Support Document for the Development of Generic Numerical Standards and Risk Assessment Procedures

The Voluntary Action Program
Division of Emergency and Remedial Response
Ohio Environmental Protection Agency

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This document was prepared as a supplemental guidance to accompany the administrative rules for the Ohio Environmental Protection Agency Voluntary Action Program concerning Generic Numerical Standards (Rule 3745-300-08 of the Administrative Code) and Property-Specific Risk Assessment Procedures (Rule 3745-300-09 of the Administrative Code). This guidance is effective upon the adoption of these rules and all other Voluntary Action Program rules filed with the Ohio General Assembly Joint Committee on Agency Rule Review into Section 3745-300 of the Administrative Code.

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Regularly updated information about the Voluntary Action Program is available on the internet from the VAP Home Page. The address is:

http://www.epa.ohio.gov/derr/volunt/volunt.aspx

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I-1. Calculation of Direct-Contact Soil Standards

The Generic Direct Contact Soil Standards listed in Tables I-III of rule 3745-300-08 of the Administrative Code were calculated probabilistically, utilizing Monte Carlo Simulation (MCS) as a technique to model heterogeneous human receptor populations exposed through each potential land use category exposure scenario (residential, or commercial/ industrial). In addition, generic direct-contact soil standards based upon exposures during construction or excavation activities have been derived. Standards generated in accordance with rule 3745-300-09 of the Administrative Code may be calculated using MCS or single point values may be used for a deterministic calculation. Point values for a deterministic standard calculation are listed in Table 1. Regardless of approach, probabilistic or point value, the mathematical models used to generate applicable standards are intended to simulate: (1) the mass of chemicals transported from soil to a receptor; (2) the mass transfer of chemicals through human epithelial barriers; and (3) the soil concentration at which an adverse human health effect may occur.

Chemical-specific values as well as toxicity data used to calculate the generic numerical standards are listed in Table 2. For chemicals not listed in rule 3745-300-08 of the Administrative Code, values should be obtained from the hierarchy of sources listed in Section I-3.

It should be noted that all of the following equations have been described elsewhere [5, 6, 7,8]. They are reproduced in the current document, primarily for convenience, however, in some instances have been modified to remain consistent with specific rule language.

A. Calculation of Intake via Inhalation

Of major importance in developing generic numerical standards is the necessity to account for uptake by the receptor through all potential exposure pathways. Thus, uptake via the inhalation pathway must account for exposure to volatile chemicals present in vapor phase, as well as volatile, semi-volatile and non-volatile chemicals adhering to small soil particles. In order to calculate exposure to vapor phase chemicals, an apparent diffusivity value must first be calculated as presented in Equation 1, below.

Equation 1. Calculation of Apparent Diffusivities (D_A) [8]

$$D_A = \frac{\left[\left(\theta_a^{10/3} \times D_i \times H' \right) + \left(\theta_w^{10/3} \times D_w \right) \right] \div n^2}{\rho_b K_d + \theta_w + \theta_a H'}$$

Where:

D_A	=	Apparent diffusivity (cm^2/s)
θ_a	=	Air-filled soil porosity (L_{air}/L_{soil}) (0.28) [8]
D_i	=	Diffusivity in air (cm^2/s) (chemical specific)
H′	=	Henry's Law Constant (dimensionless) (chemical specific)
θ_w	=	Water-filled soil porosity (L_{water}/L_{soil}) (0.15) [8]
D_w	=	Diffusivity in water (cm^2/s) (chemical specific)
n	=	Total soil porosity (L_{pore}/L_{soil}) (0.43) [8]
ρ_b	=	Dry soil bulk density (g/cm^3) (1.5) [8]
K_d	=	Soil to water partition coefficient (cm^3/gm)

Once a value for D_A has been calculated, a volatilization factor can be calculated as in Equation 2, below. Note that the Exposure Interval (T) for volatilization is specific for each exposure scenario. For residential scenarios, this time equals 30 years in seconds. For commercial/industrial scenarios, it equals 25 years in seconds. For construction scenarios, T equals 1 year in seconds.

Equation 2. Calculation of Volatilization Factor (VF) [8]

$$VF = \frac{Q}{C} \times \frac{(3.14 \times D_A \times T)^{1/2}}{(2 \times \rho_b \times D_A)} \times 10^{-4}$$

Where:

VF	=	Volatilization Factor (m^3/kg)
Q/C	=	Inverse of the mean concentration at center of square source (g/m^2-s per kg/m^3) (83.22, assuming a 0.5 acre area and Cleveland, Ohio climatic constants)[8]
D_A	=	Apparent diffusivity (cm^2/s) (from Equation 1)
T	=	Exposure Interval (specific to each exposure scenario)
ρ_b	=	Dry soil bulk density (g/cm^3) (1.5) [8]

Equation 3. Calculation of Particulate Emission Factor (PEF) [8]

In addition to calculation of intake of volatiles by application of VF, the inhalation pathway must also account for inhalation of chemicals adhering to particulates. This aspect is addressed by determining a Particulate Emission Factor (PEF), which is calculated in Equation 3.

$$PEF = \frac{Q}{C} x \frac{3600}{0.036x(1-V)x(U_m \div U_t)^3 \, x \, F_x}$$

Where:

PEF	=	Particulate Emission Factor (m^3/kg)
Q/C	=	Inverse of the mean concentration at center of square source (g/m^2-s per kg/m^3) (83.22, assuming a 0.5 acre area and Cleveland, Ohio climatic constants) [8]
V	=	Fraction of vegetative cover (unitless) (0.5) [8]
U_m	=	Mean annual windspeed (m/s) (4.83, average Cleveland, Ohio wind speed)[8]
U_t	=	Equivalent threshold value of windspeed at 7m (m/s) (11.32) [8]
F_x	=	Function dependent on U_m/U_t (unitless) (0.232) [8]

B. Calculation of Intake Factor for Inhalation Pathway

An intake factor is not calculated for the inhalation pathway. The target concentration attributable to the inhalation pathway is calculated directly for each exposure scenario using chemical specific reference concentrations (RfC) or Inhalation Unit Risk (IUR) for non-cancer and cancer endpoints, respectively. The target concentration is adjusted only for exposure duration and exposure frequency and is dependent on the fraction of soil contaminated and the calculated VF and PEF values (See Equation 6).

C. Calculation of Intake via Ingestion

In addition to inhalation, ingestion represents a major pathway by which chemicals in the soil enter the body of a receptor.

Equation 4. Intake factor for ingestion:

$$IF_{ORAL} = \frac{(IR \; x \; EF \; x \; ED \; x \; ET \; x \; FI \; x \; CF)}{(BW \; x \; AT)}$$

Where:

IF_{ORAL}	=	Ingestion-specific intake factor (kg/kg-day)
IR	=	Soil ingestion rate (mg/day) (specific to each exposure scenario)
EF	=	Exposure frequency (days/year) (specific to each exposure scenario)
ED	=	Exposure duration (years) (specific to each exposure scenario)
ET	=	Exposure time (hours/day) (specific to each exposure scenario)*
FI	=	Fractional ingestion intake from contaminated source (unitless)
CF	=	Conversion factor (10^{-6}kg/mg)
BW	=	Body weight (mass) (kg) (specific to each exposure scenario)
AT	=	Averaging time (days) (specific to each exposure scenario for cancer or non-cancer endpoints)

**Residential soil ingestion is not dependent on exposure time. Commercial/Industrial and Construction /Excavation soil ingestion is calculated based on an hourly soil ingestion rate.*

Values for all input terms included in IF_{ORAL} (except CF) are specific for each exposure scenario. In instances where a probabilistic approach is used to calculate generic standards for chemicals not listed in rule 3745-300-08 of the Administrative Code, distributions obtained from the appropriate exposure scenario distribution section can be used as input distributions for these factors. FI is derived from a uniform distribution (0.01 - 1.00) for all exposure scenarios. When standards are calculated using exposure point values, all of the ingested soil intake is assumed to be derived from a contaminated source and is, therefore, equal to 100 percent (1.0). Alternatively, property specific data reflecting upper bound point value estimates of property-specific conditions may be used in accordance with rule 3745-300-09 (D)(3)(b)(iv) of the Administrative Code.

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D. Calculation of Intake via Dermal Exposure

The dermal exposure pathway is quantitatively assessed only for a subset of semi-volatile organic compounds and metals. Volatile organic compounds are not quantitatively assessed. Values for the dermal absorption fraction (ABS) are obtained from Table 3, or can be obtained on a chemical-specific basis if available from an appropriate source and approved by Ohio EPA.

Equation 5. Intake factor for the dermal pathway:

$$IF_{DERM} = \frac{(SA\ x\ EF\ x\ ED\ x\ AF\ xABS\ x\ F_{DERM}\ x\ CF)}{(BW\ x\ AT)}$$

Where:

IF_{DERM}	=	Dermal-specific intake factor (kg/kg-day)
SA	=	Surface area of exposed skin (cm^2) (specific to each exposure scenario)
EF	=	Exposure frequency (days/year) (specific to each exposure scenario)
ED	=	Exposure duration (years) (specific to each exposure scenario)
AF	=	Soil to skin adherence factor (mg/cm^2) (specific to each exposure scenario)
ABS	=	Dermal absorption fraction from soil (Table 3, or, if available from chemical specific data)
F_{DERM}	=	Fractional dermal intake from contaminated source (unitless)
CF	=	Conversion factor (10^{-6}kg/mg)
BW	=	Body weight (kg) (specific to each exposure scenario)
AT	=	Averaging time (days) (specific to each exposure scenario for cancer or non-cancer endpoints)

Except for CF and ABS, values for all other input terms included in IF_{DERM} are specific for each exposure scenario. In instances where a probabilistic approach is used to calculate generic standards for chemicals not listed in rule 3745-300-08 of the Administrative Code, distributions obtained from specific exposure scenario sections can be used as input distributions for these factors. When standards are calculated using a point value approach, point values for these terms can be obtained from Table 1. As with the inhalation pathway, the F_{DERM} adjustment is equivalent to FI for default calculations. When standards are calculated using exposure point values, all of the soil contacted is assumed to be derived from a contaminated source and is, therefore, equal to 100 percent (1.0) Alternatively, property specific data reflecting upper bound point value estimates of property-specific conditions may be used in accordance with rule 3745-300-09 (D)(3)(b)(iv) of the Administrative Code.

E. Calculation of Generic Numerical Standard

Once intake factors have been calculated, they are combined in the following formulas for cancer and non-cancer endpoints, and compared to the appropriate chemical-specific toxicity value as indicated:

Equation 6. Calculation of cleanup standard for non-carcinogenic endpoint

Target concentrations for each chemical of concern are first calculated separately for each exposure pathway as shown below.

$$TC_{ORAL} = \frac{HQ}{\left(\frac{IF_{ORAL}}{RfD_{ORAL}}\right)}$$

$$TC_{DERM} = \frac{HQ}{\left(\frac{IF_{DERM}}{RfD_{DERM}}\right)}$$

$$TC_{INH} = \frac{HQ \times AT}{\left(\frac{1}{RfC}\right) \times FI_{inh} \times ED \times EF \times \left[\left(\frac{1}{VF}\right) + \left(\frac{1}{PEF}\right)\right]}$$

Where:

TC_{ORAL}	=	Target Concentration for Oral Pathway (mg/kg)
TC_{DERM}	=	Target Concentration for Dermal Pathway (mg/kg)
TC_{INH}	=	Target Concentration for Inhalation Pathway (mg/kg)
HQ	=	Target hazard quotient (HQ=1)
AT	=	Averaging time (days) (specific to each exposure scenario for non-cancer endpoints)
IF_{ORAL}	=	Oral intake factor (Calculated as in Equation (4))
IF_{DERM}	=	Dermal intake factor (Calculated as in Equation (5))
RfD_{ORAL}	=	Oral reference dose (Chemical specific)
RfD_{DERM}	=	Dermal reference dose (Chemical specific)
RfC	=	Inhalation reference concentration (Chemical specific)
FI_{inh}	=	Fractional inhaled from contaminated source (unitless)
EF	=	Exposure frequency (days/year) (specific to each exposure scenario)

ED = Exposure duration (years) (specific to each exposure scenario)
VF = Volatilization Factor (m^3/kg)
PEF = Particulate Emission Factor (m^3/kg)

Once target cleanup concentrations for each chemical of concern are calculated for each exposure pathway, the pathways are combined for a total target cleanup concentration as shown below.

$$TC_{TOTAL} = \frac{1}{\left(\frac{1}{TC_{ORAL}}\right) + \left(\frac{1}{TC_{DERM}}\right) + \left(\frac{1}{TC_{INH}}\right)}$$

Where:
TC_{TOTAL} = Total Target cleanup concentration (mg/kg)
TC_{ORAL} = Target Concentration for Oral Pathway (mg/kg)
TC_{DERM} = Target Concentration for Dermal Pathway (mg/kg)
TC_{INH} = Target Concentration for Inhalation Pathway (mg/kg)

Equation 7. Calculation of cleanup standard for carcinogenic endpoint

Target concentrations for each chemical of concern are first calculated separately for each exposure pathway as shown below.

$$TC_{ORAL} = \frac{Target\ Risk}{(IF_{ORAL}\ x\ SF_{ORAL})}$$

$$TC_{DERM} = \frac{Target\ Risk}{(IF_{DERM}\ x\ SF_{DERM})}$$

$$TC_{INH} = \frac{Target\ Risk \times AT}{IUR \times ED \times EF \times \left[\left(\frac{1}{VF}\right) + \left(\frac{1}{PEF}\right)\right]}$$

Where:
TC_{ORAL} = Target Concentration for Oral Pathway (mg/kg)
TC_{DERM} = Target Concentration for Dermal Pathway (mg/kg)
TC_{INH} = Target Concentration for Inhalation Pathway (mg/kg)
Target Risk = Target excess cancer rate (10^{-5})

AT	=	Averaging time (days) (specific to each exposure scenario for cancer endpoints)
IF_{ORAL}	=	Oral intake factor (Calculated as in Equation (4))
IF_{DERM}	=	Dermal intake factor (Calculated as in Equation (5))
SF_{ORAL}	=	Oral slope factor (Chemical specific)
SF_{DERM}	=	Dermal slope factor (Chemical specific)
IUR	=	Inhalation Unit Risk (Chemical specific)
EF	=	Exposure frequency (days/year) (specific to each exposure scenario)
ED	=	Exposure duration (years) (specific to each exposure scenario)
VF	=	Volatilization Factor (m^3/kg)
PEF	=	Particulate Emission Factor (m^3/kg)

Once target cleanup concentrations for each chemical of concern are calculated for each exposure pathway, the pathways are combined for a total target cleanup concentration as shown in the following equation:

$$TC_{TOTAL} = \frac{1}{\left(\frac{1}{TC_{ORAL}}\right) + \left(\frac{1}{TC_{DERM}}\right) + \left(\frac{1}{TC_{INH}}\right)}$$

Where:

TC_{TOTAL}	=	Total Target cleanup concentration (mg/kg)
TC_{ORAL}	=	Target Concentration for Oral Pathway (mg/kg)
TC_{DERM}	=	Target Concentration for Dermal Pathway (mg/kg)
TC_{INH}	=	Target Concentration for Inhalation Pathway (mg/kg)

The cleanup standards reflect cumulative effects of multiple exposure pathways. If warranted by property-specific conditions such as engineering controls, specific pathways may be eliminated. In addition to cumulative effects through multiple intake pathways, the cumulative effects of multiple contaminants must be considered. To address this concern, adjustments are made to individual TC values, such that the Total Hazard Index for non-cancer endpoints does not exceed 1, or the Target Risk Goal for carcinogenic endpoints does not exceed the appropriate level indicated in rules 3745-300-08 and 3745-300-09 of the Administrative Code. For non-carcinogens, grouping of contaminants on the basis of their target organs and mechanism of action may be appropriate and result in the derivation of multiple hazard indices.

I-2. Calculation of Generic Standards for Unrestricted Potable Use Ground Water

The risk-derived generic unrestricted potable use ground water standards listed in Table VI of rule 3745-300-08 of the Administrative Code were also developed using probabilistic simulations as described in the calculation of generic direct-contact soil standards in Section I.I. Note that the generic unrestricted potable use standards in Table V of rule 3745-300-08 of the Administrative Code are based on MCLs or other established regulatory criteria and therefore were not calculated using probabilistic simulations. As was the case for the direct-contact soil standards, chemicals that do not have a potable use standard listed in Tables V or VI of rule 3745-300-08 of the Administrative Code may have a standard derived using either a point value (deterministic) analysis or through probabilistic simulations. Both methods of standard derivation are supported by a series of mathematical models which attempt to account for the uptake of chemicals from all exposure pathways by integrating intake terms for each of the pathways. Equations for each pathway are listed as follows:

A. Calculation of Intake via Inhalation

Intake for the inhalation pathway uses a single volatilization constant as described by Andelman[5] and applied originally to a whole house exposure scenario [2]. The model has been modified for the shower by applying an exposure time term to account only for time in the shower.

Equation 8. Intake due to inhalation from potable water during showering

$$IF_{INH} = \frac{(ED \times IR \times EF \times ET \times K \times CF_2)}{(BW \times AT)}$$

Where:

IF_{INH}	=	Inhalation-specific intake (L/kg-day)
ED	=	Exposure duration (years) (specific to child or adult receptor)
IR	=	Inhalation rate in shower (m^3/hr) (specific to child or adult receptor)
EF	=	Exposure frequency (days/year)
ET	=	Exposure time (hours/day) (specific to child or adult receptor)
K	=	Volatilization constant (unitless) (1.85×10^{-3})[5]
CF_2	=	Conversion factor (1×10^3 L/m^3)[2]
BW	=	Body weight (mass) (kg)
AT	=	Averaging time (days) (specific to child or adult receptor for cancer or non-cancer endpoints)

B. Calculation of Intake via Ingestion

The intake term for ingestion accounts for the entire water consumption by the receptor.

Equation 9. Ingestion of potable water

$$IF_{ORAL} = \frac{(IR \times ED \times EF)}{(BW \times AT)}$$

Where:

IF_{ORAL}	=	Ingestion-specific intake factor (L/kg-day)
IR	=	Water ingestion rate (L/day) (specific to child or adult receptor)
ED	=	Exposure duration (years) (specific to child or adult receptor)
EF	=	Exposure frequency (days/year)
BW	=	Body weight (mass) (kg) (specific to child or adult receptor)
AT	=	Averaging time (days) (specific to child or adult receptor for cancer or non-cancer endpoints)

C. Calculation of Intake via Dermal Exposure

For dermal exposure to water, chemicals of concern are assessed when the dermal pathway contributes more than 10% of the oral pathway [7]. Table 4 identifies which chemicals of concern should be assessed.

Equation 10. Dermal Exposure to Chemicals of Concern in Ground Water

Similar to exposure through the inhalation pathway, dermal exposure to chemicals in groundwater are modeled only for time spent in the shower, as indicated in the following equation:

$$IF_{DERM} = \frac{(SA \times EF \times ED \times ET \times CF \times PC)}{(BW \times AT)}$$

Where:

IF_{DERM}	=	Dermal-specific intake factor (L/kg-day)
SA	=	Surface area (cm^2) (specific to child or adult receptor)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years) (specific to child or adult receptor)

ET	=	Exposure time (hours/day) (specific to child or adult receptor)
CF	=	Conversion factor ($1x10^{-3}L/cm^3$)
PC	=	Permeability constant (cm/hr) (chemical specific) (specific to child or adult receptor)
BW	=	Body weight (mass) (kg) (specific to child or adult receptor)
AT	=	Averaging time (days) (specific to child or adult receptor for cancer or non-cancer endpoints)

D. Calculation of Generic Standards

Once intake factors have been calculated, they are combined in the following formulas for cancer and non-cancer endpoints, and compared to the appropriate chemical-specific toxicity value as indicated:

Equation 11. Calculation of cleanup standards for non-carcinogenic endpoint

$$TC = \left[\frac{HQ}{\left(\frac{IF_{ORAL}}{RfD_{ORAL}}\right) + \left(\frac{IF_{DERM}}{RfD_{DERM}}\right) + \left(\frac{IF_{INH}}{RfD_{INH}}\right)}\right] x1000$$

Where:

TC	=	Target cleanup concentration (µg/L)
HQ	=	Target hazard quotient (HQ=1)
IF_{ORAL}	=	Oral intake factor (Equation (9))
IF_{DERM}	=	Dermal intake factor (Equation (10))
IF_{INH}	=	Inhalation intake factor (Equation (8))
RfD_{ORAL}	=	Oral reference dose (Chemical specific)
RfD_{DERM}	=	Dermal reference dose (Chemical specific)
RfD_{INH}	=	Inhalation reference dose (Chemical specific)

Equation 12. Calculation of cleanup standards for carcinogenic endpoint

$$TC = \frac{Target\ Risk}{\left[(IF_{ORAL} \ x\ SF_{ORAL}) + (IF_{DERM} \ x\ SF_{DERM}) + (IF_{INH} \ x\ SF_{INH}) \right]}$$

Where:

TC	=	Target cleanup concentration (µg/l)
Target Risk	=	Target excess cancer risk (10^{-5}or10^{-4}, as appropriate)
IF_{ORAL}	=	Oral intake factor (Equation (9))
IF_{DERM}	=	Dermal intake factor (Equation (10))
IF_{INH}	=	Inhalation intake factor (Equation (11))
SF_{ORAL}	=	Oral slope factor (Chemical specific)
SF_{DERM}	=	Dermal slope factor (Chemical specific)
SF_{INH}	=	Inhalation slope factor (Chemical specific)

I-3. Applicability of Physical/Chemical Data and Toxicity Data for Development of Generic Standards

The development of reliable cleanup standards is dependent upon several sets of data describing the physical/chemical characteristics for each chemical of concern, the uptake of chemicals of concern by a receptor from contaminated media, and possible carcinogenic or non-carcinogenic adverse health effects from exposure. The following sources of physical/chemical information are used, in order of decreasing preference, for the development of the generic standards or use in a property specific risk assessment:

A. Sources Hierarchy for Pertinent Physical/Chemical Information

The hierarchy for sources of physical/chemical data was developed from a detailed source comparison. Each parameter used in developing generic standards has a different hierarchy as follows:

<u>Molecular Weight</u>
1). Hazardous Substance Data Bank (HSDB)
2). Syracuse Research Corporation's PHYSPROP database
3). Superfund Chemical Data Matrix (SCDM)

Melting Point
1). HSDB
2). Syracuse Research Corporation's Environmental Fate DataBase (EFDB) CHEMFATE application
3). PHYSPROP
4). Oak National Laboratory, Risk Assessment Information System (RAIS)
5). SCDM

Henry's Law Constant
1). HSDB
2). PHYSPROP
3). CHEMFATE
* Most recent value supersedes

Organic Carbon Partition Coefficient (Koc)
1). 1996 Soil Screening Guidance
2). HSDB
3). RAIS
4). 2002 Supplemental Guidance for Developing Soil Screening Levels

Water Solubility
1). HSDB
2). PHYSPROP
3). CHEMFATE
4). RAIS
* Most recent value supersedes

B. Source Hierarchy for Pertinent Toxicity Information

The following sources of toxicity information are used in order of decreasing preference when selecting chronic oral, chronic inhalation, and cancer toxicity values for the development of generic standards or use in a property-specific risk assessment for the residential and commercial/industrial scenarios:

(1) Integrated Risk Information System (IRIS). IRIS is considered to be the most reliable source of toxicity information. For values obtained during a property-specific risk assessment, the most current update of IRIS should be consulted.

(2) Ohio EPA toxicity information. If the toxicity information used in the development of the generic standards or for a property-specific risk assessment is not contained in IRIS, then the volunteer must consult with an Ohio EPA Division of Emergency and Remedial Response representative to determine the appropriate toxicity data.

In general, the following hierarchy of additional sources is used by Ohio EPA to determine the most appropriate toxicity values.

(a) National Center for Environmental Assessment (NCEA) Provisional Peer Reviewed Toxicity Values (PPRTVs).

(b) Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles.

(c) California EPA, Office of Environmental Health Hazard Assessment, Toxicity Criteria Database.

(d) Health Effects and Assessment Summary Tables (HEAST) toxicity information.

(e) U.S. EPA Criteria Documents. Criteria documents include but are not limited to: drinking water criteria documents; drinking water health advisory summaries; ambient water quality criteria documents; and air quality criteria documents.

For the construction worker scenario, subchronic oral and subchronic inhalation toxicity values are applied due to the short exposure duration (1 year). The following sources of subchronic toxicity information are used in order of decreasing preference:

(1) Integrated Risk Information System (IRIS). IRIS is considered to be the most reliable source of toxicity information. Since this source is updated on a monthly basis, the most current update of IRIS should be consulted. For the construction worker scenario, IRIS chronic values are modified by removing the uncertainty factor, if applied, for extrapolation from a subchronic scenario to a chronic scenario.

(2) National Center for Environmental Assessment (NCEA) Provisional Values.

(3) Ohio EPA toxicity information. If the toxicity information required to be used in the development of the generic standards or for a property-specific risk assessment is not contained in IRIS, then the volunteer must consult with an Ohio EPA Division of Emergency and Remedial Response representative to determine the appropriate toxicity information for use. In general, the following hierarchy of additional sources is used by Ohio EPA to determine the most appropriate toxicity information:

    (a) Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles.

    (b) Health Effects and Assessment Summary Tables (HEAST) toxicity information.

(c) U.S. EPA Criteria Documents. Criteria documents include but are not limited to: drinking water criteria documents; drinking water health advisory summaries; ambient water quality criteria documents; and air quality criteria documents.

If the above does not list a subchronic value, use an appropriate chronic value, with no adjustment.

C. Adjustment and Extrapolation of Toxicity Values

Reference Concentrations (RfC) for non-cancer endpoints or Inhalation Unit Risk (IUR) values for cancer endpoints are used as they are presented in IRIS and other sources when generating cleanup standards for the direct-contact soil pathway. However, for inhalation during showering in the potable use standard, these values must first be converted to an inhalation Reference Dose (RfD_i) or inhalation Slope Factor (SF_i), using the following equations:

Equation 13. Conversion of RfC to RfD_i

$$RfD_i = \frac{RfC x\ IR_{DAILY}}{BW}$$

Where:

RfD_i = Inhalation reference dose (mg/kg-day)

RfC = Reference concentration (mg/m^3)

IR_{DAILY} = Daily inhalation rate (m^3/day) (IR_{DAILY} = 20) [1]

BW = Body weight (mass)(kg)(BW = 70 kg) [1]

Equation 14. Conversion of Inhalation Unit Risk to Inhalation Slope Factor

$$SF_i = \left(\frac{IUR}{IR_{DAILY}}\right) x BW x CF$$

Where:

SF_i	=	Inhalation slope factor (mg/kg-day)
IUR	=	Inhalation unit risk ((μg/m^3)$^{-1}$)
IR_{DAILY}	=	Daily inhalation rate (m^3/day) (IR_{DAILY} = 20) [5]
BW	=	Body weight (kg) (BW = 70 kg) [5]
CF	=	Conversion factor (1000 μg/mg)

Pathway-specific values for dermal intake are seldom available. In the absence of pathway specific toxicity values and specific information indicating that a particular pathway may not be applicable for a particular chemical constituent, extrapolated toxicity values may be used. It is important to note, however, that direct route-to-route extrapolation may not be appropriate, particularly when original data are based upon studies employing administered rather than absorbed doses. In these instances, variability in chemical specific absorption efficiencies among different absorptive epithelial could result in invalid or highly uncertain toxicity values. Thus, appropriate route-to-route extrapolation should be confirmed by an Ohio EPA Division of Emergency and Remedial Response representative.

With regard to extrapolation of oral toxicity values to dermal pathway exposures, the extrapolated toxicity values are converted to absorbed dose values, as appropriate, since the dermal intake calculation takes into account the dermal absorption fraction from soil (see Equation 5). As recommended by U.S. EPA, an oral toxicity factor needs to be adjusted for the dermal pathway only when the gastrointestinal absorption of a chemical of concern from a medium similar to the one utilized in the critical study is significantly less than 100% [7]. See Table 4 for recommendations on when adjustment is appropriate. If an adjustment is not necessary, oral toxicity values may be used.

In the absence of chemical specific data, oral toxicity values derived from studies utilizing administered dose assume a default gastrointestinal absorption efficiency of 100% (oral absorption factor 1.0). The recommendation to assume 100% absorption is based on review of the literature where it has been found that organic chemicals are generally well absorbed (>50%) across the gastrointestinal tract[7]. Although a wider range of absorption efficiencies have been reported for inorganics, the recommendation is to also assume 100% absorption for inorganics lacking a chemical-specific gastrointestinal absorption factor[7]. Thus, for example, an oral reference dose derived from an administered dose critical study must be multiplied by a chemical-specific or default oral absorption factor (1.0), such that the reference dose is adjusted to account for the absorbed dose. Similarly, an oral slope factor derived from administered dose data must be divided by a chemical-specific or default oral absorption factor such that the slope factor is adjusted to account for the absorbed dose.

Oral slope factors (SF_o) and reference doses (RfD_o) are generally not extrapolated to assess inhaled exposures for compounds lacking inhalation values. However, for pathways where inhalation is the only exposure route, it may be appropriate to extrapolate an oral value to an inhalation value. An Ohio EPA Division of Emergency and Remedial Response representative should be consulted to confirm whether extrapolation of an oral toxicity value to an inhalation toxicity value is appropriate.

D. Development of Chemical-Specific Soil Saturation Levels

It is recognized that in some instances, risk-based soil cleanup levels may exceed soil saturation levels. Under these conditions, it is possible that health hazards beyond chemical toxicity (e.g. flammability) may exist. Moreover, the ability to accurately predict receptor uptake levels from free phase chemical contamination based upon any of the preceding mathematical models becomes highly problematic and has not been incorporated into these models.

Equation 15. Calculation of Soil Saturation

Except for chemicals that may be present in solid phase at ambient soil temperature, soil saturation levels are calculated by the following formula [8]:

$$C_{SAT} = \frac{S}{\rho_b}(K_d \rho_b + \theta_W + H'\theta_a)$$

Where:

C_{Sat}	=	Soil saturation concentration (mg/kg)
S	=	Solubility in water (mg/L-water) (chemical specific) (see Table 2)
ρ_b	=	Dry soil bulk density (kg/L)(ρ_b= 1.5) [8]
K_d	=	Soil-water partition coefficient (L/kg) ($K_d=K_{oc}$ x f_{oc}) (see Table 2) (f_{oc} = fraction organic carbon of soil (f_{oc}= 0.006) [8]
θ_W	=	Water-filled soil porosity (L_{water}/L_{soil}) (θ_W=0.15) [8]
H′	=	Henry's Law Constant (dimensionless) (chemical specific) (see Table 2)

E. Use of Monte Carlo Simulation for Probabilistic Development of Cleanup Standards

Cleanup standards for soil, ground water, or any other exposure media can be developed using the preceding equations and either point values from Table 1 or point values derived from property-specific data. Additionally, levels of risk to a receptor from chemicals present in the soil or groundwater at a known concentration may be calculated by transforming the equations to solve for forward risk. The values listed in Table 1 are recommended by U.S. EPA [2-8] or are derived from primary sources by the Ohio EPA, incorporating a combination of central tendency (approximately 50^{th} percentile) and upper bound (approximately 90^{th} /95^{th} percentile) exposure factors.

If property-specific data are used as alternatives to these default input exposure parameters, the values must be derived from equivalent levels of certainty. Thus, in instances where an upper bound value is used for a default value, the corresponding property-specific value must be an upper bound (e.g. approximately 90^{th} /95^{th} percentile) value. Alternatively, when a default point value is derived from the central tendency value, a central tendency (e.g. approximately 50^{th} percentile) value from property-specific data is to be used.

The generic numeric standards listed in rule 3745-300-08 of the Administrative Code were generated using a probabilistic approach. This process involved performing iterative calculations in which the input terms were drawn from probability distributions of each of the appropriate exposure factors as listed in Section II of this document. By solving the above equations iteratively, populations of chemical concentrations which meet the appropriate cancer or non-cancer risk level (10^{-5} excess cancer risk or non-cancer hazard index of 1) under a wide range of possible exposures were developed. Values chosen for standards were selected from the resulting distributions at the 90^{th} percentile level, such that in a forward risk assessment, 90% of these derived populations of concentrations would result in risk at the desired target risk levels. Alternatively, this could be described mathematically as only 10% of the derived population exceeding the target risk levels.

A similar probabilistic approach may be used in the calculation of standards derived through a property-specific risk assessment as described in Rule 3745-300-09 of the Administrative Code. Default distributions to be used in these analyses are listed in the specific exposure scenario sections in Section II. Alternatively, if property-specific conditions indicate the inapplicability of these default distributions and are supported by sufficient property-specific data, property-specific data may be used. Note, however, that the use of alternative distributions should be approved by an Ohio EPA Division of Emergency and Remedial Response representative.

Once appropriate exposure distributions, toxicological data, and physical/chemical data are obtained, the equations may be solved, iteratively, using one of several available

Monte Carlo Simulation computer software packages. While many of the details for translating the intake equations to a computer model are specific to an individual software package, there are some minimal requirements regarding the use of probabilistic simulations. To maximize consistency and statistical validity, a minimum of 5000 iterations should be used. In addition, to facilitate sampling over the entire range of each input distribution, a Latin Hypercube Sampling protocol is preferred. Once the simulation has been completed and 90^{th} percentile values are determined for use as a generic standard or in the property-specific risk assessment report, additional documentation must be provided for complete review. This documentation minimally includes:

1. Description of the input distributions if other than default:
   The description must include the shape (normal, lognormal, random, etc.), the range, and the mean and standard deviation (if available) of the probability distribution.

2. Summary statistics of sampled input distributions:
   Summary statistics must include the mean and standard deviation (if appropriate) and the selected range of values.

3. Descriptive statistics of concentration output data:
   Descriptive statistics must include mean, median, standard deviation, coefficient of variability, minimum and maximum value.

4. Cumulative percentile values for concentration output data:
   Cumulative percentile values expressed as mg/kg, μg/L, or other appropriate units of concentration for a given medium, should be presented for each percentile from 0-100 percent.

F. Derivation of Total Petroleum Hydrocarbon (TPH) Soil Saturation Concentrations

The generic numerical standards for petroleum at residential, commercial, or industrial properties are the standards established in rules adopted under division (B) of section 3737.882 of the Revised Code, as provided in division (B)(1) of section 3746.04 of the Revised Code. The State Fire Marshal's Bureau of Underground Storage Tank Regulations administers the rules adopted under division (B) of section 3737.882 of the Revised Code.

For properties in which the petroleum standard is developed through a property-specific risk assessment, soil saturation concentrations of total petroleum hydrocarbons must be determined. The saturation limits are given in OAC 3745-300-09 and are listed below.

Total Petroleum Hydrocarbon Soil Saturation Concentration (values are in mg/kg).

Petroleum Fraction	Residual Saturation Concentrations for: Sand and Gravel; Unknown Soil Type K_V: 10^{-3} - 10^{-4} cm/s	Residual Saturation Concentrations for: Silty/Clayey Sand K_V: 10^{-4} - 10^{-5} cm/s	Residual Saturation Concentrations for: Glacial Till and Silty Clay K_V: < 10^{-5} cm/s
Light (C_6 -C_{12})	1,000	5,000	8,000
Middle (C_{10} –C_{20})	2,000	10,000	20,000
Heavy (C_{20}-C_{34})	5,000	20,000	40,000

Where: mg/kg means milligrams per kilogram, K_V means vertical hydraulic conductivity of the unsaturated soil, cm/s means centimeters per second, and C_x means carbon chain length.

The information used to obtain the petroleum fraction saturation values was condensed during the original VAP rule development (1996) from American Petroleum Institute (1993), which cited residual liquid hydrocarbon concentrations found in Mercer and Cohen (1990). The values were not directly obtained from the literature, but are interpolated values from a simplified matrix of soil types and petroleum fractions.

During the 2002 VAP rule revision, a spreadsheet was developed to calculate specific saturation limits using Monte Carlo simulations. The calculated values did not differ significantly from the values developed in 1996, therefore, the values were not changed. However, carbon ranges for TPH were changed to comport with the carbon ranges used by the BUSTR in their Corrective Action rule. Light distillate fractions are now defined as the range C6-C12, middle fractions C10-C20 and heavy fractions C20-C34.

Table 1. Summary of Recommended Standard Default Single Point Value Exposure Factors [1-8]

Exposure Factor Term	Adult Residential Land Use Category	Child Residential Land Use Category	Commercial and Industrial Land Use Category	Construction or Excavation Worker Activities
Exposure Duration (ED)	30 years*	6 years*	25 years*	1 year*
Exposure Frequency (EF)	350 days/year*	350 days/year*	250 days/year *	120 days/year **
Body Weight (BW)	70 kg**	15 kg**	70 kg**	70 kg**
Soil Ingestion Rate (IRsoil)	100 mg/day **	200 mg/day **	50 mg/day**	200 mg/day**
Surface area of exposed skin (soil contact) (SA)	5700 cm^2 **	2800 cm^2 **	3300 cm^2 **	3300 cm^2 **
Soil to Skin Adherence Factor (AF)	0.07 mg/cm^2 **	0.2 mg/cm^2 **	0.2 mg/cm^2 **	0.3 mg/cm^2 **
Inhalation Rate (IR)	0.9 m^3/hour** (showering only)	0.66 m^3/hour** (showering only)		
Particulate Emission Factor (PEF)	9.24 E+08 m^3/kg**	9.24 E+08 m^3/kg**	9.24 E+08 m^3/kg**	property-specific
Fraction Soil Contaminated (FI, FDERM, and FInh)	1*	1*	1 *	1 *
Surface area of exposed skin(showering) (SAshower)	20000 cm^2 **	8000 cm^2 **	NA	NA
Exposure Time (ETshower)	15 min**	20 min**	NA	NA
Ingestion of potable water (IRwater)	2.0 L/day*	1.3 L/day *	NA	NA
Averaging Time (AT_{CANCER})	70 years x 365 days = 25550 days*	70 years x 365 days = 25550 days*	70 years x 365 days = 25550 days*	70 years x 365 days = 25550 days*
Averaging Time ($AT_{NONCANCER}$)	ED x 365 days = 10950 days*	ED x 365 days = 2190 days*	ED x 365 days = 9125 days*	ED x 365 days = 365*

* Value represents an upper bound estimate
** Value represents a central tendency estimate

Table 2. Physical and Chemical Properties and Toxicity Data

Physical/chemical Properties of Chemicals of Concern												TOXICITY FACTORS FOR CHEMICALS OF CONCERN											
												REFERENCE DOSES (RfD) & REFERENCE CONCENTRATIONS (RFderm)								SLOPE FACTORS (SF) & INHALATION UNIT RISKS (IUR)			
												Oral		Oral (Const)		Inhalation		Inhalation (Const)		Oral		Inhalation	
Chemical	CAS Number	MW (gm/mol)	Henry's Law Constant (H')	Koc (L/kg)	Water Solubility (mg/L H2O)	Air Diffusivity (cm2/s)	Water Diffusivity (cm2/s)	Melting Point (°C)	Oral Abs.	Dermal Abs.	PC (cm/hr)	(mg/kg-d)	Source	(mg/kg-d)	Source	(mg/m³)	Source	(mg/m³)	Source	(mg/kg-d)$^{-1}$	Source	(mg/m³)$^{-1}$	Source
Volatile Organic Compounds																							
Acetone	67-64-1	58.08	7.65E-04	5.75E-01	1.00E+06	1.24E-01	1.14E-05	-94.80	1	NA	1.10E-03	9.00E-01	IRIS	2.70E+00	IRIS	3.09E+01	ATSDR	3.09E+01	ATSDR	NA	NA	NA	NA
Benzene	71-43-2	78.11	2.27E-01	6.17E+01	1.79E+03	8.80E-02	1.02E-05	5.50	1	NA	1.50E-02	4.00E-03	IRIS	1.20E-02	IRIS	3.00E-02	IRIS	9.00E-02	IRIS	1.50E-02	IRIS	2.20E-03	IRIS
Carbon Disulfide	75-15-0	76.14	5.89E-01	4.57E+01	2.86E+03	1.04E-01	1.00E-05	-111.50	1	NA	1.70E-02	1.00E-01	IRIS	1.00E-01	HEAST	7.00E-01	IRIS	2.00E-01	HEAST	NA	NA	NA	NA
Carbon Tetrachloride	56-23-5	153.82	1.24E+00	1.52E+02	1.16E+03	7.80E-02	8.80E-06	-23.00	1	NA	1.60E-02	7.00E-04	IRIS	7.00E-03	ATSDR	2.00E-03	NCEA	2.00E-02	NCEA	1.30E-01	IRIS	1.50E-02	IRIS
Chlorobenzene	108-90-7	112.56	1.27E-01	2.24E+02	5.02E+02	7.30E-02	8.70E-06	-45.20	1	NA	2.80E-02	2.00E-02	IRIS	2.00E-01	IRIS	5.00E-02	NCEA	5.00E-01	NCEA	NA	NA	NA	NA
Chloroethane	75-00-3	64.51	4.54E-01	2.40E+01	6.71E+03	2.71E-01	1.15E-05	-138.70	1	NA	6.80E-03	4.00E-01	NCEA	4.00E-01	NCEA	1.00E+01	IRIS	1.00E+01	IRIS	2.90E-03	NCEA	NA	NA
Chloroform	67-66-3	119.38	1.50E-01	5.25E+01	7.71E+03	1.04E-01	1.00E-05	-63.20	1	NA	6.80E-03	1.00E-02	IRIS	1.00E-01	ATSDR	1.00E-01	ATSDR	2.40E-01	ATSDR	3.10E-02	Cal/EPA	2.30E-02	IRIS
Dibromochloromethane	124-48-1	208.28	3.20E-02	8.40E+01	2.70E+03	3.66E-02	1.05E-05	-20.00	1	NA	4.20E-02	2.00E-02	IRIS	2.00E-01	IRIS	NA	NA	NA	NA	8.40E-02	IRIS	NA	NA
Dichlorodifluoromethane	75-71-8	120.91	1.40E+01	3.56E+02	2.80E+02	6.65E-02	9.92E-06	-158.00	1	NA	9.00E-03	2.00E-01	IRIS	9.00E-01	HEAST	2.00E-01	HEAST	2.00E+00	HEAST	NA	NA	NA	NA
Dichloroethane, 1,1 -	75-34-3	98.97	2.30E-01	5.34E+01	5.04E+03	7.42E-02	1.05E-05	-96.90	1	NA	6.70E-03	2.00E-01	NCEA	2.00E+00	NCEA	5.00E-01	HEAST	1.43E+00	HEAST	5.70E-03	Cal/EPA	1.60E-03	Cal/EPA
Dichloroethane, 1,2 -	107-06-2	98.96	4.83E-02	3.80E+01	8.60E+03	1.04E-01	9.90E-06	-35.30	1	NA	4.20E-03	2.00E-02	NCEA	2.00E-01	ATSDR	2.43E+00	ATSDR	2.43E+00	ATSDR	9.10E-02	IRIS	2.60E-02	IRIS
Dichloroethene, 1,1 -	75-35-4	96.94	1.07E+00	6.50E+01	2.42E+03	9.00E-02	1.04E-05	-122.50	1	NA	1.20E-02	5.00E-02	IRIS	9.00E-03	HEAST	2.00E-01	IRIS	2.00E-01	IRIS	NA	IRIS	NA	IRIS
Dichloroethene, *cis* - 1,2	156-59-2	96.94	1.67E-01	3.55E+01	6.41E+03	8.86E-02	1.13E-05	-80.00	1	NA	2.70E-02	1.00E-02	NCEA	1.00E-01	NCEA	NA	NA	NA	NA	NA	NA	NA	NA
Dichloroethene, *trans* - 1,2 -	156-60-5	96.94	3.84E-01	3.80E+01	4.52E+03	7.03E-02	1.19E-05	-49.80	1	NA	7.70E-03	2.00E-02	IRIS	2.00E-01	IRIS	6.00E-02	NCEA	6.00E-02	NCEA	NA	NA	NA	NA
Dichloropropane, 1,2 -	78-87-5	112.99	1.15E-01	4.70E+01	2.80E+03	7.82E-02	8.73E-06	-100.40	1	NA	7.80E-03	9.00E-02	ATSDR	7.00E-02	ATSDR	4.00E-03	IRIS	1.30E-02	HEAST	3.60E-02	Cal/EPA	1.00E-02	Cal/EPA
Dichloropropene, 1,3 -	542-75-6	110.97	1.45E-01	2.71E+01	2.80E+03	6.26E-02	1.00E-05	-48.00	1	NA	4.30E-03	3.00E-02	IRIS	4.00E-02	ATSDR	2.00E-02	IRIS	2.00E-02	IRIS	1.00E-01	IRIS	4.00E-03	IRIS
Dioxane, 1,4 -	123-91-1	88.10	1.96E-04	2.90E+01	1.00E+06	2.29E-01	1.02E-05	11.80	1	NA	3.30E-04	1.00E-01	ATSDR	6.00E-01	ATSDR	3.60E+00	ATSDR	3.60E+00	ATSDR	1.10E-02	IRIS	7.70E-03	Cal/EPA
Ethyl Ether	60-29-7	74.12	5.03E-02	7.30E+01	6.04E+04	7.82E-02	8.61E-06	-116.30	1	NA	2.30E-03	2.00E-01	IRIS	2.00E+00	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	100-41-4	106.16	3.22E-01	2.04E+02	1.69E+02	7.50E-02	7.80E-06	-94.90	1	NA	4.90E-02	1.00E-01	IRIS	1.00E+00	IRIS	1.00E+00	IRIS	1.00E+00	NCEA	NA	NA	NA	NA
Formaldehyde	50-00-0	30.03	1.38E-05	3.70E+01	4.00E+05	1.78E-01	1.98E-05	-92.00	1	NA	1.80E-03	2.00E-01	IRIS	3.00E-01	ATSDR	1.00E-02	ATSDR	4.00E-02	ATSDR	NA	NA	1.30E-02	IRIS
Formic acid	64-18-6	46.03	6.83E-06	1.20E+01	1.00E+06	7.90E-02	1.37E-06	8.40	1	NA	6.90E-04	2.00E+00	HEAST	2.00E+00	HEAST	3.00E-03	NCEA	9.00E-03	NCEA	NA	NA	NA	NA
Hexane, *n* -	110-54-3	86.17	7.49E+01	1.50E+02	1.24E+01	2.00E-01	7.77E-06	-94.30	1	NA	5.90E-01	6.00E-02	HEAST	6.00E-01	HEAST	7.00E-01	IRIS	2.10E+00	IRIS	NA	NA	NA	NA
Isobutyl Alcohol	78-83-1	74.12	4.00E-04	6.20E+01	8.50E+04	8.60E-02	9.30E-06	-108.00	1	NA	5.00E-03	3.00E-01	IRIS	3.00E+00	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Methanol	67-56-1	32.04	1.86E-04	1.00E+00	1.00E+06	1.50E-01	1.64E-05	-97.80	1	NA	3.20E-04	5.00E-01	IRIS	5.00E+00	IRIS	4.00E+00	Cal/EPA	4.00E+00	Cal/EPA	NA	NA	NA	NA
Methyl Ethyl Ketone (MEK)	78-93-3	72.11	1.92E-03	3.15E+01	3.53E+05	8.08E-02	9.80E-06	-86.00	1	NA	9.60E-04	6.00E-01	IRIS	2.00E+00	HEAST	5.00E+00	IRIS	1.00E+00	HEAST	NA	NA	NA	NA
Methyl Isobutyl Ketone (MIBK)	108-10-1	100.16	5.64E-03	1.23E+02	1.90E+04	7.50E-02	7.80E-06	-85.00	1	NA	1.20E-02	8.00E-02	HEAST	8.00E-01	HEAST	3.00E+00	IRIS	8.00E-01	HEAST	NA	IRIS	NA	IRIS
Methyl *tert*- Butyl Ether (MTBE)	1634-04-4	88.15	2.40E-02	6.00E+00	4.80E+04	8.59E-02	1.01E-05	-108.60	1	NA	7.00E-03	NA	NA	3.00E-01	ATSDR	3.00E+00	IRIS	3.00E+00	IRIS	1.80E-03	NCEA	2.60E-04	Cal/EPA

Chemical	CAS Number	MW (gm/mol)	Henry's Law Constant (H')	Koc (L/kg)	Water Solubility (mg/L H2O)	Air Diffusivity (cm2/s)	Water Diffusivity (cm2/s)	Melting Point (°C)	Oral Abs.	Dermal Abs.	PC (cm/hr)	Oral (mg/kg-d)	Source	Oral (Const) (mg/kg-d)	Source	Inhalation (mg/m^3)	Source	Inhalation (Const) (mg/m^3)	Source	Oral ($(mg/kg\text{-}d)^{-1}$)	Source	Inhalation ($(mg/m^3)^{-1}$)	Source
			Physical/chemical Properties of Chemicals of Concern									**TOXICITY FACTORS FOR CHEMICALS OF CONCERN**											
												REFERENCE DOSES (RfD) & REFERENCE CONCENTRATIONS (RFderm)								**SLOPE FACTORS (SF) & INHALATION UNIT RISKS (IUR)**			
Methylene Chloride	75-09-2	84.93	8.96E-02	1.00E+01	1.30E+04	1.01E-01	1.17E-05	-95.00	1	NA	3.50E-03	6.00E-02	IRIS	6.00E-02	HEAST	1.00E+00	ATSDR	1.00E+00	ATSDR	7.50E-03	IRIS	4.70E-04	IRIS
Styrene	100-42-5	104.15	1.12E-01	9.12E+02	3.10E+02	7.10E-02	8.00E-06	-31.00	1	NA	3.70E-02	2.00E-01	IRIS	2.00E+00	IRIS	1.00E+00	IRIS	3.00E+00	IRIS	NA	NA	NA	NA
Tetrachloroethane , 1,1,1,2 -	630-20-6	167.85	1.02E-01	9.66E+01	1.07E+03	7.10E-02	7.90E-06	-70.20	1	NA	1.40E-01	3.00E-02	IRIS	3.00E-02	HEAST	NA	NA	NA	NA	2.60E-02	IRIS	7.40E-03	IRIS
Tetrachloroethane, 1,1,2,2 -	79-34-5	167.85	1.50E-02	7.90E+01	2.90E+03	7.10E-02	7.90E-06	-43.80	1	NA	6.90E-03	6.00E-02	NCEA	5.00E-01	ATSDR	NA	NA	NA	NA	2.00E-01	IRIS	5.80E-02	IRIS
Tetrachloroethene	127-18-4	165.83	7.24E-01	2.65E+02	2.06E+02	7.20E-02	8.20E-06	-22.30	1	NA	3.30E-02	1.00E-02	IRIS	1.00E-01	IRIS	2.71E-01	ATSDR	2.71E-01	ATSDR	5.40E-01	Cal/EPA	5.90E-03	Cal/EPA
Toluene	108-88-3	92.14	2.72E-01	1.40E+02	5.26E+02	8.70E-02	8.60E-06	-94.90	1	NA	3.10E-02	8.00E-02	IRIS	8.00E-01	IRIS	5.00E+00	IRIS	9.23E-01	NCEA	NA	NA	NA	NA
Trichloroethane, 1,1,1 -	71-55-6	133.42	7.04E-01	1.35E+02	1.29E+03	7.80E-02	8.80E-06	-30.40	1	NA	1.30E-02	2.80E-01	NCEA	2.00E+01	ATSDR	2.20E+00	NCEA	2.20E+01	NCEA	NA	NA	NA	NA
Trichloroethane, 1,1,2 -	79-00-5	133.42	3.37E-02	7.50E+01	4.59E+03	7.80E-02	8.80E-06	-36.60	1	NA	6.40E-03	4.00E-03	IRIS	4.00E-02	IRIS	NA	NA	NA	NA	5.70E-02	IRIS	1.60E-02	IRIS
Trichloroethene	79-01-6	131.39	4.21E-01	9.43E+01	1.28E+03	7.90E-02	9.10E-06	-84.70	1	NA	1.20E-02	5.00E-01	Cal/EPA	5.00E-01	Cal/EPA	6.00E-01	Cal/EPA	6.00E-01	Cal/EPA	1.30E-02	Cal/EPA	2.00E-03	Cal/EPA
Trichlorofluoromethane	75-69-4	137.37	3.97E+00	9.70E+01	1.10E+03	8.70E-02	9.70E-06	-111.00	1	NA	1.30E-02	3.00E-01	IRIS	7.00E-01	HEAST	7.00E-01	HEAST	7.00E+00	HEAST	NA	NA	NA	NA
Trichloropropane, 1,2,3 -	96-18-4	147.43	1.40E-02	8.60E+01	1.75E+03	7.10E-02	7.90E-06	-14.70	1	NA	5.00E-02	6.00E-03	IRIS	6.00E-02	IRIS	NA	NA	NA	NA	7.00E+00	HEAST	NA	NA
Vinyl Chloride	75-01-4	62.50	1.14E+00	1.86E+01	2.70E+03	1.06E-01	1.23E-05	-153.70	1	NA	1.50E-04	3.00E-03	IRIS	3.00E-03	IRIS	1.00E-01	IRIS	1.00E-01	IRIS	1.40E+00	IRIS	8.80E-03	IRIS
Xylenes, Total	1330-20-7	106.16	2.86E-01	5.56E+02	1.06E+02	7.37E-02	9.34E-06	-25.20	1	NA	1.90E-01	2.00E-01	IRIS	2.00E-01	IRIS	1.00E-01	IRIS	1.00E-01	IRIS	NA	NA	NA	NA
Semi-Volatile Organic Compounds																							
Acenaphthene	83-32-9	154.21	7.53E-02	4.90E+03	3.90E+00	4.76E-02	7.69E-06	95.00	1	0.13	6.10E-01	6.00E-02	IRIS	6.00E-01	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Acetophenone	98-86-2	120.15	4.25E-04	1.00E+01	6.13E+03	6.00E-02	8.73E-06	20.50	1	0.1	1.70E-02	1.00E-01	IRIS	1.00E+00	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Acrylonitrile	107-13-1	53.06	5.64E-03	3.30E+01	7.45E+04	1.22E-01	1.34E-05	-82.00	1	0.1	1.20E-03	4.00E-02	ATSDR	1.00E-02	ATSDR	2.00E-03	IRIS	2.00E-03	IRIS	5.40E-01	IRIS	6.80E-02	IRIS
Aniline	62-53-3	93.13	8.26E-05	2.71E+02	3.60E+04	7.00E-02	8.30E-06	-6.00	1	0.1	1.90E-03	7.00E-03	NCEA	7.00E-03	NCEA	1.00E-03	IRIS	1.00E-02	IRIS	5.70E-03	IRIS	1.60E-03	Cal/EPA
Anthracene	120-12-7	178.23	2.00E-03	2.34E+04	1.29E+00	3.85E-02	7.74E-06	218.00	1	0.13	1.37E+00	3.00E-01	IRIS	3.00E+00	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Benzidine	92-87-5	184.24	2.13E-09	5.55E+05	3.22E+02	3.26E-02	1.50E-05	120.00	1	0.1	1.10E-03	3.00E-03	IRIS	3.00E-03	HEAST	NA	NA	NA	NA	2.30E+02	IRIS	6.70E+01	IRIS
Benzo(a)anthracene	56-55-3	228.29	4.91E-04	3.58E+05	9.40E-03	5.10E-02	9.00E-06	160.00	1	0.13	4.70E-01	NA	NA	NA	NA	NA	NA	NA	NA	7.30E-01	IRIS	8.80E-02	NCEA
Benzo(a)pyrene	50-32-8	252.32	1.87E-05	9.69E+05	1.60E-03	4.30E-02	9.00E-06	176.50	1	0.13	7.00E-01	NA	NA	NA	NA	NA	NA	NA	NA	7.30E+00	IRIS	8.80E-01	NCEA
Benzo(b)fluoranthene	205-99-2	252.32	2.05E-05	1.23E+06	1.50E-03	2.23E-02	5.56E-06	168.00	1	0.13	7.00E-01	NA	NA	NA	NA	NA	NA	NA	NA	7.30E-01	IRIS	8.80E-02	NCEA
Benzo(k)fluoranthene	207-08-9	252.32	2.39E-05	1.23E+06	8.00E-04	2.23E-02	5.56E-06	217.00	1	0.13	1.71E+01	NA	NA	NA	NA	NA	NA	NA	NA	7.30E-02	IRIS	8.80E-03	NCEA
Bis (2-ethylhexyl) Phthalate	117-81-7	390.56	5.32E-06	1.11E+05	2.85E-01	3.51E-02	3.66E-06	-55.00	1	0.1	1.64E+02	2.00E-02	IRIS	2.00E-01	IRIS	NA	NA	NA	NA	1.40E-02	IRIS	2.40E-03	Cal/EPA
Butyl Benzyl Phthalate	85-68-7	312.39	1.96E-04	1.37E+04	7.10E-01	1.99E-02	4.89E-06	-35.00	1	0.1	2.10E+00	2.00E-01	IRIS	2.00E+00	IRIS	NA	NA	NA	NA	1.40E-02	NCEA	NA	NA
Carbazole	86-74-8	167.20	3.54E-06	3.39E+03	1.80E+00	4.17E-02	7.45E-06	245.00	1	0.1	4.50E-01	NA	NA	NA	NA	NA	NA	NA	NA	2.00E-02	HEAST	NA	NA
Chlordane	57-74-9	409.80	1.99E-03	5.13E+04	5.60E-02	1.79E-02	4.37E-06	106.00	1	0.04	3.80E-02	5.00E-04	IRIS	6.00E-05	HEAST	7.00E-04	IRIS	7.00E-03	IRIS	3.50E-01	IRIS	1.00E-01	IRIS
Chrysene	218-01-9	228.29	2.14E-04	3.98E+05	1.89E-02	2.44E-02	6.21E-06	258.20	1	0.13	4.70E-01	NA	NA	NA	NA	NA	NA	NA	NA	7.30E-03	IRIS	8.80E-04	NCEA
Dibenz(a,h)anthracene	53-70-3	278.33	4.91E-06	1.79E+06	5.99E-04	2.11E-02	5.24E-06	266.00	1	0.13	3.10E+01	NA	NA	NA	NA	NA	NA	NA	NA	7.30E+00	IRIS	8.80E-01	NCEA

Physical/chemical Properties of Chemicals of Concern												TOXICITY FACTORS FOR CHEMICALS OF CONCERN											
												REFERENCE DOSES (RfD) & REFERENCE CONCENTRATIONS (RFderm)								SLOPE FACTORS (SF) & INHALATION UNIT RISKS (IUR)			
												Oral		Oral (Const)		Inhalation		Inhalation (Const)		Oral		Inhalation	
Chemical	CAS Number	MW (gm/mol)	Henry's Law Constant (H')	Koc (L/kg)	Water Solubility (mg/L H2O)	Air Diffusivity (cm2/s)	Water Diffusivity (cm2/s)	Melting Point (°C)	Oral Abs.	Dermal Abs.	PC (cm/hr)	(mg/kg-d)	Source	(mg/kg-d)	Source	(mg/m^3)	Source	(mg/m^3)	Source	$(mg/kg\text{-}d)^{-1}$	Source	$(mg/m^3)^{-1}$	Source
Dichlorobenzene, 1,2 - (o)	95-50-1	147.00	7.85E-02	3.79E+02	1.56E+02	6.90E-02	7.90E-06	-16.70	1	0.1	4.10E-02	9.00E-02	IRIS	9.00E-02	IRIS	2.00E-01	HEAST	2.00E+00	HEAST	NA	NA	NA	NA
Dichlorobenzene, 1,4 - (p)	106-46-7	147.00	9.86E-02	6.16E+02	7.60E+01	6.90E-02	7.90E-06	52.70	1	0.1	4.20E-02	7.00E-02	ATSDR	7.00E-02	ATSDR	8.00E-01	IRIS	2.40E+00	IRIS	5.40E-03	Cal/EPA	1.10E-02	Cal/EPA
Dichlorobenzidine, 3,3 -	91-94-1	253.13	1.15E-09	7.24E+02	3.10E+00	2.59E-02	6.74E-06	132.00	1	0.1	1.30E-02	NA	NA	NA	NA	NA	NA	NA	NA	4.50E-01	IRIS	3.40E-01	Cal/EPA
Dichlorodiphenyldichloroethane (DDD)	72-54-8	320.04	2.70E-04	4.58E+04	1.60E-01	2.27E-02	5.79E-06	109.00	1	0.03	1.80E-01	2.00E-03	NCEA	2.00E-03	NCEA	NA	NA	NA	NA	2.40E-01	IRIS	6.90E-02	Cal/EPA
Dichlorodiphenyldichloroethene (DDE)	72-55-9	318.03	1.70E-03	8.64E+04	6.50E-02	2.38E-02	5.87E-06	89.00	1	0.03	1.60E-01	NA	NA	NA	NA	NA	NA	NA	NA	3.40E-01	IRIS	9.70E-02	Cal/EPA
Dichlorodiphenyltrichloroethane (DDT)	50-29-3	354.49	3.39E-04	6.78E+05	5.50E-03	1.99E-02	4.95E-06	108.50	1	0.03	2.70E-01	5.00E-04	IRIS	5.00E-04	IRIS	NA	NA	NA	NA	3.40E-01	IRIS	9.70E-02	IRIS
Dichlorophenoxyacetic acid, 2,4 -	94-75-7	221.04	3.52E-04	7.80E+01	6.77E+02	5.88E-02	6.49E-06	138.00	1	0.1	1.10E-01	1.00E-02	IRIS	1.00E-02	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Diethyl Phthalate	84-66-2	222.24	2.50E-05	8.22E+01	1.00E+03	2.49E-02	6.35E-06	-40.50	1	0.1	3.90E-03	8.00E-01	IRIS	8.00E+00	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Dimethylphenol, 2,4 -	105-67-9	122.17	3.89E-05	2.09E+02	7.87E+03	6.43E-02	8.69E-06	24.54	1	0.1	1.10E-02	2.00E-02	IRIS	2.00E-01	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Di-n-butyl Phthalate	84-74-2	278.35	1.84E-04	1.57E+03	1.12E+01	4.38E-02	7.86E-06	-35.00	1	0.1	2.40E-02	1.00E-01	IRIS	1.00E+00	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
1,3-Dinitrobenzene, *meta* -	99-65-0	168.11	2.00E-06	1.50E+02	8.61E+02	4.55E-02	8.46E-06	90.00	1	0.1	1.50E-02	1.00E-04	IRIS	1.00E-03	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Dinitrobenzene, 1,2 -	528-29-0	168.11	2.17E-06	2.00E+02	1.33E+02	3.95E-02	7.01E-06	118.50	1	0.1	2.10E-02	1.00E-04	NCEA	1.00E-03	NCEA	NA	NA	NA	NA	NA	NA	NA	NA
Dinitrotoluene, 2,4 -	121-14-2	182.14	2.21E-06	3.60E+02	2.70E+02	2.03E-01	7.06E-06	71.00	1	0.102	3.10E-03	2.00E-03	IRIS	2.00E-03	HEAST	NA	NA	NA	NA	6.80E-01	IRIS	NA	NA
Dinitrotoluene, 2,6 -	606-20-2	182.14	3.79E-06	4.55E+01	1.82E+02	3.70E-02	7.76E-06	66.00	1	0.099	2.10E-03	1.00E-03	NCEA	1.00E-02	NCEA	NA	NA	NA	NA	6.80E-01	IRIS	NA	NA
Endrin	72-20-8	380.91	2.60E-04	1.08E+04	2.50E-01	1.92E-02	4.74E-06	200.00	1	0.1	1.20E-02	3.00E-04	IRIS	2.00E-03	ATSDR	NA	NA	NA	NA	NA	NA	NA	NA
Ethylene Glycol	107-21-1	62.07	2.45E-06	1.00E+00	1.00E+06	1.08E-01	1.22E-05	-13.00	1	0.1	2.00E-04	2.00E+00	IRIS	2.00E+00	HEAST	4.00E+00	Cal/EPA	4.00E+00	Cal/EPA	NA	NA	NA	NA
Fluoranthene	206-44-0	202.26	3.87E-04	4.91E+04	1.20E-01	2.51E-02	6.35E-06	111.00	1	0.13	2.20E-01	4.00E-02	IRIS	4.00E-01	ATSDR	NA	NA	NA	NA	NA	NA	NA	NA
Fluorene	86-73-7	166.21	3.93E-03	7.71E+03	1.69E+02	4.40E-02	7.88E-06	114.80	1	0.13	9.10E-01	4.00E-02	IRIS	4.00E-01	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor	76-44-8	373.32	1.20E-02	9.53E+03	1.80E-01	2.23E-02	5.69E-06	95.50	1	0.1	8.60E-03	5.00E-04	IRIS	1.00E-04	ATSDR	NA	NA	NA	NA	4.50E+00	IRIS	1.30E+00	IRIS
Heptachlor Epoxide	1024-57-3	389.40	8.59E-04	8.32E+04	3.50E-01	2.19E-02	5.57E-06	160.00	1	0.1	3.10E+00	1.30E-05	IRIS	1.30E-05	HEAST	NA	NA	NA	NA	9.10E+00	IRIS	2.60E+00	IRIS
Hexachloro- 1,3 - Butadiene	87-68-3	260.76	4.21E-01	5.37E+04	3.20E+00	5.61E-02	6.16E-06	-21.00	1	0.1	8.10E-02	2.00E-04	HEAST	2.00E-04	ATSDR	NA	NA	NA	NA	7.80E-02	IRIS	2.20E-02	IRIS
Hexachlorobenzene	118-74-1	284.78	2.37E-02	8.00E+04	4.70E-03	5.42E-02	5.91E-06	231.80	1	0.1	1.30E-01	8.00E-04	IRIS	1.00E-04	NCEA	NA	NA	NA	NA	1.60E+00	IRIS	4.60E-01	IRIS
Hexachloroethane	67-72-1	236.74	1.59E-01	1.78E+03	7.70E+00	2.50E-03	6.80E-06	185.00	1	0.1	3.00E-02	1.00E-03	IRIS	1.00E-02	IRIS	NA	NA	5.81E+01	ATSDR	1.40E-02	IRIS	4.00E-03	IRIS
Indeno(1,2,3-c,d)pyrene	193-39-5	276.34	1.42E-05	3.47E+06	2.20E-05	2.25E-02	5.66E-06	163.60	1	0.13	1.00E+00	NA	NA	NA	NA	NA	NA	NA	NA	7.30E-01	IRIS	8.80E-02	NCEA
Isophorone	78-59-1	138.21	2.70E-04	4.68E+01	1.20E+04	6.23E-02	6.76E-06	-8.10	1	0.1	3.40E-03	2.00E-01	IRIS	2.00E+00	IRIS	2.00E+00	Cal/EPA	2.00E+00	Cal/EPA	9.50E-04	IRIS	NA	NA
Isopropylbenzene (Cumene)	98-82-8	120.19	4.70E-01	8.20E+02	5.00E+01	6.50E-02	7.10E-06	-96.00	1	0.1	4.10E-01	1.00E-01	IRIS	3.00E-01	IRIS	4.00E-01	IRIS	4.00E+00	IRIS	NA	NA	NA	NA
Lindane	58-89-9	290.83	2.10E-04	1.35E+03	7.30E+00	2.75E-02	7.34E-06	112.50	1	0.04	1.10E-02	3.00E-04	IRIS	3.00E-03	IRIS	NA	NA	NA	NA	1.10E+00	Cal/EPA	3.10E-01	Cal/EPA
m-cresol	108-39-4	108.14	3.50E-05	4.34E+02	2.27E+04	7.40E-02	1.00E-05	12.22	1	0.1	7.80E-03	5.00E-02	IRIS	5.00E-01	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Methoxychlor	72-43-5	345.65	8.30E-06	8.00E+04	4.00E-02	1.84E-02	4.46E-06	87.00	1	0.1	3.60E+00	5.00E-03	IRIS	5.00E-03	ATSDR	NA	NA	NA	NA	NA	NA	NA	NA

Physical/chemical Properties of Chemicals of Concern												TOXICITY FACTORS FOR CHEMICALS OF CONCERN											
												REFERENCE DOSES (RfD) & REFERENCE CONCENTRATIONS (RFderm)								SLOPE FACTORS (SF) & INHALATION UNIT RISKS (IUR)			
												Oral		Oral (Const)		Inhalation		Inhalation (Const)		Oral		Inhalation	
Chemical	CAS Number	MW (gm/mol)	Henry's Law Constant (H')	Koc (L/kg)	Water Solubility (mg/L H2O)	Air Diffusivity (cm2/s)	Water Diffusivity (cm2/s)	Melting Point (°C)	Oral Abs.	Dermal Abs.	PC (cm/hr)	(mg/kg-d)	Source	(mg/kg-d)	Source	(mg/m^3)	Source	(mg/m^3)	Source	$(mg/kg\text{-}d)^{-1}$	Source	$(mg/m^3)^{-1}$	Source
Methylnaphthalene, 1 -	90-12-0	142.19	2.10E-02	2.30E+03	2.58E+01	5.27E-02	7.84E-06	-22.00	1	0.13	2.55E+00	7.00E-02	ATSDR	7.00E-02	ATSDR	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	91-20-3	128.17	1.80E-02	1.19E+03	3.10E+01	5.90E-02	7.50E-06	80.20	1	0.13	4.70E-02	2.00E-02	IRIS	2.00E-01	IRIS	3.00E-03	IRIS	3.00E-03	IRIS	NA	NA	3.40E-02	Cal/EPA
Nitrobenzene	98-95-3	123.11	9.82E-04	1.19E+02	1.80E+03	7.60E-02	8.60E-06	5.70	1	0.1	2.60E-02	5.00E-04	IRIS	5.00E-03	IRIS	2.00E-03	HEAST	2.00E-02	HEAST	NA	NA	NA	NA
Nitrosodiphenylamine, *n* -	86-30-6	198.23	4.95E-05	1.29E+03	3.51E+01	2.83E-02	7.19E-06	66.50	1	0.1	1.50E-02	2.00E-02	NCEA	2.00E-02	NCEA	NA	NA	NA	NA	4.90E-03	IRIS	2.60E-03	Cal/EPA
o-cresol	95-48-7	108.14	4.91E-05	4.43E+02	2.59E+04	7.40E-02	8.30E-06	30.00	1	0.1	7.70E-03	5.00E-02	IRIS	5.00E-01	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Octyl Phthalate, di(*n*) -	117-84-0	390.56	1.84E-05	1.00E+05	2.00E-02	1.73E-02	4.17E-06	-25.00	1	0.1	3.52E+02	4.00E-02	NCEA	4.00E-01	NCEA	NA	NA	NA	NA	NA	NA	NA	NA
p-cresol	106-44-5	108.14	4.09E-05	4.34E+02	2.50E+04	7.40E-02	1.00E-05	35.50	1	0.1	7.70E-03	5.00E-03	HEAST	5.00E-03	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorophenol	87-86-5	266.34	1.00E-06	5.92E+02	1.40E+01	5.60E-02	6.10E-06	174.00	1	0.25	3.90E-01	3.00E-02	IRIS	1.00E-03	ATSDR	NA	NA	NA	NA	1.20E-01	IRIS	4.60E-03	Cal/EPA
Phenol	108-95-2	94.11	1.36E-05	2.88E+01	8.28E+04	8.20E-02	9.10E-06	40.91	1	0.1	4.30E-03	3.00E-01	IRIS	6.00E-01	HEAST	2.00E-01	Cal/EPA	2.00E-01	Cal/EPA	NA	NA	NA	NA
Polychlorinated Biphenyls	1336-36-3	291.99	1.70E-02	3.09E+05	7.00E-01	2.22E-02	8.00E-06	122.32	1	0.14	7.70E+01	2.00E-05	IRIS	6.00E-05	IRIS	NA	NA	NA	NA	2.00E+00	IRIS	1.00E-01	IRIS
Pyrene	129-00-0	202.26	4.91E-04	6.80E+04	1.35E-01	2.77E-02	7.24E-06	151.20	1	0.13	2.64E+00	3.00E-02	IRIS	3.00E-01	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Pyridine	110-86-1	79.10	4.50E-04	5.00E+01	1.00E+06	9.10E-02	7.60E-06	-41.60	1	0.1	4.00E-03	1.00E-03	IRIS	1.00E-02	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Silvex (2,4,5-T)	93-72-1	261.51	3.71E-07	8.04E+01	1.40E+02	2.30E-02	5.83E-06	181.60	1	0.1	5.10E-01	8.00E-03	IRIS	8.00E-03	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Toxaphene	8001-35-2	414.00	2.45E-04	9.58E+04	5.50E-01	2.16E-02	5.51E-06	77.00	1	0.1	1.20E-02	NA	NA	1.00E-03	ATSDR	NA	NA	NA	NA	1.10E+00	IRIS	3.20E-01	IRIS
Trichlorophenol, 2,4,5 -	95-95-4	197.45	6.54E-05	1.60E+03	1.20E+03	2.91E-02	7.03E-06	69.00	1	0.1	4.50E-01	1.00E-01	IRIS	1.00E+00	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Trichlorophenol, 2,4,6 -	88-06-2	197.45	1.06E-04	3.81E+02	8.00E+02	2.61E-02	6.36E-06	69.00	1	0.1	3.50E-02	NA	NA	NA	NA	NA	NA	NA	NA	1.10E-02	IRIS	3.10E-03	IRIS
Trimethylbenzene, 1,2,4	95-63-6	120.20	2.52E-01	7.20E+02	5.70E+01	6.06E-02	7.92E-06	-43.80	1	0.1	5.00E-01	5.00E-02	NCEA	5.00E-02	NCEA	6.00E-03	NCEA	6.00E-03	NCEA	NA	NA	NA	NA
Trimethylbenzene, 1,3,5	108-67-8	120.19	3.59E-01	6.60E+02	4.82E+01	6.02E-02	8.67E-06	-44.80	1	0.1	3.00E-01	5.00E-02	NCEA	5.00E-01	NCEA	6.00E-03	NCEA	6.00E-02	NCEA	NA	NA	NA	NA
Trinitrobenzene, 1,3,5 - (s)	99-35-4	213.11	1.35E-08	1.09E+03	2.78E+02	2.44E-02	6.15E-07	122.50	1	0.1	1.00E-02	3.00E-02	IRIS	5.00E-04	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl Acetate	108-05-4	86.09	2.09E-02	5.25E+00	2.00E+04	8.50E-02	9.20E-06	-93.20	1	0.1	5.00E-03	1.00E+00	HEAST	1.00E+00	HEAST	2.00E-01	IRIS	3.50E-02	ATSDR	NA	NA	NA	NA
Inorganic Analytes																							
Antimony	7440-36-0	121.75	NA	NA	2.30E+04	7.72E-02	9.57E-06	630.00	0.15	NA	1.00E-03	4.00E-04	IRIS	2.00E-04	NCEA	NA	NA	4.00E-04	NCEA	NA	NA	NA	NA
Arsenic, Inorganic	7440-38-2	74.92	NA	NA	3.47E+04	7.72E-02	9.57E-06	817.00	1	0.03	1.00E-03	3.00E-04	IRIS	3.00E-04	HEAST	NA	NA	NA	NA	1.50E+00	IRIS	4.30E+00	IRIS
Barium and Compounds	7440-39-3	137.327	NA	NA	5.48E+04	7.72E-02	9.57E-06	727.00	0.07	NA	1.00E-03	2.00E-01	IRIS	7.00E-02	HEAST	5.00E-04	HEAST	5.00E-03	HEAST	NA	NA	NA	NA
Beryllium and Compounds	7440-41-7	9.012	NA	NA	1.49E+05	7.72E-02	9.57E-06	1287.00	0.007	NA	1.00E-03	2.00E-03	IRIS	5.00E-03	HEAST	2.00E-05	IRIS	2.00E-05	IRIS	NA	NA	2.40E+00	IRIS
Cadmium	7440-43-9	112.41	NA	NA	1.23E+05	7.72E-02	9.57E-06	321.00	0.05	0.001	1.00E-03	5.00E-04	IRIS	5.00E-04	IRIS	NA	NA	9.00E-04	NCEA	NA	NA	1.80E+00	IRIS
Chromium (III)	16065-83-1	52.00	NA	NA	0.00E+00	NA	NA	1900.00	0.013	NA	1.00E-03	1.50E+00	IRIS	1.50E+00	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Chromium (VI)	18540-29-9	52.00	NA	NA	1.69E+06	NA	NA	1900.00	0.025	NA	2.00E-03	3.00E-03	IRIS	2.00E-02	HEAST	1.00E-04	IRIS	1.00E-04	IRIS	NA	NA	1.20E+01	IRIS
Chromium (Total)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cobalt	7440-48-4	58.93	NA	NA	0.00E+00	7.72E-02	9.57E-06	1495.00	1	NA	4.00E-04	2.00E-02	NCEA	2.00E-02	NCEA	2.00E-05	NCEA	2.00E-05	NCEA	NA	NA	2.80E+00	NCEA

Physical/chemical Properties of Chemicals of Concern											
Chemical	CAS Number	MW (gm/mol)	Henry's Law Constant (H')	Koc (L/kg)	Water Solubility (mg/L H2O)	Air Diffusivity (cm2/s)	Water Diffusivity (cm2/s)	Melting Point (°C)	Oral Abs.	Dermal Abs.	PC (cm/hr)
Cyanide, Free	57-12-5	26.02	NA	NA	9.54E+04	1.56E-01	1.77E-05	NA	1	NA	1.00E-03
Fluorine (soluble fluoride)	7782-41-4	37.997	NA	NA	1.69E+00	1.56E-01	1.71E-05	-219.61	1	NA	1.00E-03
Mercury	7439-97-6	200.59	NA	NA	6.00E-02	7.14E-02	3.01E-05	-38.87	1	NA	1.00E-03
Nickel (Soluble Salts)	Various	NA	NA	NA	NA	NA	NA	NA	0.04	NA	2.00E-04
Selenium and Compounds	7782-49-2	78.96	NA	NA	2.06E+03	7.72E-02	9.57E-06	221.00	1	NA	1.00E-03
Silver	7440-22-4	107.86	NA	NA	7.05E+04	7.72E-02	9.57E-06	960.50	0.04	NA	6.00E-04
Thallium	7440-28-0	204.38	NA	NA	2.65E+04	7.72E-02	9.57E-06	304.00	1	NA	1.00E-03
Vanadium	7440-62-2	50.9415	NA	NA	0.00E+00	7.72E-02	9.57E-06	1910.00	0.026	NA	1.00E-03
Zinc and Compounds	7440-66-6	65.38	NA	NA	3.44E+05	7.72E-02	9.57E-06	419.50	1	NA	6.00E-04

TOXICITY FACTORS FOR CHEMICALS OF CONCERN												
	REFERENCE DOSES (RfD) & REFERENCE CONCENTRATIONS (RFderm)								SLOPE FACTORS (SF) & INHALATION UNIT RISKS (IUR)			
	Oral		Oral (Const)		Inhalation		Inhalation (Const)		Oral		Inhalation	
Chemical	(mg/kg-d)	Source	(mg/kg-d)	Source	(mg/m^3)	Source	(mg/m^3)	Source	$(mg/kg\text{-}d)^{-1}$	Source	$(mg/m^3)^{-1}$	Source
Cyanide, Free	2.00E-02	IRIS	2.00E-02	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Fluorine (soluble fluoride)	6.00E-02	IRIS	6.00E-02	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Mercury	1.00E-04	IRIS	1.00E-04	HEAST	3.00E-04	IRIS	3.00E-04	HEAST	NA	NA	NA	NA
Nickel (Soluble Salts)	2.00E-02	IRIS	2.00E-02	HEAST	9.00E-05	ATSDR	2.00E-04	ATSDR	NA	NA	NA	NA
Selenium and Compounds	5.00E-03	IRIS	5.00E-03	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Silver	5.00E-03	IRIS	5.00E-03	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Thallium	8.00E-05	IRIS	8.00E-04	IRIS	NA	NA	NA	NA	NA	NA	NA	NA
Vanadium	9.00E-03	IRIS	9.00E-03	HEAST	NA	NA	NA	NA	NA	NA	NA	NA
Zinc and Compounds	3.00E-01	IRIS	3.00E-01	ATSDR	NA	NA	NA	NA	NA	NA	NA	NA

Table 3. Dermal Absorption Fraction from Soil [7]

Compound	Dermal Absorption Fraction (ABS)	Source
Acenapthylene	0.13	Wester et al. (1990)
Acenaphthene	0.13	Wester et al. (1990)
Anthracene	0.13	Wester et al. (1990)
Arsenic	0.03	Wester et al. (1993a)
Benzo(a)anthracene	0.13	Wester et al. (1990)
Benzo(a)pyrene	0.13	Wester et al. (1990)
Benzo(b)fluoranthene	0.13	Wester et al. (1990)
Benzo(k)fluoranthene	0.13	Wester et al. (1990)
Benzo(g,h,i)perylene	0.13	Wester et al. (1990)
Cadmium	0.001	Wester et al. (1992a)
Chlordane	0.04	Wester et al. (1992b)
Chrysene	0.13	Wester et al. (1990)
2,4-Dichlorophenoxyacetic acid	0.05	Wester et al. (1996)
Dibenz(a,h)anthracene	0.13	Wester et al. (1990)
4,4'-DDT	0.03	Wester et al. (1990)
2,4 -Dinitrotoluene	0.102	Reifenrath, WG et al. (2002)
2,6 -Dinitrotoluene	0.099	Reifenrath, WG et al. (2002)
Fluorene	0.13	Wester et al. (1990)
Fluoranthene	0.13	Wester et al. (1990)
Indeno(1,2,3-cd)pyrene	0.13	Wester et al. (1990)
Lindane (gamma BHC)	0.04	Duff & Kissel (1996)
1-Methylnaphthalene	0.13	Wester et al. (1990)
Naphthalene	0.13	Wester et al. (1990)
PCBs	0.14	Wester et al. (1993b)
Pentachlorophenol	0.25	Wester et al. (1993b)
Phenanthrene	0.13	Wester et al. (1990)
Pyrene	0.13	Wester et al. (1990)
TCDD and other dioxins -if soil organic content is >10%	0.03 0.001	U.S. EPA (1992)
Semivolatile organic compounds	0.1	U.S. EPA (2004)

Table 4. Oral – Dermal Adjustment [7]

Chemical	GI (oral) Adsorption					IRIS Critical Study			Adjust for dermal?
	Study reference	Study Year	Study Species	Dosing Regimen	% Adsorbed	Study Species	Dosing Regimen	Toxicity Factor	
Organics									
Chlordane	Ewing; Ohno	1985; 1986	rat	assume aqueous gavage	80%	Mice	diet; inhalation	SF; RfD	No
Dichlorophenoxyacetic acid, 2,4 -	Knopp; Pelletier	1992; 1989	rat	assume aqueous gavage	>90%	Rat	diet	RfD	No
Dichlorodiphenyltrichloroethane (DDT)	Keller	1980	rat	vegetable oil	70-90%	rat	dissolved in oil, mixed in diet	RfD	No
Pentachlorophenol	Korte; Meerman	1978; 1983	rat	diet; water	76%; 100%	rat	diet	RfD	No
Polychlorinated Biphenyls	Albro; Muhlebach	1972; 1981	rat	squalene; emulsion	96%; 80%	Rat	diet	SF	No
Polycyclic Aromatic Hydrocarbons	Chang; Hecht	1943; 1979	rat	diet; water	89%	mice	diet	SF	No
All Other Organic Chemicals	multiple	multiple	multiple	multiple	generally >50%	multiple	multiple	RfD or SF	No
Inorganics									
Antimony	Waitz	1965	rat	water	15%	rat	water	RfD	Yes
Arsenic, Inorganic	Bettley	1975	human	assume aqueous	95%	human	water	SF	No
Barium and Compounds	Cuddihy and Griffith; Taylor	1972; 1962	dog	water	7%	human	water	RfD	Yes
Beryllium and Compounds	Reeves	1965	rat	water	0.70%	rat	water	RfD	Yes
Cadmium	IRIS	1999	human	diet/water	2.5%; 5%	human	diet/water	RfD	Yes
Chromium (III)	Donaldson and Barreras; Keim	1996; 1987	rat	diet/water	1.30%	rat	diet	RfD	Yes
Chromium (VI)	Donaldson and Barreras; MacKenzie; Sayato	1996; 1959; 1980	rat	water	2.50%	rat	water	RfD	Yes
Mercury (elemental)	ATSDR	1999	human	acute inhalation of Hg vapor	74%-80%	human	inhalation	RFderm	No
Methyl Mercury	Aberg	1969	human	aqueous	95.00%	human	diet	RfD	No
Nickel (Soluble Salts)	Elakhovskaya	1972	human	diet/water	4.00%	rat	diet	RfD	Yes
Selenium and Compounds	Young	1982	human	diet	30-80%	human	diet	RfD	No
Silver	Furchner; IRIS	1968; 1999	dog	aqueous	4.00%	human	IV dose	RfD	Yes
Thallium	Lie	1960	rat	aqueous	100%	rat	water gavage	RfD	No
Vanadium	Conklin	1982	rat	gavage	2.60%	rat	diet	RfD	Yes
Zinc and Compounds	ATSDR	1994b	human	diet	highly variable	human	diet supplement	RfD	No

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Section II:

Exposure Factor Value Derivations and Justifications

Section II-1. Derivation of the Exposure Factor Values for Adult Residential Receptors

1. ($ED_{residential\text{-}adult}$) Exposure Duration: This term is defined by a custom probability distribution based on the U.S. Census 2000 Supplementary Survey Summary Tables for the residency occupancy period data for Ohio.

Years at One Residence	Relative Probability
1	0.078
2 to 5	0.378
6 to 10	0.154
11 to 20	0.156
21 to 30	0.107
31 to 50	0.127

The selected distribution is based on data for both rural and urban areas and both owner and renter occupied units.

2. ($EF_{residential\text{-}adult}$) Exposure Frequency: This term is defined by a triangular distribution based on climate data and best professional judgment.

	Ingestion and Inhalation	*Dermal Contact*
Maximum value:	365 days year $^{-1}$	365 events year^{-1}
Likeliest value:	330 days year^{-1}	330 events year^{-1}
Minimum value:	261 days year^{-1}	261 events year^{-1}

The maximum value assumes constant occupancy by a resident in an area of the state which does not have, on the average, one or more months of an average temperature below 32^{o} F. Based on the soil surveys for Ohio counties, this is applicable to residences in parts of southern Ohio.

The likeliest value assumes that a resident will have minimal exposure to soil from outside during 4 weeks (28 days) of frozen ground and one week (7 days) of vacation. The minimum value assumes a resident will have minimal exposure to soil from outside for 3 months (90 days), due to average temperatures below 32^{o} F primarily in northern counties in Ohio or by residents who spend winters away. In addition, during the warmer weather months, it is assumed a resident is away from his home for 2 weeks (14 days) vacation.

3. ($BW_{residential\text{-}adult}$) Body Weight: This term is defined by a normal distribution for an equal population of men and women from Finley, *et al*. (1994).

Arithmetic Mean:	71 kg
Standard Deviation:	15.9 kg
Minimum:	32 _kg
Maximum:	115 _kg

The minimum body weight was truncated at the lower end of the distribution at 32 kg accounting for elderly residents who may weigh less than other adults considered in the industrial worker scenario.

Reference: Finley, B., Proctor, D., Scott, P., Harrington, N., Paustenbach, D., and Price, P. (1994). Recommended distributions for exposure factors frequently used in health risk assessment. *Risk Analysis* 14(4):533-553. These values from Table II, for age > 18 years, both genders.

4. ($IR\ so_{\text{residential-adult}}$) Soil Ingestion Rate: This term is defined by a uniform distribution based on the following key studies: Binder *et al*. (1986); Calabrese *et al*. (1989); Calabrese *et al.* (1990); Calabrese *et al.* (1997); Clausing *et al.* (1987), Davis *et al*. (1990); Hawley (1985); Stanek *et al.* (1997); Van Wijnen *et al.* (1990); and Walker and Griffin (1998).

Minimum:	10 mg day^{-1}
Maximum:	200 mg day^{-1}

The U.S. EPA standard default value for soil ingestion for adults in a residential setting of 100 mg day $^{-1}$ is derived as one-half of the 200 mg day^{-1} default average soil ingestion rate for children. The key studies indicate a range of 10 mg day^{-1} to 250 mg day^{-1} for average soil ingestion rates for children (the upper percentile recommended value for children is 400 mg day $^{-1}$, without including pica behavior), and adult daily soil ingestion range of 10 mg day^{-1} to 200 mg day^{-1}. Because of the high level of uncertainty associated with the limited data in the literature, upper bound values were not incorporated into the distribution, and rather a protective estimate of average values was used, including 200 mg/day which is a 90th percentile of the median of the best four trace elements reported by Stanek et al. (1997). The uniform distribution was selected as representative of adult soil ingestion rates for the range of residential activities including regular indoor activities as well as working in attics and other dusty places, and outdoor activities such as gardening and yard work.

References: Binder, S., Sokal, D., and Maughan, D. (1986. Estimating soil ingestion: the use of tracer elements in estimating the amount of soil ingested by young children. *Archives of Environmental Health* 41(6):341-345.

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5. ($FI_{residential\text{-}adult}$) Fraction of Ingested of Soil that is Contaminated; ($Fderm_{residential\text{-}adult}$) Fraction of Dermally Contacted Soil that is Contaminated; And ($Finh_{residential\text{-}adult}$) Fraction of Air Inhaled Containing Volatiles and Particulates from Soil that is Contaminated:

   These terms represent the proportion of soil that is contaminated by the chemical of concern at a Property. The terms are expressed as the fraction of the surface area of the Property which is represented by the identified area(s) or exposure unit(s) for that chemical of concern and assumes random activity and exposure patterns for a particular receptor at a Property. Thus exposure to soil concentrations of a chemical of concern, as represented by the exposure point concentration determined from the analytical results from the soil samples in the identified area(s) or exposure unit(s), is assumed to occur only for those parts of the Property where the chemical of concern has been identified and quantified. On a property-specific basis, the terms can be uniquely constructed for each chemical of concern, or groups of chemicals of concern which are associated with a particular identified area(s) or exposure unit(s), in accordance with paragraph (D)(3)(b)(iv)(*a*) of rule 3745-300-09 of the Administrative Code. If these terms are determined separately for each chemical of concern, the terms determined for each chemical of concern must be determined on the basis of all identified areas or exposure units on a Property for which the chemical of concern has been identified and from which the exposure point concentration has been determined. Alternatively, the terms determined on a Property-specific basis may consider the spatial distribution of the chemical(s) of concern and the receptor activity patterns on a Property; the derivation of such property-specific $FI_{residential\text{-}adult}$, $Fderm_{residential\text{-}adult}$, and $Finh_{residential\text{-}adult}$ terms on the basis of receptor activity patterns and their relationship to the identified area(s) or exposure unit(s) must be performed in accordance with paragraph (D)(3)(b)(iv)(*b*) of rule 3745-300-09 of the Administrative Code. For purposes of the generic numerical direct-contact soil standards, these terms have been defined by a uniform distribution:

Minimum: 0.01 (unitless)
Maximum: 1.00 (unitless)

A uniform distribution assumes equal probability of all combinations of contamination and activity patterns upon a property. For purposes of the generic numerical direct-contact soil standards, these terms have been defined by a uniform distribution from which, for each iteration, a value is selected for the $FI_{residential\text{-}adult}$ term; the correlation between the Fraction Ingested, Fraction Dermally Contacted and Fraction Inhaled terms was accounted for by setting the value for the $Fderm_{residential\text{-}adult}$ and $Finh_{residential\text{-}adult}$ terms equal to the value selected from the $FI_{residential\text{-}adult}$ distribution such that, for each iteration:

$$FI_{residential\text{-}adult} = Fderm_{residential\text{-}adult} = Finh_{residential\text{-}adult} .$$

In the course of performing a Property-specific risk assessment, distributions may be developed for each of the $FI_{residential\text{-}adult}$, $Fderm_{residential\text{-}adult}$ and $Finh_{residential\text{-}adult}$ terms. In this case, the selection of a value from a distribution for the $FI_{residential\text{-}adult}$ term may be correlated to the selection of a value from the distributions for the $Fderm_{residential\text{-}adult}$ and $Finh_{residential\text{-}adult}$ terms on a Property-specific basis in accordance with paragraph (D)(3)(b)(iv) of rule 3745-300-09 of the Administrative Code.

6. (<u>$SA_{residential\text{-}adult}$</u>) <u>Skin</u> <u>Surface</u> <u>Area</u> <u>Exposed</u>: This term is defined as the product of the two distributions described as follows, Total Skin Surface Area and Percent Skin Surface Area Exposed:

$$SA_{residential\text{-}adult} = SAtotal_{residential\text{-}adult} \times SAfrac_{residential\text{-}adult}$$

These two distributions are described as follows:

6a. ($SAtotal_{residential-adult}$) <u>Total</u> <u>Skin</u> <u>Surface</u> <u>Area</u>: This distribution is dependent upon the distribution for Body Weight ($BW_{residential-adult}$) by means of a distribution of surface area to body weight ratios derived by Phillips *et al*. (1993), who observed a strong correlation between surface area and body weight. The total skin surface area for adults was calculated based on the following Equation:

$$SAtotal_{residential-adult}\ (cm^2) = x\ cm^2\ kg^{-1} \times BW_{residential-adult}\ (kg),$$

Based on a correlation coefficient between the surface area to body weight ratio and body weight, *x* is selected from a distribution of surface area to body weight ratios for male and female adults aged 18 years and older described as follows:

Minimum:	200 $cm^2\ kg^{-1}$
Mean:	284 $cm^2\ kg^{-1}$
Maximum:	351 $cm^2\ kg^{-1}$
Standard deviation:	28 $cm^2\ kg^{-1}$

The correlation coefficient of -0.841 for the relationship of adult surface area: body weight ratio to body weight was derived on the basis of personal communication with Phillips (1996).

Reference: Phillips, L.J., Fares, R.J., and Schweer, L.G. (1993). Distributions of total skin surface area to body weight ratios for use in dermal exposure assessments. *J. Expos. Anal. Environ. Epid.* 3:331-338.

Phillips, L.J. personal communication with Ohio EPA, 17 October 1996.

6b. ($SAfrac_{residential-adult}$) <u>Percent</u> <u>Skin</u> <u>Surface</u> <u>Area</u> <u>Exposed</u>: This term is defined by a triangular distribution based upon assumptions about clothing associated with various residential activity and season scenarios and, consequently, the proportion of total skin surface area corresponding to the exposed body parts.

Maximum:	0.59
Likeliest:	0.42
Minimum:	0.17

The dermal contact pathway is an event-driven pathway, assuming that single or multiple contact events with soil per day result in an exposure to total dose. The quantification of daily exposure through the dermal contact pathway is therefore independent of the time spent in contact with the soil.

The minimum value assumes that a resident is wearing short-sleeved shirt and pants and that the hands, forearms, head and neck are exposed in the eight warm weather months per year, and that only the hands and head are exposed in the four cold weather months per year. The body part surface areas for the exposed areas for each weather period were added and a time-weighted average value for the year thus derived.

The likeliest value assumes that a resident is wearing short pants and short-sleeved shirt and that the head, neck, forearms, hands, legs and feet (allowing for bare feet or sandal shoes) are exposed in the eight warm weather months per year, and that only the head and hands are exposed in the four cold weather months per year. The body part surface areas for the exposed areas for each weather period were added and a time-weighted average value for the year thus derived.

The maximum value assumes that a resident is wearing short pants, and that the head, neck, arms, hands, one-half the trunk and legs and feet (allowing for bare feet or sandal shoes) are exposed in the eight warm weather months per year and that only the head and hands are exposed in the cold weather months per year. The body part surface areas for the exposed areas for each weather period were added and a time-weighted average value for the year thus derived.

Reference: U.S. EPA. (1997). *Exposure Factors Handbook.* EPA/600/8-89/043.

7. ($AF_{\text{residential-adult}}$) Soil Skin Adherence Factor: This term is defined by a triangular distribution based the data presented in Exhibit 3-3 of RAGS Part E.

Minimum:	0.01	mg cm^{-2}
Likeliest:	0.07	mg cm^{-2}
Maximum:	0.3	mg cm^{-2}

References: U.S. EPA. 2004. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment*. EPA/540/R/99/005. July 2004.

8. (ABS) Absorption Factor. Chemical-specific. Refer to Table 3 in Section I.

9. (AT) Averaging Time.

for Non-carcinogens: ATncar $= ED \times 365 \text{ days year}^{-1}$ $= 10950$ days

for Carcinogens: ATcar $= 70 \text{ years} \times 365 \text{ days year}^{-1}$ $= 25550$ days

References: U.S. EPA. (1989). *Risk assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A.* EPA/540/1-89/002.

U.S. EPA. (1991). *Human Health Exposure Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER Directive 9285.6-03.

10. (CF) Conversion Factor. Point value.

$$CF = 1 \times 10^{-6} \text{ kg mg}^{-1}$$

Reference: U.S. EPA (1989). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A.* EPA/540/1-89/002.

11. (VF) Volatilization Factor: This term is defined as a point value, which is calculated on a chemical-specific basis, according to the equation described in Equation 2 in Section I -1 of this document. Calculation of the VF term requires chemical-specific values for the following as described by U.S. EPA (1996):

- D_i: Diffusivity in air ($cm^2 s^{-1}$)
- H': Dimensionless Henry's law constant
- D_w: Diffusivity in water ($cm^2 s^{-1}$)
- K_d: Soil-water partitioning coefficient ($cm^3 g^{-1}$)
- K_{oc}: Soil organic carbon-water partitioning coefficient ($cm^3 g^{-1}$),

Reference: U.S. EPA. (1996). *Soil Screening Guidance: Technical Background Document.* Section 2.4.2. Office of Solid Waste and Emergency Response. EPA/540/R-95/128. PB96-963502. May 1996. 168 pp. plus appendices.

12. (T) Exposure Interval for Volatilization: This term is defined as a point value and is used for the calculation of the Volatilization Factor.

$$T = 9.5 \times 10^8 \text{ s}$$

Reference: U.S. EPA. 1996. *Soil Screening Guidance: Technical Background Document.* Section 2.4.5. Office of Solid Waste and Emergency Response. EPA/540/R-95/128. PB96-963502. May 1996. 168 p. plus appendices.

13. (PEF) Particulate Emissions Factor: This term is defined as a point value calculated according to the methodology described in Section I of this document. It incorporates climate data from Cleveland, Ohio.

$$PEF = 9.24 \times 10^8 \text{ m}^3 \text{ kg}^{-1}$$

Calculation of this term on a Property-specific basis as described in Equation 3 Section I-

1 of this document and must be performed in accordance with paragraph (D)(3)(b)(iv)(*a*) of rule 3745-300-09 of the Administrative Code.

Reference: U.S. EPA (. 1996). *Soil Screening Guidance: Technical Background Document.* Section 2.4.5. Office of Solid Waste and Emergency Response. EPA/540/R-95/128. PB96-963502. May 1996. 168 pp. plus appendices.

Section II-2. Derivation of the Exposure Factor Values for Child Residential Receptors

1. ($ED_{residential\text{-}child}$) Exposure Duration: This term is defined by a custom probability distribution based on U.S. Census 2000 Supplementary Survey Summary Tables for the residency occupancy period data for Ohio.

Years at One Residence	Relative Probability
1	0.078
2 to 5	0.378
6	0.544

The adult distribution was used for the child receptor except that all the probabilities above 6 years were truncated and added to the sixth year. If the simulation picks up a number higher than six years, then this distribution assures that a maximum of 6 years are accounted for a child.

2. ($EF_{residential\text{-}child}$) Exposure Frequency: This term is defined by a triangular distribution based on climate data and best professional judgment.

	Ingestion and Inhalation	*Dermal Contact*
Maximum value:	365 days $year^{-1}$	365 events $year^{-1}$
Likeliest value:	330 days $year^{-1}$	330 events $year^{-1}$
Minimum value:	261 days $year^{-1}$	261 events $year^{-1}$

The maximum value assumes constant occupancy by a child resident in an area of the state which does not have, on the average, one or more months of an average temperature below 32°F. Based on the soil surveys for Ohio counties, this is applicable to residences in southern Ohio.

The likeliest value assumes that a child will have minimal exposure to soil from the property during 4 weeks (28 days) of frozen ground and one week (7 days) of vacation. The minimum value assumes a child will have minimal exposure to soil from outside during 3 months (90 days) due to average temperatures below 32°F, primarily in northern Ohio counties, or due to children that spend time away from one residence to live at another residence based on divorce/joint custody cases. In addition, during the warmer weather months, it is assumed a child is away from the residence for 2 weeks (14 days) vacation.

3. ($BW_{residential\text{-}child}$) Body Weight: This term is defined as a normal distribution for an equal population of male and female children from Smith (1994).

Mean:	15 kg
Standard deviation:	2.00 kg

Reference: Smith, R.L. (1994). Use of Monte Carlo simulation for human exposure assessment at a Superfund site. *Risk Analysis* 14:433-439.

4. (IR soil $_{residential\text{-}child}$) Soil Ingestion Rate: Custom distribution based on the following key studies for children: Binder et al. (1986); Bruhn and Panghorn (1971); Calabrese et al. (1989); Calabrese et al. (1997); Clausing et al. (1987); Danford (1982); Davis et al. (1990); Van Wijnen et al. (1990); and Walker and Griffin (1998).

Range	Relative Probability
10 to 100 mg per day	0.2
101 to 250 mg per day	0.6
251 to 592 mg per day	0.2

Soil ingestion studies cited for the determination of the soil ingestion rate are based on studies in which the subjects (children) were generally outside for limited time periods for play, etc. The studies measured daily soil ingestion rates with the children being outside for normal activity patterns, including play, but not for the whole day or for extended periods of the day. Therefore, corrections for indoor versus outdoor time are not appropriate, and no hourly adjustments are made. In addition, children tend to exhibit periods of intensive mouthing behavior which results in soil and dust being transferred from their hands and play objects to their mouths. Child soil ingestion is considered here to be more of an event or periodic occurrence and less a continual process.

10 to 100 mg day^{-1}: relative probability 0.2. This lower range accounts for the lower estimates of soil ingestion reported in the key studies.

101 to 250 mg day^{-1}: relative probability 0.6. This range is based on an analysis of the mean soil ingestion estimates for children summarized in the key studies. These key studies vary in survey designs and study populations and several account for food and non-food sources of trace elements. Several studies adjust the soil ingestion rates to account for household dust. The mean soil ingestion estimates from these key studies are relatively consistent and generally fall within this range.

251 to 590 mg day^{-1}: relative probability 0.2. This upper range accounts for the upper percentile values reported in the key studies. It also attempts to account for the prevalence of soil pica behavior. Bruhn and Pangborn (1971) estimated that the prevalence of pica for "dirt" was approximately 19 percent for children. A number of articles in the scientific literature report the incidence of pica for substances other than

soil itself and include sand, clay, paint, paper, etc. These studies report pica incidence rates between 10 and 60 percent (Lourie *et al.* 1963; Vermeer and Frate 1979; Danford 1982; Kaplan and Sadock 1985; Sayetta 1986). The Calabrese *et al*. (1989) study included one pica child with an average soil ingestion rate of 5 to 7 g day^{-1}. However, significant pica behavior generally occurs for a short time period and not for the entire duration of exposure.

The upper range for the child soil ingestion rate was derived by defining a pica period (4 years duration) and a normal period (2 years duration) for the upper end of the population distribution. Pica soil ingestion was calculated as a soil ingestion rate of 1000 mg day^{-1} for 4 days week^{-1} and 500 mg day^{-1} for 3 days week^{-1}. The normal period ingestion rate was set uniformly at 200 mg day^{-1}. The derivation can be mathematically expressed as follows:

$$
\begin{array}{lllll}
 & 1000 \text{ mg day}^{-1} & \times (4 \text{ day}/ 7 \text{ day}) & \times (4 \text{ year} / 6 \text{ year}) & = 381 \\
+ & 500 \text{ mg day}^{-1} & \times (3 \text{ day} / 7 \text{ day}) & \times (4 \text{ year} / 6 \text{ year}) & = 143 \\
+ & \underline{200 \text{ mg day}^{-1}} & \underline{\times (7 \text{ day} / 7 \text{ day})} & \underline{\times (2 \text{ year} / 6 \text{ year})} & \underline{=\ 67} \\
 & & & & 591 \text{ mg day}^{-1}
\end{array}
$$

References: Binder, S., Sokal, D., and Maughan, D. (1986). Estimating soil ingestion: the use of tracer elements in estimating the amount of soil ingested by young children. *Archives of Environmental Health* 41(6):341-345.

Bruhn, C.M. and Pangborn, R.M. (1971). Reported incidence of pica among migrant families. *Journal of the American Dietetic Association* 58:417-420.

Calabrese, E.J., Barnes, R., Stanek, E.J., Pastides, H., Gilbert, C.E., Veneman, P., Wang, X., Lasztity, A. and Kostecki, P. (1989). How much soil do young children ingest: an epidemiologic study.? *Regulatory Toxicology and Pharmacology* 10:123-137.

Calabrese, E.J., Stanek, E.J., Pekow, P., and Barnes, R.M. (1997). Soil ingestion estimates for children residing on a superfund site. *Ecotox. Environ. Safety.* 36:258-268.

Clausing, P., Brunekreef, B., and van Wijnen, J.H. (1987). A method for estimating soil ingestion by children. *Int Arch Occup Environ Health* 59:73-82.

Danford, D.C. (1982). Pica and nutrition. *Annual Review of Nutrition* 2:303-322.

Davis, S., Walker, P., Buschbom, R., Ballou, J. And White, P. (1990).

Quantitative estimates of soil ingestion in normal children between the ages of 2 and 7 years: population-based estimates using aluminum, silicon, and titanium as soil tracer elements. *Archives of Environmental Health* 45:112-122.

Kaplan, H.I., and Sadock, B.J. (1985). Comprehensive textbook of psychiatry/IV. Baltimore, MD: Williams and Wilkins.

Lourie, R.S., Layman, E.M., and Millican, F.K. (1963). Why children eat things that are not food. *Children* 10:143-146.

Sayetta, R.B. (1986). Pica: an overview. *American Family Physician* 33(5):181-185.

Van Wijnen, J.H., Clausing, P. And Brunekreef, B. (1990). Estimated soil ingestion by children. *Environmental Research* 51:147-162.

Vermeer, D.E. and Frate, D.A. (1979). Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications. *Am. J. Clin. Nutr.* 32:2129-2135.

Walker, S., and Griffin, S. (1998). Site-specific data confirm arsenic exposure predicted by the U.S. Environmental Protection Agency. *Environ. Health Perspectives.* 106(3):133-139.

5. ($FI_{residential\text{-}child}$) Fraction Ingested of Soil that is Contaminated;
($Fderm_{residential\text{-}child}$) Fraction of Dermally Contacted Soil that is Contaminated;
And ($FInh_{residential\text{-}child}$) Fraction of Air Inhaled Containing Volatiles and Particulates from Soil that is Contaminated::

These terms represent the proportion of soil that is contaminated by the chemical of concern at a Property. The terms are expressed as the fraction of the surface area of the Property which is represented by the identified area(s) or exposure unit(s) for that chemical of concern and assumes random activity and exposure patterns for a particular receptor at a Property. Thus exposure to soil concentrations of a chemical of concern, as represented by the exposure point concentration determined from the analytical results from the soil samples in the identified area(s) or exposure unit(s), is assumed to occur only for those parts of the Property where the chemical of concern has been identified and quantified. On a property-specific basis, the terms can be uniquely constructed for each chemical of concern, or groups of chemicals of concern which are associated with a particular identified area(s) or exposure unit(s), in accordance with paragraph (D)(3)(b)(iv)(*a*) of rule 3745-300-09 of the Administrative Code. If these terms are determined separately for each chemical of concern, the terms determined for each chemical of concern must be determined on the basis of all identified areas or exposure unit(s) on a Property for which the chemical of concern has been identified and from which the exposure point concentration has been determined. Alternatively, the terms determined on a Property-specific basis may consider the spatial distribution of the chemical(s) of concern and the receptor activity patterns on a Property; the derivation of such property-specific $FI_{residential\text{-}child}$, $Fderm_{residential\text{-}child}$, and $Finh_{residential\text{-}child}$ terms on the basis of receptor activity patterns and their relationship to the identified area(s) or exposure unit(s) must be performed in accordance with paragraph (D)(3)(b)(iv)(*b*) of rule 3745-300-09 of the Administrative Code. For purposes of the generic numerical direct-contact soil standards, these terms have been defined by a uniform distribution:

Minimum:	0.01 (unitless)
Maximum:	1.00 (unitless)

A uniform distribution assumes equal probability of all combinations of contamination and activity patterns upon a property. For purposes of the generic numerical direct-contact soil standards, these terms have been defined by a uniform distribution from which, for each iteration, a value is selected for the $FI_{residential\text{-}child}$ term; the correlation between the Fraction Ingested, Fraction Dermally Contacted and Fraction Inhaled terms was accounted for by setting the value for the $Fderm_{residential\text{-}child}$ and $Finh_{residential\text{-}child}$ terms equal to the value selected from the $FI_{residential\text{-}child}$ distribution such that, for each iteration:

$$FI_{residential\text{-}child} = Fderm_{residential\text{-}child} = Finh_{residential\text{-}child}$$

In the course of performing a Property-specific risk assessment, distributions may be developed for each of the $FI_{residential\text{-}child}$, $Fderm_{residential\text{-}child}$ and $Finh_{residential\text{-}adult}$ terms. In this case, the selection of a value from a distribution for the $FI_{residential\text{-}child}$ term may be correlated to the selection of a value from the distributions for the $Fderm_{residential\text{-}child}$ and $Finh_{residential\text{-}child}$ terms on a Property-specific basis in accordance with paragraph (D)(3)(b)(iv) of rule 3745-300-09 of the Administrative Code.

6. ($SA_{residential\text{-}child}$) <u>Skin Surface Area Exposed</u>: This term is defined as the product of the two distributions described as follows, Total Skin Surface Area and Fraction Skin Surface Area Exposed:

$$SA_{residential\text{-}child} = SAtotal_{residential\text{-}child} \times SAfrac_{residential\text{-}child}$$

These two distributions are described as follows:

6a. ($SAtotal_{residential\text{-}child}$) <u>Total Skin Surface Area</u>: This distribution is dependent upon the distribution for Body Weight ($BW_{residential\text{-}child}$) by means of a distribution of surface area to body weight ratios derived by Phillips *et al*. (1993), who observed a strong correlation between surface area and body weight. The total skin surface area for children was calculated based on the following Equation:

$$SAtotal_{residential\text{-}child}\,(cm^2) = x\ cm^2\ kg^{-1} \times BW_{residential\text{-}child}\,(kg).$$

Where, based on a correlation coefficient between the surface area to body weight ratio and body weight, *x* is selected from a distribution of surface area to body weight ratios for male and female children, aged 2.1 to 17.9 years of age.

Minimum:	268 cm^2 kg^{-1}
Mean:	422 cm^2 kg^{-1}
Maximum:	670 cm^2 kg^{-1}
Standard deviation:	76 cm^2 kg^{-1}

The correlation coefficient of -0.819 for the relationship of child surface area: body weight ratio to body weight was derived on the basis of personal communication with Phillips (1996).

Reference: Phillips, L.J., Fares, R.J., and Schweer, L.G. (1993). Distributions of total skin surface area to body weight ratios for use in dermal exposure assessments. *J. Expos. Anal. Environ. Epid.* 3:331-338.

Phillips, L.J. personal communication with Ohio EPA, 17 October 1996.

6b. ($SAfrac_{residential-child}$) <u>Fraction</u> <u>Skin</u> <u>Surface</u> <u>Area</u> <u>Exposed</u>: This term is defined by a triangular distribution based upon assumptions about clothing associated with various residential activity and season scenarios and, consequently, the proportion of total skin surface area corresponding to the exposed body parts.

Minimum:	0.24
Likeliest:	0.46
Maximum:	0.62

The dermal contact pathway is an event-driven pathway, assuming that single or multiple contact events with soil per day result in an exposure to total dose. The quantification of daily exposure through the dermal contact pathway is therefore independent of the time spent in contact with the soil.

All values were derived from data in U.S. EPA (1989). The values for the proportion of body part surface area were determined from the average of the sum of the mean values for the age cohorts <1, 1<2, 2<3, 3<4, 4<5 and, to represent a value for 5<6 for which no data existed, {(4<5 + 6<7) / 2}. The values in this distribution were calculated as a time-weighted average of the exposed surface area in four cold weather months and the skin surface area exposed during eight warm weather months. The minimum, likeliest and maximum fraction skin surface area exposed for the cold weather months was determined from the same exposure scenario, and assumed a child with only head and hands exposed. The fraction skin surface area exposed for the eight warm weather months were defined as follows:

The minimum value assumes that a child resident is wearing short-sleeved shirt and pants and that the hands, forearms, head and neck are exposed during the warm weather months.

The likeliest value assumes that a child resident is wearing short-sleeved shirt and short pants and that hands, forearms, head, neck, legs and feet (allowing for bare feet or sandal shoes) are exposed during the warm weather months.

The maximum value assumes that a child resident is wearing short pants and that the hands, head, neck, arms, legs and one-half the trunk are exposed during the warm weather months.

Reference: U.S. EPA (1997). *Exposure Factors Handbook.* EPA/600/8-89/043.

7. ($AF_{residential\text{-}child}$) Soil Skin Adherence Factor: This term is defined by a triangular distribution based on Exhibit 3-3 in RAGS Part E.

Minimum:	0.04	mg/cm^2
Likeliest:	0.2	mg/cm^2
Maximum:	0.4	mg/cm^2

The minimum value combines central tendency weighted AFs for children primarily indoors and in a day care setting, as well as upper bound AFs for children in a day care setting.

The likeliest value combines upper bound weighted AFs for children in a day care setting and also incorporates periodic exposures to wet soil.

The maximum value combines upper bound weighted AFs for children playing in dry soil and also incorporates periodic exposures to wet soil.

References: U.S. EPA. 2004. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment*. EPA/540/R/99/005. July 2004.

8. (ABS) Absorption Factor. Chemical-specific. Refer to Table I in Section I.

9. (AT) Averaging Time.

for Noncarcinogens: $ncAT = ED \times 365 \text{ days year}^{-1}$

for Carcinogens (point value): $cAT = 70 \text{ years} \times 365 \text{ days year}^{-1} = 25550 \text{ days}$

References: U.S. EPA (1989). *Risk Assessment Guidance for Superfund, Volume I:*

Human Health Evaluation Manual, Part A. Exhibit 6-14. EPA/540/1-89/002.

U.S. EPA (1991). *Human Health Exposure Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER Directive 9285.6-03.

10. (CF) Conversion Factor: This term is defined as a point value.

$$CF = 1 \times 10^{-6}\ kg\ mg^{-1}$$

Reference: U.S. EPA (1989). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A.* Exhibit 6-14. EPA/540/1-89/002.

11. (VF) Volatilization Factor: This term is defined as a point value, which is calculated on a chemical-specific basis, according to Equation 3 in Section I-1 of this document. Calculation of the VF term requires chemical-specific values for the following as described by U.S. EPA (1996):

D_i: Diffusivity in air ($cm^2\ s^{-1}$)
H′: Dimensionless Henry's law constant
D_w: Diffusivity in water ($cm^2\ s^{-1}$)
K_d: Soil-water partitioning coefficient ($cm^3\ g^{-1}$)
K_{oc}: Soil organic carbon-water partitioning coefficient ($cm^3\ g^{-1}$),

Reference: U.S. EPA (. 1996). *Soil Screening Guidance: Technical Background Document.* Section 2.4.2. Office of Solid Waste and Emergency Response. EPA/540/R-95/128. PB96-963502. May 1996. 168 pp. plus appendices.

12. (T) Exposure Interval for Volatilization: This term is defined as a point value and is used for the calculation of the Volatilization Factor.

$$T = 9.5 \times 10^{8}\ s$$

Reference: U.S. EPA. 1996. *Soil Screening Guidance: Technical Background Document.* Section 2.4.5. Office of Solid Waste and Emergency Response. EPA/540/R-95/128. PB96-963502. May 1996. 168 p. plus appendices.

13. (PEF) Particulate Emissions Factor: This term is defined as a point value calculated according to the methodology described in Section I-1 of this document. It incorporates climate data from Cleveland, Ohio.

$$PEF = 9.24 \times 10^{8}\ m^{3}\ kg^{-1}$$

Calculation of this term on a Property-specific basis as described Equation 3 of Section I - 1 of this document must be performed in accordance with paragraph (D)(3)(b)(iv)(*a*) of rule 3745-300-09 of the Administrative Code.

Reference: U.S. EPA (. 1996). *Soil Screening Guidance: Technical Background Document.* Section 2.4.5. Office of Solid Waste and Emergency Response. EPA/540/R-95/128. PB96-963502. May 1996. 168 pp.. plus appendices.

Section II-3. Derivation of the Exposure Factor Values for Commercial and Industrial Receptors

1. ($ED_{commercial/industrial}$) Exposure Duration: This term is defined by a custom probability distribution based on the U.S. Bureau of Labor Statistics 2000 tenure data.

Years at One Job	Relative Probability
1	0.202
2 to 5	0.284
6 to 9	0.197
10 to 14	0.131
15 to 19	0.072
20 to 40	0.116

The relevant criterion for determining the Exposure Duration value is the length of worker's employment at a particular property. The available data set which was determined to best represent this term is employment tenure with a specific employer. The selected distribution is based on the data obtained through a Bureau of Labor Statistics survey which posed questions relating to age and length of current employment. These survey results do not exactly satisfy the requirements of the Exposure Duration term. For instance it does not account for how much longer younger workers will stay at the present job; for older workers, this survey does not account for worker tenures at jobs previous to the present one. The distribution for the Exposure Duration term was derived, however, by using survey data for workers age 25 and older in all worker categories. The survey data for relatively young workers (ages 16-24) were not used because these workers were judged to be too transient to be representative of the chronically exposed worker population.

2. ($EF_{commercial/industrial}$) Exposure Frequency: This term is defined by a triangular distribution based on climate patterns in different regions of Ohio, and assumptions about the vacation leave, sick leave, holidays, and part-time/full-time status accrued to workers.

Pathway:	*Ingestion and Inhalation*	*Dermal Contact*
Maximum value:	290 days $year^{-1}$	290 events $year^{-1}$
Likeliest value:	214 days $year^{-1}$	214 events $year^{-1}$
Minimum value:	132 days $year^{-1}$	132 events $year^{-1}$

The maximum value assumes that a worker is present at the location of employment for 290 days per year (6 days per week for 50 weeks, subtracting out 2 week vacation time and 10 days heavy rain precluding outside work). This is applicable to a worker in southern Ohio who is not affected by extreme weather conditions like frozen conditions or snow cover during winter, but is affected by 10 days heavy rain per year. Climate data indicate that some southern counties in Ohio have no months with an average air temperature below 32^{o}F and thus no days when frozen or snow-covered ground would preclude exposure.

The likeliest value assumes that a worker is present at the location for 214 days per year. This is based on a normal work schedule of 5 days per week for 52 weeks, subtracting out 10 days of vacation time, 6 days of holiday, 20 working days when frozen or snow-covered conditions preclude exposure, and 10 days when heavy rain precludes outdoor exposure. Climate data indicate that the number of months when the average monthly temperature is below 32^{o}F varies across Ohio from none (southern counties) to 3 months (northern counties), with many counties indicating 2 months with an average monthly temperature of below 32^{o} F. These data also indicate that Ohio generally has about 20 days per year during non-winter months with rainfall of 0.5 inch or more. Some of the frozen or snow covered days of these months may occur on weekends, holidays, vacation, or sick days. Similarly, some of the heavy rain incidents may occur on days or during parts of the day when the worker is not present at the property. Accordingly it was assumed that there would be 20 days of frozen ground and 10 days of heavy rain during which exposure would be precluded.

The minimum value assumes a part-time worker who works four days per week, 52 weeks per year (208 days) in the northern part of the state which experiences three months of frozen ground. Deductions from the 208 days of exposure were made for the frozen ground days (12 weeks × 4 days per week = 48 days) and 80% of the total number of vacation, holiday and rain days described for the likeliest scenario (0.8 × [10 days vacation + 6 days holiday + 20 days heavy rain] = 28 days). Thus, 208 days - 48 days - 28 days = 132 days.

3. ($BW_{commercial/industrial}$) Body Weight: This term is defined by a normal distribution for a population composed equally of men and women from Finley, *et al.,* truncated at the lower end to represent a minimum weight of 45 kg deemed likely for commercial and industrial workers.

Arithmetic Mean:	71 kg
Standard Deviation:	15.9 kg
Minimum:	45 kg
Maximum:	115 kg

Reference: Finley, B., Proctor, D., Scott, P., Harrington, N., Paustenbach, D., and Price, P. (1994). Recommended distributions for exposure factors frequently used in health risk assessment. *Risk Analysis* 14(4):533-553. These values from Table II, for age > 18 years, both genders.

4. ($IRso_{commercial/industrial}$) Daily Soil Ingestion Rate: This term is defined as the product of two distributions described in this document, Hourly Soil Ingestion Rate and Exposure Time as follows:

$$IRso_{commercial/industrial} = IRsohr_{commercial/industrial} \times ET_{commercial/industrial}$$

The term Hourly Soil Ingestion Rate is defined as follows:

($IRsohr_{commercial/industrial}$) Hourly Soil Ingestion Rate: This term is defined by a uniform distribution of a range of hourly soil ingestion rates, based on the average range of results for adult daily rates found in the literature subsequently divided by 16 waking hours. This is done to take into account that workers are only present at the property for a portion of the day.

Minimum:	(1/16) mg $hour^{-1}$
Maximum:	(132/16) mg $hour^{-1}$

Only three published studies have attempted to estimate adult soil ingestion rates. None of them have focused on adult worker receptor populations. In addition, the number of subjects analyzed was very low. The minimum daily soil ingestion rate of 0.5 mg day^{-1} was converted to an integer value of 1.0 and then divided by 16 to equal 1/16 mg $hour^{-1}$, the minimum hourly soil ingestion rate. The maximum daily soil ingestion rate of 132 mg day^{-1} was derived by assuming a soil ingestion rate at the high rate of 330 mg day^{-1} described by Stanek et al. (1997) as the 95^{th} percentile soil ingestion rate using the median of the best four trace elements for 10% of the work days (29 days) and a higher average soil ingestion rate of 110 mg day^{-1} for the remaining 261 days of the 290 day work year defined by the maximum Exposure Frequency ($EF_{commercial/industrial}$) value. The maximum daily rate of 132 mg day^{-1} divided by 16 to equal 132/16 mg $hour^{-}$, the maximum hourly soil ingestion rate.

References: Calabrese, E.J., Stanek, E.J., Gilbert, C.E., and Barnes, R.M. (1990). Preliminary adult soil ingestion estimates: results of a pilot study. *Regulatory Toxicology and Pharmacology* 12:88-95

Hawley, J.K. (1985). Assessment of health risk from exposure to contaminated soil. *Risk Analysis* 5: 289-302.

Stanek, E.J., Calabrese, E.J., Barnes, R., and Pekow, P. (1997). Soil ingestion in adults - results of a second pilot study. *Ecotox. Environ. Safety.* 36:249-257.

U.S. EPA. (1997). *Exposure Factors Handbook*. EPA/600/8-89/043.

5. ($ET_{commercial/industrial}$) Exposure Time: This term is defined by a custom distribution based upon best professional judgment.

0.90 relative frequency: 8 hours day^{-1}
0.10 relative frequency: 12 hours day^{-1}

This distribution was based on the assumption that most workers are at the property for 8 hours per day, and that 10% of workers are present at the property for workdays as long as 12 hours.

6. ($FI_{commercial/industrial}$) Fraction Ingested of Soil that is Contaminated;
($Fderm_{commercial/industrial}$) Fraction of Dermally Contacted Soil that is Contaminated;
And ($Finh_{commercial/industrial}$) Fraction of Air Inhaled Containing Volatiles and Particulates from Soil that is Contaminated::

These terms represent the proportion of all soil at a Property, ingested, dermally contacted and inhaled; by the receptor population described which is contaminated by the chemical of concern. In the simplest interpretation, they represent the proportion of the soil at a Property which is contaminated by a chemical of concern. They are expressed as the fraction of the surface area of the Property which is represented by the identified area(s) or exposure unit(s) for that chemical of concern and assumes random activity and exposure patterns for a particular receptor at a Property. Thus, exposure to soil concentrations of a chemical of concern, as represented by the exposure point concentration determined from the analytical results from the soil samples in the identified area(s) or exposure unit(s), is assumed to occur only for those parts of the Property where the chemical of concern has been identified and quantified. On a property-specific basis, the terms can be uniquely constructed for each chemical of concern, or groups of chemicals of concern which are associated with a particular identified area(s) or exposure unit(s), in accordance with paragraph (D)(3)(b)(iv)(*a*) of rule 3745-300-09 of the Administrative Code. If these terms are determined separately for each chemical of concern, the terms determined for each chemical of concern must be determined on the basis of all identified areas or exposure unit(s) on a Property for which the chemical of concern has been identified and from which the exposure point concentration has been determined.

Alternatively, the terms determined on a Property-specific basis may consider the spatial distribution of the chemical(s) of concern and the receptor activity patterns on a Property; the derivation of such property-specific $FI_{commercial/industrial}$, $Fderm_{commercial/industrial}$, and $Finh_{commercial/industrial}$ terms on the basis of receptor activity patterns and their relationship to the identified area(s) or exposure unit(s) must be performed in accordance with paragraph (D)(3)(b)(iv)(*b*) of rule 3745-300-09 of the Administrative Code. For purposes of the generic numerical direct-contact soil standards, these terms have been defined by a uniform distribution:

Minimum:	0.01	(unitless)
Maximum:	1.00	(unitless)

A uniform distribution assumes equal probability of all combinations of contamination and activity patterns upon a property. For purposes of the generic numerical direct-contact soil standards, these terms have been defined by a uniform distribution from which, for each iteration, a value is selected for the $FI_{commercial/industrial}$ term; the correlation between the Fraction Ingested, Fraction Dermally Contacted and Fraction Inhaled terms was accounted for by setting the value for the $Fderm_{commercial/industrial}$ and $Finh_{commercial/industrial}$ terms equal to the value selected from the $FI_{commercial/industrial}$ distribution such that, for each iteration:

$$FI_{commercia/industrial} = Fderm_{commercial/industrial} = Finh_{commercial/industrial}.$$

In the course of performing a Property-specific risk assessment, distributions may be developed for each of the $FI_{commercial/industrial}$, $Fderm_{commercial/industrial}$ and $Finh_{commercial/industrial}$ terms. In this case, the selection of a value from a distribution for the $FI_{commercial/industrial}$ term may be correlated to the selection of a value from the distributions for the $Fderm_{commercial/industrial}$ and $Finh_{commercial/industrial}$ terms on a Property-specific basis in accordance with paragraph (D)(3)(b)(iv) of rule 3745-300-09 of the Administrative Code.

7. ($SA_{commercial/industrial}$) <u>Skin</u> <u>Surface</u> <u>Area</u> <u>Exposed</u>: This term is defined as the product of the two distributions described as follows, Total Skin Surface Area and Percent Skin Surface Area Exposed: $SA_{commercial/industrial} = SAtotal_{commercial/industrial} \times SAfrac\ exp_{commercial/industrial}$

These two distributions are described as follows:

7a. ($SAtotal_{commercial/industrial}$) <u>Total</u> <u>Skin</u> <u>Surface</u> <u>Area</u>: This distribution is dependent upon the distribution for Body Weight ($BW_{commercial/industrial}$) by means of a distribution of surface area to body weight ratios derived by Phillips *et al*. (1993), who observed a strong correlation between surface area and body weight. The total skin surface area for adults was calculated based on the following Equation:

$$SAtotal_{commercial/industrial}\ (cm^2) = x\ cm^2\ kg^{-1} \times BW_{commercial/industrial}\ (kg)$$

Where, based on a correlation coefficient between the surface area to body weight ratio and body weight, x is selected from a distribution of surface area to body weight ratios for male and female adults aged 18 years and older described as follows:

Minimum:	200 $cm^2\ kg^{-1}$
Mean:	284 $cm^2\ kg^{-1}$
Maximum:	351 $cm^2\ kg^{-1}$
Standard deviation:	28 $cm^2\ kg^{-1}$

The correlation coefficient of -0.841 for the relationship of adult surface area: body weight ratio to body weight was derived on the basis of personal communication with Phillips (1996).

Reference: Phillips, L.J., Fares, R.J., and Schweer, L.G. (1993). Distributions of total skin surface area to body weight ratios for use in dermal exposure assessments. *J. Expos. Anal. Environ. Epid.* 3:331-338.

Phillips, L.J. personal communication with Ohio EPA, 17 October 1996.

7b. ($SAfrac_{commercial/industrial}$) <u>Fraction Skin Surface Area Exposed</u>: This term is defined by a triangular distribution based on best professional judgments concerning clothing and, consequently, the fraction of total skin surface area corresponding to exposed body parts. The minimum, likeliest and maximum values were determined using data describing the percentage of total body surface area by parts of the adult body in U.S. EPA (1997).

Minimum:	0.100
Likeliest:	0.160
Maximum:	0.175

Dermal contact is an event-driven pathway, assuming that single or multiple contact events with soil per day result in exposure to total dose. The quantification of exposure through the dermal contact pathway is therefore independent of the time spent in contact with soil.

The minimum value of 0.100 assumes that a worker is wearing long-sleeved shirt and pants and that the hands, head and neck are exposed.

The likeliest value of 0.160 assumes that a worker is wearing short-sleeved shirt and the forearms, hands, head and neck are exposed.

The maximum value of 0.175 assumes that a worker wears short pants, short-sleeved shirt and shoes, and that the head, neck, hands, forearms and one-half the legs are exposed for four months per year, and that the worker wears short-sleeved shirt and that the forearms, hands, head and neck are exposed for eight months per year.

Reference: U.S. EPA. (1997). *Exposure Factors Handbook*. EPA/600/8-89/043.

8. ($AF_{commercial/industrial}$) Soil Skin Adherence Factor: This term is defined by a triangular distribution based the data presented in Exhibit 3-3 of RAGS Part E.

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Minimum:	0.02	mg cm^{-2}
Likeliest:	0.2	mg cm^{-2}
Maximum:	0.5	mg cm^{-2}

The minimum value represents central tendency weighted AFs for activities associated with lower soil contact rates that a worker may engage in.

The likeliest value combines central tendency and upper bound weighted AFs for a range of activities.

The maximum value combines upper bound weighted AFs with higher soil direct contact activities.

References: U.S. EPA. 2004. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment*. EPA/540/R/99/005. July 2004.

9. (ABS) Absorption Factor. Chemical-specific. Refer to Table 3 in Section I-1.

10. (AT) Averaging Time.

for Noncarcinogens: ncAT = ED × 365 days $year^{-1}$

for Carcinogens (point value): cAT = 70 years × 365 days $year^{-1}$ = 25550 days

References: U.S. EPA (. 1997). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A.* EPA/540/1-89/002.

U.S. EPA (. 1991). *Human Health Exposure Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER Directive

9285.6-03.

11. (CF) Conversion Factor. Point value.

$$CF = 1 \times 10^{-6} \text{ kg mg}^{-1}$$

Reference: U.S. EPA. (1989). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A.* EPA/540/1-89/002.

12. (VF) Volatilization Factor: This term is defined as a point value, which is calculated on a chemical-specific basis, according to the Equation 2 in Section I-1 of this document. Calculation of the VF term requires chemical-specific values for:

D_i: Diffusivity in air ($cm^2\ s^{-1}$)
H': Dimensionless Henry's law constant
D_w: Diffusivity in water ($cm^2\ s^{-1}$)
K_d: Soil-water partitioning coefficient ($cm^3\ g^{-1}$)
K_{oc}: Soil organic carbon-water partitioning coefficient ($cm^3\ g^{-1}$),

Reference: U.S. EPA. (1996). *Soil Screening Guidance: Technical Background Document.* Section 2.4.2. Office of Solid Waste and Emergency Response. EPA/540/R-95/128. PB96-963502. May 1996. 168 pp.. plus appendices.

13. (T) Exposure Interval for Volatilization: This term is defined as a point value which is equal to the exposure duration in seconds. This term is used for the calculation of the Volatilization Factor.

$$T = 7.88 \times 10^8 \text{ s}$$

Reference: U.S. EPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.

14. (PEF) Particulate Emissions Factor: This term is defined as a point value calculated according to the methodology described in Section I of this document. It incorporates climate data from Cleveland, Ohio.

$$PEF = 9.24 \times 10^8 \text{ m}^3 \text{ kg}^{-1}$$

Calculation of this term on a Property-specific basis as described Equation 3 Section I-1 of this document and must be performed in accordance with paragraph (D)(3)(b)(iv)(A) of rule 3745-300-09 of the Administrative Code.

Reference: U.S. EPA. (1996). *Soil Screening Guidance: Technical Background Document.* Section 2.4.5. Office of Solid Waste and Emergency Response. EPA/540/R-95/128. PB96-963502. May 1996. 168 pp.. plus appendices.

Section II-4. Derivation of the Exposure Factor Values for Construction or Excavation Activities

1. ($ED_{construction/excavation}$) Exposure Duration: Exposures during construction or excavation activities are generally for short durations as defined in rule 3745-300-08 of the Administrative Code.

2. ($EF_{construction/excavation}$) Exposure Frequency: This term is defined by a triangular distribution based on a range of potential activities conducted by construction or excavation workers.

Pathway:	*Ingestion and Inhalation*	*Dermal Contact*
Maximum value:	250 days $year^{-1}$	250 events $year^{-1}$
Likeliest value:	120 days $year^{-1}$	120 events $year^{-1}$
Minimum value:	10 days $year^{-1}$	10 events $year^{-1}$

The minimum value represents short term construction or excavation activities including but not limited to maintenance and installation of utility lines, sewer maintenance, and small construction projects.

The likeliest value represents the majority of activities that occur during development and redevelopment activities at a property including but not limited to maintenance and installation of building footers and foundations, grading, and general construction on the property.

The maximum value represents larger scale development and redevelopment activities at a property including but not limited to the installation of building footers and foundations, grading, and general construction activities on the property.

3. ($BW_{construction/excavation}$) Body Weight: This term is defined by a normal distribution for a population composed equally of men and women from Finley, *et al.,* truncated at the lower end to represent a minimum weight of 45 kg deemed likely construction and excavation workers.

Arithmetic Mean:	71 kg
Standard Deviation:	15.9 kg
Minimum:	45 kg
Maximum:	115 kg

Reference: Finley, B., Proctor, D., Scott, P., Harrington, N., Paustenbach, D., and Price, P. (1994). Recommended distributions for exposure factors frequently used in health risk assessment. *Risk Analysis* 14(4):533-553. These values from Table II, for age > 18 years, both genders.

4. ($IR\ soil_{construction/excavation\ l}$) Daily Soil Ingestion Rate: This term is defined as the product

of two distributions described in this document, Hourly Soil Ingestion Rate and Exposure Time as follows:

$$IR\ soil_{construction/excavation} = h\ IR\ soil_{construction/excavation} \times ET_{construction/excavation}$$

The term Hourly Soil Ingestion Rate is defined as follows:

($hIR\ soil_{construction/excavation}$) <u>Hourly</u> <u>Soil</u> <u>Ingestion</u> <u>Rate</u>: This term is defined by a uniform distribution of a range of hourly soil ingestion rates, based on the higher end of the results for adult daily rates found in the literature subsequently divided by 16 waking hours. This is done to take into account that workers are only present at the property while working.

Minimum: (100/16) mg $hour^{-1}$
Maximum: (330/16) mg $hour^{-1}$

Only three published studies have attempted to estimate adult soil ingestion rates. None of them contain data on soil ingestion rates for workers performing outdoor construction or excavation activities. As a result, best professional judgment was used to construct this distribution. A higher *average* soil ingestion rate of 100 mg day^{-1} was used as the minimum value. The maximum value is based on the 95^{th} percentile soil ingestion rate using the *median* of the best four trace elements reported by Stanek et al. (1997).

References: Calabrese, E.J., Stanek, E.J., Gilbert, C.E., and Barnes, R.M. (1990). Preliminary adult soil ingestion estimates: results of a pilot study. *Regulatory Toxicology and Pharmacology* 12:88-95

Hawley, J.K. (1985). Assessment of health risk from exposure to contaminated soil. *Risk Analysis* 5: 289-302.

Stanek, E.J., Calabrese, E.J., Barnes, R., and Pekow, P. (1997). Soil ingestion in adults - results of a second pilot study. *Ecotox. Environ. Safety.* 36:249-257.

U.S. EPA (. 1997). *Exposure Factors Handbook*. EPA/600/8-89/043.

5. ($ET_{construction/excavation}$) <u>Exposure</u> <u>Time</u>: This term is defined by a custom distribution based upon best professional judgment.

0.90 relative frequency: <u>8 hours</u> day^{-1}
0.10 relative frequency: <u>12 hours</u> day^{-1}

This distribution was based on the assumption that most workers are at the property for 8 hours per day, and that 10% of workers are present at the property for workdays as long as 12 hours.

6. ($FI_{construction/excavation}$) Fraction Ingested of Soil that is Contaminated; ($Fderm_{construction/excavation}$) Fraction of Dermally Contacted Soil that is Contaminated; and ($FInh_{construction/excavation}$ Fraction of Air Inhaled Containing Volatiles and Particulates from Soil that is Contaminated::

These terms represent the proportion of all soil at a Property, ingested, dermally contacted and inhaled,; by the receptor population described, which is contaminated by the chemical of concern. In the simplest interpretation, they represent the proportion of the soil at a Property which is contaminated by a chemical of concern. They are expressed as the fraction of the surface area of the Property which is represented by the identified area(s) or exposure unit(s) for that chemical of concern and assumes random activity and exposure patterns for a particular receptor at a Property. Thus exposure to soil concentrations of a chemical of concern, as represented by the exposure point concentration determined from the analytical results from the soil samples in the identified area(s) or exposure unit(s), is assumed to occur only for those parts of the Property where the chemical of concern has been identified and quantified. On a property-specific basis, the terms can be uniquely constructed for each chemical of concern, or groups of chemicals of concern which are associated with a particular identified area(s) or exposure unit(s), in accordance with paragraph (D)(3)(b)(iv)(A) of rule 3745-300-09 of the Administrative Code. If these terms are determined separately for each chemical of concern, the terms determined for each chemical of concern must be determined on the basis of all identified areas or exposure unit(s) on a Property for which the chemical of concern has been identified and from which the exposure point concentration has been determined. Alternatively, the terms determined on a Property-specific basis may consider the spatial distribution of the chemical(s) of concern and the receptor activity patterns on a Property; the derivation of such property-specific $FI_{construction/excavation}$, $Fderm_{construction/excavation}$, and $FInh_{construction/excavation}$ terms on the basis of receptor activity patterns and their relationship to the identified area(s) or exposure unit(s) must be performed in accordance with paragraph (D)(3)(b)(iv)(B) of rule 3745-300-09 of the Administrative Code. For purposes of the generic numerical direct-contact soil standards, these terms have been defined by a uniform distribution:

Minimum: 0.01 (unit less)
Maximum: 1.00 (unit less)

A uniform distribution assumes equal probability of all combinations of contamination and activity patterns upon a property. For purposes of the generic numerical direct-contact soil standards, these terms have been defined by a uniform distribution from which, for each iteration, a value is selected for the $FI_{construction/excavation}$ term; the correlation between the Fraction Ingested, Fraction Dermally Contacted and Fraction Inhaled terms was accounted for by setting the value for the $Fderm_{construction/excavation}$ and $FInh_{construction/excavation}$ terms equal to the value selected from the $FI_{construction/excavation}$ distribution such that, for each iteration:

$$FI_{construction/excavation} = Fderm_{construction/excavation} = FInh_{construction/excavation}.$$

In the course of performing a Property-specific risk assessment, distributions may be developed for each of the $FI_{construction/excavation}$, $Fderm_{construction/excavation}$ and $FInh_{construction/excavation}$ terms. In this case, the selection of a value from a distribution for the $FI_{construction/excavation}$ term may be correlated to the selection of a value from the distributions for the $Fderm_{construction/excavation}$ and $FInh_{construction/excavation}$ terms on a Property-specific basis in accordance with paragraph (D)(3)(b)(iv) of rule 3745-300-09 of the Administrative Code.

7. ($SA_{construction/excavation}$) Skin Surface Area Exposed: This term is defined as the product of the two distributions described as follows, Total Skin Surface Area and Fraction Skin Surface Area Exposed:

$$SA_{construction/excavation} = SA\ total_{construction/excavation} \times SAfrac_{construction/excavation}$$

These two distributions are described as follows:

7a. ($SA\ total_{construction/excavation}$) Total Skin Surface Area: This distribution is dependent upon the distribution for Body Weight ($BW_{construction/excavation}$) by means of a distribution of surface area to body weight ratios derived by Phillips *et al*. (1993), who observed a strong correlation between surface area and body weight. The total skin surface area for adults was calculated based on the following Equation:

$$SAtotal_{construction/excavation}\ (cm^2) = x\ cm^2\ kg^{-1} \times BW_{construction/excavation}\ (kg)$$

Where, based on a correlation coefficient between the surface area to body weight ratio and body weight, x is selected from a distribution of surface area to body weight ratios for male and female adults aged 18 years and older described as follows:

Minimum:	200 $cm^2\ kg^{-1}$
Mean:	284 $cm^2\ kg^{-1}$
Maximum:	351 $cm^2\ kg^{-1}$
Standard deviation:	28 $cm^2\ kg^{-1}$

The correlation coefficient of -0.841 for the relationship of adult surface area: body weight ratio to body weight was derived on the basis of personal communication with Phillips (1996).

Reference:Phillips, L.J., Fares, R.J., and Schweer, L.G. (1993). Distributions of total skin surface area to body weight ratios for use in dermal exposure assessments. *J. Expos. Anal. Environ. Epid.* 3:331-338.

Phillips, L.J. personal communication with Ohio EPA, 17 October 1996.

7b. ($SAfrac_{construction/excavation}$) Fraction Skin Surface Area Exposed: This term is defined by a triangular distribution based on best professional judgments concerning clothing and, consequently, the fraction of total skin surface area corresponding to exposed body parts. The minimum, likeliest and maximum values were determined using data describing the percentage of total body surface area by parts of the adult body in U.S. EPA (1997).

Minimum:	0.100
Likeliest:	0.160
Maximum:	0.175

Dermal contact is an event-driven pathway, assuming that single or multiple contact events with soil per day result in exposure to total dose. The quantification of exposure through the dermal contact pathway is therefore independent of the time spent in contact with soil.

The minimum value of 0.100 assumes that a worker is wearing long-sleeved shirt and pants and that the hands, head and neck are exposed.

The likeliest value of 0.160 assumes that a worker is wearing short-sleeved shirt and the forearms, hands, head and neck are exposed.

The maximum value of 0.175 assumes that a worker wears short pants, short-sleeved shirt and shoes, and that the head, neck, hands, forearms and one-half the legs are exposed for four months per year, and that the worker wears short-sleeved shirt and that the forearms, hands, head and neck are exposed for eight months per year.

Reference: U.S. EPA (. 1997). *Exposure Factors Handbook*. EPA/600/8-89/043.

8. ($AF_{construction/excavation}$) Soil Skin Adherence Factor: This term is defined by a triangular distribution based the data presented in Exhibit 3-3 of RAGS Part E.

Minimum:	0.1	mg cm^{-2}
Likeliest:	0.3	mg cm^{-2}
Maximum:	0.9	mg cm^{-2}

The minimum value represents central tendency weighted AFs for activities associated with higher soil contact rates that a construction or excavation worker may engage in.

The likeliest value combines central tendency and upper bound weighted AFs for activities associated with higher soil contact rates that a construction or excavation worker may engage in.

The maximum value combines upper bound weighted AFs for activities associated with higher soil contact rates that a construction or excavation worker may engage in.

References: U.S. EPA. 2004. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment*. EPA/540/R/99/005. July 2004.

9. (ABS) Absorption Factor. Chemical- specific. Refer to Table I in Section I.

10. (AT) Averaging Time.

for Noncarcinogens: ncAT = ED × 365 days $year^{-1}$

for Carcinogens (point value): cAT = 70 years × 365 days $year^{-1}$
= 25550 days

References: U.S. EPA (. 1997). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A.* EPA/540/1-89/002.

U.S. EPA (. 1991). *Human Health Exposure Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER Directive 9285.6-03.

11. (CF) Conversion Factor.

$$CF = 1 \times 10^{-6} \text{ kg mg}^{-1}$$

Reference: U.S. EPA (1989). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A.* EPA/540/1-89/002.

12. (VF) Volatilization Factor: This term is defined as a point value, which is calculated on a chemical-specific basis, according to the equation described in paragraph I.A.2 of Section I of this document. Calculation of the VF term requires chemical-specific values for:

- D_i: Diffusivity in air ($cm^2\ s^{-1}$)
- H′: Dimensionless Henry's law constant
- D_w: Diffusivity in water ($cm^2\ s^{-1}$)
- K_d: Soil-water partitioning coefficient ($cm^3\ g^{-1}$)
- K_{oc}: Soil organic carbon-water partitioning coefficient ($cm^3\ g^{-1}$)

Reference: U.S. EPA. (2002). *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002

13. (T) Exposure Interval for Volatilization: This term is defined as a point value which is equal to the exposure duration in seconds. This term is used for the calculation of the Volatilization Factor.

$$T = 3.15 \times 10^7 \text{ s}$$

Reference: U.S. EPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002.

14. (PEF) Particulate Emissions Factor: This term is defined as a uniform distribution. The minimum value represents the PEF calculated for wind erosion and for construction activities (e.g. dozing and grading activities) other than unpaved road traffic. The maximum value represents the PEF for unpaved road traffic. A uniform distribution was used to incorporate a range of possible scenarios.

Maximum: 4.90 E+06 m^3/kg
Minimum: 3.31 E+08 m^3/kg

See Appendix A for detailed equations used to calculate PEF for the construction/ excavation worker.

Calculation of this term on a Property-specific basis must be performed in accordance with paragraph (D)(3)(b)(iv) of rule 3745-300-09 of the Administrative Code.

Reference: U.S. EPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* Office of Solid Waste and Emergency Response. OSWER 9355.4-24. December 2002

Section II-5. Derivation And Justification Of Exposure Factor Values For Residential Potable Ground Water Use Scenario

1a. ($ED_{potable-adult}$) Exposure Duration: Adult: This term is defined by a custom probability distribution based on U.S. Census 2000 Supplementary Survey Summary Tables for the residency occupancy period data for Ohio.

Years at One Residence	Relative Probability
1	0.078
2 to 5	0.378
6 to 10	0.154
11 to 20	0.156
21 to 30	0.107
31 to 50	0.127

The selected distribution is based on data taking into account both rural and urban areas and both owner and renter occupied units.

1c. ($ED_{potable-child}$) Exposure Duration: Child: This term is defined as a custom probability distribution based on U.S. Census 2000 Supplementary Survey Summary Tables for the residency occupancy period data for Ohio.

Years at One Residence	Relative Probability
1	0.078
2 to 5	0.378
6	0.544

The adult distribution was used for the child receptor except that all the probabilities above 6 years were truncated and added to the 6th year. If the simulation picks up a number higher than six years, then this distribution assures that a maximum of 6 years are accounted for a child.

2a. ($EF_{potable-adult}$) Exposure Frequency: Adult: This term is defined by a triangular distribution based upon best professional judgment.

Maximum:	365 days $year^{-1}$
Likeliest:	351 days $year^{-1}$
Minimum:	323 days $year^{-1}$

The maximum value assumes an adult receptor in the residential scenario who is home every day of the year.

The likeliest value assumes an adult in the residential scenario who is away from home 14 days per year, as in two weeks vacation.

The minimum value assumes an adult in the residential scenario 14 days away from home due to vacation, plus 28 additional days away per year due to additional vacation, weekends and business travel.

2c. ($EF_{potable\text{-}child}$) <u>Exposure Frequency: Child</u>: This term is defined as a triangular distribution based upon best professional judgment.

Maximum:	365 days $year^{-1}$
Likeliest:	351 days $year^{-1}$
Minimum:	323 days $year^{-1}$

The maximum value assumes a child receptor in the residential scenario at home every day of the year.

The likeliest value assumes a child receptor in the residential scenario away from home for a period equivalent to two weeks vacation (14 days) per year.

The minimum value assumes a child receptor in the residential scenario away from home for two weeks vacation, and an additional 28 days (4 weeks or 14 weekends), due to additional vacation, family visits and weekend travel.

3a. ($BW_{potable\text{-}adult}$) <u>Body Weight: Adult</u>: This term is defined by a normal distribution for an equal population of men and women from Finley, *et al.* (1994).

Mean:	71 kg
Standard Deviation:	15.9 kg
Minimum:	32 kg
Maximum:	115 kg

The minimum body weight was truncated at the lower end of the distribution at 32 kg accounting for elderly residents who may weigh less than other adults considered in the industrial worker scenario.

3c. ($BW_{potable-child}$) Body Weight: Child: This term is defined as a normal distribution based on data from the National Center for Health Statistics (1987).

Mean:	16.8 kg
Standard deviation:	3.0 kg

A time-averaged distribution of childhood body mass was developed by probabilistic modeling of varying exposure durations (1-6 years) beginning at varying ages of onset (0.5-5 years of age). Body mass for males for each age was sampled based upon the above parameters from body mass distributions for each age selected and added in yearly increments over the selected exposure duration. The time-averaged body mass (kg) for each iteration was calculated by adding body mass for each year and dividing by the exposure duration (yrs). To ensure statistical integrity, male distributions were employed. Although actual values varied between genders, no significant differences were detected at the ages sampled (6 months - 5 years).

References: Finley, B., Proctor, D., Scott, P., Harrington, N., Paustenbach, D., and Price, P. (1994). Recommended distributions for exposure factors frequently used in health risk assessment. *Risk Analysis* 14(4):533-553. These values from Table II, for age > 18 years, both genders.

National Center for Health Statistics. (1987). Anthropometric reference data and prevalence of overweight, United States, 1876 - 80. Data from National Health Survey, Series 11, No. 238. Hyattsville, MD: U.S. Department of Health and Human Services, Public Health Service, National Center for Health Statistics. DHHS Publication No. (PHS) 87-1688.

Smith, R.L. (1994). Use of Monte Carlo simulation for human exposure assessment at a Superfund site. *Risk Analysis* 14:433-439.

4a. ($IR_{potable-adult}$) Tap Water Ingestion Rate: Adult: This term is defined by a lognormal distribution based on data from Ershow and Cantor (1989).

1 percentile value:	0.148 L day^{-1}
Median:	1.252 L day^{-1}
Mean:	1.366 L day^{-1}
99 percentile value:	3.780 L day^{-1}

4c. ($IR_{potable-child}$) Tap Water Ingestion Rate: Child: This term is defined by a normal distribution based on data from Ershow and Cantor (1989).

Mean:	0.685 L day^{-1}
Standard deviation:	0.276 L day^{-1}

A time-averaged distribution of childhood drinking water ingestion rates was developed by probabilistic modeling of varying exposure durations (1-6 years) beginning at varying ages of onset (0.1-5 years of age). Drinking water rates for each age were sampled based upon the above parameters from drinking water ingestion rate distributions for each age selected and added in yearly increments over the selected exposure duration. The time-averaged rate (L day^{-1} $year^{-1}$) for each iteration was calculated by dividing total consumption during the exposure duration by the exposure duration.

Reference: Ershow, A.G., Cantor, K.P. (1989). Total water and tap water intake in the United States: population-based estimates of quantities and sources. Life Sciences Research Office, Federation of American Societies for Experimental Biology.

5. (AT) Averaging Time

for Noncarcinogens: $ncAT = ED \times 365 \text{ days year}^{-1}$

for Carcinogens (point value): $cAT = 70 \text{ years} \times 365 \text{ days year}^{-1} = 25550 \text{ days}$

References: U.S. EPA (. 1991). *Human Health Exposure Manual, Supplemental Guidance: Standard Default Exposure Factors.* OSWER Directive 9285.6-03.

U.S. EPA (. 1989). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A.* Exhibit 6-14. EPA/540/1-89/002.

6a. ($SA_{potable\text{-}adult}$) Total Skin Surface Area: Adult: This distribution is dependent upon the distribution for Body Weight ($BW_{potable\text{-}adult}$) by means of a distribution of surface area to body weight ratios derived by Phillips *et al*. (1993), who observed a strong correlation between surface area and body weight. The total skin surface area for adults was calculated based on the following Equation:

$$SA \text{ total}_{potable\text{-}adult} (cm^2) = x \text{ cm}^2 \text{ kg}^{-1} \times BW_{potable\text{-}adult} (kg)$$

Where, based on a correlation coefficient between the surface area to body weight ratio and body weight, x is selected from a distribution of surface area to body weight ratios for male and female adults aged 18 years and older described as follows:

Minimum:	200 cm^2 kg^{-1}
Mean:	284 cm^2 kg^{-1}
Maximum:	351 cm^2 kg^{-1}
Standard deviation:	28 cm^2 kg^{-1}

The correlation coefficient of -0.841 for the relationship of adult surface area: to body weight ratio to body weight was derived on the basis of personal communication with Phillips (1996).

Reference: Phillips, L.J., Fares, R.J., and Schweer, L.G.

6c. ($SA_{potable/child}$) Total Skin Surface Area: Child: This distribution is dependent upon the distribution for $BW_{potable\text{-}child}$, by means of two distributions of surface area: body weight ratios developed by Phillips, *et al.* (1993). Distributions of total These two SA to BW ratios were described for the age cohorts of 0 to 2 years and 2.1 to 17.9 years. Based upon the distributions for age of exposure onset, developed for the term $IR_{potable\text{-}child}$, and exposure duration for the child receptor, $ED_{potable\text{-}child}$, a value from the appropriate SA to BW distribution is selected, and total body surface area is thus derived for each value selected from the $BW_{potable\text{-}child}$ distribution, by means of the equation:

$$SA_{potable\text{-}child} = x \text{ cm}^2 \text{ kg}^{-1} \times BW_{potable\text{-}child} \text{ (kg)}$$

The value for *x* is selected from the composite distribution for the SA to BW ratio for the age cohort 0.5 years to 6 years, (the age range of the child receptor in this potable ground water use scenario) which is described by the following distribution:

Minimum:	269 cm^2 kg^{-1}
Mean:	453 cm^2 kg^{-1}
Maximum:	1083 cm^2 kg^{-1}
Standard deviation:	80 cm^2 kg^{-1}

The distributions for $BW_{potable\text{-}child}$ and the composite surface area to body weight ratio for children were related by a correlation coefficient of -0.734, based on personal communication with Phillips (1996).

Reference: Phillips, L.J., Fares, R.J., and Schweer, L.G. 1993. Distributions of total skin surface area to body weight ratios for use in dermal exposure assessments. *J. Expos. Anal. Environ. Epid.* 3:331-338.

Phillips, L.J. personal communication with Ohio EPA, 17 October 1996.

7. (PC) Dermal Permeability Coefficient of Chemicals in Water: This term is a chemical-specific point value for organic compounds, and a single point value for all inorganic compounds, as described below:

Organic molecules:

The values for PC were obtained as K_p values from Exhibit B-4 in Appendix B in U.S. EPA (2004), or derived by the following equation (Equation 3.8 in U.S. EPA, 2004):

$$\log K_p \text{ (cm hour}^{-1}) = -2.80 + 0.66 \log K_{o/w}$$

Where:

$\underline{K_p}$ = the permeability constant;
$K_{o/w}$ = the octanol/water partitioning coefficient; and
MW = molecular weight.

Inorganic molecules:

The default value for inorganics recommended by U.S. EPA (2004) is:

$$K_p \text{ (cm hour}^{-1}) = 1\text{x}10^{-3} \text{ cm hour}^{-1}$$

Reference: U.S. EPA *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment*. EPA/600/8-91/011B, January 1992540/R/99/005. July 2004.

8a. ($ET_{potable/adult}$) <u>Exposure Time for Daily Showering/Bathing</u>: This term is defined as a point value.

Point value: 15 minutes day^{-1} = 0. 25 hour day^{-1}

8b. ($ET_{potable/child}$) <u>Exposure Time for Daily Showering/Bathing</u>: This term is defined as a point value.

Point value: 20 minutes day^{-1} = 0.33 hour day^{-1}

Reference: U.S. EPA. 2004. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment*. EPA/540/R/99/005. July 2004.

9. ($CF_{potable\text{-}dermal}$) Conversion Factor for dermal contact with chemicals in water: This term is defined as the point value in U.S. EPA (1989, Exhibit 6-13).

$$CF_{potable\text{-}dermal} = 0.001 \text{ L cm}^{-3}$$

Reference: U.S. EPA (1989). *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A*. EPA/540/1-89/002. December 1989.

10.($IRinh_{potable}$) Inhalation Rate while Showering or Bathing

a. ($IRinh_{potable-child}$): Point value: 0.83 m^3 $hour^{-1}$
b. ($IRinh_{potable-adult}$): Point value: 0.83 m^3 $hour^{-1}$

This point value is based on the U.S. EPA recommended inhalation rate of 20 m^3/day converted to an hourly rate.

Reference: U.S. EPA. 1997. *Exposure Factors Handbook.* EPA/600/8-89/043.

11. ($K_{potable}$) Volatilization Constant: This term is defined as a point value for all chemicals with a Henry's Law Constant greater than 1×10^{-5} atm m^3 mol^{-1} during showering (Andelman, 1990):

$$K_{potable} = 1.875 \times 10^{-3} \text{ (unitless)}$$

Reference: Andelman, J.B. (1990). . "Total exposure to organic chemicals in potable water. Chapter 20 in Cantor, K.P., Christman, R.F., Ram, N.M.(editors),". Significance and treatment of volatile organic compounds in water supplies. Cantor, K.P., Christman, R.F., Ram, N.M. (editors). Lewis Publishers. pp.. 485-504.

12. ($CF_{potable-inhalation}$) Conversion Factor for inhalation of volatiles from potable water: This term is defined as a point value:

$$CF_{potable-inhalation} = 1000 \text{ L m}^{-3}$$

Section III: Development of Generic Direct-Contact Soil Standards for Lead

Generic direct-contact soil standards were developed for many chemicals that are important and common contaminants at brownfield or similar sites. These standards were developed using target risk levels, toxicological data, exposure assumptions and modeling techniques described in Sections I and II of this document. Lead, however, is a unique chemical in that it has important noncancer adverse effects upon human health, but does not appear to have a threshold exposure level. Therefore, lead is generally evaluated somewhat differently than other chemicals.

There are no appropriate toxicological benchmarks (i.e., slope factor or reference dose) for lead. Rather, the generally accepted methodology for evaluating exposures to lead is the estimation of blood lead (PbB) concentrations from media exposures with a comparison to blood lead levels considered to be indicative of adverse health effects.

Using this approach, the Ohio EPA VAP has developed generic numerical direct contact soil standards for lead for three populations: a residential child, a commercial/industrial worker, and a construction worker. The derivations of these standards are described below. The information contained in these sections can also be used by volunteers or certified professionals who choose to evaluate lead in a property-specific risk assessment. Further information regarding lead modeling can be obtained from following website:

http://www.epa.gov/superfund/health/contaminants/lead/pbrisk.htm

A. Derivation of a Generic Direct-Contact Soil Lead Standard for a Residential Child

The **generic numerical standard for direct contact soils, protective of a child in the residential land use category is 400 mg/kg**. This value is the U.S. EPA-recommended screening level for lead in residential soils. The value is recommended in two U.S. EPA documents providing interim guidance: 1) the Toxic Substances Control Act (TSCA) Section 403 guidance from the Office of Prevention, Pesticides, and Toxic Substances (U.S. EPA, 1994d) and 2) Office of Solid Waste and Emergency Response guidance (U.S. EPA, 1994c).

Children are regarded as a sensitive subpopulation with regard to lead toxicity. The U.S. EPA derived this recommended lead screening level by use of the Integrated Exposure Uptake Biokinetic Model (IEUBK) developed for children (U.S. EPA, 1994a,b; 2001). The model uses four interrelated modules to estimate blood lead (PbB) levels in children exposed to lead-contaminated media. The modules account for exposure, uptake, and the biokinetics of lead in the body and predict a probability distribution of PbB levels. From this distribution, the model estimates the risk that a child's PbB will exceed a level of concern, which is typically considered to be 10 ug/dL. The basis of the 400 mg/kg screening level was the use of the IEUBK Model with default input values for physiological parameters (e.g., soil ingestion rates, absorption and bioavailability) and media concentrations (i.e., drinking water, air, diet, dust, etc.). Under these default conditions and including an approximately 400 mg/kg level of lead in soil, the model predicts that no more than 5% of the modeled population would exceed a target PbB of 10 ug/dL

The VAP reevaluated the IEUBK model defaults (i.e., soil ingestion rates, dietary lead levels, etc.). In addition, model runs were evaluated assuming no more than 10% of a modeled population would exceed PbB concentrations of 10 ug/dL. Although the resulting soil concentrations varied somewhat (some higher, some lower), the variability in the modeling results was considered trivial and therefore 400 mg/kg has been retained as the generic direct contact soil standard for lead for residential land uses under the VAP.

Volunteers or Certified Professionals electing to perform a property-specific risk assessment for lead are required to use the IEUBK model to determine risks to children from exposures to lead. Changes to the U.S. EPA default values should, however, be approached with caution. Valid, defensible, site-specific information and monitoring data will be required by VAP to support any changes in the recommended default values.

B. Derivation of the Generic Direct-Contact Soil Standard for Lead for the Commercial and Industrial Land Use Categories

The generic direct-contact soil standard for lead for the **commercial and industrial land use categories is 1,800 mg/kg**. This value was also derived using U.S. EPA methodology.

The U.S. EPA's Technical Review Workgroup for Lead has developed an approach for assessing risks associated with adult exposures to lead in soil and establishing cleanup goals that will protect adults and fetuses from lead in soil (U.S. EPA, 2003). This guidance does not recommend a specific target soil lead cleanup level, but proposes a methodology that allows for the input of either property-specific data or default values to assess risk and develop property-specific cleanup goals. The methodology is intended for use until an integrated exposure Biokinetic model for adults is developed by the U.S. EPA. Although it is acknowledged that other adult lead models are available and useable, the U.S. EPA concludes that this Adult Lead Model is the most appropriate methodology for modeling adult exposures to lead for scenarios, primarily occupational, where relatively steady patterns of exposure are or are expected to occur.

The VAP adopted the U.S. EPA's Adult Lead Model as its preferred methodology for calculating generic numerical standards for adult populations and recommends its use in any property-specific evaluation of lead risks for a number of technical reasons that include the following: 1) the inclusion of inter-individual variability within the exposed population; 2) the inclusion of assumptions regarding existing baseline blood lead levels; 3) the explicit protection of the developing fetus of a worker as the most sensitive subpopulation; 4) the acceptance of the model's use in the scientific and regulatory communities; and 5) the level of peer review and technical support documentation developed for the model. The spreadsheets used by the VAP along with the technical documentation supporting the input parameters can be found on the U.S. EPA Technical Review Workgroup for Lead website;

http://www.epa.gov/superfund/health/contaminants/lead/products.htm

C. Basis of the U.S. EPA Adult Lead Model:

The primary assumption in the Adult Lead Model is that the receptor of concern in the workplace is the fetus. The methodology assumes that fetuses, like children, are more sensitive to the effects of lead in blood than are adults. The Adult Lead Model relates soil lead concentrations to PbB in the mother and the developing fetus based on the following assumptions: 1) expected fetal PbB levels are proportional to maternal PbB levels; 2) maternal PbB levels can be estimated as the sum of an expected initial PbB without property exposures and an expected property-related increase; 3) the property-related increase in maternal PbB can be estimated using a linear Biokinetic slope factor, multiplied by an estimated lead uptake; 4) lead uptake can be estimated based on concentrations of lead in soil by assuming an adult soil ingestion rate and an estimated absorbed fraction of ingested lead from the soil; and 5) the distribution of PbB levels in a given adult population who contact similar levels of lead in soil is lognormal.

A standard for lead in soil can therefore, be calculated (using the Adult Lead Model) that corresponds to a specific acceptable PbB in mothers and fetuses. This can be done by using either property specific or default exposure assumptions. The acceptable blood lead distribution used by the VAP was set such that at least 90 percent of the fetuses in a population of women are predicted to have PbB levels of 10 ug/dL or less. The 90th percentile is the level of protection assumed for all VAP generic numerical standards (GNSs).

Equation 16. U.S. EPA Adult Lead Model Methodology:

The U.S. EPA Adult Lead Model estimates the geometric mean blood lead concentration in adults based on soil lead concentrations using the following equation:

$$PbB_{GM} = PbB_{0} + \left(\frac{Pb_{s} * BKSF * IR_{s} * AF_{s} * EF_{s}}{AT} \right)$$

Where:

PbB_{GM}	=	Geometric mean estimate of blood lead concentrations in adults (i.e., of child-bearing age) that have site exposures (μg/dL).
$PbB_{adult,\ 0}$	=	Baseline blood lead concentrations in women of child-bearing age in the absence of exposures at the property (μg/dL).
Pb_{s}	=	Average soil lead concentration (μg/g).
BKSF	=	Biokinetic slope factor relating increase in typical lead level to

average daily uptake of lead (µg/dL blood lead increase per µg/day lead uptake).

IR_s = Intake rate of soil, including soil contained in indoor dust (g/day)

AF_s = Absolute gastrointestinal absorption fraction for ingested lead in soil and dust (unitless).

EF_s = Exposure frequency for contact with soils and/or dust (days/year)

AT = Averaging time (365 days/year)

Equation 16 can be rearranged to calculate the soil standard (or concentration) associated with a given exposure scenario and target adult blood lead concentration distribution:

$$GNS = Pb_s = \frac{(PbB_{adult,\ central,\ goal} - PbB_{adult,\ o}) * AT}{(BKSF * IR_s * AF_s * EF_s)}$$

The above equation is then used to calculate $PbB_{adult,central,goal}$:

$$PbB_{adult,\ central,\ goal} = \frac{PbB_{fetal,0.90,\ goal}}{GSD_i^{1.282} * R}$$

Where:

$PbB_{fetal,0.90,goal}$ = Goal for the 90th percentile blood lead concentration (ug/dL) among fetuses in a population of exposed women. The goal is intended to ensure that $PbB_{fetal,0.90,goal}$ does not exceed 10 ug/dL.

R = Constant of proportionality between fetal and maternal blood lead concentration (dimensionless).

GSD_I = Estimated value of the individual geometric standard deviation among women of child-bearing age in the exposed population. This value represents the expected variation in blood lead levels from a population of women that have exposures to similar property-specific lead concentrations, but have a nonuniform response (intake, absorption, biokinetics) to lead exposures and nonuniform off-property lead exposures. The exponent, 1.282, is the value used to calculate the 90th percentile from a lognormal distribution of blood lead concentration.

Selection of Model Parameter Inputs:

The U.S. EPA Adult Lead Model guidance recommends the use of site-specific data in the model wherever feasible and recommends default values when site-specific information is not available (U.S. EPA, 2003). In the calculation of the GNS for lead, the VAP used default values either recommended by U.S. EPA, or exposure factors used in the derivation of GNSs for other chemicals. The parameter values selected are described as follows:

Target 90th Percentile Fetal Blood Lead Concentration ($PbB_{fetal,0.90,goal}$):

The weight-of-evidence from the scientific literature suggests that delayed or impaired neurodevelopment during the first 12 months of postnatal life can be associated with maternal blood lead levels during pregnancy or neonatal blood lead levels at birth (U.S. EPA,1996). The scientific literature evaluating maternal blood lead concentrations associated with adverse effects on the fetus is not as well documented. To account for this uncertainty, a **fetal blood lead level of 10 µg/dL** was selected by U.S. EPA for use in the Adult Lead Model, based on the assumption that the blood lead level of concern for fetuses is the same as that for children. Using the U.S. EPA-recommended value of **0.9 for R**, a fetal blood lead level of 10 µg/dL is associated with a maternal blood lead level of 11.1 µg/dL.

Constant of Proportionality Between Fetal and Maternal Blood Lead Concentration (R):

The U.S. EPA has recommended a **fetal/maternal blood lead ratio of 0.9**, based on weight-of-evidence from studies that have explored the relationship between cord and maternal blood lead. The strongest evidence supporting this value is from a study by Graziano et al. (1990) comparing maternal blood lead and umbilical cord blood lead at delivery in 888 mother-infant pairs between 28 and 44 weeks of gestation. The relationship between maternal blood lead and umbilical cord blood lead in this study was linear with a slope of 0.93; the correlation coefficient was 0.92.

Individual Blood Lead Geometric Standard Deviation (GSD_i):

The U.S. EPA acknowledges that there is uncertainty associated with this parameter and recommends that site-specific blood lead data be collected wherever possible. Since this is not possible in the development of a generic standard, the U.S. EPA-recommended **default** an average value of 2.1 was used in the GNS derivation (U.S. EPA, 1999). This value represents the approximate midpoint from the plausible range of values of 1.8 to 2.1. The 1.8 value represents the GSD_i for homogenous populations, and 2.1 represents the GSD_i for diverse, urban populations. This information is from an analysis of blood lead concentration data collected in the NHANES III data collection effort (Brody et al., 1994).

Baseline Blood Lead Concentration (PbB_0):

The assumed. This value is based on the Phase 1 and 2 statistical assessments of the National Health and Nutrition Evaluation Survey (NHANES III) (U.S. EPA, 2002) based on stratifying the data by census region. The range of GSD values reported in U.S. EPA (2002) is 2.0 to 2.2. U.S. EPA recommends PbB_0 (µg/dL) values of 1.7 for whites, 2.0 for Hispanics, and 2.2 for blacks. These recommendations are(2002) also provided a result of the analysis of NHANES III data collected and evaluated by Brody et al. (1994). The higher blood lead values for black and Hispanic females may be related more to socioeconomic factors such as place of residence than to actual racial differences (e.g., lead in soil and dust is higher in urban areas than in rural areas, because lead from automobile exhaust and lead-based paint has had a greater impact on soil and dust in urban areas).range of GSD values based on race/ethnicity groups of 2.1-2.3.

For the GNS calculation, the approximate midpoint of the recommended range of PbB_0 was selected (**2 µg/dL**). This is the recommended U.S. EPA default for evaluation at sites where the population demographics are unknown (U.S. EPA, 1999).

Baseline Blood Lead Concentration (PbB_0):

The analysis in U.S. EPA (2002) also provided updated information regarding a range for PbB_0 (µg/dL) values. Based on the four census regions, the range of estimated PbB_0 values would be 1.4 to 2.2; based on race/ethnicity groups the range is 1.4 to 1.9. A value of 1.7 ug/dL was assumed since this average value is within both ranges and most closely represents a heterogeneous population in the Midwest.

Biokinetic Slope Factor (BKSF):

The U.S. EPA recommends a BKSF of 0.4 (µg/dL per µg lead uptake from water/day) for adults based on an evaluation of Pocock et al. (1983). This value is based on the assumption (derived from the Pocock analysis) that the slope factor for lead ingested in water is 0.09 (µg/dL per µg lead ingested in water/day) and the fraction of lead absorbed from water by pregnant women ranges from 0.20 to 0.25. The BKSF for lead uptake from water was back calculated: 0.4 µg/dL per µg lead uptake/day = (0.09 µg/dL per µg lead ingested/day)/0.20.

Bowers et al. (1994) derived a similar BKSF of 0.375 µg/dL per µg lead uptake/day. This analysis used the same data set as Pocock et al. (1983), but with different assumptions and without the adjustments for a mixture of first draw and flushed water intake assumed in the Pocock et al. (1983) study.

Daily Soil Ingestion Rate (IRs):

The U.S. EPA recommends a **default value of 0.05 g/day** as a plausible point estimate for average daily soil intake from all occupational sources, including soil in indoor dust. This is representative of noncontact-intensive activities, which would be reasonably expected at most VAP properties. This value is also the U.S. EPA standard default for average (central tendency) occupational exposures (U.S. EPA , 1993).

Absolute Gastrointestinal Absorption Fraction for Ingested Lead in Soil and Dust (AFs):

The U.S. EPA recommends a default value of 0.12 as an estimate of the fraction of lead in soil ingested daily that is subsequently absorbed by the gastrointestinal tract. This value is based on assumptions regarding the gastrointestinal absorption of soluble lead and the relative bioavailability of lead in soil compared to soluble lead.

A **default value of 0.2 for absorption of soluble lead** is based on a U.S. EPA weight-of-evidence approach that evaluated experimental results of bioavailability of ingested lead in adult humans, considering variability in food intake and lead intake. In the absence data regarding different species of lead and particle sizes, the U.S. EPA considers 0.6 to be a plausible default point estimate for relative bioavailability based on experimental studies (Weis et al. 1994; Maddaloni et al. 1996).

The **default value of 0.6 for relative bioavailability of lead** in soil compared to soluble lead coupled with the default value of 0.2 for the absorption factor for soluble lead results in a **soil absorption factor of 0.12 (0.6 * 0.2)**. The U.S. EPA considers this value to be a plausible point estimate for use in assessments where site-specific information on lead bioavailability is not available.

Exposure Frequency (EF_s):

The exposure frequency used is **214 days**. This is the likeliest value from the distribution used by the VAP in the development of GNS values for other chemicals. This value is similar to U.S. EPA-recommended default value of 219 days/year.

Averaging Time (AT):

An **averaging time of 365 days** is recommended by U.S. EPA. This default assumption represents sufficient time for the PbB to reach quasi-steady state conditions.

C. Derivation of the Generic Direct-Contact Soil Standard for Lead for Construction or Excavation Activities

The U.S. EPA Adult Lead Model described above for the commercial and industrial land use categories was similarly used for the development of a generic direct-contact soil standard for lead of **750 mg/kg for construction or excavation activities**. The following parameters were modified for the construction or excavation activities to reflect differences in assumed exposures. The other input assumptions not described below are the same as those used for the commercial and industrial land use categories.

Daily Soil Ingestion Rate (IRs):

There is a considerable lack of reliable scientific information regarding adult soil ingestion rates for intensive soil contact scenarios. Given that the model inputs should be based on central tendency estimates, the U.S. EPA recommends an appropriate default soil ingestion rate for construction worker scenarios of **100 mg/day** (U.S. EPA, 2006).

Exposure Frequency (EF_s):

In developing GNS values for the construction worker, the VAP assumed a triangular distribution for exposure frequency. The likeliest value assumed in this distribution is 120 days. The U.S. EPA Adult Lead Model recommends the use of central tendency values, therefore, **120 days** is the EF_s assumed in the calculation of a construction worker lead GNS.

Averaging Time (AT)

For more intermittent exposures, the assumed averaging time should not be prorated over an entire year. Construction workers are assumed to work 120 days per year, which is equivalent to 24 weeks of work (based on a 5-day work week). The averaging time is therefore 24 weeks or 168 days (U.S. EPA, 2006).

D. Property-Specific Lead Evaluations for Adult Populations:

The VAP recommends that Volunteers or Certified Professionals electing to perform a property-specific risk assessment for lead, use the U.S. EPA Adult Lead Model described above to assess risks to adults from exposures to lead. Use of other, similar models for the evaluation of adult exposures may be considered based on property-specific conditions.

Changes to the default values assumed by the VAP should, however, be approached with caution. Valid, defensible, site-specific information and monitoring data will be required by VAP to support any changes in the recommended default values per rule 3745-300-09 of the Administrative Code.

References:

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Weiss, CP, Henningsen, GM, Poppenga, RL, Thacker, BJ, Curtis, A., Jolly, R. and

Harpstead, T. 1994. Use of an immature swine model to sensitively differentiate lead absorption from soluble and mineralogical matrices. Presented at the Society for Environmental Geochemistry and Health, Salt Lake City, UT, July 18-19, 1994.

Appendix A
Equations for Calculation of Particulate Emission Factor (PEF) for the Construction/Excavation Worker

The PEF for the construction/excavation worker is defined as a uniform distribution. The maximum value represents the PEF for unpaved road traffic. The minimum value represents the PEF calculated for wind erosion and for construction activities (e.g. dozing and grading activities) other than unpaved road traffic. The example scenarios used to calculate these PEFs are from U.S. EPA, *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Appendix E* (Supplemental SSG), December 2002, pages E-27 to E-29.

Ohio VAP specific assumptions were incorporated into the input parameters as appropriate. For the Q/C term, the value for Cleveland, Ohio was substituted. For the T value, the VAP-specific exposure assumptions were used (exposure duration of 1 year and exposure frequency 120 days instead of the 5 days per week for 6 months in the example. For the p term, 120 days was used for Ohio based on Exhibit E-1 in Appendix E in the Supplemental SSG.

A uniform distribution was used to incorporate a range of possible scenarios as defined below:

Maximum PEF for unpaved road traffic:	4.90 E+06 m^3/kg
Minimum PEF for construction activities other than unpaved road traffic:	3.31 E+08 m^3/kg

The equations and assumptions used in the PEF derivations are summarized as follows:

PEF Equation for unpaved road traffic (urt), Supplemental SSG, Equations E-18 and E-19 and page E-27

$$PEF_{urt} = Q/C_{sr} \times \frac{1}{F_D} \times \frac{T \times A_R}{\frac{2.6 \times (s/12)^{0.8}\,(W/3)^{0.4}}{(M_{dry}/\,0.2)^{0.3}} \times \frac{(365d/yr - p)}{365d/yr} \times 281.9 \times \Sigma VKT}$$

Parameter/Definition	Default Value
Q/C_{sr} ((inverse of mean concentration of center square source in g/m^2-s per kg/m^3)	85.63
F_D (dispersion correction factor, unitless)	0.185
T (total time over which construction occurs, in s)	7.2E+06
A_R (surface area of contaminated road segment in m^2)	274.213
s (road surface silt content (%))	8.5
W (mean vehicle weight in tons)	8.0
M_{dry} (road surface material moisture content (%))	0.2
p (number of days with at least 0.01 inches of precipitation, for Ohio)	120
ΣVKT (sum of fleet vehicle kilometers traveled during the exposure duration in km)	1067.51

PEF equation for Construction Activities other than traffic on unpaved roads (ca), Supplemental SSG,
Equations E-22 to E-26 and pages E-28 and E-29

$$PEF_{ca} = Q/C_{sa} \times \frac{1}{F_D} \times \frac{1}{<J'_T>}$$

Parameter/Definition	Default Value
Q/C_{ca} (inverse of mean concentration at center of source in g/m^2-s per kg/m^3)	85.63
F_D (dispersion correction factor)	0.185
$<J'_T>$ (Total time-averaged PM_{10} unit emission flux for construction activities other than traffic on unpaved roads in g/m^2-s)	1.40E-06

Equations for Calculation of PEF

(2002 Supplemental SSG, Equation E-19)

$$Q/C = A \times \exp \frac{(\ln A_s - B)^2}{C}$$

For Cleveland, OH (See Exhibit E-3 of 2002 Supplemental SSG)
A = 12.8612
B = 20.5164
C = 237.2798

Assume A_s (areal extent of site soil contamination) = 0.5 acres

(2002 Supplemental SSG, Equation E-25)

$$\langle J'_T \rangle = \frac{(M_{wind} + M_{excav} + M_{doz} + M_{grade} + M_{till})}{A_c + T}$$

$\langle J'_T \rangle$ = Total time-averaged PM_{10} unit emission flux for construction activities other than unpaved road traffic (g/m^2-s)
M_{wind} = Unit mass emitted from wind erosion (g)
M_{excav} = Unit mass emitted from excavation soil dumping (g)
M_{doz} = Unit mass emitted from dozing operations (g)
M_{grade} = Unit mass emitted from grading operations (g)
M_{till} = Unit mass emitted from tilling operations (g)
A_c = Areal extent of soil contamination
T = Duration of Construction

(2002 Supplemental SSG, Equation E-20)

$$M_{wind} = 0.036 \times (1\text{-}V) \times \frac{U_m}{U_t} \times F(x) \times A_{surf} \times ED \times 8{,}760 \text{ hr/yr}$$

M_{wind} = Unit mass emitted from wind erosion (g)
V = Fraction of vegetative cover (unitless), default = 0
U_m = Mean windspeed during construction (m/s), default = 4.69 m/s
U_t = Equivalent threshold value of windspeed at 7m (m/s), default = 11.32 m/s
F(x) = Functions dependent on U_m/U_t (unitless), 0.194
A_{surf} = Areal extent of site with surface soil contamination (m^2)
ED = Exposure Duration (1 yr)

(2002 Supplemental SSG, Equation E-21)

$$M_{excav} = 0.35 \times 0.0016 \times \frac{(U_m/2.2)^{1.3}}{(M/2)^{1.4}} \times \rho_{soil} \times A_{excav} \times d_{excav} \times N_A \times 10^3 \text{ g/kg}$$

M_{excav} = Unit mass emitted from excavation soil dumping (g)
0.35 = PM_{10} particle size multiplier
U_m = Mean windspeed during construction (m/s)
M = Gravimetric soil moisture content (%), default = 12%, EPA (1985) Table 13.2.4-1, mean value for municipal land cover

ρ_{soil} = In situ soil density (includes water) (mg/m^3), default 1.68 mg/m^3
A_{excav} = Areal extent of excavation (m^2)
d_{excav} = Average depth of excavation (m)
N_A = Number of times soil is dumped, default = 2

(2002 Supplemental SSG, Equation E-22)

$$M_{doz} = 0.75 \times \frac{0.45(s)^{1.5}}{(M)^{1.4}} \times \frac{\Sigma VKT}{S} \times 10^3 \text{ g/kg}$$

M_{doz} = Unit mass emitted from dozing operations (g)
0.75 = PM_{10} scaling factor
s = soil silt content (%), default = 6.9%, EPA (1985) Table 11.9-3, mean value for overburden
M = Gravimetric soil moisture content (%), default = 7.9%
ΣVKT = Sum of dozing kilometers traveled (km)
S = Average dozing speed (kph), default = 11.4 kph, EPA (1985) Table 11.9-3, mean value for graders

(2002 Supplemental SSG, Equation E-23)

M_{grade} = 0.60 x 0.0056(S)$^{2.0}$ x ΣVKT x 10^3 g/kg

M_{grade} = Unit mass emitted from grading operations (g)
0.60 = PM_{10} scaling factor
S = Average grading speed (kph), default = 11.4 kph, EPA (1985) Table 11.9-3, mean value for graders
ΣVKT = Sum of grading kilometers traveled (km)

(2002 Supplemental SSG, Equation E-24)

M_{till} = 1.1(s)$^{0.6}$ x A_{till} x 4,4047 m^2/acre x 10^{-4}ha/ m^2 x 10^3 g/kg x N_A
M_{till} = Unit mass emitted from tilling operations (g)
s = soil silt content (%), default = 18%, EPA (1992a) Section2.6.1.1
A_{till} = Areal extent of tilling (acres)
N_A = Number of times soil is tilled, default = 2