes-	no	C
3-Methylthiophene	616-44-4	no	no	NR
3-Pentanone	96-22-0	no	no	NR
4-Methyl-1-pentene	691-37-2	no	no	NR
4-Methyl-2-pentanone	108-10-1	yes	no	NA
4-Methylbenzonitrile	104-85-8	no	no	NR
4-Methylphenol	106-44-5	yes-	no	C
5-Methyl-2-furaldehyde	620-02-0	no	no	NR
6-Methyl-2-heptanone	928-68-7	no	no	NR
6-Methyl-5-hepten-2-one	110-93-0	no	no	NR
Acenaphthylene	208-96-8	no	no	D
Acetaldehyde	75-07-0	yes-	yes-	B2
Acetic Acid	64-19-7	no	no	NR
Acetone	67-64-1	yes-	no	NA
Acetonitrile	75-05-8	yes	No	D
Acetophenone	98-86-2	yes	no	D
Acetylene	74-86-2	no	no	NR
Acrolein	107-02-8	yes	no	NA
Acrylonitrile	107-13-1	yes	yes	B1
Aluminum	7429-90-5	yes	no	NR
Antimony	7440-36-0	yes-	no	NA
Barium	7440-39-3	yes	no	NR

(Sheet 2 of 4)

Table 10 (Continued)

Chemical	CAS Number	HI	Risk	Carcinogenicity Assessment
Benzofuran	271-89-6	no	no	NR
Benzoic acid	65-85-0	yes-	no	D
Benzonitrile	100-47-0	no	no	NR
Benzyl alcohol	100-51-6	yes-	no	NR
Beryllium	7440-41-7	yes	yes	B1
bis(2-Ethylhexyl)phthalate	117-81-7	yes-	yes-	B2
Butanal	123-72-8	no	no	NR
Butyl Acetate	123-86-4	no	no	NR
Butylbenzylphthalate	85-68-7	yes-	no	C
Carbon Dioxide	124-38-9	no	no	NR
Carbonyl Sulfide	463-58-1	no	no	NR
Chlorobenzene	108-90-7	yes	no	D
Chloroethene	75-01-4	yes	yes	A
cis 1,3-Dichloro-1-propene	10061-01-5	no	no	NR
cis-2-Butene	590-18-1	no	no	NR
cis-2-Hexene	7688-21-3	no	no	NR
cis-2-Pentene	627-20-3	no	no	NR
Cobalt	7440-48-4	yes	yes-	NR
Copper	7440-50-8	yes-	no	D
Cyclohexane	110-82-7	yes-	no	NA
Cyclohexanone	108-94-1	yes-	no	NA
Cyclopentane	278-92-3	no	no	NR
Cyclopentanone	120-92-3	no	no	NR
Cyclopentene	142-29-0	no	no	NR
Decanal	112-31-2	no	no	NR
Dichloroacetonitrile	3018-12-0	no	no	NR
Dichlorodifluoromethane	75-71-8	yes	no	NA
Diethylphthalate	84-66-2	yes-	no	D
Dimethyldisulfide	624-92-0	no	no	NR
Di-n-butylphthalate	84-74-2	yes-	no	D
d-Limonene	5989-27-5	no	no	NA
Ethane	74-84-0	no	no	NR
Ethanol	64-17-5	no	no	NR
Ethylchloride	75-00-3	yes-	no	NA
Ethylene	74-85-1	no	no	NR
Fluorene	86-73-7	yes-	no	D
Heptanal	111-71-7	no	no	NR
Hexachlorobutadiene	87-68-3	yes-	yes	C
Hexachlorocyclopentadiene	77-47-4	yes	no	E
Hexachloroethane	67-72-1	yes-	yes	C
Hexachloropropene	1888-71-7	no	no	NR
Hexanal	66-25-1	no	no	NR
Indane	496-11-7	no	no	NR
Isobutane	75-28-5	no	no	NR
Isobutene	115-11-7	no	no	NR
Isopentane	78-78-4	no	no	NR
Isoprene	78-79-5	no	no	NR
Isopropylbenzene	98-82-8	yes	no	D
Isothiocyanatomethane	556-61-6	no	no	NR
Magnesium	7439-95-4	no	no	NR
Manganese	7439-96-5	yes	no	D

(Sheet 3 of 4)

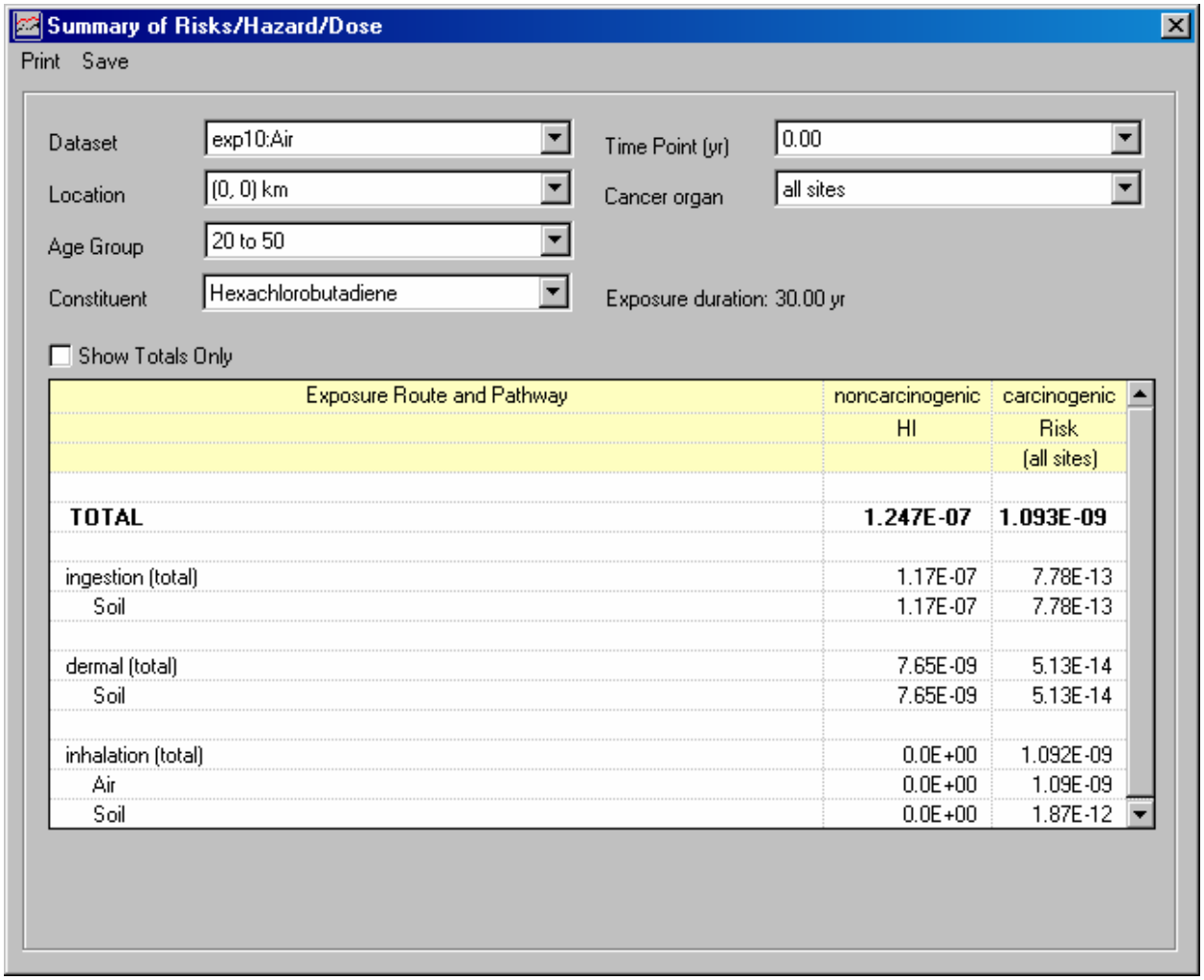
Table 10 (Concluded)

Chemical	CAS Number	HI	Risk	Carcinogenicity Assessment
Mercury	7439-97-6	yes-	no	D
Methacrolein	78-85-3	no	no	NR
Methylbromide	74-83-9	yes	no	D
Methylchloroform	71-55-6	yes	no	D
Methylcyclohexane	108-87-2	yes-	no	NR
Methylcyclopentane	96-37-7	no	no	NR
Methylnitrite	624-91-9	no	no	NR
m-Ethyltoluene	620-14-4	no	no	NR
Methyl-vinyl Ketone	78-94-4	no	no	NR
MTBE	1634-04-4	yes-	no	NA
m-Xylene	108-38-3	yes-	no	NA
n-Butane	106-97-8	no	no	NR
n-Decane	124-18-5	no	no	NR
n-Heptane	142-82-5	no	no	D
n-Hexane	110-54-3	yes	no	NR
Nickel	7440-02-0	yes	no	A
Nitromethane	75-52-5	no	no	NR
n-Nonane	111-84-2	no	no	NR
n-Octane	111-65-9	no	no	NR
Nonanal	124-19-6	no	no	NR
n-Pentane	109-66-0	no	no	NR
n-Propylbenzene	103-65-1	no	no	NR
Octanal	124-13-0	no	no	NR
o-Ethyltoluene	611-14-3	no	no	NR
o-Xylene	95-47-6	yes-	no	NA
Pentachloro-1-propene	1600-37-9	no	no	NR
Pentanal	110-62-3	no	no	NR
p-Ethyltoluene	622-96-8	no	no	NR
Phenol	108-95-2	yes-	no	D
Phenylacetylene	536-74-3	no	no	NR
Propanal	123-38-6	no	no	NR
Propane	74-98-6	no	no	NR
Propanenitrile	107-12-0	no	no	NR
Propene	115-07-1	no	no	NR
p-Xylene	106-42-3	no	no	NA
Sec-Butylbenzene	135-98-8	no	no	NR
Selenium	7782-49-2	yes-	no	D
Silver	7440-22-4	yes-	no	D
Styrene	100-42-5	yes	no	NA
Tetrahydrofuran	109-99-9	no	no	NR
Thiophene	110-02-1	no	no	NR
trans 1,3-Dichloro-1-propene	10061-02-6	no	no	NR
trans-2-Butenal	123-73-9	no	no	C
trans-2-Butene	624-64-6	no	no	NR
trans-2-Hexene	4050-45-7	no	no	NR
trans-2-Pentene	646-04-8	no	no	NR
trans-3-Penten-2-one	3102-33-8	no	no	NR
Trichloroacetonitrile	545-06-2	no	no	NR
Trichloromonofluoromethane	75-69-4	yes	no	NA
Vinylidene chloride	75-35-4	yes	yes	C
Zinc	7440-66-6	yes	no	D

(Sheet 4 of 4)

The air concentrations and deposition rates provided by the CHPPM were used as load input to ARAMS to predict potential health risk from air and soil exposure to visitors or trespassers entering the MMR. In addition, we completed a screening-level model of the subsurface fate/transport processes to predict the movement of chemicals through the vadose zone and into the groundwater. The subsurface calculations determined travel time of the peak concentration to reach the water table for each chemical and the peak water concentration in the aquifer at point of interception. One hundred-ninety-five (195) chemicals were evaluated in this study, which are in addition to the 24 chemicals addressed in the earlier study of Zakikhani et al. (2004).

The ARAMS output can be shown in graphical or text form. Figure 3 shows, as an example, a summary table of risks for hexachlorobutadiene. The simulation results from all ARAMS summary tables are organized in Tables 11 and 12. Table 11 provides a summary of hazard indices (HI) and cancer risks (Risk) associated with inhalation of the chemicals only from the air pathway. Table 12 provides a summary of hazard indices (HI) and cancer risks (Risk) expected for the chemicals from inhalation, ingestion, or dermal contact of contaminated soil.



Exposure Route and Pathway	noncarcinogenic HI	carcinogenic Risk (all sites)
TOTAL	**1.247E-07**	**1.093E-09**
ingestion (total)	1.17E-07	7.78E-13
Soil	1.17E-07	7.78E-13
dermal (total)	7.65E-09	5.13E-14
Soil	7.65E-09	5.13E-14
inhalation (total)	0.0E+00	1.092E-09
Air	0.0E+00	1.09E-09
Soil	0.0E+00	1.87E-12

Figure 3. Summary of risk/hazard/dose output from MEPAS Health-Impact Module of ARAMS/FRAMES

Table 11
Summary of Hazard Index and Risk for Each Chemical (Air Pathway)

Chemical	CAS Number	Noncarcinogenic HI		Carcinogenic Risk	
		Initial	Final	Initial	Final
1,1,2,2-Tetrachloroethane	79-34-5	NA	NA	1.16E-11	1.16E-11
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	1.53E-10	1.53E-10	NA	NA
1,1,2-Trichloroethane	79-00-5	NA	NA	8.68E-12	8.68E-12
1,1-Dichloro-2-propanone	513-88-2	NA	NA	NA	NA
1,1-Dichloroethane	75-34-3	1.08E-09	1.08E-09	NA	NA
1,2,3-Trichloropropane	96-18-4	NA	NA	NA	NA
1,2,4-Trichlorobenzene	120-82-1	8.50E-08	8.50E-08	NA	NA
1,2-Dichloro-2-methylpropane	594-37-6	NA	NA	NA	NA
1,2-Dichloro-3-methylbenzene	32768-54-0	NA	NA	NA	NA
1,2-Dichlorobenzene	95-50-1	2.68E-08	2.68E-08	NA	NA
1,2-Dichlorobutane	616-21-7	NA	NA	NA	NA
1,2-Dichloroethane	107-06-2	7.24E-05	7.24E-05	3.10E-10	3.10E-10
1,2-Dichloropropane	78-87-5	8.95E-07	8.95E-07	NA	NA
1,3,5-Trimethylbenzene	108-67-8	8.30E-03	8.30E-03	NA	NA
1,3-Butadiene	106-99-0	1.38E-03	1.38E-03	3.54E-08	3.54E-08
1,3-Dichlorobenzene	541-73-1	NA	NA	NA	NA
1,4-Dichlorobenzene	106-46-7	1.10E-09	1.10E-09	NA	NA
1-Acetoxyacetone	592-20-1	NA	NA	NA	NA
1-Bromo-2-chloroethane	107-04-0	NA	NA	NA	NA
1-Butanol	71-36-3	NA	NA	NA	NA
1-Butene	106-98-9	NA	NA	NA	NA
1-Chloro-2-methylbenzene	95-49-8	NA	NA	NA	NA
1-Chloro-3-methylbenzene	108-41-8	NA	NA	NA	NA
1-Chloro-4-ethylbenzene	622-98-0	NA	NA	NA	NA
1-Chlorobutane	109-69-3	NA	NA	NA	NA
1-Hexene	592-41-6	NA	NA	NA	NA
1-Hydroxy-2-propanone	116-09-6	NA	NA	NA	NA
1-Penten-3-one	1629-58-9	NA	NA	NA	NA
1-Pentene	109-67-1	NA	NA	NA	NA
2,2,4-Trimethylhexane	16747-26-5	NA	NA	NA	NA
2,2,4-Trimethylpentane	540-84-1	NA	NA	NA	NA
2,2-Dimethylbutane	75-83-2	NA	NA	NA	NA
2,2-Dimethylpropane	463-82-1	NA	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	NA	NA	NA	NA
2,3-Butanedione	431-03-8	NA	NA	NA	NA
2,3-Dihydro-1-methyl-1H-indene	767-58-8	NA	NA	NA	NA
2,3-Dimethylbutane	79-29-8	NA	NA	NA	NA
2,3-Dimethylhexane	584-94-1	NA	NA	NA	NA
2,3-Dimethylpentane	565-59-3	NA	NA	NA	NA
2,3-Pentanedione	600-14-6	NA	NA	NA	NA
2,4-Dimethylhexane	589-43-5	NA	NA	NA	NA
2,4-Dimethylpentane	108-08-7	NA	NA	NA	NA
2,5-Dimethylfuran	625-86-5	NA	NA	NA	NA
2,5-Dimethylhexane	592-13-2	NA	NA	NA	NA
2-Bromo-1-chloropropane	3017-95-6	NA	NA	NA	NA
2-Butoxyethanol	111-76-2	NA	NA	NA	NA
2-Furaldehyde	98-01-1	2.49E-06	2.49E-06	NA	NA

(Sheet 1 of 4)

Note: NA = Not Available.

Table 11 (Continued)

Chemical	CAS Number	Noncarcinogenic HI		Carcinogenic Risk	
		Initial	Final	Initial	Final
2-Heptanone	110-43-0	NA	NA	NA	NA
2-Hexanone	591-78-6	NA	NA	NA	NA
2-Methyl-1-butene	563-46-2	NA	NA	NA	NA
2-Methyl-1-pentene	763-29-1	NA	NA	NA	NA
2-Methyl-2-butene	513-35-9	NA	NA	NA	NA
2-Methyl-2-pentene	625-27-4	NA	NA	NA	NA
2-Methylfuran	534-22-5	NA	NA	NA	NA
2-Methylheptane	592-27-8	NA	NA	NA	NA
2-Methylhexane	591-76-4	NA	NA	NA	NA
2-Methylnaphthalene	91-57-6	NA	NA	NA	NA
2-Methylpentane	107-83-5	NA	NA	NA	NA
2-Methylthiophene	554-14-3	NA	NA	NA	NA
2-Nitrophenol	88-75-5	NA	NA	NA	NA
2-Octanone	111-13-7	NA	NA	NA	NA
2-Pentanone	107-87-9	NA	NA	NA	NA
2-Propanol	67-63-0	NA	NA	NA	NA
2-Thiophenecarboxaldehyde	98-03-3	NA	NA	NA	NA
3-Ethylhexane	619-99-8	NA	NA	NA	NA
3-Heptanone	106-35-4	NA	NA	NA	NA
3-Methyl-1-butene	563-45-1	NA	NA	NA	NA
3-Methyl-2-butanone	563-80-4	NA	NA	NA	NA
3-Methylfuran	930-27-8	NA	NA	NA	NA
3-Methylhexane	589-34-4	NA	NA	NA	NA
3-Methylpentane	96-14-0	NA	NA	NA	NA
3-Methylphenol	108-39-4	NA	NA	NA	NA
3-Methylthiophene	616-44-4	NA	NA	NA	NA
3-Pentanone	96-22-0	NA	NA	NA	NA
4-Methyl-1-pentene	691-37-2	NA	NA	NA	NA
4-Methyl-2-pentanone	108-10-1	3.42E-10	3.42E-10	NA	NA
4-Methylbenzonitrile	104-85-8	NA	NA	NA	NA
4-Methylphenol	106-44-5	NA	NA	NA	NA
5-Methyl-2-furaldehyde	620-02-0	NA	NA	NA	NA
6-Methyl-2-heptanone	928-68-7	NA	NA	NA	NA
6-Methyl-5-hepten-2-one	110-93-0	NA	NA	NA	NA
Acenaphthylene	208-96-8	NA	NA	NA	NA
Acetaldehyde	75-07-0	3.97E-05	3.97E-05	3.37E-10	3.37E-10
Acetic Acid	64-19-7	NA	NA	NA	NA
Acetone	67-64-1	NA	NA	NA	NA
Acetonitrile	75-05-8	4.87E-07	4.87E-07	NA	NA
Acetophenone	98-86-2	1.86E-03	1.86E-03	NA	NA
Acetylene	74-86-2	NA	NA	NA	NA
Acrolein	107-02-8	5.55E-02	5.55E-02	NA	NA
Acrylonitrile	107-13-1	1.94E-05	1.94E-05	1.13E-09	1.13E-09
Aluminum	7429-90-5	2.16E-01	2.16E-01	NA	NA
Antimony	7440-36-0	NA	NA	NA	NA
Barium	7440-39-3	3.72E-01	3.72E-01	NA	NA
Benzofuran	271-89-6	NA	NA	NA	NA
Benzoic acid	65-85-0	NA	NA	NA	NA
Benzonitrile	100-47-0	NA	NA	NA	NA
Benzyl alcohol	100-51-6	NA	NA	NA	NA
Beryllium	7440-41-7	1.34E-04	1.34E-04	2.76E-09	2.76E-09

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Table 11 (Continued)

Chemical	CAS Number	Noncarcinogenic HI		Carcinogenic Risk	
		Initial	Final	Initial	Final
bis(2-Ethylhexyl)phthalate	117-81-7	NA	NA	NA	NA
Butanal	123-72-8	NA	NA	NA	NA
Butyl Acetate	123-86-4	NA	NA	NA	NA
Butylbenzylphthalate	85-68-7	NA	NA	NA	NA
Carbon Dioxide	124-38-9	NA	NA	NA	NA
Carbonyl Sulfide	463-58-1	NA	NA	NA	NA
Chlorobenzene	108-90-7	3.52E-07	3.52E-07	NA	NA
Chloroethene	75-01-4	6.01E-08	6.01E-08	2.27E-11	2.27E-11
cis 1,3-Dichloro-1-propene	10061-01-5	NA	NA	NA	NA
cis-2-Butene	590-18-1	NA	NA	NA	NA
cis-2-Hexene	7688-21-3	NA	NA	NA	NA
cis-2-Pentene	627-20-3	NA	NA	NA	NA
Cobalt	7440-48-4	2.63E-03	2.63E-03	6.31E-08	6.31E-08
Copper	7440-50-8	NA	NA	NA	NA
Cyclohexane	110-82-7	1.04E-06	1.04E-06	NA	NA
Cyclohexanone	108-94-1	NA	NA	NA	NA
Cyclopentane	278-92-3	NA	NA	NA	NA
Cyclopentanone	120-92-3	NA	NA	NA	NA
Cyclopentene	142-29-0	NA	NA	NA	NA
Decanal	112-31-2	NA	NA	NA	NA
Dichloroacetonitrile	3018-12-0	NA	NA	NA	NA
Dichlorodifluoromethane	75-71-8	7.08E-07	7.08E-07	NA	NA
Diethylphthalate	84-66-2	NA	NA	NA	NA
Dimethyldisulfide	624-92-0	NA	NA	NA	NA
Di-n-butylphthalate	84-74-2	NA	NA	NA	NA
d-Limonene	5989-27-5	NA	NA	NA	NA
Ethane	74-84-0	NA	NA	NA	NA
Ethanol	64-17-5	NA	NA	NA	NA
Ethylchloride	75-00-3	6.92E-11	6.92E-11	NA	NA
Ethylene	74-85-1	NA	NA	NA	NA
Fluorene	86-73-7	NA	NA	NA	NA
Heptanal	111-71-7	NA	NA	NA	NA
Hexachlorobutadiene	87-68-3	NA	NA	1.09E-09	1.09E-09
Hexachlorocyclopentadiene	77-47-4	4.22E-04	4.22E-04	NA	NA
Hexachloroethane	67-72-1	NA	NA	6.85E-11	6.85E-11
Hexachloropropene	1888-71-7	NA	NA	NA	NA
Hexanal	66-25-1	NA	NA	NA	NA
Indane	496-11-7	NA	NA	NA	NA
Isobutane	75-28-5	NA	NA	NA	NA
Isobutene	115-11-7	NA	NA	NA	NA
Isopentane	78-78-4	NA	NA	NA	NA
Isoprene	78-79-5	NA	NA	NA	NA
Isopropylbenzene	98-82-8	7.35E-07	7.35E-07	NA	NA
Isothiocyanatomethane	556-61-6	NA	NA	NA	NA
Magnesium	7439-95-4	NA	NA	NA	NA
Manganese	7439-96-5	4.15E-02	4.15E-02	NA	NA
Mercury	7439-97-6	NA	NA	NA	NA
Methacrolein	78-85-3	NA	NA	NA	NA
Methylbromide	74-83-9	9.51E-07	9.51E-07	NA	NA
Methylchloroform	71-55-6	3.75E-10	3.75E-10	NA	NA
Methylcyclohexane	108-87-2	3.65E-06	3.65E-06	NA	NA

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Table 11 (Concluded)

Chemical	CAS Number	Noncarcinogenic HI		Carcinogenic Risk	
		Initial	Final	Initial	Final
Methylcyclopentane	96-37-7	NA	NA	NA	NA
Methylnitrite	624-91-9	NA	NA	NA	NA
m-Ethyltoluene	620-14-4	NA	NA	NA	NA
Methyl-vinyl Ketone	78-94-4	NA	NA	NA	NA
MTBE	1634-04-4	4.46E-05	4.46E-05	NA	NA
m-Xylene	108-38-3	NA	NA	NA	NA
n-Butane	106-97-8	NA	NA	NA	NA
n-Decane	124-18-5	NA	NA	NA	NA
n-Heptane	142-82-5	NA	NA	NA	NA
n-Hexane	110-54-3	7.15E-05	7.15E-05	NA	NA
Nickel	7440-02-0	1.73E-05	1.73E-05	NA	NA
Nitromethane	75-52-5	NA	NA	NA	NA
n-Nonane	111-84-2	NA	NA	NA	NA
n-Octane	111-65-9	NA	NA	NA	NA
Nonanal	124-19-6	NA	NA	NA	NA
n-Pentane	109-66-0	NA	NA	NA	NA
n-Propylbenzene	103-65-1	NA	NA	NA	NA
Octanal	124-13-0	NA	NA	NA	NA
o-Ethyltoluene	611-14-3	NA	NA	NA	NA
o-Xylene	95-47-6	NA	NA	NA	NA
Pentachloro-1-propene	1600-37-9	NA	NA	NA	NA
Pentanal	110-62-3	NA	NA	NA	NA
p-Ethyltoluene	622-96-8	NA	NA	NA	NA
Phenol	108-95-2	NA	NA	NA	NA
Phenylacetylene	536-74-3	NA	NA	NA	NA
Propanal	123-38-6	NA	NA	NA	NA
Propane	74-98-6	NA	NA	NA	NA
Propanenitrile	107-12-0	NA	NA	NA	NA
Propene	115-07-1	NA	NA	NA	NA
p-Xylene	106-42-3	NA	NA	NA	NA
sec-Butylbenzene	135-98-8	NA	NA	NA	NA
Selenium	7782-49-2	NA	NA	NA	NA
Silver	7440-22-4	NA	NA	NA	NA
Styrene	100-42-5	1.81E-06	1.81E-06	NA	NA
Tetrahydrofuran	109-99-9	NA	NA	NA	NA
Thiophene	110-02-1	NA	NA	NA	NA
trans 1,3-Dichloro-1-propene	10061-02-6	NA	NA	NA	NA
trans-2-Butenal	123-73-9	NA	NA	NA	NA
trans-2-Butene	624-64-6	NA	NA	NA	NA
trans-2-Hexene	4050-45-7	NA	NA	NA	NA
trans-2-Pentene	646-04-8	NA	NA	NA	NA
trans-3-Penten-2-one	3102-33-8	NA	NA	NA	NA
Trichloroacetonitrile	545-06-2	NA	NA	NA	NA
Trichloromonofluoromethane	75-69-4	1.27E-08	1.27E-08	NA	NA
Vinylidene chloride	75-35-4	1.39E-07	1.39E-07	9.61E-11	9.61E-11
Zinc	7440-66-6	1.65E-06	1.65E-06	NA	NA

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Table 12
Summary of Hazard Indices and Risks for Each Chemical (Soil Pathway)

Chemicals	CAS Number	Noncarcinogenic HI						Carcinogenic Risk					
		Ingestion		Dermal		Inhalation		Ingestion		Dermal		Inhalation	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1,1,2,2-Tetrachloroethane	79-34-5	1.75E-14	1.77E-14	1.45E-15	1.45E-15	NA	NA	9.04E-17	9.04E-07	7.45E-18	7.48E-18	2.23E-16	2.23E-16
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	1.11E-15	1.11E-15	7.30E-17	7.33E-17	9.44E-15	9.49E-15	NA	NA	NA	NA	NA	NA
1,1,2-Trichloroethane	79-00-5	4.97E-13	5.00E-13	3.30E-14	3.30E-14	NA	NA	4.87E-17	4.88E-17	3.21E-18	3.22E-18	1.17E-16	1.17E-16
1,1-Dichloro-2-propanone	513-88-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethane	75-34-3	8.12E-15	8.13E-15	5.36E-16	5.37E-16	1.38E-14	1.38E-14	NA	NA	NA	NA	NA	NA
1,2,3-Trichloropropane	96-18-4	1.34E-12	1.34E-12	8.82E-14	8.83E-14	NA	NA	2.41E-14	2.41E-14	1.59E-15	1.59E-15	NA	NA
1,2,4-Trichlorobenzene	120-82-1	1.47E-12	1.53E-12	9.70E-14	1.01E-13	3.14E-11	3.26E-11	NA	NA	NA	NA	NA	NA
1,2-Dichloro-2-methylpropane	594-37-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloro-3-methylbenzene	32768-54-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	95-50-1	7.38E-13	7.46E-13	4.87E-14	4.92E-14	2.84E-12	2.87E-12	NA	NA	NA	NA	NA	NA
1,2-Dichlorobutane	616-21-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	107-06-2	NA	NA	NA	NA	8.46E-10	8.48E-10	1.49E-15	1.49E-15	1.09E-16	1.09E-16	3.63E-15	3.64E-15
1,2-Dichloropropane	78-87-5	NA	NA	NA	NA	1.25E-11	1.25E-11	1.71E-16	1.71E-16	1.13E-17	1.13E-17	NA	NA
1,3,5-Trimethylbenzene	108-67-8	1.21E-08	1.22E-08	7.96E-10	8.04E-10	8.60E-07	8.65E-07	NA	NA	NA	NA	NA	NA
1,3-Butadiene	106-99-0	NA	NA	NA	NA	1.93E-08	1.93E-08	NA	NA	NA	NA	4.96E-13	4.96E-13
1,3-Dichlorobenzene	541-73-1	5.33E-11	5.40E-11	3.52E-12	3.57E-12	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	106-46-7	NA	NA	NA	NA	1.19E-13	1.20E-13	1.15E-16	1.16E-16	7.56E-18	7.68E-18	NA	NA
1-Acetoxyacetone	592-20-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Bromo-2-chloroethane	107-04-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Butanol	71-36-3	1.35E-14	1.33E-14	8.77E-16	8.78E-16	NA	NA	NA	NA	NA	NA	NA	NA
1-Butene	106-98-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Chloro-2-methylbenzene	95-49-8	6.20E-11	6.25E-11	4.10E-12	4.14E-12	NA	NA	NA	NA	NA	NA	NA	NA
1-Chloro-3-methylbenzene	108-41-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Chloro-4-ethylbenzene	622-98-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Chlorobutane	109-69-3	1.52E-14	1.53E-14	1.01E-15	1.01E-15	NA	NA	NA	NA	NA	NA	NA	NA
1-Hexene	592-41-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Hydroxy-2-propanone	116-09-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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Note: NA = Input Data were not available.

Table 12 (Continued)

Chemicals	CAS Number	Noncarcinogenic HI						Carcinogenic Risk					
		Ingestion		Dermal		Inhalation		Ingestion		Dermal		Inhalation	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1-Penten-3-one	1629-58-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1-Pentene	109-67-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,2,4-Trimethylhexane	16747-26-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,2,4-Trimethylpentane	540-84-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,2-Dimethylbutane	75-83-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,2-Dimethylpropane	463-82-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,4-Trimethylpentane	565-75-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Butanedione	431-03-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dihydro-1-methyl-1H-indene	767-58-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylbutane	79-29-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylhexane	584-94-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Dimethylpentane	565-59-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3-Pentanedione	600-14-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dimethylhexane	589-43-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dimethylpentane	108-08-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,5-Dimethylfuran	625-86-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,5-Dimethylhexane	592-13-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Bromo-1-chloropropane	3017-95-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Butoxyethanol	111-76-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Furaldehyde	98-01-1	5.23E-11	5.23E-11	3.43E-12	3.47E-12	2.67E-11	2.68E-11	NA	NA	NA	NA	NA	NA
2-Heptanone	110-43-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Hexanone	591-78-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-1-butene	563-46-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-1-pentene	763-29-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-2-butene	513-35-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methyl-2-pentene	625-27-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylfuran	534-22-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylheptane	592-27-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylhexane	591-76-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 12 (Continued)

Chemicals	CAS Number	Noncarcinogenic HI						Carcinogenic Risk					
		Ingestion		Dermal		Inhalation		Ingestion		Dermal		Inhalation	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
2-Methylnaphthalene	91-57-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylpentane	107-83-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylthiophene	554-14-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Nitrophenol	88-75-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Octanone	111-13-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Pentanone	107-87-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Propanol	67-63-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Thiophenecarboxaldehyde	98-03-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Ethylhexane	619-99-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Heptanone	106-35-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methyl-1-butene	563-45-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methyl-2-butanone	563-80-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylfuran	930-27-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylhexane	589-34-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylpentane	96-14-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylphenol	108-39-4	2.54E-12	2.56E-12	1.68E-13	1.69E-13	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylthiophene	616-44-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Pentanone	96-22-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Methyl-1-pentene	691-37-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	108-10-1	1.70E-14	1.70E-14	1.12E-15	1.12E-15	3.86E-15	3.87E-15	NA	NA	NA	NA	NA	NA
4-Methylbenzonitrile	104-85-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Methylphenol	106-44-5	2.44E-11	2.44E-11	1.61E-12	1.62E-12	NA	NA	NA	NA	NA	NA	NA	NA
5-Methyl-2-furaldehyde	620-02-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6-Methyl-2-heptanone	928-68-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6-Methyl-5-hepten-2-one	110-93-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acenaphthylene	208-96-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetaldehyde	75-07-0	NA	NA	NA	NA	4.24E-10	4.24E-10	NA	NA	NA	NA	3.59E-15	3.59E-15
Acetic Acid	64-19-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acetone	67-64-1	3.01E-12	3.01E-12	2.49E-13	2.49E-13	NA	NA	NA	NA	NA	NA	NA	NA

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Table 12 (Continued)

Chemicals	CAS Number	Noncarcinogenic HI						Carcinogenic Risk					
		Ingestion		Dermal		Inhalation		Ingestion		Dermal		Inhalation	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Acetonitrile	75-05-8	6.03E-12	6.05E-12	3.98E-13	3.98E-13	5.16E-12	5.17E-12	NA	NA	NA	NA	NA	NA
Acetophenone	98-86-2	5.20E-13	5.21E-13	3.43E-14	3.44E-14	2.22E-08	2.22E-08	NA	NA	NA	NA	NA	NA
Acetylene	74-86-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Acrolein	107-02-8	2.76E-09	2.76E-09	1.82E-10	1.82E-10	5.88E-07	5.90E-07	NA	NA	NA	NA	NA	NA
Acrylonitrile	107-13-1	4.86E-11	4.84E-11	3.99E-12	4.00E-12	2.07E-10	2.07E-10	1.12E-14	1.13E-14	9.25E-16	9.25E-16	1.20E-14	1.20E-14
Aluminum	7429-90-5	1.68E-05	9.44E-05	1.11E-04	6.23E-04	2.86E-02	1.61E-01	NA	NA	NA	NA	NA	NA
Antimony	7440-36-0	1.20E-04	1.24E-04	3.94E-03	4.08E-03	NA	NA	NA	NA	NA	NA	NA	NA
Barium	7440-39-3	4.07E-05	2.14E-04	3.36E-03	1.77E-02	4.85E-02	2.56E-01	NA	NA	NA	NA	NA	NA
Benzofuran	271-89-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzoic acid	65-85-0	2.02E-15	2.02E-15	1.33E-16	1.33E-16	NA	NA	NA	NA	NA	NA	NA	NA
Benzonitrile	100-47-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzyl alcohol	100-51-6	3.70E-13	3.70E-13	4.87E-14	4.88E-14	NA	NA	NA	NA	NA	NA	NA	NA
Beryllium	7440-41-7	1.99E-08	9.85E-08	2.20E-05	1.08E-04	1.71E-05	8.39E-05	7.35E-11	3.62E-10	8.10E-08	3.98E-07	3.50E-10	1.72E-09
bis(2-Ethylhexyl)phthalate	117-81-7	3.57E-09	2.01E-08	1.17E-09	6.60E-09	NA	NA	4.27E-13	2.41E-12	1.41E-13	7.91E-13	NA	NA
Butanal	123-72-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Butyl Acetate	123-86-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Butylbenzylphthalate	85-68-7	7.00E-11	8.50E-11	9.21E-12	1.12E-11	NA	NA	NA	NA	NA	NA	NA	NA
Carbon Dioxide	124-38-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbonyl Sulfide	463-58-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene	108-90-7	1.46E-12	1.47E-12	9.65E-14	9.65E-14	1.25E-11	1.25E-11	NA	NA	NA	NA	NA	NA
Chloroethene	75-01-4	2.83E-12	2.83E-12	1.87E-13	1.87E-13	7.24E-13	7.24E-13	5.10E-15	5.10E-15	3.36E-16	3.36E-16	2.73E-16	2.74E-16
cis 1,3-Dichloro-1-propene	10061-01-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-2-Butene	590-18-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-2-Hexene	7688-21-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
cis-2-Pentene	627-20-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt	7440-48-4	3.74E-09	3.93E-09	8.23E-08	8.65E-08	3.19E-05	3.36E-05	NA	NA	NA	NA	7.66E-10	8.05E-10
Copper	7440-50-8	9.08E-07	1.58E-06	1.05E-05	1.74E-05	NA	NA	NA	NA	NA	NA	NA	NA
Cyclohexane	110-82-7	NA	NA	NA	NA	1.12E-10	1.13E-10	NA	NA	NA	NA	NA	NA
Cyclohexanone	108-94-1	3.04E-16	3.04E-16	4.00E-17	4.00E-17	NA	NA	NA	NA	NA	NA	NA	NA

Table 12 (Continued)

Chemicals	CAS Number	Noncarcinogenic HI						Carcinogenic Risk					
		Ingestion		Dermal		Inhalation		Ingestion		Dermal		Inhalation	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Cyclopentane	278-92-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclopentanone	120-92-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclopentene	142-29-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Decanal	112-31-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dichloroacetonitrile	3018-12-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dichlorodifluoromethane	75-71-8	1.31E-12	1.31E-12	8.65E-14	8.65E-14	1.12E-11	1.12E-11	NA	NA	NA	NA	NA	NA
Diethylphthalate	84-66-2	4.90E-14	4.91E-14	3.24E-15	3.24E-15	NA	NA	NA	NA	NA	NA	NA	NA
Dimethyldisulfide	624-92-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-butylphthalate	84-74-2	2.19E-10	2.45E-10	2.90E-11	3.24E-11	NA	NA	NA	NA	NA	NA	NA	NA
d-Limonene	5989-27-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethane	74-84-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethanol	64-17-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylchloride	75-00-3	NA	NA	NA	NA	7.97E-16	7.97E-16	NA	NA	NA	NA	NA	NA
Ethylene	74-85-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	86-73-7	1.23E-14	1.29E-14	1.35E-15	1.43E-15	NA	NA	NA	NA	NA	NA	NA	NA
Heptanal	111-71-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobutadiene	87-68-3	1.17E-07	1.46E-07	7.65E-09	9.60E-09	NA	NA	7.78E-13	9.75E-13	5.13E-14	6.43E-14	1.87E-12	2.35E-12
Hexachlorocyclopentadiene	77-47-4	4.23E-09	6.45E-09	2.78E-10	4.25E-10	1.08E-06	1.65E-06	NA	NA	NA	NA	NA	NA
Hexachloroethane	67-72-1	2.25E-09	2.36E-09	1.48E-10	1.56E-10	NA	NA	1.35E-14	1.41E-14	8.9E-16	9.34E-16	3.29E-14	3.44E-14
Hexachloropropene	1888-71-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexanal	66-25-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indane	496-11-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isobutane	75-28-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isobutene	115-11-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isopentane	78-78-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isoprene	78-79-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Isopropylbenzene	98-82-8	5.90E-11	5.99E-11	3.89E-12	3.96E-12	1.26E-10	1.28E-10	NA	NA	NA	NA	NA	NA
Isothiocyanatomethane	556-61-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Magnesium	7439-95-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

(Sheet 5 of 7)

Table 12 (Continued)

Chemicals	CAS Number	Noncarcinogenic HI						Carcinogenic Risk					
		Ingestion		Dermal		Inhalation		Ingestion		Dermal		Inhalation	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Manganese	7439-96-5	1.65E-07	1.91E-07	1.09E-05	1.26E-05	1.29E-03	1.50E-03	NA	NA	NA	NA	NA	NA
Mercury	7439-97-6	5.17E-08	2.12E-07	2.27E-06	9.33E-06	NA	NA	NA	NA	NA	NA	NA	NA
Methacrolein	78-85-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylbromide	74-83-9	4.44E-12	4.44E-12	2.93E-13	2.93E-13	1.06E-11	1.06E-11	NA	NA	NA	NA	NA	NA
Methylchloroform	71-55-6	1.03E-14	1.04E-14	6.80E-16	6.80E-16	8.00E-15	8.01E-15	NA	NA	NA	NA	NA	NA
Methylcyclohexane	108-87-2	NA	NA	NA	NA	1.15E-10	1.15E-10	NA	NA	NA	NA	NA	NA
Methylcyclopentane	96-37-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylnitrite	624-91-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
m-Ethyltoluene	620-14-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methyl-vinyl Ketone	78-94-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTBE	1634-04-4	NA	NA	NA	NA	4.87E-10	4.87E-10	NA	NA	NA	NA	NA	NA
m-Xylene	108-38-3	6.40E-10	6.45E-10	5.30E-11	5.32E-11	NA	NA	NA	NA	NA	NA	NA	NA
n-Butane	106-97-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Decane	124-18-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Heptane	142-82-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Hexane	110-54-3	2.55E-10	2.55E-10	2.10E-11	2.10E-15	6.53E-10	6.53E-10	NA	NA	NA	NA	NA	NA
Nickel	7440-02-0	4.10E-08	5.85E-08	9.02E-07	1.29E-06	1.0E-06	1.43E-06	NA	NA	NA	NA	NA	NA
Nitromethane	75-52-5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Nonane	111-84-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Octane	111-65-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nonanal	124-19-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Pentane	109-66-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
n-Propylbenzene	103-65-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Octanal	124-13-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Ethyltoluene	611-14-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	95-47-6	3.61E-10	3.63E-10	2.98E-11	2.99E-11	NA	NA	NA	NA	NA	NA	NA	NA
Pentachloro-1-propene	1600-37-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentanal	110-62-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
p-Ethyltoluene	622-96-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 12 (Concluded)

Chemicals	CAS Number	Noncarcinogenic HI						Carcinogenic Risk					
		Ingestion		Dermal		Inhalation		Ingestion		Dermal		Inhalation	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Phenol	108-95-2	1.72E-15	1.73E-15	1.14E-16	1.14E-16	NA	NA	NA	NA	NA	NA	NA	NA
Phenylacetylene	536-74-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propanal	123-38-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propane	74-98-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propanenitrile	107-12-0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Propene	115-07-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
p-Xylene	106-42-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sec-Butylbenzene	135-98-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	7782-49-2	5.62E-09	6.1E-09	7.40E-07	8.08E-07	NA	NA	NA	NA	NA	NA	NA	NA
Silver	7440-22-4	2.78E-10	2.84E-10	9.14E-09	9.35E-09	NA	NA	NA	NA	NA	NA	NA	NA
Styrene	100-42-5	1.24E-11	1.24E-11	8.20E-13	8.20E-13	2.12E-11	2.12E-11	NA	NA	NA	NA	NA	NA
Tetrahydrofuran	109-99-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thiophene	110-02-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans 1,3-Dichloro-1-propene	10061-02-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-2-Butenal	123-73-9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-2-Butene	624-64-6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-2-Hexene	4050-45-7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-2-Pentene	646-04-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
trans-3-Penten-2-one	3102-33-8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroacetonitrile	545-06-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloromonofluoromethane	75-69-4	1.10E-14	1.10E-14	7.27E-14	7.27E-14	2.68E-14	2.68E-14	NA	NA	NA	NA	NA	NA
Vinylidene chloride	75-35-4	1.32E-13	1.32E-13	8.70E-13	8.70E-13	3.21E-13	3.21E-13	3.05E-16	3.05E-16	2.02E-15	2.02E-15	2.23E-16	2.23E-16
Zinc	7440-66-6	8.4E-08	3.87E-07	2.77E-09	1.28E-08	2.05E-07	9.43E-07	NA	NA	NA	NA	NA	NA

The soil concentration of a chemical changes with time due to continual loading and leaching but will eventually reach a steady-state value as a result of the constant deposition rate over time. The concentrations of some chemicals in the soil and subsurface reach steady-state values quickly within a short period (e.g., 1 year), and others with high sorption partition coefficients take a long time (e.g., 1,000 years or more). The HI and risk values indicated as initial in Tables 11 and 12 are those expected after 1 year of pollutant deposition. The final HI and risk values in the tables are the values calculated after 70 years of simulation. The same initial and final year values were used for the soil concentrations presented in Appendix A for the screening-level ecological risk assessment.

Calculated HI values were compared against the threshold of concern value of 1.0 and cancer risk values were compared against the threshold of concern value of 10^{-6}. Tables 11 and 12 show that none of the HI values were greater than 1.0 and none of the calculated risks were greater than 10^{-6} for the 195 chemicals evaluated in this study. In other words, none of the chemicals that had input toxicological benchmark data will pose human health problems if all of the assumptions and conditions imposed on the model and calculations remain unchanged. However, as shown in the tables, most of the chemicals in the list do not have calculated HI or cancer risk because of lack of toxicological benchmark data. For the 24 chemicals evaluated by Zakikhani et al. (2004), only one chemical, Cr(VI), showed a potential human health concern, where risk was 2.4×10^{-6}.

ARAMS also provides the breakthrough curves (time variation) of the concentrations at the water table. As an example, Figure 4 shows concentration versus time for chlorobenzene at the water table (note the chlorobenzene peak concentration is much less than the EPA MCL of 0.1 mg/L). It should be noted that the groundwater concentration is immediately at the contact point of the vadose zone flux. Thus, this concentration will be greatly reduced at locations down gradient due to dilution and dispersion. Table 13 shows the peak concentration (at water table interception) and the associated travel times to the groundwater. For chemicals such as bis(2-ethylhexyl)phthalate, which has a very high K_d value, the peak concentration was not calculated because simulation time to reach the water table was extremely large (greater than 10,000 years).

Groundwater concentrations are normally compared to a USEPA drinking water safe minimum concentration level (MCL). However, for most of the chemicals evaluated in this study, an MCL was not available. Hence, we ranked the chemicals by arrival time to the water table into seven classes (A, B, C, D, E, and F, see Table 14) and peak concentration at the water table into eight classes (AA, BB, CC, DD, and EE, see Table 15). Table 14 shows the number and percentage of chemicals for each of class of arrival times to the water table. For example, the chemicals ranked A (Tables 13 and 14) have a maximum arrival time of 20 years. Table 15 shows the number and percentage of chemicals within a class of peak water table concentrations. For example, chemicals ranked AA have peak concentrations between 1.0E-04 to 1.0E-01 ppm (Tables 13 and 15). Only 6 percent (12 chemicals) have concentrations between 1.0E-04 and 1.0E-04 ppm. All of these 12 chemicals, with the exception of carbon dioxide,

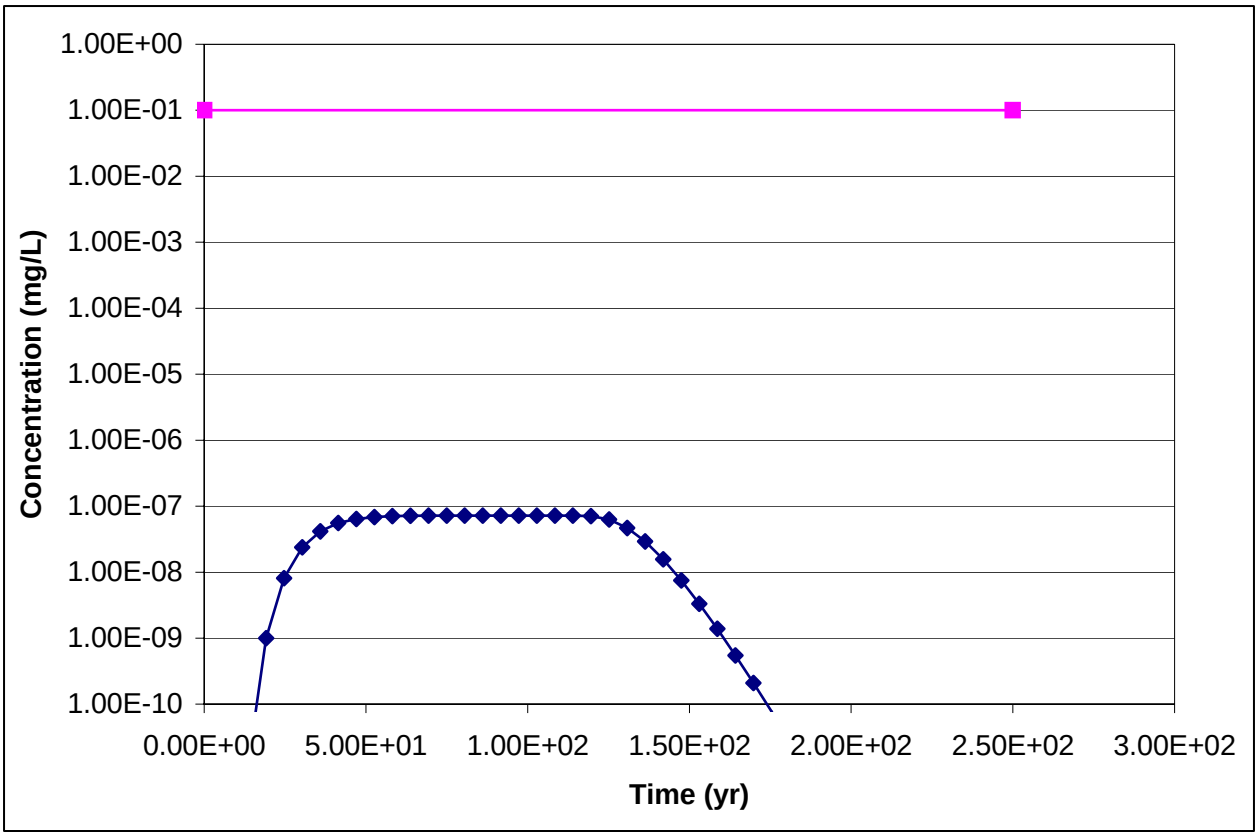

Figure 4. Time-series of chlorobenzene concentration at water table (points and blue colored line) and MCL (0.1 mg/L) for chlorobenzene (pink colored line)

Table 13
Summary of Subsurface Arrival Time and Groundwater Peak Concentration

ID	Chemicals	CAS Number	Time, yr	Rank of Time [1]	Peak Concentration mg/L [2]	Rank of Concentration [3]
1	1,1,2,2-Tetrachloroethane	79-34-5	41	C	4.75E-09	CC
2	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	127	D	4.68E-08	CC
3	1,1,2-Trichloroethane	79-00-5	24	B	1.30E-08	CC
4	1,1-Dichloro-2-propanone	513-88-2	19	A	4.76E-08	CC
5	1,1-Dichloroethane	75-34-3	24	B	5.50E-09	CC
6	1,2,3-Trichloropropane	96-18-4	35	B	4.00E-08	CC
7	1,2,4-Trichlorobenzene	120-82-1	429	D	1.32E-09	CC
8	1,2-Dichloro-2-methylpropane	594-37-6	51	C	2.60E-07	CC
9	1,2-Dichloro-3-methylbenzene	32768-54-0	378	D	1.77E-08	CC
10	1,2-Dichlorobenzene	95-50-1	158	D	5.05E-08	CC
11	1,2-Dichlorobutane	616-21-7	53	C	1.60E-08	CC
12	1,2-Dichloroethane	107-06-2	20	A	2.80E-07	CC

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[1] See Table 14.
[2] Concentration at point of vadose zone flux interception with water table.
[3] See Table 15.
** Concentration is zero because deposition rate was reported as zero.
*** High adsorption coefficient resulted in extremely long time to reach water table (see text for detail).

Table 13 (Continued)

ID	Chemicals	CAS Number	Time, yr	Rank of Time [1]	Peak Concentration mg/L [2]	Rank of Concentration [3]
13	1,2-Dichloropropane	78-87-5	21	B	3.60E-08	CC
14	1,3,5-Trimethylbenzene	108-67-8	155	D	5.00E-04	AA
15	1,3-Butadiene	106-99-0	25	B	2.80E-05	BB
16	1,3-Dichlorobenzene	541-73-1	189	D	2.74E-08	CC
17	1,4-Dichlorobenzene	106-46-7	161	D	8.30E-09	CC
18	1-Acetoxyacetone	592-20-1	19	A	6.34E-07	CC
19	1-Bromo-2-chloroethane	107-04-0	24	B	6.40E-08	CC
20	1-Butanol	71-36-3	19	A	1.06E-08	CC
21	1-Butene	106-98-9	37	B	3.36E-06	BB
22	1-Chloro-2-methylbenzene	95-49-8	155	D	9.70E-07	CC
23	1-Chloro-3-methylbenzene	108-41-8	142	D	8.40E-08	CC
24	1-Chloro-4-ethylbenzene	622-98-0	231	D	9.23E-09	CC
25	1-Chlorobutane	109-69-3	49	C	2.00E-08	CC
26	1-Hexene	592-41-6	159	D	5.65E-07	CC
27	1-Hydroxy-2-propanone	116-09-6	19	A	7.97E-07	CC
28	1-Penten-3-one	1629-58-9	19	A	1.40E-07	CC
29	1-Pentene	109-67-1	54	C	1.20E-06	BB
30	2,2,4-Trimethylhexane	16747-26-5	1,350	E	2.60E-07	CC
31	2,2,4-Trimethylpentane	540-84-1	455	D	6.93E-06	BB
32	2,2-Dimethylbutane	75-83-2	28	B	6.14E-06	BB
33	2,2-Dimethylpropane	463-82-1	111	D	1.12E-07	CC
34	2,3,4-Trimethylpentane	565-75-3	457	D	1.30E-06	BB
35	2,3-Butanedione	431-03-8	19	A	1.16E-06	BB
36	2,3-Dihydro-1-methyl-1H-indene	767-58-8	319	D	3.43E-05	BB
37	2,3-Dimethylbutane	79-29-8	155	D	2.25E-05	BB
38	2,3-Dimethylhexane	584-94-1	485	D	1.77E-05	BB
39	2,3-Dimethylpentane	565-59-3	211	D	1.77E-05	BB
40	2,3-Pentanedione	600-14-6	19	A	3.60E-07	CC
41	2,4-Dimethylhexane	589-43-5	485	D	4.00E-06	BB
42	2,4-Dimethylpentane	108-08-7	212	D	1.08E-05	BB
43	2,5-Dimethylfuran	625-86-5	31	B	1.65E-07	CC
44	2,5-Dimethylhexane	592-13-2	485	D	3.46E-06	BB
45	2-Bromo-1-chloropropane	3017-95-6	32	B	8.10E-08	CC
46	2-Butoxyethanol	111-76-2	**	F	**	EE
47	2-Furaldehyde	98-01-1	19	A	1.27E-06	BB
48	2-Heptanone	110-43-0	25	B	3.09E-09	CC
49	2-Hexanone	591-78-6	23	B	3.49E-08	CC
50	2-Methyl-1-butene	563-46-2	52	C	1.70E-06	BB
51	2-Methyl-1-pentene	763-29-1	127	D	1.04E-06	BB
52	2-Methyl-2-butene	513-35-9	50	C	6.70E-07	CC
53	2-Methyl-2-pentene	625-27-4	106	D	6.70E-07	CC
54	2-Methylfuran	534-22-5	24	B	1.80E-07	CC
55	2-Methylheptane	592-27-8	577	E	9.22E-06	BB
56	2-Methylhexane	591-76-4	246	D	5.20E-05	BB
57	2-Methylnaphthalene	91-57-6	306	D	9.50E-06	BB
58	2-Methylpentane	107-83-5	127	D	1.00E-04	AA
59	2-Methylthiophene	554-14-3	32	B	2.97E-08	CC

(Sheet 2 of 5)

Table 13 (Continued)

ID	Chemicals	CAS Number	Time, yr	Rank of Time [1]	Peak Concentration mg/L [2]	Rank of Concentration [3]
60	2-Nitrophenol	88-75-5	20	A	1.99E-07	CC
61	2-Octanone	111-13-7	33	B	8.37E-10	DD
62	2-Pentanone	107-87-9	19	A	6.03E-07	CC
63	2-Propanol	67-63-0	19	A	1.34E-07	CC
64	2-Thiophenecarboxaldehyde	98-03-3	19	A	5.38E-08	CC
65	3-Ethylhexane	619-99-8	577	E	4.80E-09	CC
66	3-Heptanone	106-35-4	23	B	8.92E-08	CC
67	3-Methyl-1-butene	563-45-1	46	C	5.97E-07	CC
68	3-Methyl-2-butanone	563-80-4	19	A	5.45E-08	CC
69	3-Methylfuran	930-27-8	24	B	5.95E-08	CC
70	3-Methylhexane	589-34-4	246	D	5.65E-05	BB
71	3-Methylpentane	96-14-0	198	D	6.91E-05	BB
72	3-Methylphenol	108-39-4	25	B	7.94E-07	CC
73	3-Methylthiophene	616-44-4	32	B	2.75E-08	CC
74	3-Pentanone	96-22-0	19	A	6.26E-08	CC
75	4-Methyl-1-pentene	691-37-2	106	D	4.50E-07	CC
76	4-Methyl-2-pentanone	108-10-1	19	A	1.04E-08	CC
77	4-Methylbenzonitrile	104-85-8	25	B	9.08E-08	CC
78	4-Methylphenol	106-44-5	24	B	8.00E-07	CC
79	5-Methyl-2-furaldehyde	620-02-0	19	A	4.20E-07	CC
80	6-Methyl-2-heptanone	928-68-7	30	B	3.22E-09	CC
81	6-Methyl-5-hepten-2-one	110-93-0	25	B	2.02E-10	DD
82	Acenaphthylene	208-96-8	363	D	3.88E-07	CC
83	Acetaldehyde	75-07-0	19	A	3.65E-06	BB
84	Acetic Acid	64-19-7	19	A	2.92E-05	BB
85	Acetone	67-64-1	19	A	2.22E-05	BB
86	Acetonitrile	75-05-8	19	A	2.97E-07	CC
87	Acetophenone	98-86-2	20	A	3.77E-07	CC
88	Acetylene	74-86-2	19	A	2.50E-05	BB
89	Acrolein	107-02-8	19	A	1.13E-05	BB
90	Acrylonitrile	107-13-1	22	B	3.96E-07	CC
91	Aluminum	7429-90-5	***	F	***	EE
92	Antimony	7440-36-0	393	D	5.10E-03	AA
93	Barium	7440-39-3	***	F	***	EE
94	Benzofuran	271-89-6	49	C	1.68E-07	CC
95	Benzoic acid	65-85-0	24	B	5.24E-08	CC
96	Benzonitrile	100-47-0	19	A	4.71E-07	CC
97	Benzyl alcohol	100-51-6	19	A	8.73E-07	CC
98	Beryllium	7440-41-7	10,000	E	1.66E-07	CC
99	bis(2-Ethylhexyl)phthalate	117-81-7	***	F	***	EE
100	Butanal	123-72-8	19	A	2.53E-07	CC
101	Butyl Acetate	123-86-4	24	B	1.04E-07	CC
102	Butylbenzylphthalate	85-68-7	1,890	E	6.15E-08	CC
103	Carbon Dioxide	124-38-9	19	A	1.53E-01	AA
104	Carbonyl Sulfide	463-58-1	19	A	3.29E-06	BB
105	Chlorobenzene	108-90-7	64	C	7.14E-08	CC
106	Chloroethene	75-01-4	23	B	6.13E-08	CC

(Sheet 3 of 5)

Table 13 (Continued)

ID	Chemicals	CAS Number	Time, yr	Rank of Time [1]	Peak Concentration mg/L [2]	Rank of Concentration [3]
107	cis 1,3-Dichloro-1-propene	10061-01-5	25	B	6.40E-08	CC
108	cis-2-Butene	590-18-1	32	B	7.45E-07	CC
109	cis-2-Hexene	7688-21-3	105	D	4.48E-07	CC
110	cis-2-Pentene	627-20-3	46	C	5.96E-07	CC
111	Cobalt	7440-48-4	513	E	3.93E-06	BB
112	Copper	7440-50-8	4,960	E	3.11E-05	BB
113	Cyclohexane	110-82-7	161	D	5.80E-05	BB
114	Cyclohexanone	108-94-1	19	A	1.22E-08	CC
115	Cyclopentane	287-92-3	89	C	1.02E-05	BB
116	Cyclopentanone	120-92-3	19	A	1.05E-07	CC
117	Cyclopentene	142-29-0	39	B	5.20E-07	CC
118	Decanal	112-31-2	250	D	1.62E-05	BB
119	Dichloroacetonitrile	3018-12-0	19	A	1.25E-08	CC
120	Dichlorodifluoromethane	75-71-8	26	B	1.43E-06	BB
121	Diethylphthalate	84-66-2	33	B	1.69E-07	CC
122	Dimethyldisulfide	624-92-0	20	A	9.28E-08	CC
123	Di-n-butylphthalate	84-74-2	1,120	E	2.53E-07	CC
124	d-Limonene	5989-27-5	**	F	**	EE
125	Ethane	74-84-0	20	A	1.25E-06	BB
126	Ethanol	64-17-5	19	A	4.88E-08	CC
127	Ethylchloride	75-00-3	19	A	7.03E-09	CC
128	Ethylene	74-85-1	19	A	3.00E-05	BB
129	Fluorene	86-73-7	553	E	2.23E-11	DD
130	Heptanal	111-71-7	35	B	7.90E-06	BB
131	Hexachlorobutadiene	87-68-3	2,120	E	8.36E-08	CC
132	Hexachlorocyclopentadiene	77-47-4	3,690	E	3.38E-08	CC
133	Hexachloroethane	67-72-1	507	E	1.20E-07	CC
134	Hexachloropropene	1888-71-7	859	E	1.44E-07	CC
135	Hexanal	66-25-1	24	B	1.36E-07	CC
136	Indane	496-11-7	114	D	2.00E-04	AA
137	Isobutane	75-28-5	59	C	4.24E-06	BB
138	Isobutene	115-11-7	32	B	8.70E-06	BB
139	Isopentane	78-78-4	52	C	1.20E-04	AA
140	Isoprene	78-79-5	33	B	2.90E-07	CC
141	Isopropylbenzene	98-82-8	225	D	2.17E-06	BB
142	Isothiocyanatomethane	556-61-6	19	A	6.75E-08	CC
143	Magnesium	7439-95-4	10,000	E	7.58E-22	DD
144	Manganese	7439-96-5	1,420	E	5.64E-05	BB
145	Mercury	7439-97-6	10,000	E	4.73E-14	DD
146	Methacrolein	78-85-3	19	A	2.40E-07	CC
147	Methylbromide	74-83-9	19	A	4.83E-08	CC
148	Methylchloroform	71-55-6	39	B	8.41E-09	CC
149	Methylcyclohexane	108-87-2	203	D	4.15E-05	BB
150	Methylcyclopentane	96-37-7	154	D	5.07E-05	BB
151	Methylnitrite	624-91-9	19	A	5.30E-05	BB
152	m-Ethyltoluene	620-14-4	394	D	1.30E-05	BB
153	Methyl-vinyl Ketone	78-94-4	19	A	3.88E-07	CC

(Sheet 4 of 5)

Table 13 (Concluded)

ID	Chemicals	CAS Number	Time, yr	Rank of Time [1]	Peak Concentration mg/L [2]	Rank of Concentration [3]
154	MTBE	1634-04-4	22	B	1.36E-03	AA
155	m-Xylene	108-38-3	126	D	2.35E-03	AA
156	n-Butane	106-97-8	90	C	2.27E-05	BB
157	n-Decane	124-18-5	3,410	E	1.04E-07	CC
158	n-Heptane	142-82-5	1,610	E	1.02E-05	BB
159	n-Hexane	110-54-3	333	D	7.14E-05	BB
160	Nickel	7440-02-0	3,090	E	1.41E-06	BB
161	Nitromethane	75-52-5	19	A	7.58E-06	BB
162	n-Nonane	111-84-2	2,020	E	6.90E-07	CC
163	n-Octane	111-65-9	5,040	E	1.14E-06	BB
164	Nonanal	124-19-6	140	D	2.87E-05	BB
165	n-Pentane	109-66-0	159	D	1.00E-04	AA
166	n-Propylbenzene	103-65-1	237	D	1.19E-05	BB
167	Octanal	124-13-0	60	C	2.15E-05	BB
168	o-Ethyltoluene	611-14-3	174	D	1.69E-05	BB
169	o-Xylene	95-47-6	112	D	1.48E-03	AA
170	Pentachloro-1-propene	1600-37-9	163	D	3.92E-08	CC
171	Pentanal	110-62-3	19	A	6.22E-08	CC
172	p-Ethyltoluene	622-96-8	211	D	4.00E-04	AA
173	Phenol	108-95-2	19	A	3.87E-09	CC
174	Phenylacetylene	536-74-3	40	B	4.17E-07	CC
175	Propanal	123-38-6	19	A	4.88E-07	CC
176	Propane	74-98-6	32	B	3.87E-07	CC
177	Propanenitrile	107-12-0	19	A	5.07E-08	CC
178	Propene	115-07-1	24	B	1.37E-05	BB
179	p-Xylene	106-42-3	102	D	2.32E-03	AA
180	sec-Butylbenzene	135-98-8	1,320	E	1.19E-05	BB
181	Selenium	7782-49-2	848	E	5.57E-07	CC
182	Silver	7440-22-4	272	D	3.00E-07	CC
183	Styrene	100-42-5	90	C	1.85E-05	BB
184	Tetrahydrofuran	109-99-9	19	A	1.34E-07	CC
185	Thiophene	110-02-1	24	B	5.30E-07	CC
186	trans 1,3-Dichloro-1-propene	10061-02-6	19	A	1.30E-08	CC
187	trans-2-Butenal	123-73-9	19	A	3.01E-07	CC
188	trans-2-Butene	624-64-6	32	B	2.38E-06	BB
189	trans-2-Hexene	4050-45-7	105	D	8.20E-07	CC
190	trans-2-Pentene	646-04-8	42	C	1.05E-06	BB
191	trans-3-Penten-2-one	3102-33-8	19	A	8.72E-08	CC
192	Trichloroacetonitrile	545-06-2	25	B	9.80E-09	CC
193	Trichloromonofluoromethane	75-69-4	40	B	1.35E-07	CC
194	Vinylidene chloride	75-35-4	29	B	4.45E-08	CC
195	Zinc	7440-66-6	10,000	E	8.63E-17	DD

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Table 14
Ranking of Arrival Time to Water Table

Chemical Rank	Years	Number of Chemicals	Percent of Chemicals
A	0 – 20	51	26
B	20 – 40	46	24
C	40- 100	18	9
D	100- 500	51	26
E	500- 10,000	24	12
F	No results (see Table 13)	5	3

Table 15
Ranking of Water Table Concentration

Chemical Rank	Concentration Level Range, ppm	Number of Chemicals	Percent of Chemicals
AA	1.0E-04 – 1.0E-01	12	6
BB	1.0E-06 – 1.0E-05	60	31
CC	1.0E-09 – 1.0E-07	112	57
DD	1.0E-22 – 1.0E-10	6	3
EE	No Results (see Table 13)	5	3

had groundwater concentrations at the low end of the AA class, on the order of 10^{-3} to 10^{-4} mg/L. Tables 13-15 suggest that none of the chemicals in groundwater should pose health risk problems. Although comparison to MCL values was not possible for most of the chemicals, these results may be used as a guide to prioritize the chemicals for further studies. The twenty-four chemicals evaluated in the first phase of the study (Zakikhani et al. 2004) had groundwater concentrations lower than the USEPA MCL values.

6 Summary and Conclusions

This project required a significant amount of data discovery (especially for toxicological data). In addition, a large number of chemical properties and toxicological data had to be input into the ARRAMS/FRAMES constituent database to fill data gaps. Data search utilized on-line databases, including the Risk Assessment Information System (RAIS), IRIS, and International Toxicity Estimates for Risk (ITER) databases. A summary table (Table 10) shows that the required toxicological benchmark data were not available for calculation of risks for most of the chemicals in the list. Non-carcinogenic benchmarks for 59 of the chemicals were available for HI calculations, while carcinogenic toxicological data were available only for 13 of the chemicals.

For the chemicals that had toxicological data available, the potential human health risks associated with exposure resulting from future military training at MMR were evaluated. Two modeling scenarios, one for human health impacts to a site visitor and one for migration of chemicals through the vadose zone, were utilized in this study. Additionally, CHPPM conducted a screening level ecological risk assessment using soil concentration results from ARAMS (see Appendix A). CHPPM also provided air concentrations and deposition rates (fluxes) for chemicals that could be released from future training activities. EPA's ISCST3 air fate/transport model was used as discussed by Zakikhani et al. (2004). The air model was run for a 4-year period using historical meteorology, and the annual average results for the four years were processed for each sector of the site. The air modeling scenario was based on anticipated future training for the National Guard. Weekend training was assumed during the fall, winter, and spring, while weeklong training was assumed for the summer.

Future training will result in chemicals potentially moving from air to soil through deposition. Thus, air and soil are the exposure media. The MMR human receptor consisted of an adult individual moving around or within the site as a trespasser or visitor. The exposure pathways were air inhalation, soil dermal contact, incidental soil ingestion, and suspended soil inhalation. One hundred-ninety-five (195) chemicals were considered in this study, in addition to the 24 chemicals that were evaluated in the earlier study (Zakikhani et al. 2004). The spatially averaged values of annual average deposition rates and air concentrations computed over the site by the air model were used for ARAMS input. Losses resulting from site runoff and all types of chemical degradation (e.g., biodegradation and volatilization) losses from soil were not included, thus, resulting in very conservative estimates for soil concentrations. Leaching into the vadose zone was the only soil loss pathway considered for the study report

herein. Chemical degradation was included in the earlier study of 24 chemicals (Zakikhani et al. 2004), in addition to leaching. The calculated risks are based on an exposure frequency of 2 hr/day, 50 days/year, with 30 years exposure duration, and 100 years of continual training activities and chemical loadings.

With regard to the air and soil pathways for the chemicals with available toxicological parameters, none of the chemicals evaluated in this study posed health concerns, since all the calculated risks were less than the acceptable risk of 10^{-6} used by the USEPA, and all hazard indices were less than 1.0. Of the 24 chemicals evaluated in the earlier study (Zakikhani et al. 2004), only one chemical, chromium VI, slightly exceeded the human health thresholds, where it had a cancer risk of 2.4×10^{-6}.

Air deposition to soil can also result in chemicals migrating from soil through the vadose zone to groundwater. For the groundwater analysis, although MCLs were not available for comparison for most of the chemicals, the calculated concentrations were very low (Table 13). Groundwater that is further down gradient from the point of water table interception will have even lower concentrations because of dilution and dispersion. For chemicals with high K_d values, such as bis(2-ethylhexyl)phthalate, aluminum, and barium, the peak concentrations were not calculated because simulation times to reach the water table were extremely large (greater than 10,000 years). The travel time of the peak concentration was calculated to range from as low as 18.5 years for several chemical in the list to 10,000 years for beryllium and greater for a few other chemicals with high K_d values. The peak concentration should be compared to safe drinking water levels (MCL) recommended by USEPA. However, MCLs for most of the chemicals in the list are not available. Hence, we grouped the chemicals into ranges of peak concentration and arrival times to groundwater. This classification can be used to prioritize the chemicals for further studies. The results indicate that the migration through the vadose zone to groundwater is not expected to be a future problem for all of the chemicals.

The results of this study are based on the highly conservative assumption used in the application of emission factors to obtain compound-specific air concentrations and deposition rates. As explained by Zakikhani et al. (2004), continuous emissions for each munitions type and for each training event were assumed, thus, resulting in a total mass released that is greater than would be expected, which translates into greater, but more conservative, exposure and risks.

Lack of input toxicological data for most of the chemicals of concern limited the scope of this study. Given the expense of laboratory studies to derive these data, more attention should be given to computational and extrapolation methods to estimate toxicological effects. In addition, the conservative approach that was used for emissions and transport overestimated the impacts. More realistic emission durations could be used and would reduce conservatism. The assumption of no degradation overestimated exposure concentrations. However, obtaining degradation rates is highly problematic when so many chemicals are involved, rates are often site specific, and available data on such rates are very limited.

The analysis and conclusions for the screening-level ecological risk assessment are presented in Appendix A and in Zakikhani et al. (2004) for the first 24 chemicals studied. This study showed that two chemicals, m-xylene and p-xylene, exceeded the low-effect toxicity benchmarks, but not the moderate-effect benchmarks. Aluminum exceeded the screening-level soil benchmark; however, it did not exceed the background 95 percent upper tolerance limit. The initial soil concentration for barium exceeded the low-effect screening-level benchmark slightly. However, the modeled (initial and final) soil concentrations fell within the range of background soil concentrations for barium. Of the 24 chemicals evaluated in the first study (Zakikhani et al. 2004), only hexachlorobenzene was considered a chemical of potential concern (COPC) due to exceedence of the toxicity benchmark. Uncertainties associated with the modeled soil concentrations and conservative soil benchmarks should be recognized. The potential for impacts to ecological receptors resulting from exposure to chemicals in the surface soil via training activities at MMR is low.

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Appendix A
Screening-Level Ecological Assessment at MMR

MMR Screening- Level Ecological Evaluation

The purpose of this report is to qualitatively assess the potential for impacts to ecological receptors resulting from exposure to chemicals in the surface soil via training activities at MMR. The qualitative discussion was structured according to the framework for ecological risk assessment provided in the USEPA (1998)[1] "Guidelines for Ecological Risk Assessment." The problem formulation step, which includes describing habitats and potential exposure resources at the site, identifying potential exposure pathways, potential ecological receptors, and potential chemicals of potential concern (COPC) was primarily utilized for the qualitative discussion. The problem formulation step resulted in:

a. Identification of adequate assessment endpoints.

b. A conceptual site model that described relationships between stressor(s) and assessment endpoint(s).

c. An analysis plan.

Problem Formulation

The purpose of the problem formulation section is to identify COPCs and the ecological receptors and exposure pathways for evaluation. Available information is evaluated regarding site history, past and present land use activities, habitat and wildlife, and COPCs associated with the site in order to identify the pathways by which ecological receptors could be exposed to chemicals.

[1] References cited in this appendix are included in the References section at the end of the main text.

Site history

(Chapter 2, “Site Description,” 2nd paragraph, and Chapter 3, “Modeling Approach,” subparagraph “Human Health Analysis.”)

Past and present land use activities

(Chapter 2, “Site Description,” 2nd paragraph.)

Habitats and wildlife

MMR contains the single largest tract of open space on Cape Cod. Much of Cape Cod has been extensively developed and many plant and animal species lack sufficient habitat. Rare plant and animal species are having greater success on MMR (especially on Camp Edwards) due to the lack of habitat fragmentation and development. Camp Edwards contains the largest pine-barrens north of the renowned New Jersey Pine Barrens. Many state listed threatened, endangered, and of-special-concern species inhabit the area (MNGE&RC et al. 2001)

The Impact Area, which is part of the Camp Edwards Training site, is comprised primarily of Scrub Oak Barrens habitat; however, Pitch Pine forest is interspersed throughout the area. The plant community represents one of the earliest states of vegetative succession. Shrub species prevalent in the Scrub Oak Barrens include huckleberry, blueberry, cat brier, and wintergreen (CEEPO 2000).

Camp Edwards represents an island of natural resources surrounded by a sea of development (CEEPO 2000). Small mammal and bird populations have been surveyed since 1993 and faunal populations have been surveyed for several years as well. Invertebrates have also been studied; however, they are one of the least studied due to their high diversity. Moths, dragonflies, and aquatic invertebrates have been the main focus of past surveys. The scrub oak barrens and pitch pine/scrub oak communities provide habitat for several state-listed rare moth species. The scrub oak barrens is a highly preferred habitat for many state-listed rare moth species.

Populations of small mammals have been monitored on Camp Edwards since 1994. The most abundant small mammal species captured during the surveys were the white-footed mouse and the southern red-backed vole. The pitch pine/scrub oak community produced a relatively moderate number of individuals. Whitetail deer are also abundant on Camp Edwards. According to deer harvest data, the whitetail deer population has not fluctuated greatly. Bat surveys were also conducted at Camp Edwards in 1999 and 2000. Three species, the big brown bat, the red bat, and the northern myotis, were documented during the surveys (CEEPO 2000).

Camp Edwards contains the second highest number of state-listed rare species within the Cape Cod Ecoregion with 37 state-listed (i.e., endangered, threatened, and special concern) species. Species identified as threatened,

endangered, or of-special-concern include 3 species of plants, 19 species of moths/butterflies, 2 species of turtles, 8 species of birds, and 5 species of dragonflies and damselflies (MNGE&RC et al. 2001). The management of the ecology and endangered species by various environmental agencies and organizations serves to maintain the biological diversity at Camp Edwards, making it a unique area for native flora and fauna.

Conceptual site model

The suspected source of the contaminants is air emissions that result from the use of munitions during military training and deposit onto the surface soil. Refer to Figure A1 for the conceptual site model (CSM) that includes the general environmental fate of substances released from munitions on the impact area.

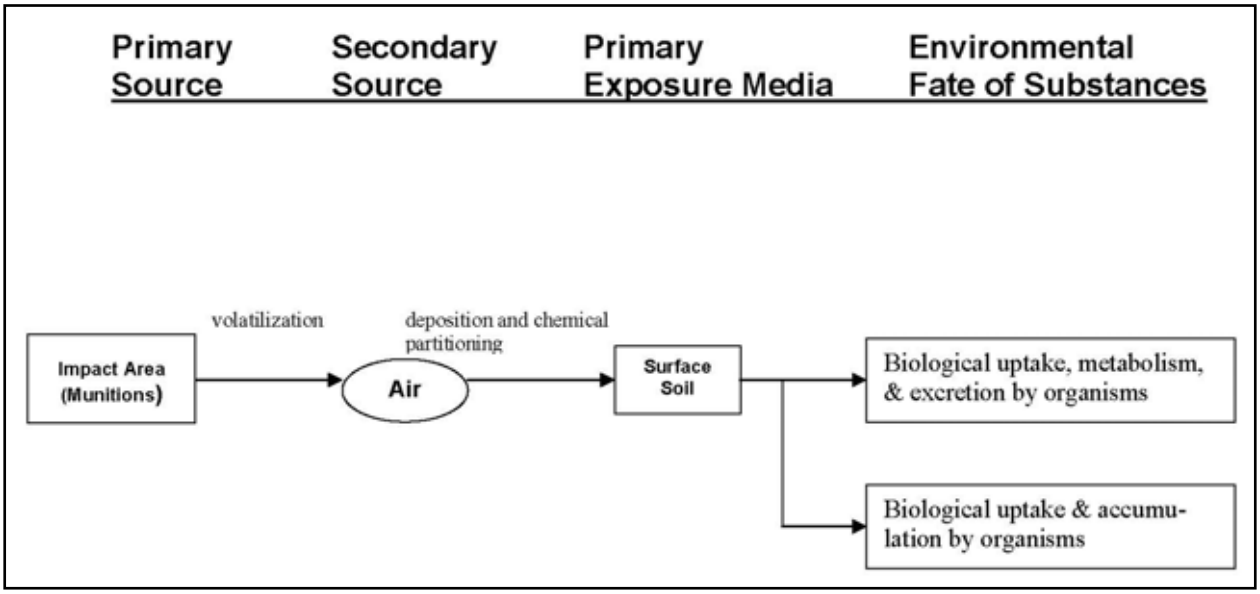

Figure A1. General environmental fate of substances released from munitions on the impact area at MMR

Specific substances in the munitions may accumulate in the soil to sufficient levels to induce the following effects:

a. Increased stress on individual organisms that may reduce population densities (e.g., through reduced reproductive performance, less resistance to disease, or impaired development).

b. Stressed populations of organisms.

c. Altered structure and function and decreased productivity of ecological communities.

d. Altered, and potentially decreased, biological diversity.

Toxicological effects (i.e., decrease reproductive potential and developmental impairment of organisms) can lead to stressed populations of organisms if those effects become sufficiently prevalent. Then, such stressed populations are expected to potentially lead to changes in population dynamics and community interactions that can alter the actual kinds of species (structure) and processes (function) within the affected ecological community. In general, the assumption is that such changes can lead to decreased community productivity and biological diversity. Figure A2 illustrates the hypothesized ecological consequences that munitions emissions may have on terrestrial communities. This particular ecological assessment will focus on the first bullet (i.e., the potential for toxicological effects in organisms). Individual species or organisms (e.g., meadow vole) are usually selected to represent wildlife populations (i.e., all herbivore, all small mammals, or all herbivorous small mammals). These species are representative in the sense that they may be a sensitive species, have intimate contact with contaminated media, and/or are easy to study because they are abundant in the field.

Selection of assessment endpoints

Assessment endpoints are explicit expressions of the actual environmental values that are to be protected, operationally defined by an ecological entity and its attributes (USEPA 1998). The ecological entities within each assessment endpoint are those that are considered to be susceptible to the stress. The specific assessment endpoints for this ecological assessment are as follows:

1. Community structure of Pitch Pine/Scrub Oak forest.

2. Survival of wildlife populations.

3. Survival of individuals of threatened or endangered species.

Analysis plan

The analysis plan is the final stage of problem formulation and includes a description of the assessment design, data needs, and measures. This ecological assessment will evaluate the potential for adverse changes in each of the three assessment endpoints in context with the risk hypothesis that was stated in the conceptual model.

Measures to Evaluate the Risk Hypothesis. Two categories of measures will be employed in this assessment and are as follows:

a. *Measures of exposure*. These measure the movement of stress through the environment and how exposure may occur to receptors (e.g., modeled media concentrations).

b. *Measures of effect*. These are measurable changes in an attribute of an assessment endpoint in response to a stressor to which it is exposed (e.g., surface soil toxicity benchmarks).

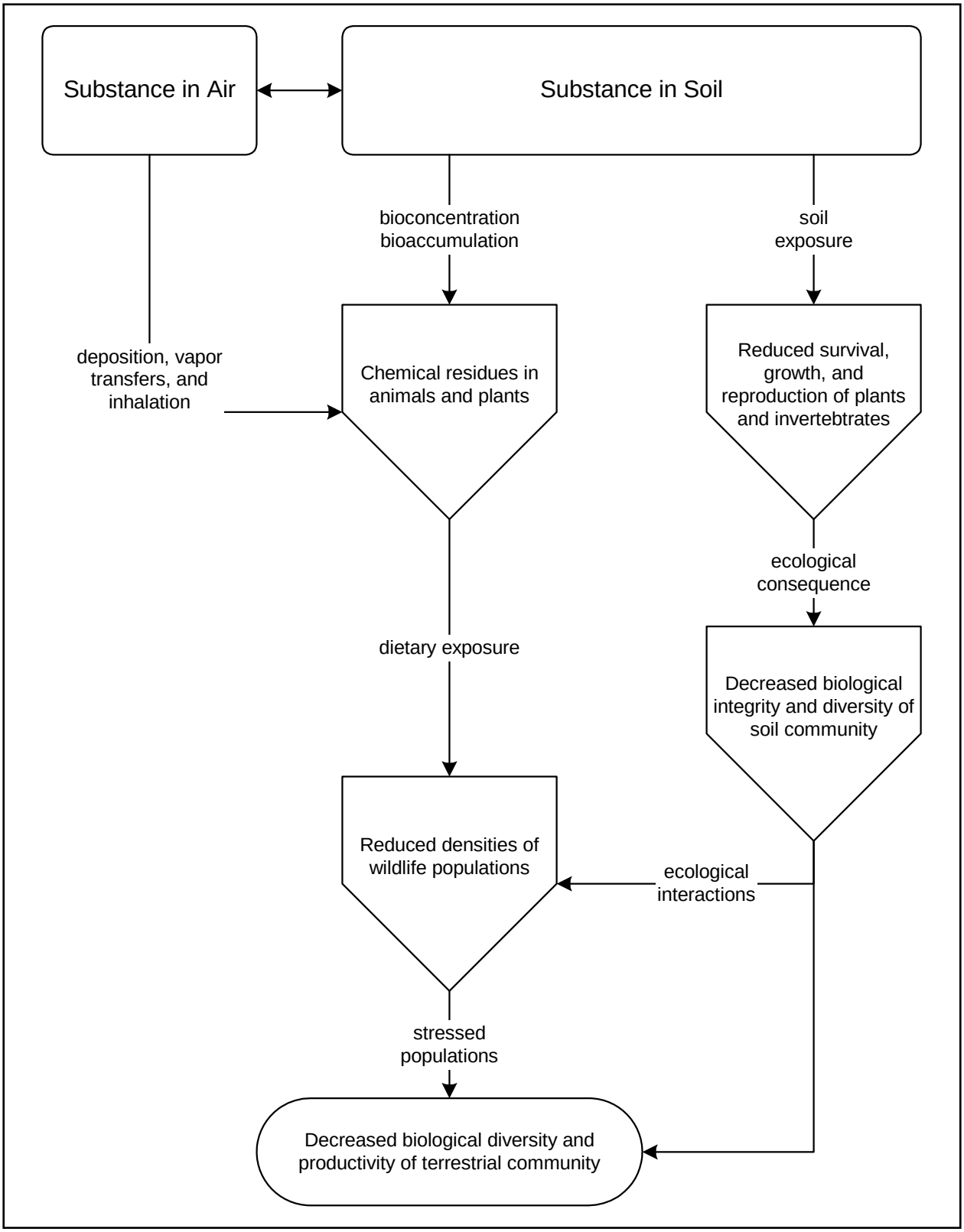

Figure A2. Hypothesized ecological consequences in terrestrial environments if munition emissions are determined to be ecologically adverse

For assessment endpoint number 1 (Pitch Pine/Scrub Oak community structure), the following measures were selected.

a. *Measures of exposure* – Modeled concentrations of substances in the surface soil.

b. *Measures of effect* – Surface soil toxicity benchmarks.

For assessment endpoint number 2 (Survival of wildlife populations), the following measures were selected.

a. *Measures of exposure* – Modeled concentrations of substances in the surface soil.

b. *Measures of effect* – Surface soil toxicity benchmarks.

For assessment endpoint number 3 (Survival of individuals of threatened or endangered species), the following measures were selected.

a. *Measures of exposure* – Modeled concentrations of substances in the surface soil

b. *Measures of effect* – Surface soil toxicity benchmarks.

For this screening-level assessment, the measures exposure (i.e., modeled surface soil concentrations) will be compared to the measures of effect (i.e., surface soil toxicity benchmarks) in order to identify any chemicals that may be of potential concern to ecological receptors.

Chemicals of potential concern

Emissions data from munitions were modeled to predict the fate and transport of combustion byproducts from the air to the surface soil. An initial screen was set forth to determine COPCs by comparing modeled average soil concentrations for 195 chemicals to conservative soil quality benchmarks (see Table A1). The average (initial) soil concentration (i.e., the soil concentration we would expect after 1 year of deposition) and the average (final) soil concentrations (i.e., the soil concentrations we would expect after 70 years of deposition) are provided in Table A1. To remain consistent with the Human Health assessment (see Human Health Section), final average soil concentrations were used in this assessment. Most chemicals, with the exception of xylene (i.e., m-xylene and p-xylene), aluminum, and barium, did not exceed the surface soil benchmarks. Several chemicals did not have a soil benchmark for comparison purposes; therefore, they were not evaluated. Two ecotoxicological benchmarks were provided, when available, for each chemical that represent different levels of effect. The lower values (i.e., low-effect benchmarks) represent basic screening-level benchmarks that, if exceeded, indicate that the exposures need to be further investigated. The higher values (i.e., moderate-effect benchmarks) represent

Table A1
Chemicals of Potential Concern (Chemicals that exceeded the low-effect soil benchmark are in bold text)

COPC	CAS Number	Average (Initial) Soil Concentration mg/kg	Average (Final) Soil Concentration mg/kg	Low-effect Soil Benchmark mg/kg	Moderate-effect Soil Benchmark mg/kg
1,1,2,2-Tetrachloroethane	79-34-5	6.47E-08	6.47E-08	.13 [9]	---
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	2.05E-06	2.05E-06	---	---
1,1,2-Trichloroethane	79-00-5	1.23E-07	1.23E-07	0.4 [6*]	---
1,1-Dichloro-2-propanone	513-88-2	3.59E-07	3.59E-07	---	---
1,1-Dichloroethane	75-34-3	4.99E-08	4.99E-08	.02 [6*]	42 [7i]
1,2,3-Trichloropropane	96-18-4	4.92E-07	4.92E-07	3.36 [9]	---
1,2,4-Trichlorobenzene	120-82-1	9.35E-07	9.35E-07	20 [5]	---
1,2-Dichloro-2-methylpropane	594-37-6	5.29E-06	5.29E-06	---	---
1,2-Dichloro-3-methylbenzene	32768-54-0	9.66E-06	9.66E-06	---	---
1,2-Dichlorobenzene	95-50-1	4.11E-06	4.11E-06	2.96 [9]	---
1,2-Dichlorobutane	616-21-7	3.46E-07	3.46E-07	---	---
1,2-Dichloroethane	107-06-2	2.35E-06	2.35E-06	4.0 [8]	---
1,2-Dichloropropane	78-87-5	3.61E-07	3.61E-07	700 [8]	---
1,3,5-Trimethylbenzene	108-67-8	3.73E-02	3.73E-02	---	---
1,3-Butadiene	106-99-0	2.77E-04	2.77E-04	---	---
1,3-Dichlorobenzene	541-73-1	2.98E-06	2.98E-06		
1,4-Dichlorobenzene	106-46-7	6.91E-07	6.91E-07	20 [5]	---
1-Acetoxyacetone	592-20-1	4.76E-06	4.76E-06	---	---
1-Bromo-2-chloroethane	107-04-0	6.05E-07	6.05E-07	---	---
1-Butanol	71-36-3	8.16E-08	8.16E-08	---	---
1-Butene	106-98-9	4.65E-05	4.65E-05	---	---
1-Chloro-2-methylbenzene	95-49-8	7.69E-05	7.69E-05	---	---
1-Chloro-3-methylbenzene	108-41-8	4.75E-06	4.75E-06	---	---
1-Chloro-4-ethylbenzene	622-98-0	1.64E-06	1.64E-06	---	---
1-Chlorobutane	109-69-3	3.75E-07	3.75E-07	---	---
1-Hexene	592-41-6	4.15E-05	4.15E-05	---	---
1-Hydroxy-2-propanone	116-09-6	5.96E-06	5.96E-06	---	---
1-Penten-3-one	1629-58-9	1.07E-06	1.07E-06	---	---
1-Pentene	109-67-1	2.27E-05	2.27E-05	---	---
2,2,4-Trimethylhexane	16747-26-5	2.23E-03	2.23E-03	---	---
2,2,4-Trimethylpentane	540-84-1	6.69E-03	6.69E-03	---	---

(Sheet 1 of 6)

Note: NA = Not available; --- **=** Data gap.
[1] Efroymson et al. 1997a.
[2] CCME 1997.
[3] Crommentuijn et al. 1997.
[4] Beyer 1990.
[5] Efroymson et al. 1997b.
[6*] MHSPE 1994 (Dutch Target Value) Also taken from Swartjes 1999.
[7i] MHSPE 1994 (Dutch Intervention Value) Also taken from Swartjes 1999.
[8] USEPA 2001b.
[9] USEPA 2003.

Table A1 (Continued)

COPC	CAS Number	Average (Initial) Soil Concentration mg/kg	Average (Final) Soil Concentration mg/kg	Low-effect Soil Benchmark mg/kg	Moderate-effect Soil Benchmark mg/kg
2,2-Dimethylbutane	75-83-2	1.88E-03	1.88E-03	---	---
2,2-Dimethylpropane	463-82-1	4.45E-06	4.45E-06	---	---
2,3,4-Trimethylpentane	565-75-3	1.06E-03	1.06E-03	---	---
2,3-Butanedione	431-03-8	8.66E-06	8.66E-06	---	---
2,3-Dihydro-1-methyl-1H-indene	767-58-8	1.34E-02	1.34E-02	---	---
2,3-Dimethylbutane	79-29-8	1.78E-03	1.78E-03	---	---
2,3-Dimethylhexane	584-94-1	2.17E-03	2.17E-03	---	---
2,3-Dimethylpentane	565-59-3	2.66E-03	2.66E-03	---	---
2,3-Pentanedione	600-14-6	2.68E-06	2.68E-06	---	---
2,4-Dimethylhexane	589-43-5	4.38E-03	4.38E-03	---	---
2,4-Dimethylpentane	108-08-7	1.63E-03	1.63E-03	---	---
2,5-Dimethylfuran	625-86-5	1.95E-06	1.95E-06	---	---
2,5-Dimethylhexane	592-13-2	3.77E-03	3.77E-03	---	---
2-Bromo-1-chloropropane	3017-95-6	1.06E-06	1.06E-06	---	---
2-Butoxyethanol	111-76-2	NA	NA	---	---
2-Furaldehyde	98-01-1	9.62E-06	9.62E-06	---	---
2-Heptanone	110-43-0	3.05E-08	3.05E-08	---	---
2-Hexanone	591-78-6	2.82E-07	2.82E-07	12.6 [9]	---
2-Methyl-1-butene	563-46-2	3.55E-05	3.55E-05	---	---
2-Methyl-1-pentene	763-29-1	5.04E-05	5.04E-05	---	---
2-Methyl-2-butene	513-35-9	1.29E-05	1.29E-05	---	---
2-Methyl-2-pentene	625-27-4	2.78E-05	2.78E-05	---	---
2-Methylfuran	534-22-5	1.66E-06	1.66E-06	---	---
2-Methylheptane	592-27-8	1.43E-02	1.43E-02	---	---
2-Methylhexane	591-76-4	1.05E-02	1.05E-02	---	---
2-Methylnaphthalene	91-57-6	3.40E-03	3.40E-03	3.24 [9]	---
2-Methylpentane	107-83-5	5.94E-03	5.94E-03	---	---
2-Methylthiophene	554-14-3	3.83E-07	3.83E-07	---	---
2-Nitrophenol	88-75-5	1.81E-06	1.81E-06	1.6 [9]	---
2-Octanone	111-13-7	1.13E-08	1.13E-08	---	---
2-Pentanone	107-87-9	4.62E-06	4.62E-06	---	---
2-Propanol	67-63-0	1.01E-06	1.01E-06	220 [7i]	---
2-Thiophenecarboxaldehyde	98-03-3	4.15E-07	4.15E-07	---	---
3-Ethylhexane	619-99-8	7.42E-06	7.42E-06	---	---
3-Heptanone	106-35-4	7.87E-07	7.87E-07	---	---
3-Methyl-1-butene	563-45-1	1.03E-05	1.03E-05	---	---
3-Methyl-2-butanone	563-80-4	4.15E-07	4.15E-07	---	---
3-Methylfuran	930-27-8	5.64E-07	5.64E-07	---	---

(Sheet 2 of 6)

Table A1 (Continued)

COPC	CAS Number	Average (Initial) Soil Concentration mg/kg	Average (Final) Soil Concentration mg/kg	Low-effect Soil Benchmark mg/kg	Moderate-effect Soil Benchmark mg/kg
3-Methylhexane	589-34-4	1.14E-02	1.14E-02	---	---
3-Methylpentane	96-14-0	9.31E-03	9.31E-03	---	---
3-Methylphenol	108-39-4	7.83E-06	7.83E-06	---	---
3-Methylthiophene	616-44-4	3.61E-07	3.61E-07	---	---
3-Pentanone	96-22-0	4.83E-07	4.83E-07	---	---
4-Methyl-1-pentene	691-37-2	1.69E-05	1.69E-05	---	---
4-Methyl-2-pentanone	108-10-1	8.34E-08	8.34E-08	443 [9]	---
4-Methylbenzonitrile	104-85-8	9.62E-07	9.62E-07	---	---
4-Methylphenol	106-44-5	7.51E-06	7.51E-06	163 [9]	---
5-Methyl-2-furaldehyde	620-02-0	3.15E-06	3.15E-06	---	---
6-Methyl-2-heptanone	928-68-7	3.56E-08	3.56E-08	---	---
6-Methyl-5-hepten-2-one	110-93-0	2.08E-09	2.08E-09	---	---
Acenaphthylene	208-96-8	9.93E-07	9.93E-07	682 [9]	---
Acetaldehyde	75-07-0	2.74E-05	2.74E-05	---	---
Acetic Acid	64-19-7	2.19E-04	2.19E-04	---	
Acetone	67-64-1	1.66E-04	1.66E-04	2.5 [9]	---
Acetonitrile	75-05-8	2.22E-06	2.22E-06	1.37 [9]	---
Acetophenone	98-86-2	3.19E-06	3.19E-06	300 [9]	---
Acetylene	74-86-2	1.95E-04	1.95E-04	---	---
Acrolein	107-02-8	8.47E-05	8.47E-05	5.27 [9]	---
Acrylonitrile	107-13-1	2.97E-06	2.97E-06	1000 [8]	---
Aluminum	7429-90-5	**1.03E+03**	**5.79E+03**	50 [8]	600 [5]
Antimony	7440-36-0	2.93E+00	3.03E+00	3.5 [8]	5 [1]
Barium	7440-39-3	**1.75E+02**	**9.20E+02**	165 [8]	200 [6*]
Benzofuran	271-89-6	3.22E-06	3.22E-06	---	---
Benzoic acid	65-85-0	4.96E-07	4.96E-07	---	---
Benzonitrile	100-47-0	3.98E-06	3.98E-06	---	---
Benzyl alcohol	100-51-6	6.80E-06	6.80E-06	65.8 [9]	---
Beryllium	7440-41-7	2.45E-03	1.21E-02	1.1 [8]	10 [1]
bis(2-Ethylhexyl)phthalate	117-81-7	4.50E-03	2.87E-02	0.93 [9]	---
Butanal	123-72-8	1.95E-06	1.95E-06	---	---
Butyl Acetate	123-86-4	9.43E-07	9.43E-07	196 [7i]	---
Butylbenzylphthalate	85-68-7	8.50E-04	1.05E-03	0.24 [9]	---
Carbon Dioxide	124-38-9	1.17E+00	1.17E+00	---	---
Carbonyl Sulfide	463-58-1	2.46E-05	2.46E-05	---	---
Chlorobenzene	108-90-7	1.80E-06	1.80E-06	0.05 [8]	2 [4]
Chloroethene	75-01-4	5.21E-07	5.21E-07	0.018	60 [7i]
cis 1,3-Dichloro-1-propene	10061-01-5	6.64E-07	6.64E-07	0.397 [9]	---

(Sheet 3 of 6)

Table A1 (Continued)

COPC	CAS Number	Average (Initial) Soil Concentration mg/kg	Average (Final) Soil Concentration mg/kg	Low-effect Soil Benchmark mg/kg	Moderate-effect Soil Benchmark mg/kg
cis-2-Butene	590-18-1	9.61E-06	9.61E-06	---	---
cis-2-Hexene	7688-21-3	1.66E-05	1.66E-05	---	---
cis-2-Pentene	627-20-3	1.02E-05	1.02E-05	---	---
Cobalt	7440-48-4	4.59E-03	4.82E-03	20 [8]	33 [3]
Copper	7440-50-8	2.23E+00	3.88E+00	40 [8]	50 [5]
Cyclohexane	110-82-7	4.87E-03	4.87E-03	0.1 [8]	6.0 [4]
Cyclohexanone	108-94-1	9.32E-08	9.32E-08	0.1 [8]	270 [6*]
Cyclopentane	278-92-3	3.32E-04	3.32E-04	---	---
Cyclopentanone	120-92-3	7.98E-07	7.98E-07	---	---
Cyclopentene	142-29-0	7.79E-06	7.79E-06	---	---
Decanal	112-31-2	3.94E-03	3.94E-03	---	---
Dichloroacetonitrile	3018-12-0	9.43E-08	9.43E-08	---	---
Dichlorodifluoromethane	75-71-8	1.61E-05	1.61E-05	39.5 [9]	---
Diethylphthalate	84-66-2	2.41E-06	2.41E-06	100 [8]	---
Dimethyldisulfide	624-92-0	8.37E-07	8.37E-07	---	---
Di-n-butylphthalate	84-74-2	1.34E-03	1.50E-03	2008 [5]	---
d-Limonene	5989-27-5	NA	NA	---	---
Ethane	74-84-0	1.14E-05	1.14E-05	---	---
Ethanol	64-17-5	3.65E-07	3.65E-07	---	---
Ethylchloride	75-00-3	5.74E-08	5.74E-08	---	---
Ethylene	74-85-1	2.34E-04	2.34E-04	---	---
Fluorene	86-73-7	3.18E-08	3.18E-08	30 [8]	122 [9]
Heptanal	111-71-7	9.78E-05	9.78E-05	---	---
Hexachlorobutadiene	87-68-3	1.79E-03	1.79E-03	.039 [9]	---
Hexachlorocyclopentadiene	77-47-4	2.37E-03	2.37E-03	10 [8]	---
Hexachloroethane	67-72-1	1.45E-04	1.45E-04	.59 [9]	---
Hexachloropropene	1888-71-7	4.98E-04	4.98E-04	---	---
Hexanal	66-25-1	1.23E-06	1.23E-06	---	---
Indane	496-11-7	9.94E-03	9.94E-03	---	---
Isobutane	75-28-5	9.27E-05	9.27E-05	---	---
Isobutene	115-11-7	1.14E-04	1.14E-04	---	---
Isopentane	78-78-4	2.50E-03	2.50E-03	---	---
Isoprene	78-79-5	4.11E-06	4.11E-06	---	---
Isopropylbenzene	98-82-8	3.68E-04	3.68E-04	---	---
Isothiocyanatomethane	556-61-6	5.18E-07	5.18E-07	---	---
Magnesium	7439-95-4	1.11E+03	5.48E+03	---	---
Manganese	7439-96-5	4.65E-01	5.39E-01	100 [8]	500 [1]
Mercury	7439-97-6	9.48E-04	3.90E-03	0.1 [8]	0.3 [1]

(Sheet 4 of 6)

Table A1 (Continued)

COPC	CAS Number	Average (Initial) Soil Concentration mg/kg	Average (Final) Soil Concentration mg/kg	Low-effect Soil Benchmark mg/kg	Moderate-effect Soil Benchmark mg/kg
Methacrolein	78-85-3	1.83E-06	1.83E-06	---	---
Methylbromide	74-83-9	3.81E-07	3.81E-07	0.24 [9]	---
Methylchloroform	71-55-6	1.27E-07	1.27E-07	---	---
Methylcyclohexane	108-87-2	2.48E-03	2.48E-03	---	---
Methylcyclopentane	96-37-7	4.74E-04	4.74E-04	---	---
Methylnitrite	624-91-9	4.07E-04	4.07E-04	---	---
m-Ethyltoluene	620-14-4	7.71E-03	7.71E-03	---	---
Methyl-vinyl Ketone	78-94-4	2.93E-06	2.93E-06	---	---
MTBE	1634-04-4	1.05E-02	1.05E-02	125 [7i]	---
m-Xylene	108-38-3	**7.91E-02**	**7.91E-02**	5.0E-02 [8]	1.0 [2]
n-Butane	106-97-8	1.44E-05	1.44E-05	---	---
n-Decane	124-18-5	6.35E-03	6.35E-03	---	---
n-Heptane	142-82-5	2.40E-03	2.40E-03	---	---
n-Hexane	110-54-3	9.39E-04	9.39E-04	---	---
Nickel	7440-02-0	5.03E-02	7.19E-02	30 [8]	35 [6*]
Nitromethane	75-52-5	5.67E-05	5.67E-05	---	---
n-Nonane	111-84-2	1.41E-03	1.41E-03	---	---
n-Octane	111-65-9	2.61E-03	2.61E-03	---	---
Nonanal	124-19-6	1.57E-03	1.57E-03	---	---
n-Pentane	109-66-0	2.87E-04	2.87E-04	---	---
n-Propylbenzene	103-65-1	2.22E-03	2.22E-03	---	---
Octanal	124-13-0	4.86E-04	4.86E-04	---	---
o-Ethyltoluene	611-14-3	1.85E-03	1.85E-03	---	---
o-Xylene	95-47-6	4.44E-02	4.44E-02	5.0E-02 [8]	1.0 [2]
Pentachloro-1-propene	1600-37-9	3.34E-06	3.34E-06	---	---
Pentanal	110-62-3	4.97E-07	4.97E-07	---	---
p-Ethyltoluene	622-96-8	5.97E-02	5.97E-02	---	---
Phenol	108-95-2	3.18E-08	3.18E-08	.05 [8]	1.0 [4]
Phenylacetylene	536-74-3	6.63E-06	6.63E-06	---	---
Propanal	123-38-6	3.68E-06	3.68E-06	---	---
Propane	74-98-6	6.64E-08	6.64E-08	---	---
Propanenitrile	107-12-0	3.81E-07	3.81E-07	---	---
Propene	115-07-1	1.25E-04	1.25E-04	---	---
p-Xylene	106-42-3	**7.44E-02**	**7.44E-02**	5.0E-02 [8]	1.0 [2]
sec-Butylbenzene	135-98-8	9.72E-02	9.72E-02	---	---
Selenium	7782-49-2	1.72E-03	1.87E-03	0.81 [8]	1.0 [5]
Silver	7440-22-4	8.49E-05	8.68E-05	2 [8]	15 [7i]
Styrene	100-42-5	1.52E-04	1.52E-04	0.1 [8]	5 [4]

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Table A1 (Concluded)

COPC	CAS Number	Average (Initial) Soil Concentration mg/kg	Average (Final) Soil Concentration mg/kg	Low-effect Soil Benchmark mg/kg	Moderate-effect Soil Benchmark mg/kg
Tetrahydrofuran	109-99-9	3.08E-07	3.08E-07	0.1 [4]	4.0 [4]
Thiophene	110-02-1	4.81E-06	4.81E-06	---	---
trans 1,3-Dichloro-1-propene	10061-02-6	8.11E-08	8.11E-08	---	---
trans-2-Butenal	123-73-9	2.28E-06	2.28E-06	---	---
trans-2-Butene	624-64-6	3.02E-05	3.02E-05	---	---
trans-2-Hexene	4050-45-7	3.03E-05	3.03E-05	---	---
trans-2-Pentene	646-04-8	1.91E-05	1.91E-05	---	---
trans-3-Penten-2-one	3102-33-8	6.81E-07	6.81E-07	---	---
Trichloroacetonitrile	545-06-2	1.07E-07	1.07E-07	---	---
Trichloromonofluoromethane	75-69-4	2.02E-07	2.02E-07	---	---
Vinylidene chloride	75-35-4	7.28E-08	7.28E-08	---	---
Zinc	7440-66-6	1.54E+00	7.12E+00	50 [8]	100 [5]

(Sheet 6 of 6)

exposures that are likely to result in observable effects, if exposures in the field match those assumed in the evaluation. The higher values can be useful during interpretation of any predicted exceedences of the lower values.

Selection of Surface Soil Benchmarks. Measures of effects in soil invertebrates and plants are evaluated by a soil concentration benchmark for each chemical. Various sources for the development of these values are discussed below.

The primary source for selecting low-effect soil benchmarks was the USEPA Region IV document, "Supplemental Guidance to RAGS: Ecological Bulletin No. 2: Ecological Screening Values" (USEPA 2001b). If unavailable from the above source, low-effect benchmarks (the lowest value), as well as moderate-effect benchmarks (the next highest value from the low-effect benchmark) were selected from Friday (1998). Sources from Friday (1998) included the following: U.S. Fish and Wildlife (Beyer 1990); Oak Ridge National Laboratory (Efroymson et al. 1997a and 1997b); the Canadian Council of Ministers of the Environment (CCME 1997); the Dutch Ministry Standards which included the Ministry of Housing, Spatial Planning, and Environment (MHSPE 1994); and Crommentuijn et al. (1997).

Beyer (1990) (U.S. Fish and Wildlife) listed over 200 contaminants from Japan, Netherlands, Canada, United States, and the former Soviet Union. Screening levels from the Netherlands, which are sanctioned by USEPA Region IV, were taken from the interim Dutch Soil Cleanup Act (Richardson 1987).

During the 1980s, the Dutch government issued three categories of soil quality values (i.e., A, B, and C). In 1994, the ABC benchmarks were redefined

as follows: (1) "A" values are "target values," (2) "B" values are the sum of the target value and intervention value divided by two, and (3) "C" values are "intervention values" (MHSPE 1994). The target values for soil are related to negligible risk for ecosystems. This is assumed to be 1 percent of the Maximal Permissible Risk (MPR) level for ecosystems, where the MPR is the concentration expected to be hazardous for 5 percent of the species in the ecosystem, or the 95 percent protection level. For metals, background concentrations are taken into account in arriving at a value. The relationship between soil concentration and irreparable damage to terrestrial species composition and the relationship between soil concentration and adverse effects on microbial and enzymatic processes were derived to quantify the ecotoxicological effects on ecosystems. Site concentrations less than target values indicate that no restrictions are necessary. However, concentrations between target values and intervention values suggest that further evaluation or restrictions may be necessary (Swartjes 1999).

The ecological intervention value is the concentration expected to be hazardous to 50 percent of the species in the ecosystem. It cannot be assumed that sensitive species will be protected at the intervention levels. Site concentrations exceeding the intervention value indicate that remediation is necessary (Swartjes 1999).

In 1997 the Dutch Ministry issued Maximum Permissible Concentrations (MPC's) for 18 metals (Crommentuijn et al. 1997) using three methods. When No Observed Effect Concentrations (NOEC's) were available for at least four taxons, statistical extrapolation was used. When only LC50 or a few NOEC's were available, a modification of the USEPA method was used. When no laboratory data were available, equilibrium partitioning was used to derive a benchmark value. The Dutch values are based on ecotoxicological effects that are quantified in terms of the concentration at which 50 percent of the species and 50 percent of the microbial processes in the ecosystem are threatened or adversely affected (Friday 1998).

The Oak Ridge screening benchmarks for terrestrial plants and soil invertebrates (Efroymson et al. 1997a and 1997b) were utilized for determining whether the modeled soil concentrations had potential for causing adverse effects to soil organisms and plants. These benchmarks were based on laboratory toxicity tests that evaluated a variety of plant responses ranging from germination to root growth. The confidence in most of these benchmarks is low due to the limited number of studies. Many of the species used in these studies are agricultural species, and the study results may not be representative of the vegetation in the study area; however, they are the best available data. The soil benchmarks for invertebrates were derived using NOAA's Effects Range-Low (Long and Morgan 1990) approach supported by information from field and laboratory studies, bibliographic databases, and the published literature. Lowest Observed Effect Concentrations (LOECs) were ranked and a value representing the 10th percentile of the distribution was selected. If less than ten values were available, the lowest NOEC was used. Some benchmarks were derived by utilizing the author's expert judgment and interpolation (Efroymson et al. 1997a,b). Terrestrial plant benchmarks were derived similarly to that used for invertebrates and microbial processes (Efroymson et al. 1997b).

The Canadian Council of Ministers of the Environment (CCME 1997) issued soil quality guidelines for 20 substances that were derived specifically for the protection of ecological receptors in the environment. The derivation process for soil quality guidelines (SQGs) considers adverse effects from direct soil contact and from the ingestion of soil and food. Four approaches were used to evaluate contact with soil including:

a. Weight of evidence.

b. LOEC method.

c. Median effects method.

d. Comparison with nutrient and energy cycling.

The weight of evidence method, which is a modification of Long and Morgan (1990), estimates no adverse effects (Friday 1998).

Other sources were utilized when benchmark values were not provided by the above sources. For instance, the USEPA Region V Ecological Screening Levels (ESLs), which are initial screening levels with which the site contaminant concentrations can be compared, were utilized when no other above sources were available. The soil ESLs, which are based on exposure to a masked shrew, meadow vole, plant, or soil invertebrate (i.e., earthworm), help to focus the investigation on those areas and chemicals that are most likely to pose an unacceptable risk to the environment (USEPA 2003).

Validated background soil concentrations that represent an uncontaminated site should be used as a check for these benchmarks. Screening benchmarks lower than the background should not be used if the exposed site does not contain forms of the chemicals that are more bioavailable or more toxic than forms at the background sites (Suter and Tsao 1996).

Discussion

Of the chemicals that had surface soil benchmarks, most had soil concentrations that did not exceed the screening-level (i.e., low-effect) soil benchmarks. M-xylene and p-xylene had a soil concentration that did exceed the low-effect benchmark, however, they exceeded the benchmarks only slightly (modeled soil concentration of 0.08 mg/kg compared to a screening soil benchmark of 0.05 mg/kg for m-xylene, and a modeled soil concentration of 0.07 mg/kg compared to a screening soil benchmark of 0.05 mg/kg for p-xylene). The moderate-effect benchmarks, which represent exposures that are likely to result in observable effects, were not exceeded for m-xylene and p-xylene (moderate-effect benchmark is 1.0 mg/kg). Due to the slight exceedence, conservative nature of the soil benchmark, and the fact that the moderate-effect benchmarks were not exceeded, m-xylene and p-xylene will not be retained as COPCs.

Aluminum exceeded the screening-level soil benchmark (modeled soil concentration of 5,791 mg/kg compared to a screening low-effect benchmark of 50 mg/kg). However, a range of background soil concentrations (20,000-30,000 mg/kg) collected from Cape Cod (Shacklette and Boerngen 1984) and cited by the Air National Guard (1994) were much higher than the modeled soil concentration. The modeled soil concentration also did not exceed the 95 percent upper tolerance limit (9,774 mg/kg) that was obtained from the background soil concentrations collected at MMR. Due to the fact that the background soil concentration (i.e., 95 percent upper tolerance limit) was not exceeded, aluminum will not be retained as a COPC.

Barium exceeded the screening-level soil benchmark with a modeled soil concentration of 175 mg/kg (initial) and 920 mg/kg (final) compared to a screening low-effect benchmark of 165 mg/kg. The initial soil concentration exceeded the initial soil benchmark slightly; however, it did not exceed the moderate-effect benchmark of 200 mg/kg. The moderate-effect benchmark represents exposures that are likely to result in observable effects. Background data was collected from Cape Cod for barium (Shacklette and Boerngen 1984) as cited by the Air National Guard (1994) and a range of background soil concentrations (10-200 mg/kg) were provided. The initial soil concentration was within the background range. Background data was collected from sandy surface soils (typical of MMR soil) for barium (Kabata-Pendias and Pendias 1984) as cited by the Air National Guard (1994), and the range of background soil concentrations was reported as follows: 20-1500 mg/kg. Both the initial and final modeled soil concentrations fell within the background range. Although the final soil concentration exceeded the screening-level benchmarks, it is within the background range and assuming the same deposition rate for 70 years may overestimate risks. Other factors that may overestimate risks are provided in the following paragraph and should be considered.

Uncertainties

Soil concentrations were not obtained via collecting samples from the impact area. However, munitions emissions data were modeled to predict the fate and transport of combustion by-products from the air to the surface soil. Important natural processes, such as photodegradation and environmental degradation (e.g., half-life) of the COPCs were not included in the fate and transport modeling process. This uncertainty tends to overestimate risks.

The modeled average final soil concentrations (after 70 years) assumed a continual deposition for every year, which tends to overestimate risks. Additionally, soil-water distribution coefficients (K_d) are uncertain for inorganic constituents, especially metals due to speciation, complexation, and soil chemistry interactions. Reasonable, yet high, K_d values were used for the metals, which resulted in high soil concentrations after years of continual deposition.

Discussion of ecological effects from modeled chemical concentrations in the surface soil is limited to a qualitative analysis and rudimentary comparison to toxicological benchmarks. The predictive model focused only on the fate and transport of compounds through abiotic media that oversimplifies the ecosystem

because it ignores confounding factors that likely have a greater impact on ecological resources than the compounds being modeled. Confounding factors include the effects of physical disturbance (i.e., fire, vehicle traffic) from training on habitat and regional influences (i.e., weather patterns). Such confounding factors are important in the fact that they may determine the presence or absence of particular species at the site.

The screening-level benchmark used for m-xylene and p-xylene is total xylene. Soil quality benchmarks were not available for several chemicals, therefore, chemicals that contained data gaps could not be evaluated.

Summary and Conclusions of Ecological Assessment

Of the 195 chemicals used in this study, 4 exceeded surface soil screening toxicity benchmarks. M-xylene and p-xylene slightly exceeded the low-effect toxicity benchmarks but did not exceed the moderate-effect benchmarks. Aluminum exceeded the screening-level soil benchmark; however, it did not exceed the background 95 percent upper tolerance limit. The initial soil concentration for barium exceeded the low-effect screening-level benchmark slightly. However, the modeled (initial and final) soil concentrations fell within the range of background soil concentrations. Uncertainties associated with the modeled soil concentrations and conservative soil benchmarks should be recognized. The potential for impacts to ecological receptors resulting from exposure to chemicals in the surface soil via training activities at MMR is low.

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Mansour Zakikhani, Mark S. Dortch, Jeffrey A. Gerald, Melanie S. Hawkins

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U.S. Army Engineer Research and Development Center, Environmental Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180-6199;
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14. ABSTRACT

This study was conducted to evaluate potential human and ecological health risks associated with emission of pyrotechnic chemical constituents during future training exercises at the Massachusetts Military Reservation. Air dispersion modeling was used to determine air concentrations and deposition rates for emissions. Annual average and spatially averaged air concentrations and deposition rates were used to perform the risk assessments. The Army Risk Assessment Modeling System (ARAMS) was used to conduct the human health risk assessment, which evaluated a site visitor or trespasser exposed to air and soil using air concentrations and deposition rates from the air dispersion modeling. ARAMS was also used to evaluate the time for deposited compounds to reach groundwater and the peak concentration upon contact with the water table. This study completed the evaluation of the remaining 195 chemicals following the first part of the study that was conducted in 2003 for 24 chemicals and reported in Zakikhani et al. (2004). Of all 219 chemicals, only Cr(VI), with an incremental cancer risk of 2.4×10^{-6}, posed a potential concern for human health with the maximum exposure and effect through the air inhalation pathway/route. However, lack of input toxicological data for most of the 219 chemicals limited the scope of the analysis for human health risk. None of the compounds are suspected to cause a groundwater problem. Computed soil concentrations were compared to soil screening toxicity benchmarks for the ecological risk assessment for the purpose of retaining or eliminating chemicals from the assessment. Toluene and hexachlorobenzene exceeded the soil toxicity benchmarks as reported in

(Continued)

15. SUBJECT TERMS

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"Risk-Characterization for Future Training Scenarios at the Massachusetts Military Reservation (MMR)," ERDC/EL TR-04-2, by Zakikhani et al. (2004). However, because of the slight exceedence and its nonbioaccumulating properties, toluene is not considered to be a chemical of potential concern. Although hexachlorobenzene exceeded the toxicity benchmark, uncertainties and conservative assumptions associated with the modeled soil concentrations and conservative soil benchmarks should be recognized. Two other chemicals, m-xylene and p-xylene, exceeded the low-effect toxicity benchmarks, but not the moderate-effect benchmarks. Aluminum exceeded the screening-level soil benchmark; however, it did not exceed the background 95 percent upper tolerance limit. The initial soil concentration for barium exceeded the low-effect screening-level benchmark slightly. However, the modeled (initial and final) soil concentrations fell within the range of background soil concentrations for barium. Additionally, the conservative approach that was used for emissions and transport overestimated the impacts. More realistic emission durations could be used and would reduce conservatism. The assumption of no degradation overestimated exposure concentrations. However, obtaining degradation rates is highly problematic when so many chemicals are involved, rates are often site specific, and available data on such rates are very limited.