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Part 1

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7. Abstract

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ACRONYMS

DOE-RL	United States Department of Energy, Richland Operations Office
EPA	U.S. Environmental Protection Agency
ERA	Emergency Response Action
FSG	Fuller, Schettler and Giddings
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient
IARC	International Agency for Research on Cancer
ICR	lifetime incremental cancer risk
IRIS	Integrated Risk Information System
K_{oc}	organic-carbon partition coefficient
PAH	polyaromatic hydrocarbon
PEF	particulate emission factor
RAGS	Risk Assessment Guidance for Superfund
RfD	reference dose
RPD	relative percent difference
SEAM	Superfund Exposure Assessment Manual
SF	slope factor
TCLP	Toxicity Characteristic Leachate Procedure
VF	volatilization factor

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1.0 SITE DESCRIPTION

The maintenance pad site consists of a concrete pad and underlying soils, approximately 15 by 46 m in area, and a drainage ditch with dimensions of 2.4 by 91 m. The ditch is located approximately 60 m from the concrete pad and is oriented parallel to the pads long axis. The facility was built in 1943, at which time the concrete pad was the floor of a maintenance shed for railroad activities. In 1955, use of the facility as a maintenance shed was discontinued. Between 1955 and 1957, the facility was used as a radioactivity decontamination area for railroad cars; acetone-soaked rags were used to remove surface contamination from the cars. The concrete pad was washed down with a mixture of water and diesel fuel, which was then flushed via clay pipe to the drainage ditch. In 1963, the maintenance shed was torn down and the concrete pad covered with approximately one-half meter of fill. The concrete pad was re-exposed in 1993.

In order to avoid subdividing the site into two areas, the concrete pad area and the ditch area are combined as one site-area having a square configuration for the purposes of the risk assessment.

The Riverland ERA operable unit is located on the Hanford Site, occupying the area west of Highway 24 as it runs in a north-south direction between the Vernita Bridge and the intersection of Highway 240. Within the Riverland ERA, the maintenance pad site is located on rail line, one-quarter mile from Highway 24 along Midway Substation Rd.

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2.0 DATA ANALYSIS

The site was sampled for Toxicity Characteristic Leachate Procedure (TCLP) metals, volatile, and semi-volatile compounds, as well as for extractable fuel hydrocarbons. A total of 17 samples were collected from surface concrete, soil beneath surface concrete, and ditch soil. One concrete sample and one ditch soil sample were split. The ditch soil sample was also duplicated. The relative percent difference (RPD) in extractable hydrocarbons of the two split samples, one from concrete and one from ditch soil are, respectively, 52% and 186%. The RPD for the duplicate sample, taken from the same ditch soil sample from which one of the splits was taken, is 39%

Diesel concentrations in these samples range from 34 to 6,740 mg/kg. In general, diesel concentrations in soil lying beneath concrete are lower than in either concrete or ditch soil. In the six ditch soil samples, which are the samples of primary concern for analysis of site risk, diesel concentrations range from 340 to 4,300 mg/kg with a mean of 2,100 and a standard deviation of 1,700.

TCLP volatile and semi-volatile compound analysis revealed no compounds detected above the quantitation level. TCLP metals analysis revealed barium present at 490 ug/L, chromium at 12.7 ug/L, and cadmium at 24.2 ug/L. Previous assessment of metals and pesticides has been conducted for this site.

Due to the relatively small sample size (6) and high standard deviation (1,700) associated with the ditch soil samples the maximum detected concentration (4,300 mg/kg) is conservatively assumed to represent actual soil contamination levels in soil at the site.

3.0 DETERMINATION OF CONSTITUENTS OF POTENTIAL CONCERN

Diesel fuel is a complex mixture of straight-chain and branched hydrocarbons and aromatics, with traces of various other organic compounds and elements. The relative contribution of these various components varies depending upon grade and source of fuel. Furthermore, once diesel is released into the environment a "weathering" process begins which alters the chemical make-up of the fuel. Processes which contribute to weathering include volatilization, biodegradation, biotransformation, and dissolution (Millner et al., 1992). The result of this process is removal of many of the toxic volatile components of diesel and an increase in the relative concentrations of higher molecular weight hydrocarbons.

Due to the lack of site-specific information for specific components of diesel at this site, and because unweathered fuel is simpler to characterize, diesel present in site soil is conservatively assumed to be in an unweathered state. The diesel fuel present is assumed to be diesel fuel No. 2, which is the common grade for heating and automotive applications. All components of diesel fuel are assumed to be present, with the exception of benzene. Benzene is dropped from the analysis because it was assayed for but not detected in the TCLP volatile compound analysis.

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Organic components of diesel fuel No. 2, presented in Table 1, are taken from an International Agency for Research on Cancer (IARC) publication quoted in Millner, et al. The IARC study presents data on three fuel oils; the average value is utilized in this risk assessment. The concentrations of each class of compound in diesel fuel are presented in % volume and are converted to mg/gr diesel using densities presented in the Handbook of Chemistry and Physics, 47th edition, 1966. Alkenes, indans/tetralins, and dinaphthenobenzenes/indenes, accounting for approximately 4.8%, by volume, of the IARC fuels sampled, are not included in the risk assessment due to a lack of relevant toxicity data.

Metals presented in Table 1 are those which were identified in the TCLP analysis. Values for concentrations of metals are taken from an analysis of the chemical composition of diesel fuel in Hockensmith, (1990).

The value of 0.8 gr/ml for density of diesel fuel No. 2 is an average value taken from an EPA report (Dickerman, et al., 1977).

4.0 RISK ASSESSMENT

The risk assessment follows the general procedures outlined in the Hanford Site Baseline Risk Assessment Methodology, Rev. 2 (HSBRAM, DOE-RL, 1993). Acceptable levels of risk are considered to be equivalent to a hazard index (HI) of 1 and a lifetime incremental cancer risk (ICR) of 1E-06 (DOE-RL, 1993). A summary of the risk assessment is presented in Table 2. Scenario-specific exposure parameters and equations for calculating risk, are presented in Appendix A.

4.1 SITE CONTAMINATION

A number of conservative assumptions have been introduced to the risk assessment regarding the extent and type of site contamination. Due to the limited number of soil samples, the highest soil sample value for diesel (4,300 mg/kg) is assumed to be the actual soil contamination level, uniformally distributed in ditch soil and soil beneath the concrete pad. In reality, soil beneath the concrete pad is likely less contaminated than ditch soil near the outlet of the drainage pipe from the maintenance pad. Furthermore, soil from the farther end of the drainage ditch is probably less contaminated than soil nearer the drain outlet.

4.2 EXPOSURE SCENARIOS AND PATHWAYS

The risk assessment is conducted for recreational (occasional-use) and residential (frequent-use) scenarios, as requested by site managers, considering soil ingestion, inhalation of fugitive dust, and inhalation of volatile compounds as possible exposure pathways. The residential scenario considers risk to residents living on-site at some time in the future. As such, it is more conservative than the recreational-use scenario and reflects unconditional release of the site. The two scenarios provide a bounding of risk with the primary variable being the amount of time a potential site user is estimated to spend on-site.

Although each scenario and pathway can be considered conservative with regard to the frequency and duration of exposure, the inhalation pathways in particular for each exposure scenario are especially conservative due to assumptions used in the calculation of the soil-to-air particulate emission/volatilization factors. For both pathways it is assumed that 100% of the site area contributes to air emissions, when in fact it is known that the maintenance pad area is currently covered with a concrete layer.* For future use, particularly residential use, it is likely that even if the concrete is removed and disposed of some fraction of the land surface will be covered with similarly impermeable material.* It is also assumed that surface structures and vegetation are absent.

The volatilization pathway is shown to be the risk-driving exposure route at the maintenance pad site (see Table 2). An implicit assumption in this pathway is that the soil contamination which currently exists is, in effect, an inexhaustible source of volatile contaminants at current concentrations throughout the exposure duration.

Equations and necessary default values for calculating the volatilization factor (VF) and particulate emission factor (PEF), used in the risk assessment for the volatiles inhalation and fugitive dust inhalation pathways, respectively, are taken from Risk Assessment Guidance for Superfund (RAGS), Part B (EPA 1991). For calculating the VF for alkyl benzenes (as toluene) and total saturated hydrocarbons (as hexadecane), certain physical properties were estimated due to a lack of data in the literature (see Appendix A for equation).

For hexadecane, the Henry's Law constant was determined as vapor pressure/solubility. Values for solubility, molecular weight, and boiling point were taken from Verschueren (1983). Vapor pressure was estimated using a modified Watson correlation (Lyman, 1990). Diffusivity was estimated by the Fuller, Schettler and Giddings

*Note: This risk assessment was performed before the decision was made to remove the concrete. The work area would be recontoured with existing onsite soil.

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(FSG) method (Lyman, 1990). The organic carbon partition coefficient (K_{oc}) was estimated using equation 4-5 in Lyman (1990).

For toluene, Henry's Law constant and Koc were taken from Howard (1990). Diffusivity was estimated by the FSG method (Lyman, 1990) and corroborated by comparison with diffusivity values for toluene in the Superfund Exposure Assessment Manual (SEAM) (EPA 1988).

4.3 SITE CONTAMINANTS AND THE USE OF SURROGATES

Based upon data from an IARC report presented in Millner, et al (1992), diesel contamination at the maintenance pad site was fractionated into the following components: alkyl benzenes, polyaromatic hydrocarbons (PAHs) with four or more benzene rings, biphenyls/acenaphthenes, fluorenes/acenaphthylenes, naphthalenes, phenanthrenes, and total saturated hydrocarbons (paraffins). The metals barium, cadmium, and chromium were also included in the risk assessment because they were detected in site soil samples using TCLP extraction methods.

These components and their concentrations are representative of unweathered No. 2 diesel fuel. Because the diesel contamination on-site is expected to be approximately 30 years old, it is highly unlikely that these relative concentrations are representative of site contamination. It is suspected that the more volatile components, such as the alkyl benzenes and lower molecular weight PAHs and alkanes, have already volatilized from exposed soils by this time. This suspicion is corroborated by the absence of benzene in site soil samples. The remaining components of diesel are susceptible to biodegradation to varying degrees. In particular, the normal alkanes are readily susceptible to biodegradation (Millner, et al.).

Perhaps the most significant conservative assumptions used in the risk assessment concern the use of toxicity surrogates for classes of chemical compounds in diesel fuel, notably the use of n-hexane as a toxicity surrogate for total saturated hydrocarbons (paraffins). n-Hexane was chosen as a toxicity surrogate because it is the longest chain-length saturated hydrocarbon for which an EPA (IRIS or HEAST) human toxicity value exists. n-Hexane, however, is unusual as an alkane for it's pronounced effects on the nervous system, on which the oral and inhalation reference doses (RfDs) are based (HEAST, 1992; IRIS, 1993). The higher molecular weight hydrocarbons are of toxicological concern primarily for their narcotic and irritant effects (Patty's Industrial Hygiene and Toxicology, 3rd edition, 1981; Sax, 1984), which are manifested at significantly higher concentrations than those associated with this waste site. Thus, risks associated with total petroleum hydrocarbons at the maintenance pad site must be interpreted as being, to a significant degree, an artifact of the use of n-hexane as a toxicity surrogate.

Conservative toxicity assumptions are also utilized for other classes of components in diesel fuel. For the alkyl benzenes, toluene is used for an inhalation RfD and ethylbenzene for an oral RfD because these RfDs are the most conservative among this group of compounds for their respective pathways. For PAHs with four or more benzene rings, the slope factor (SF) for benzo(a)pyrene is used because of a lack of specific toxicity data for similar compounds present in diesel. The SF for benzo(a)pyrene is considered to be a conservative estimator of toxicity for this class of compounds. For biphenyls/acenaphthenes and fluorenes/acenaphthylenes, the toxicity values for biphenyl

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yand fluorene are used, respectively, because they are the most conservative. For all naphthalenes and phenanthrenes, toxicity values for naphthalene and pyrene are used, respectively. Toxicity data for derivatives of naphthalene are unavailable. Pyrene is used as a surrogate for phenanthrene based on structure-activity relationship. Chromium is assumed to be present as chromium VI because this is the most toxic valence state.

Surrogate values for physical properties of the alkyl benzenes and total saturated hydrocarbons are based upon the most common representative of these classes of compounds in unweathered No. 2 diesel fuel. For the alkyl benzenes, toluene is used as a surrogate for density when calculating soil concentration from % volume, for total saturated hydrocarbons, hexadecane (C_{16}) is used. Hexadecane was chosen because carbon chain lengths are distributed normally in diesel fuel with C_{16} and C_{17} lengths being the mean (Hockensmith, 1990).

5.0 SUMMARY

The diesel pad maintenance site is evaluated for soil ingestion and inhalation pathways using residential and recreational exposure scenario parameters. As reported in Table 2, site-risk is estimated to meet or exceed acceptable levels, as presented in HSBRAM (DOE-RL, 1993), for inhalation of volatiles in the residential exposure scenario.

Due to the qualitative nature of the risk assessment, numerous simplifying assumptions are made in the risk assessment. As described in Section 4 of this report, these assumptions tend to bias the risk assessment in a conservative manner. The cumulative effect of a series of conservative assumptions on the risk estimates provided in Table 2 must be considered when utilizing such a risk assessment for planning purposes. The assumptions with the greatest effect upon the estimated risks are likely to be the use of n-hexane as a toxicity surrogate for total saturated hydrocarbons and the assumption that the entire site is uniformally contaminated with the highest detected soil concentration of diesel.

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Table 1. Maximum Expected Concentrations and Toxicity Values for Components of Diesel Fuel at the Maintenance Pad Site.

Maximum soil concentration of diesel = 4300 mg/kg

Component[j,k]	Conc[j,k] % volume	Density[m] g/ml	Conc. mg/g diesel	Conc. mg/kg soil	Oral RfD mg/(kg-d)	Inh RfD mg/(kg-d)	Source	Oral SF (kg-d)/mg	Inh SF (kg-d)/mg	Source
Alkyl Benzenes[a,h]	6.4	0.8669	6.9E+01	3.0E+02	1.0E-01[b]	1.0E-01[c]	I,I	-	-	-
Benzo(a)pyrene[d]	-	-	8.0E-02	3.4E-01	-	-	-	7.3E+00	-	I
Biphenyls/acenaphthenes	1.8	1.9896	4.5E+01	1.9E+02	5.0E-02	-	I	-	-	-
Fluorenes/acenaphthylenes	0.77	1.203	1.2E+01	5.0E+01	4.0E-02	-	I	-	-	-
Total Saturated Hydrocarbons[g,i]	74.5	0.7731	7.2E+02	3.1E+03	6.0E-02	6.0E-02	H,I	-	-	-
Naphthalenes[e]	6.9	1.145	9.9E+01	4.2E+01	4.0E-02	-	H	-	-	-
Phenanthrenes[f]	0.47	1.182	6.9E+00	3.0E+01	3.0E-02	-	I	-	-	-
Barium	-	-	7.0E-04	3.0E-03	7.0E-02	1.0E-04	I,H	-	-	-
Cadmium	-	-	7.0E-05	3.0E-04	1.0E-03	-	I	-	6.3E+00	I
Chromium (as Cr VI)	-	-	7.0E-04	3.0E-03	5.0E-03	-	I	-	4.1E+01	I

I = IRIS database.
H = HEAST, 1992.

[a]Alkyl benzenes include toluene, ethyl benzene, xylenes, styrene, etc.
[b]Alkyl benzene oral RfD as ethylbenzene (most conservative).
[c]Alkyl benzene inhalation RfD as toluene (most conservative).
[d]Benzo(a)pyrene used as a toxicity surrogate for all PAHs with four or more benzene rings (most conservative).
[e]Naphthalene used as a toxicity surrogate for all naphthalenes.
[f]Pyrene used as a toxicity surrogate for phenanthrene based on structure-activity relationship.
[g]n-Hexane used as a toxicity surrogate for total saturated hydrocarbons.
[h]Toluene used as a density surrogate for alkyl benzenes.
[i]Hexadecane used as a density surrogate for total saturated hydrocarbons.
[j]Speciation and concentrations of organic components in diesel are taken from an IARC report quoted in Millner et al., 1992.
[k]Concentrations of metals from Hockensmith, 1990.
[m]Density of Diesel Fuel No. 2 = 0.8g/ml (Dickerman, 1977). Density of diesel fuel components from Handbook of Chemistry and Physics, 47th edition.
4.8 % of diesel components, consisting of indans/tetralins, dinaphthenobenzenes/indenes, and olefins not accounted for due to lack of toxicity data.

NOTE: n-Hexane is used as a toxicity surrogate because of a lack of specific toxicity data for higher molecular weight hydrocarbons. n-Hexane (C_6) is significantly more toxic than the hydrocarbons common in diesel fuel (C_{11} - C_{20}).

Table 2. Summary of the Risk Assessment for Diesel Contamination in Soil at the Maintenance Pad Site.

RECREATIONAL EXPOSURE SCENARIO									
Component	Conc. mg/kg soil	Soil Ingestion		Fugitive Dust Inhalation		Inhalation of Volatiles			
		HQ	ICR	HQ	ICR	HQ	ICR		
Alkyl Benzenes	300	7E-04	-	5E-09	-	2E-02	-		
Benzo(a)pyrene	0.34	-	7E-08	-	-	-	-		
Biphenyls/acenaphthenes	190	9E-04	-	-	-	-	-		
Fluorenes/acenaphthylenes	50	3E-04	-	-	-	-	-		
Total Saturated Hydrocarbons	3100	1E-02	-	9E-08	-	1E-01	-		
Naphthalenes	420	3E-03	-	-	-	-	-		
Phenanthrenes	30	2E-04	-	-	-	-	-		
Barium	0.003	1E-08	-	5E-11	-	-	-		
Cadmium	0.0003	7E-08	-	-	6E-16	-	-		
Chromium (as Cr VI)	0.003	1E-07	-	-	4E-14	-	-		
	HI	2E-02		1E-07		1E-01		Total HI =	1E-01
	ICR		7E-08		4E-14			Total ICR =	7E-08
RESIDENTIAL EXPOSURE SCENARIO									
Component	Conc. mg/kg soil	Soil Ingestion		Fugitive Dust Inhalation		Inhalation of Volatiles			
		HQ	ICR	HQ	ICR	HQ	ICR		
Alkyl Benzenes	300	4E-02	-	3E-07	-	1E+00	-		
Benzo(a)pyrene	0.34	-	4E-06	-	-	-	-		
Biphenyls/acenaphthenes	190	5E-02	-	-	-	-	-		
Fluorenes/acenaphthylenes	50	2E-02	-	-	-	-	-		
Total Saturated Hydrocarbons	3100	7E-01	-	5E-06	-	5E+00	-		
Naphthalenes	420	1E-01	-	-	-	-	-		
Phenanthrenes	30	1E-02	-	-	-	-	-		
Barium	0.003	6E-07	-	3E-09	-	-	-		
Cadmium	0.0003	4E-06	-	-	3E-14	-	-		
Chromium (as Cr VI)	0.003	8E-06	-	-	2E-12	-	-		
	HI	9E-01		5E-06		6E+00		Total HI =	7E+00
	ICR		4E-06		2E-12			Total ICR =	4E-06

HQ = Hazard Quotient.
HI = Hazard Index (sum of HQ).
ICR = Lifetime Incremental Cancer Risk.
Equations for calculation of HQ and ICR from HSBRAM, (DOE-RL 1993).
Equations and default values for determining the volatilization factor (used in calculating risk from inhalation of volatiles), and particulate emission factor (used in calculating risk from inhalation of fugitive dust), are taken from RAGS, Part B, (EPA 1991).
NOTE: Risks from Total Petroleum Hydrocarbons are significant overestimations, due to use of surrogate toxicity data for n-hexane (see text).

APPENDIX A - EXAMPLE CALCULATIONS

DOE-RL, 1993, *Hanford Site Baseline Risk Assessment Methodology*, DOE/RL 91-45, Rev. 2, U.S. Department of Energy, Richland, Washington.

EPA, 1989, *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual, Part A, Interim Final*, EPA/540/1-89/002, U.S. Environmental Protection Agency, Washington, D.C.

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A-1.0 CALCULATION OF CONTAMINANT INTAKES

Standard EPA equations for calculation of intakes, as provided in the Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A. (RAGS, EPA 1989) and the HSBRAM (DOE-RL 1993), are used as the basis for all intake calculations.

Calculation of Non-radioactive Contaminant Intakes. The basic equation for calculating intakes of non-radioactive contaminants via soil ingestion or inhalation of soil contaminants is:

$$\text{Intake} = \frac{C \times IR \times EF \times ED \times CF}{BW \times AT \times OF} \qquad \text{A-1}$$

where:

Intake	=	chronic daily intake of the contaminant (mg/kg-d)
C	=	contaminant concentration in the medium (mg/kg)
IR	=	contact rate (mg/d or m^3/d)
ED	=	exposure duration (yr)
EF	=	exposure frequency (d/yr)
CF	=	conversion factor (as appropriate)
BW	=	body weight (kg)
AT	=	averaging time (yr x 365 d/yr)
OF	=	Other factor, as appropriate (e.g., PEF, VF)

A-1.1 INTAKE CALCULATIONS

The following subsections present example intake calculations for the soil ingestion, inhalation of fugitive dust, and inhalation of volatile soil contaminant pathways. All examples are presented for the residential-use scenario. Recreational-use intakes are calculated using the same equations with parameters for the recreational-use scenario appropriately substituted. The exposure parameters are summarized in Table A-1.

A-1.1.1 Soil Ingestion

<u>Carcinogenic - Non-Radioactive</u>

Intake (mg/kg-d) =

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$$\frac{C\ (mg/kg)\left[\frac{(200\ mg/d \times 365\ d/yr \times 6\ yr)}{(16\ kg)} + \frac{(100\ mg/d \times 365\ d/yr \times 24\ yr)}{(70\ kg)}\right]}{(365\ d/yr)(70\ yr)(1E{+}06\ mg/kg)} \qquad \text{A-2}$$

Noncarcinogenic

Intake (mg/kg-d) =

$$\frac{(C\ mg/kg)(200\ mg/d)(365\ d/yr)(6\ yr)(1E{-}06\ kg/mg)}{(16\ kg)(6\ yr \times 365\ d/yr)} \qquad \text{A-3}$$

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A-1.1.2 Inhalation of Fugitive Dust

Carcinogenic - Non-Radioactive

Intake (mg/kg-d) =

$$\frac{(C\ mg/kg)(20\ m^3/d)(365\ d/yr)(30\ yr)}{(70\ kg)(70\ yr \times 365\ d/yr)(PEF)} \qquad \text{A-4}$$

Note: PEF is a site-specific, soil to air emission factor. Derivation of a PEF is provided as follows:

$$PEF(m^3/kg) = \frac{LS \times V \times DH \times 3600\ s/hr}{A} \cdot \frac{1000\ g/kg}{0.036 \times (1-G) \times (U_m/U_t)^3 \times F(x)} \qquad \text{A-5}$$

Where:

LS = width of contaminated area (m)
V = wind speed in mixing zone (m/s)
DH = diffusion height (m)
A = area of contamination (m^2)
0.036 = respirable fraction [$g/(m^2 \cdot hr)$]
G = fraction of vegetative cover (unitless)
U_m = mean annual wind speed (m/s)
U_t = equivalent threshold value of wind speed at 10m (m/s)
F(x) = function dependent on U_m/U_t (unitless)

Noncarcinogenic

$$\text{Intake (mg/kg-d)} = \frac{(C\ \text{mg/kg})(10\ \text{m}^3/\text{d})(365\ \text{d/yr})(6\ \text{yr})}{(16\ \text{kg})(6\ \text{yr} \times 365\ \text{d/yr})\ (\text{PEF})} \qquad \text{A-6}$$

A-1.1.3 Inhalation of Volatile Soil Contaminants

Noncarcinogenic

$$\text{Intake (mg/kg-d)} = \frac{(C\ \text{mg/kg})(10\ \text{m}^3/\text{d})(365\ \text{d/yr})(6\ \text{yr})}{(10\ \text{kg})(6\ \text{yr} \times 365\ \text{d/yr})(\text{VF})} \qquad \text{A-7}$$

Note: VF is a contaminant specific, soil to air volatilization factor. Derivation of a VF is provided as follows:

$$\text{VF}\ (\text{m}^3/\text{kg}) = \frac{\text{LS} \times \text{V} \times \text{MH}}{\text{A}} \cdot \frac{(3.14 \times \alpha \times \text{T})^{1/2}}{(2 \times D_{ei} \times \text{E} \times K_{as} \times \text{CF})} \qquad \text{A-8}$$

$$\text{Where:} \quad \alpha(\text{cm}^2/\text{s}) = \frac{D_{ei} \times \text{E}}{\text{E} + (p_s)(1-\text{E})/K_{as}} \qquad \text{A-9}$$

where

LS	=	width of contaminated area (m)
V	=	site-specific wind speed in mixing zone (m/s)
MH	=	mixing height (2 m)
A	=	area of contamination (cm^2)
D_{ei}	=	effective diffusivity [$D_i \times E^{.33}$]
E	=	soil porosity (unitless)
K_{as}	=	soil/air partition coefficient [$(H/K_d) \times 41$] (g soil/cm^3) where 41 is a units conversion factor
p_s	=	true soil density (g/cm^3)
T	=	exposure interval (s)
OC	=	organic carbon content of soil (unitless)
D_i	=	molecular diffusivity (cm^2/s)
H	=	Henry's Law constant (atm-m^3/mol)
K_d	=	soil-water partition coefficient [$K_{oc} \times$ OC (cm^3/g)]

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K_{oc}	=	organic-carbon partition coefficient (cm^3/g)
CF	=	conversion factor (0.001 kg/g)

A-2.0 CALCULATION OF HUMAN HEALTH RISK ASSESSMENT

Lifetime Incremental Cancer Risk

The basic equation for determining the lifetime incremental cancer risk (ICR) for the ingestion and inhalation pathways is:

$$ICR = I \times SF \qquad \text{A-10}$$

where:

ICR	=	lifetime incremental cancer risk (unitless)
I	=	intake (mg/kg-d)
SF	=	contaminant-specific slope factor $(mg/kg\text{-}d)^{-1}$

Hazard Quotient

The basic equation for determining the hazard quotient for the ingestion and inhalation pathways is:

$$HQ = I/RfD \qquad \text{A-11}$$

where:

HQ	=	hazard quotient (unitless)
I	=	intake (mg/kg-d)
RfD	=	contaminant-specific chronic reference dose (mg/kg-d)

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Table A-1. Summary of Recreational and Residential Scenario Exposure Factors.

Exposure Factors	HSBRAM Reasonable Maximum Exposure[a]	
	Recreational	Residential
Intake Rate		
Soil Ingestion	200(C) 100(A) mg/d	200(C) 100(A) mg/d
Inhalation		
Noncarcinogens	10 m^3/d	10 m^3/d
Carcinogens	20 m^3/d	20 m^3/d
Exposure Frequency		
Soil Ingestion	7 d/yr	365 d/y
Inhalation	7 d/yr	365 d/y
Exposure Duration		
Soil Ingestion	6(C) 24(A) yr	6(C) 24(A) yr
Inhalation		
Noncarcinogens	6 yr	6 yr
Carcinogens	30 yr	30 yr
Body Weight	16(C) 70(A) kg	16(C) 70(A) kg
Averaging Time		
Noncarcinogens	6 yr x 365 d/yr	6 yr x 365 d/yr
Carcinogens	70 yr x 365 d/yr	70 yr x 365 d/yr

(C) Child
(A) Adult
[a]DOE-RL 1993

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