INHALATION EXPOSURE PATHWAY
SOIL REMEDIATION STANDARDS

BASIS AND BACKGROUND

JUNE 2008

Table of Contents

I. Introduction

The Department has been directed by the Legislature to develop human health based soil remediation standards for residential and non-residential exposure scenarios, N.J.S.A. 58:10B-1 et seq. To prevent the unacceptable risk to human health from inhalation of contaminated particulates or vapors emanating from contaminated soil, the Department has developed soil remediation standards for the inhalation exposure pathway. The Department considered human health effects for both carcinogenic and noncarcinogenic contaminants. The Legislature determined that standards would be set at one additional cancer risk in one million ($1x10^{-6}$) for carcinogens and a hazard quotient not to exceed one for noncarcinogens.

Specifically, this document will explain and describe the approach developed by the Department to assess the inhalation exposure pathway. The inhalation exposure pathway is a primary route of human exposure to contamination and is found at residential and non-residential sites. Generally accepted methods, models, and assumptions have already been developed to evaluate this pathway. This includes a large volume of material gathered by the USEPA. The USEPA documents entitled Soil Screening Guidance: Technical Background Document (USEPA, 1996a), and Supplemental Guidance for Developing Soil Screening levels for Superfund Sites (USEPA, 2001) serve as the basis for the Department's development of soil cleanup standards for the inhalation exposure pathway. These USEPA guidance documents will be collectively referred to hereafter as the soil screening guidance documents (SSG).

The Soil Remediation Standards for the Inhalation Exposure Pathway are to be used at any site. However, the Department recognizes that the inclusion of site-specific conditions may be appropriate in determining alternative remediation standards. If the soil contamination levels at the site are below the Inhalation Soil Remediation Standards (InhSRS), then no further action is required relative to this exposure pathway. When contaminant levels exceed the InhSRS, one could remediate the contamination levels below the appropriate standard(s) and no further action would be required relative to this exposure pathway.

Site-specific characteristics may be substituted for default inputs in the algorithm in order to calculate alternative remediation standards for the site. The site-specific factors that may be substituted are discussed further within Section VI of this Basis and Background document and are subject to Department approval. A third approach could be taken to evaluate the specific contamination levels at a site. This approach could involve using alternative models and assumptions. In addition, the specific size and shape of a site could be modeled as well as distance traveled by the vehicles, vehicle activity and type other than the default, etc. Such an approach is not discussed in Section VI but may be permissible with Department oversight and acceptance. Please note that the Department also has the right to utilize an ARS when it is appropriate to accurately reflect site conditions.

The remainder of this basis and background document is divided into a discussion of the development of InhSRS for contamination in both volatile and particulate form. Within each section, the equations and assumptions used in developing the standards are explained. Exposure in residential and non-residential settings using carcinogenic and noncarcinogenic endpoints is assessed. Subsequent sections present the methods and information that are needed to develop alternative remediation standards. Determination of the appropriate standard represents the initial phase of the process. Finally, sensitivity analyses for volatile and particulate contaminants were conducted and are presented.

The Department is fully cognizant that the inhalation exposure pathway was previously only addressed to a limited extent. Because the approach is being implemented at all sites and is more complex in nature (more regulated compounds, different assumptions, compliance averaging, etc.), the Department reserves the eventual right to approve all proposals for evaluating the inhalation exposure pathway. Furthermore, the Department recommends consultation with the Department early in the remedial process to avoid misinterpretation and other errors that could result in wasted resources and effort.

II. Methodology for Developing Standards

A. Overview

USEPA toxicity data indicate that the risks from exposure to some contaminants in the soil via the inhalation exposure pathway are greater than the risks via other pathways, such as direct ingestion. Therefore, InhSRS were developed by the Department to be protective of the air exposure route.

The central principle employed in developing the standards was to establish viable methodologies for calculating values and to apply these to the full range of exposure scenarios and contaminants that need to be assessed. Having established a potential universe of proposed standards, the products of these efforts were evaluated with the goal of selecting the process that was the most technically sound and defensible.

The inhalation exposure pathway has two components that were used to develop soil remediation standards, the volatile organic compounds and the particulate compounds.

USEPA's Soil Screening Guidance: Technical Background Document explains that the volatile organic compounds and the particulate compounds were dealt with separately because the "Inhalation risk from fugitive dusts results from particle entrainment from the soil surface; thus contaminant concentrations in the surface soil horizon (e.g., the top two (2) centimeters) are of primary concern for this pathway under the current scenario. While the entire column of contaminated soil can contribute to volatile emissions at a site, the top two (2) centimeters are likely to be depleted of volatile contaminants at most sites. Thus, contaminant concentrations in subsurface soil, which are measured using core samples, are of primary concern for quantifying the risk from volatile emissions" (USEPA 1996a, page 21). It should be noted that subsurface soil may be brought to the surface in a future use scenario and may then present an unacceptable inhalation risk from volatile organic compounds and particulates. Because of this, the Department has elected to evaluate particulate contamination at the surface via a two (2)-foot deep interval without a separate evaluation of the top two (2) centimeters.

In the SSG, soil screening levels (SSL) are developed to address the residential exposure scenario for volatile organic compounds and particulates using updated versions of the models, assumptions, and risk assessment methods originally presented in the USEPA document entitled Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual - Part B (USEPA, 1991c). Of particular note with regard to updates is the use of the Jury, Farmer, and Spencer (1984) model to replace the model originally used to calculate the volatilization factor for volatile organic compound SSL. As indicated before, the SSG documents were selected as the best starting point for the development of the overall methodology.

For the non-residential exposure scenario where volatile organic compounds are involved, the guidance provided in the USEPA Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2001) will be employed. Consultation with the USEPA indicated that a modification of SSG's short-term construction scenario, which includes a vehicular component, was not recommended to address the inhalation of particulates. Consequently, an alternative course of action was necessary. Clearly, the USEPA thought the inclusion of vehicular traffic was appropriate for a short-term construction scenario. Such a scenario represents an extreme worst case relative to the potential for the generation of dust. Examination of the residential and non-residential exposure scenarios led the Department to conclude that vehicular traffic was also typical of the general non-residential exposure scenario and a major distinction between these two exposure scenarios. Evaluation of the magnitude of the impact of truck traffic indicated that it would exceed a solely wind generated component by a wide margin. The Department's concern about dust generated by more typical vehicle activity is merely an extension of the USEPA's logic in the short-term construction scenario. However, why the USEPA does not consider vehicle activity under its other non-residential exposure scenarios and the Department does consider vehicle activity is based more on the requirement for the Department to evaluate future use situations without consideration of institutional or engineering controls. Consequently, the Department will apply to all non-residential sites, regardless of site size, standards for particulate contaminants that are based on a wind generated component and a truck traffic generated component.

While the Department tries to be consistent with the USEPA, differences in their respective approaches exist. The USEPA tends to focus on current use or known future use in assessing what is an appropriate expectation. The Department takes a more conservative approach, particularly in dealing with sites where a potential unconditional no further action determination is being considered. Future use is assessed by evaluating the site excluding all institutional and engineering controls. This is done even if such features or their equivalents are currently present. If a site subject to truck traffic is evaluated assuming an absence of paving, the concern about fugitive dust emissions would necessarily be greatly magnified. On the other hand, if paving is assumed to be present at the same facility, the concern is reduced to an insignificant level. This probably accounts for why the USEPA is concerned with vehicular traffic under a short-term construction scenario, but not under a standard non-residential exposure scenario, in contrast to the Department.

USEPA models were investigated as a way to develop particulate related standards for these non-residential exposure scenarios. This process led to the conclusion that pairing the AP-42 emission factors (Compilation of Air Pollutant Emission factors, Volume I: Stationary Point and Area Sources USEPA, 1998a) and the Industrial Source Complex Short Term Version 3 (ISCST3) (USEPA, 2002) model was the best choice to address this situation. AP-42 estimates emissions while the ISCST3 assesses the dispersion of these emissions, making it possible to assess the impact of vehicular traffic. AP-42 in combination with another dispersion model, the Fugitive Dust Model (FDM) (USEPA, 1992), has a similar capability. AP-42 and ISCST3 were selected by the Department to use as the default because first, these are the methods of choice for the USEPA. Secondly, the calculation of alternative site-specific values can more readily be done using this combination. Finally, the output from the AP-42 and ISCST3 pairing is more protective of human health than the output from AP-42 and the FDM model.

The net result was that for the residential exposure scenario, the standards for the particulate compounds were calculated using the SSG methodology. The particulate compounds under a non-residential exposure scenario would employ AP-42 and the ISCST3 model to derive a standard. Nonvolatile and semi-volatile organic compounds were evaluated as inhalable particulates emitted by wind erosion and by mechanical resuspension by vehicular traffic to evaluate whether the adherence of these compounds to dust particles represented a significant hazard.

B. Toxicity Factors for Inhalation Exposure Pathway

All of the toxicity data used to develop InhSRS for volatile, semivolatile, and particulate contamination can be found in Appendix A. The unit risk factors (URFs) for carcinogens and reference concentrations (RfCs) for noncarcinogens that are used for the evaluation of inhalation toxicity were taken from a number of sources, which are described below. Each chemical-specific reference is given in Appendix A. The following describes the hierarchy used specifically for the inhalation exposure pathway. This hierarchy is consistent with the hierarchies established for the other pathways, taking into account the preference for inhalation-based data.

The Department has determined a hierarchy for obtaining toxicity information that is generally applied to all exposure pathways for the development of soil remediation standards. USEPA's on-line Integrated Risk Information System (IRIS) (USEPA, 2003a) is the first choice under the Department's hierarchy for current inhalation toxicity data. It is the source of 33 URFs and 28 RfCs.

The next preferred source of inhalation toxicity data preferred for inhalation exposure pathway use is the California Environmental Protection Agency, which is an umbrella agency that includes the Office of Environmental Health Hazard Assessment and the California Air Resources Board (California Air Resources Board, 2002; California Environmental Protection Agency, 1998, 2002, and 2003; California Office of Environmental Health Hazard Assessment, 2002). 27 URFs and 9 RfCs came from this source.

Another major source of toxicity data is the USEPA's Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997a) which were last revised in 1997. This source is used when data are not available from the above two sources. HEAST was referred to for 4 URFs and 7 RfCs.

Other sources of toxicity data include Toxicology Excellence for Risk Assessment (TERA)(TERA, 1999), the Agency for Toxic Substances and Disease Registry (ATSDR)(ATSDR, 2003), and a paper by I.C.T. Nisbet and P.K. LaGoy on toxic equivalency factors for polycyclic aromatic hydrocarbons (Nisbet and LaGoy, 1992).

A RfC for lead was developed by the Department's Bureau of Air Quality Evaluation (BAQEv) using USEPA's LEAD5 Model, Version 5 (NJDEP/BAQEv, 2003).

For antimony (total), an IRIS RfC for antimony trioxide was used. The arsenic URF is based on an IRIS URF for inorganic arsenic. For chlordane, an IRIS RfC for technical grade chlordane was used.

For a number of contaminants, there were no inhalation toxicity data to be found. If oral toxicity data were available, they were converted to inhalation units. Most of these converted oral data came from IRIS and HEAST, some from the Department's drinking water quality standards (A280)(NJDWQI, 1987; NJDWQI, 1994), and a few from the National Center for Environmental Assessment (NCEA), part of USEPA's Superfund Technical Support Center in Cincinnati, Ohio (USEPA, 2003b). Listed in Appendix A are the compounds that are impacted by this action.

Class C carcinogens are those classified by USEPA as "possible human carcinogens." There is limited evidence of their carcinogenicity in animals, and inadequate human data. For the development of soil remediation standards, the Department has developed a policy for Class C carcinogens with RfCs (for noncarcinogenic effects). To add an additional safety factor to the toxicity data for these possible carcinogens, the RfC is divided by ten. This policy and its standardized application for all pathways were discussed in the Interested Party Review introduction. Listed in Appendix B are the compounds that are impacted by the Class C carcinogen policy. The Department is aware that USEPA has recently finalized Guideline for Carcinogen Risk Assessment (March 2005), and that these guidelines recommend using narrative descriptors for weight of evidence of carcinogenicity in place of the existing alphabetic classification system. The contaminants for which the Department is proposing soil standards were evaluated under the alphabetic classification system, and our policy will remain unchanged for chemicals categorized as Group C, Possible Human Carcinogen, under this system. As the practical implications of the narrative descriptors in the new guidelines become clear, the Department will consider adapting its policy for chemicals that are evaluated under these narrative descriptors.

III. The Development Of Inhalation Standards For Volatiles

A. Calculations

The equations for the InhSRS of carcinogenic and noncarcinogenic volatile contaminants in soil are given below. The target cancer risk of $1\text{x}10^{-6}$ and the target hazard quotient of one are used by USEPA and are also mandated by the Brownfield Contaminated Site Remediation Act (N.J.S.A. 58:10B-1 et seq.). The Department uses the USEPA SSG methodology for volatile organic contaminants for both residential and non-residential exposure.

Equations for Calculating Inhalation Soil Remediation Standards for Volatile Organics:

Carcinogens

$$\text{Inh}_v\text{SRS}_c = \frac{TR \times AT \times 365 \,{}^{days}\!/_{year}}{URF \times 1000 \,{}^{\mu g}\!/_{mg} \times EF \times ED \times \left(\frac{1}{VF}\right)}$$

Equation 1

Noncarcinogens

$$Inh_vSRS_n = \frac{THQ \times AT \times 365 \,{}^{days}\!/_{year}}{EF \times ED \times \left(\frac{1}{RfC}\right) \times \left(\frac{1}{VF}\right)}$$

Equation 2

Inh_vSRS_c = Inhalation soil remediation standard for volatile carcinogens (mg/kg)

Inh_vSRS_n = Inhalation soil remediation standard for volatile noncarcinogens (mg/kg)

TR = Target cancer risk (unitless)

THQ = Target hazard quotient (unitless)

AT = Averaging time (years)

URF = Inhalation unit risk factor $(\mu g/m^3)^{-1}$

RfC = Inhalation reference concentration (mg/m^3)

EF = Exposure frequency (day/year)

ED = Exposure duration (years)

VF = Soil-to-air volatilization factor (m^3/kg)

Equation for Calculating Volatilization Factor (VF):

$$VF = Q/C_{vol} \times \frac{\left(3.14 \times D_A \times T\right)^{1/2}}{2 \times \rho b \times D_A} \times 10^{-4} \, {}^{m^2}\!/_{cm^2}$$ **Equation 3**

VF = Soil-to-air volatilization factor (m^3/kg)

Q/C_{vol} = Inverse concentration at center of source (g/m^2-s per kg/m^3) (specific to volume)

D_A = Apparent diffusivity (cm^2/s)

T = Exposure interval (seconds)

ρb = Dry soil bulk density (g/cm^3)

Equation for Calculating Apparent Diffusivity (D_A):

$$D_A = \frac{\left[\left(\theta_a^{10/3} \times D_i \times H'\right) + \left(\theta_w^{10/3} \times D_w\right)\right] / n^2}{\left(\rho b \times K_d\right) + \theta_w + \left(\theta_a \times H'\right)}$$ **Equation 4**

D_A = Apparent diffusivity (cm^2/s)

θ_a = Air-filled soil porosity (L_{air}/L_{soil})

D_i = Diffusivity in air (cm^2/s)

H' = Henry's Law Constant (unitless)

θ_w = Water-filled soil porosity (L_{water}/L_{soil})

D_w = Diffusivity in water (cm^2/s)

n = Total soil porosity (L_{pore}/L_{soil})

ρb = Dry soil bulk density (g/cm^3)

K_d = Soil-water partition coefficient (cm^3/g)

Equation for Calculating Soil-Water Partition Coefficient (K_d):

$$K_d = K_{oc} \times f_{oc}$$ **Equation 5**

K_d = Soil-water partition coefficient (cm^3/g)

K_{oc} = Soil organic carbon-water partition coefficient (cm^3/g)

f_{oc} = Organic carbon content of soil (g/g)

Equation for Calculating Air-Filled Soil Porosity (θ_a):

$$\theta_a = n - \theta_w$$ **Equation 6**

θ_a = Air-filled soil porosity (L_{air}/L_{soil})

θ_w = Water-filled soil porosity (L_{water}/L_{soil})

n = Total soil porosity (L_{pore}/L_{soil})

Equation for Calculating Soil Moisture Content:

$$\theta_w = n(I / K_s)^{1/(2b+3)}$$ **Equation 7**

n = total soil porosity

I = soil moisture infiltration rate (m/yr)

K_s = saturated hydraulic conductivity of the soil (m/yr)

1/(2b+3) = determined by soil type, provided in *Soil Screening Guidance: Technical Background Document EPA/540/R-95/128 (May 1996); Attachment A - "Conceptual Site Model," Table A-2*

Appendix D contains additional information regarding this equation.

B. Default Input Parameters

The methodology for calculating InhSRS for volatile contaminants is taken from USEPA's Soil Screening Guidance: Technical Background Document (USEPA 1996a,). The input parameters used by the Department were the same as those used by USEPA (1996a, 2001), except for air dispersion and certain soil characteristics. These exceptions are noted in Tables 1 and 2, below. For the volatile pathway, the difference between the residential and non-residential scenarios is exposure time, including averaging time (AT), exposure frequency (EF), exposure duration (ED), and exposure interval (T).

A sensitivity analysis of the inhalation model for volatile contaminants is presented in Appendix C. Some of these analyses are discussed further below.

The Q/C value gives an estimate of dispersion based on meteorological conditions. It was changed from USEPA's default value based on meteorological modeling for New Jersey.

Soil texture may significantly affect the soil moisture content, which in turn has a substantial effect on the volatilization rate of volatile organic chemicals. Heavier soils such as loam soils, or those with significant clay content tend to have higher moisture contents that can significantly reduce volatilization. The USEPA uses loam as its default soil texture, based on nationwide data. However, because the southern half of New Jersey is primarily composed of sandy loam, loamy sand and sand soils (Tedrow, 1986), it was determined that a loam soil texture would not be protective of many areas of the state. Sand is adequately protective for all soil types, however it was not used as the default soil texture because sand is too porous to be representative of northern New Jersey, which consists largely of sandy loam, loam and silt loam soils. Sandy loam soil was selected as a mid-range soil texture to represent the state as a whole when calculating generic remediation standards.

The USEPA default characteristics were altered slightly to generate default values for New Jersey. These values are representative of a sandy loam soil: total soil porosity (n); water-filled soil porosity (θ_w); air -filled soil porosity (θ_a); and organic carbon content of soil (f_{oc}). Comparison of USEPA's and the Department's default parameters are given in Table 1 below.

Table 1

Comparison of Input Parameters

Parameters		NJDEP Default	USEPA Default
θ_w	water-filled soil porosity	0.23 L_{water}/L_{soil}	0.15 L_{water}/L_{soil}
n	total soil porosity	0.41 L_{pore}/L_{soil}	0.43 L_{pore}/L_{soil}
θ_a	air -filled soil porosity	0.18 L_{air}/L_{soil}	0.28 L_{air}/L_{soil}
f_{oc}	organic carbon content of soil	0.002 g/g	0.006 g/g surface

AIR-FILLED SOIL POROSITY (θ_a)

Air-filled soil porosity is the most significant soil parameter affecting the final steady-state flux of volatile contaminants from soil. The higher the air-filled soil porosity, the greater the emission flux of volatile constituents. (USEPA 1996a). USEPA used an air-filled porosity of 0.28 (v/v) for loam soil, its default soil texture. The Department default soil texture is sandy loam, and a default air-filled soil porosity of 0.18 (v/v) was determined as the difference between the total porosity (0.41 (v/v)) and the soil moisture content (0.23 (v/v)). The appropriate values for these two latter parameters were determined as follows:

TOTAL SOIL POROSITY

The Department obtained the value of 0.41(v/v) for total soil porosity for sandy loam soil, from Carsel and Parrish (1988), which is one of the data sources cited by the USEPA in the soil screening guidance.

SOIL MOISTURE CONTENT

Soil moisture content is highly specific to soil type and climate (Sanders and Talimcioglu, 1997). The moisture content will vary according to season and short-term weather. In New Jersey, this variation for a sandy loam soil has been estimated to lie within the range of 0.18 to 0.26 (v/v) (Sanders and Talimcioglu, 1997). For purposes of the New Jersey generic remediation standard calculation, it is best to use local climate data to determine average water content for a targeted soil. USEPA's soil moisture value corresponds to a moisture level in between the field capacity of sandy loam soils and the saturation volume for loam soils, and is higher than the actual average moisture level for sandy loam soil in New Jersey (Sanders and Talimcioglu, 1997). For New Jersey, an average soil moisture content specific to sandy loam soil and New Jersey climate and weather conditions was calculated using a simple relationship described in the USEPA SSG User's Guide (USEPA, 1996b). A value of 0.23 (v/v) was calculated. Appendix D contains additional information regarding determination of the generic soil moisture level.

SOIL pH

Although soil pH is not a direct input parameter used in the Inhalation pathway, it may affect the K_{oc} value for ionizable organic contaminants and the K_d value for inorganic contaminants. The default pH of 6.8 used in the USEPA SSL guidance document is an overall overage pH for United States soils. However, it is well known that soils in the eastern United States are more acidic than those in the western part of the country (Foth 1984). Therefore, it is appropriate to use New Jersey-specific information regarding soil pH. The pH of New Jersey soils typically range from about pH 4 to pH 6.5 (Lee et al. 1996, Yin et al. 1996). A pH value of 5.3 is appropriate for New Jersey use.

FRACTION ORGANIC CARBON CONTENT (f_{oc})

Regarding the fraction organic carbon content (f_{oc}), the NJDEP deviates from USEPA's default value of 0.006. The reason for this is that the Jury model calculates contaminant transport for the entire soil column, using a single value for f_{oc}. Using a surface default value of 0.006 in the model may be appropriate for the surface layer of the soil column, but may underestimate volatile migration in the subsurface portion of the soil column. Therefore, to provide a better estimate of contaminant volatilization, the USEPA subsurface default value for f_{oc} (0.002) was used instead of the surface default value (0.006). This latter value does not represent typical soil organic carbon values in the subsurface, and would reduce the extent of contaminant volatilization.

The subsurface default f_{oc} value was determined after review of data published by Carsel et al. (1988). Organic carbon content can vary from near zero (beach sands and other sandy soils at subsurface depths) to several percent (surface soils in forests). The USEPA judged that a fraction organic carbon content of 0.002 was appropriate for subsurface soils. The organic carbon content of soil has not been well documented below 1-2 m depth, but Carsel et al. (1988) performed statistical analysis of a large soil dataset and reported distributions of soil organic matter contents at various depth intervals up to 1.2 m depth. The average fraction organic carbon content of the three mean subsurface values for Class B and Class C soils was 0.002. These hydrologic soil groups include sandy loam soils. Therefore, the NJDEP has decided that a default fraction organic carbon content of 0.002 is appropriate.

CHEMICAL PROPERTIES OF CONTAMINANTS

Chemical properties for all regulated contaminants are listed in Appendix E. When possible, chemical properties were taken from values in USEPA's SSL Guidance document (USEPA 1996a). For contaminants not listed in the USEPA SSL guidance document, properties were generally obtained from the same data sources that USEPA used in its guidance document.

Water solubilities and Henry's law constants for contaminants not listed in the guidance document were usually taken from the Superfund Chemical Data Matrix (USEPA 1996c). The few exceptions are noted in the appendix.

K_{oc} values for contaminants not listed in the guidance document were calculated from octanol-water partition coefficients using Equations 70 or 71 provided in the USEPA SSL document. Octanol-water partition coefficients were obtained from the Superfund Chemical Data Matrix in most cases. For ionizable organic contaminants, Attachment C of the USEPA SSL User's Guide lists K_{oc} values for any environmental pH value (USEPA 1996b). The pH selected for New Jersey remediation standard calculations was 5.3 (see below). K_d (soil-water partition coefficients) values for organic compounds were calculated by multiplying the K_{oc} value by the default fraction organic content of 0.002 (Equation 5). For inorganic contaminants, K_d were determined directly. K_d values were taken at pH 5.3 for those inorganic contaminants with pH dependant values reported in USEPA (1996b). For inorganic contaminants without K_d values in USEPA (1996a) or (1996b), values from USEPA (1996c) were used.

Diffusion coefficients for contaminants not reported in USEPA (1996a) were either taken from or calculated using CHEMDAT8 or WATER8 (see USEPA (1994a) and USEPA (1994b)). The few exceptions to the above data sources are footnoted in the chemical property table (Appendix E).

VOLATILIZATION FACTOR (VF)

The soil-to-air volatilization factor (VF) defines the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air, taking into consideration chemical-specific properties and soil characteristics. The equation for VF is based on the volatilization model developed by Jury et al. (1984) for infinite sources.

INVERSE CONCENTRATION AT CENTER OF SOURCE (Q/C)

Dispersion of a contaminant in the air was determined by modeling a square area source of one-half -acre with a unit emission rate of one gram per second. The normalized concentration at or near the center of the square area was found to represent the maximum annual average concentration. However, when using this technique, there is an exponential relationship in which the emission flux decreases as the site size increases. Therefore, rather than directly using the normalized concentration as a dispersion coefficient, the inverse concentration, or Q/C, was developed so as to be equally protective regardless of the size of the site. The Q/C is simply the average rate of contaminant flux (g/cm^2-s) based on an overall site emission rate of one gram per second divided by the maximum normalized air concentration in kg/m^3.

Meteorological conditions (i.e., the intensity and frequency of wind) affect both the dispersion and emissions of particulate matter. Since the Q/C accounts for the average concentration from wind erosion over an entire year, it should be used only to develop chronic health criteria. The ratio of emissions to maximum concentration is not appropriate to evaluate the potential for acute health criteria. Results from dispersion modeling by the Department with the ISCST3 dispersion model and site-specific surface meteorological observations from Newark International Airport produce a Q/C value of 90.4 g/m^2–sec per kg/m^3 for a half -acre site and 138.7 for a two acre site. Other potential sources of data were from Philadelphia, Pennsylvania and Atlantic City. The Department recognizes that this value may not specifically represent all sites in New Jersey. However, suitable data do not exist for other locations in New Jersey to generate a comparable Q/C. See Table 2, below, for the other default volatile exposure input parameters.

Table 2
Volatile Exposure Input Parameters

Parameters		Value	Source
THQ	target hazard quotient	1	USEPA (1996a)
TR	target cancer risk	$1x10^{-6}$	USEPA (1996a); N.J.S.A. 58:10B-1 et seq.
AT	averaging time	Carcinogenic: 70 years	USEPA (1996a)
		Noncarc./Residential: 30 years	USEPA (1996a)
		Noncarc./Non-residential: 25 years	USEPA (2001)
EF	exposure frequency	Residential: 350 days/year	USEPA (1996a)
		Non-residential: 225 days/year	USEPA (2001)
ED	exposure duration	Residential: 30 years	USEPA (1996a)
		Non-residential: 25 years	USEPA (2001)
Q/C	inverse concentration at center of source	Residential: 90.4 $(g/m^2\text{-}s)/(kg/m^3)$ Non-residential: 138.7 $(g/m^2\text{-}s)/(kg/m^3)$	This document Section III.B
T	exposure interval	Residential: 9.5×10^8 seconds	USEPA (1996a)
		Non-residential: 7.9×10^8 seconds	USEPA (2001)
ρ_b	dry soil bulk density	1.5 g/cm^3	USEPA (1996a)
θ_a	air -filled soil porosity	0.18 L_{air}/L_{soil}	This document Section III.B
θ_w	water-filled soil porosity	0.23 L_{water}/L_{soil}	

Table 2 Volatile Exposure Input Parameters			
Parameters		**Value**	**Source**
n	total soil porosity	0.41 L_{pore}/L_{soil}	Carsel and Parrish (1988)
f_{oc}	organic carbon content of soil	0.002 g/g	This document Section III. B

C. Soil Saturation Limit (C_{sat})

The soil saturation concentration (C_{sat}) corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the soil contaminant may be present in free phase, i.e., nonaqueous phase liquids (NAPLs) for contaminants that are liquid at ambient soil temperatures and pure solid phases for compounds that are solid at ambient soil temperatures (USEPA 1996a).

To determine the soil saturation limit for each contaminant, the Department used Equation 8. For chemical-specific values for solubility in water (S), see the chemical properties table in Appendix E. The soil characteristics are the same as those used above to calculate risk-based soil remediation standards.

USEPA recommends that when the risk-based inhalation soil screening level is calculated using Equations 5 or 6, and that value exceeds C_{sat} for liquid compounds, the soil screening level should be set at C_{sat}. For chemicals that are solid at ambient soil temperatures, when inhalation soil remediation standards are above C_{sat}, USEPA recommends that the soil cleanup decisions should be based on another pathway of concern (USEPA 1996a).

The USEPA recommends the regulation of contaminants at the C_{sat} level because of concerns about the presence of liquid, free product. The Department also has similar concerns, but liquid, free product remediation is addressed within the context of other rules and regulations, such as the Technical Requirements for Site Remediation (N.J.A.C. 7:26E) and the Ground Water Quality Standards (N.J.A.C. 7:9C).

What this means is when C_{sat} is exceeded by a calculated standard for a liquid contaminant, the calculated values cannot be achieved and therefore the compound cannot be regulated via this exposure pathway. Therefore, the C_{sat} number will not be specified as the InhSRS. However, this is not the case for the evaluation of those liquid chemicals acting as particulates (i.e., where the chemical is adsorbed to airborne dust particles or is a condensate). Consequently, the particulate standard values may be above C_{sat}, but as long as they do not exceed 10^6 parts per million, the calculated values will be used as the standard for the inhalation exposure pathway.

Equation for Calculating Soil Saturation Limit (C_{sat}):

$$C_{sat} = \frac{S}{\rho_b}\left[\left(K_d \times \rho_b\right) + \theta_w + \left(H' \times \theta_a\right)\right] \qquad \textbf{Equation 8}$$

C_{sat} = Soil saturation concentration (mg/Kg)

S = Solubility in water (mg/L water) - *chemical-specific*

ρ_b = Dry soil bulk density (g/cm^3)

K_d = Soil-Water partition coefficient (cm^3/g)

θ_a = Air-filled soil porosity (L_{air}/L_{soil})

θ_w = Water-filled soil porosity (L_{water}/L_{soil})

H' = Henry's law constant (unitless) - *chemical-specific*

Table 3

Soil Saturation Input Parameters

Parameter		Value	Source
ρ_b	Dry soil bulk density	1.5 g/cm^3	USEPA (1996a)
θ_a	Air-filled soil porosity	0.18 L_{water}/L_{soil}	This document Section III.B
θ_w	Water-filled soil porosity	0.23 L_{water}/L_{soil}	This document Section III.B

IV. The Development of Inhalation Standards for Particulates

A. Residential Calculations

For the residential exposure scenario for particulates, the Department utilizes the methodology for calculating inhalation soil screening levels from the USEPA's Soil Screening Guidance: Technical Background Document (1996a). The residential soil screening level relates soil concentrations of a contaminant to harmful emissions from wind erosion only. The default site size of one-half acre is used to calculate the residential Inh_pSRS.

Equations for Calculating Inhalation Soil Remediation Standards (Residential) for Particulates:

Carcinogens

$$Inh_pSRS_c = \frac{TR \times AT \times 365 \text{ days/year}}{URF \times 1{,}000\ \mu g/mg \times EF \times ED \times \left(\frac{1}{PEF}\right)} \qquad \textbf{Equation 9}$$

Noncarcinogens

$$Inh_pSRS_n = \frac{THQ \times AT \times 365 \text{ days/year}}{EF \times ED \times \left(\frac{1}{RfC}\right) \times 1000\ \mu g/mg \times \left(\frac{1}{PEF}\right)} \qquad \textbf{Equation 10}$$

Inh_pSRS_c = Inhalation Soil Remediation Standard for carcinogens (mg/kg)
Inh_pSRS_n = Inhalation Soil Standard for noncarcinogens (mg/kg)
TR = Target cancer risk (unitless)
AT = Averaging time (years)

URF = Inhalation unit risk factor ($\mu g/m^3$)$^{-1}$

EF = Exposure frequency (days/year)

ED = Exposure duration (years)

PEF = Particulate emission factor (m^3/kg)

THQ = Target hazard quotient (unitless)

RfC = Inhalation reference concentration ($\mu g/m^3$)

<u>Equation for Calculating the Particulate Emission Factor (PEF):</u>

$$PEF = Q/C \times \left(\frac{3{,}600 \ sec/hr}{0.036 \times (1 - v) \times \left(\frac{U_m}{U_t} \right)^3 \times F(x)} \right)$$

Equation 11

PEF = Particulate emission factor (m^3/kg)

Q/C = Inverse concentration at center of source (g/m^2-s)/(kg/m^3)

V = Fraction of vegetative cover (unitless)

U_m = Mean annual wind speed (m/s)

U_t = Equivalent threshold value of wind speed at 7 m (m/s)

F(x) = Function dependent on U_m/U_t derived using Cowherd et al. (1985) (unitless)

<u>Equation for calculating the Q/C, Inverse Concentration Factor for Dispersion:</u>

$$\frac{Q}{C} = \frac{J_{s^{ave}}}{C_{air} \times 10^{-9} \, kg/\mu g}$$

Equation 12

Q/C = Inverse concentration factor for air dispersion [(g/m^2-s)/(kg/m^3)]

J_s^{ave} = Average rate of contaminant flux (g/m^2-s)

C_{air} = Maximum contaminant concentration ($\mu g/m^3$)

Equation for calculating the average rate of contaminant flux:

$$J_{s^{ave}} = \frac{ER}{A}$$ **Equation 13**

J_s^{ave} = Average rate of contaminant flux (g/m^2-s)

ER = Emission rate (normalized) 1 g/s

A = Area (1/2 acre = 2,023 m^2)

B. Residential Default Input Parameters

The emissions in the Particulate Emission Factor (PEF) equation above are based on the "unlimited reservoir" model from Cowherd et al. (1985) which was developed to estimate particulate emissions due to wind erosion. The unlimited reservoir model is sensitive to the threshold friction velocity, which is a function of particle size distribution. The threshold friction velocity has the greatest effect on emissions and resulting concentration. For this reason, a conservative soil aggregate size of 500 µm was selected as the default value for calculating Inh_pSRS. The soil size aggregate is related to how much wind is needed before dust is generated at a site. A soil aggregate size of 500 µm yields a threshold friction velocity of 0.5 m/s. This means that the wind speed must be at least 0.5 m/s before any fugitive dust is generated (Cowherd et al., 1985). However, the threshold friction velocity should be corrected to account for the presence of nonerodible elements. Nonerodible elements are described in Cowherd et al. (1985) as clumps of grass or stones larger than 1 cm in diameter that can deflect a wind which otherwise would impact erodible soil. The amount of vegetative cover assumed for wind erosion was 50%, as a reasonable compromise between no vegetation and complete cover. This is not a conservative value since a significant number of sites have less than 50 percent vegetative cover. Please note that an assessment of the potential impact of some of these parameters is in Appendix F.

Exposure via the inhalation exposure pathway was determined by modeling a square area source of one-half acre with a unit emission rate of one gram per second. A normalized concentration at or near the center of the square area was found to represent the maximum annual average concentration. When using this technique, there is an exponential relationship in which the emission flux decreases as the site size increases. Therefore, rather than directly using the normalized concentration as a dispersion coefficient, the inverse concentration, or Q/C, was developed so as to be equally protective regardless of the size of the site. The Q/C is simply the average rate of contaminant flux (g/cm^2-s) based on an overall site emission rate of one gram per second divided by the maximum normalized air concentration in kg/m^3. In developing the InhSRS for a half-acre site, dispersion modeling was done with Newark International Airport meteorological observations which resulted in a Q/C value of 90.4 (g/m^2- s)/(kg/m^3). This is the least conservative value of three locations with meteorological data representative of New Jersey (Newark, Philadelphia, and Atlantic City). See Table 4 for the Q/C value used as well as other default residential exposure parameters.

Table 4
Residential Exposure Parameters

Parameters		Input Value	Source
Q/C	Inverse concentration at center of source	90.4 $(g/m^2\text{-}s)/(kg/m^3)$	This document Section IV.B
V	Fraction of vegetative cover	50 %	USEPA (1996a)
U_m	Mean annual wind speed	4.56 m/s	NOAA (2002b)
U_t	Equivalent threshold wind speed at 7 m	11.32 m/s	USEPA (1996a)
F(x)	Function of wind speed over threshold wind speed	0.159	This document Section IV.A
AT	Averaging time	Carcinogen: 70 years	USEPA (1996a)
		Noncarcinogen: 30 years	
EF	Exposure frequency	350 days	USEPA (1996a)
ED	Exposure duration	30 years	USEPA (1996a)

C. Non-residential Calculations

Because the methodology used for calculating a residential InhSRS for particulate contamination (particulates) could not be adapted for calculating a non-residential inhalation soil standard, another methodology, derived from USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Peer Review Draft*, OSWER 9355.4-24 (March 2001), was used. Following are the equations comprising this methodology.

Equations for Calculating Inhalation Soil Remediation Standards (Non-residential) for Particulates:

Carcinogens

$$Inh_pSRS_c = \frac{TR}{CSF \times DOSE} \times \frac{10^6\,mg}{kg}$$ **Equation 14**

Noncarcinogens

$$Inh_pSRS_n = \frac{1}{DOSE \big/ RfD} \times \frac{10^6\,mg}{kg}$$ **Equation 15**

Inh_pSRS_c = Health-based soil cleanup level for carcinogens (mg/kg)

Inh_pSRS_n = Health-based soil cleanup level for noncarcinogens (mg/kg)

TR = Target risk ($1x10^{-6}$)

CSF = Cancer slope factor $(mg/kg\text{-}day)^{-1}$

DOSE = Exposure dose calculation (mg/kg-day)

RfD = Reference dose (mg/kg-day)

Equation for Converting Unit Risk Factor to Cancer Slope Factor:

$$CSF = \frac{URF \times BW}{DIR} \times \frac{10^3\,\mu g}{mg}$$ **Equation 16**

CSF = Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$

URF = Unit Risk Factor $(\mu g/m^3)^{-1}$

BW = Body weight (70 kg)

DIR = Daily inhalation rate (20 m^3/day)

Equation for Converting Reference Concentration to Reference Dose:

$$RfD = RfC \times DIR \times \left(1 \big/ BW\right) \times \left(mg \big/ 10^3\,\mu g\right)$$ **Equation 17**

RfD = Reference dose (mg/kg-day)

RfC = Reference concentration ($\mu g/m^3$)

DIR = Daily inhalation rate (20 m^3/day)

BW = Body weight (70 kg)

Equation for Calculating the Exposure Dose:

$$DOSE = \frac{PEF_s \times IR \times EF \times ED}{BW \times AT}$$ **Equation 18**

DOSE = Exposure dose calculation (mg/kg-day)

PEF$_s$ = Particulate emission factor from site activity (mg/m^3); this differs from "PEF" noted in Equations 10 and 11

IR = Inhalation rate (m^3/day)

EF = Exposure frequency (days at site per year)

ED = Exposure duration (years)

BW = Body weight (kg)

AT = Averaging time (days)

Equation for Calculating the Particulate Emission Factor:

$$PEF_s = CF \times \left((D_{isc} \times ER_{wind}) + (D_{isc} \times ER_{traffic}) \times \left(\frac{A_{traf}}{A_s} \right) \right)$$ **Equation 19**

PEF$_s$ = Particulate emission factor from site activity (mg/m^3)

CF = Conversion factor (10^{-3} mg/μg)

D$_{isc}$ = Air dispersion factor for unit emission rate of 1 g/s (units = (μg-sec)/(m^3-g))

ER$_{wind}$ = Wind generated particulate emission rate per year (g/s)

ER$_{traffic}$ = Particulate emission rate for site traffic (g/s)

A$_{traf}$ = Area of traffic (m^2)

A$_s$ = Site area (m^2)

Equation 19 is derived from USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Peer Review Draft*, OSWER 9355.4-24 (March 2001), Equation 5-9.

USEPA guidance is concerned with only worker exposure to inhalation of resuspended dust from traffic. However, the "*Supplemental Guidance*" includes a method to evaluate the exposure of off-site residents from both dust emitted from traffic on unpaved roads and dust emitted from wind erosion. This equation, Equation 5-9, was adapted to assess worker exposure to contaminated dust originating from both wind and traffic sources.

Similar to the March 2001 "*Supplemental Guidance*," Equation 19 calculates a Particulate Emission Factor, but, instead of including a Q/C as a dispersion factor, "D_{isc}" represents the average air concentration over an 8,093.65 m^2-area (two acre) source divided by a unit emission rate of 1 gram per second. An emission rate of 1.235E-4 g/m^2-sec was input to the ISCST3 Model to reflect this unit emission rate for a two acre area source. The D_{isc} can be interpreted as the result of combining the Q/C and J_T terms in "*Supplemental Guidance*" Equation 5-9.

ER_{wind} in Equation 19 is derived in Equation 22. It is an emission rate (g/s) rather than emission mass (g) in "*Supplemental Guidance*" Equation 5-9.

$ER_{traffic}$ in Equation 19 is derived in Equation 20. Again, it is an emission rate (g/s), as compared to an emission mass (g) in Equation 5-9.

A_{traf} in Equation 19 is an input variable established by the Department. The default is the two acre (8,093 m^2) area, based on a site of equal area.

A_s in Equation 19 reflects the extent of the area being evaluated for compliance, in this case, the default two acre (8,093 m^2) site area.

ED, exposure duration, is included in Equation 18.

Equation for Calculating the Particulate Emission Rate:

$$ER_{traffic} = \frac{E_{10} \times TC \times D \times TF}{(28{,}800\ \text{seconds}/8\text{-}hr\ day) \times EF} \qquad \textbf{Equation 20}$$

ER$_{traffic}$ = Particulate emission rate for site traffic (g/s)
E$_{10}$ = Particulate emission factor (g/VKT)
TC = Daily traffic count for the unpaved area (vehicles/day)
D = Average distance a vehicle travels through the unpaved area (km)
TF = Traffic frequency (days with traffic/year)
EF = Exposure frequency (days at site/year)

Equation 21 is the empirical expression used to estimate PM-10 particulate emissions per vehicle kilometer traveled on an unpaved road taken from the USEPA document AP-42, Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources (USEPA, 1998a). It is the basis for estimating non-residential exposure from particulate emissions.

Equation for Calculating the Particulate Emission Factor:

$$E_{10} = (281.9\ \ g/VKT) \times \left[k(s/12)^{0.9}(W/3)^{0.45}\right] \times \left[\frac{(365 - p)}{365\ days}\right] \qquad \textbf{Equation 21}$$

E$_{10}$ = Particulate emission factor per kilometer traveled (g/VKT)
k = Particle size multiplier (unitless) = 1.5 for PM10
s = Silt content of unpaved surface (%)
W = Mean vehicle weight (tons)
p = days with at least 0.254 mm (0.01 in) of precipitation per year

Equations 22 through 25 are the same equations for Industrial Wind Erosion listed in Section 13.2.5 of U.S. EPA's AP-42, Compilation of Air Pollutant Emission Factors, Volume I:

Stationary, Point, and Area Source. These are listed in this document with several New Jersey-specific values for convenience.

Equation for Calculating the Particulate Emission Rate from Wind Erosion:

$$ER_{wind} = \frac{k \times N \times P \times SA}{31{,}536{,}000\,\text{sec}/\,year}$$ **Equation 22**

ER_{wind} = Wind generated particulate emission rate per year (g/s)
k = Particle size multiplier (0.5 for PM10)
N = Number of disturbances per year
P = Erosion Potential (g/m^2)
SA = Surface area of the site (m^2)

Equation for Calculating the Erosion Potential for a Dry Exposed Surface:

$$P = 58 \times (u^* - u^t)^2 + 25 \times (u^* - u^t)$$ **Equation 23**

P = Erosion potential (g/m^2)
u* = Friction velocity (m/s)
u^t = Threshold Friction Velocity (m/s)

A threshold friction velocity of 1.33 m/s for roadbed material is assumed. This value is taken from Table 13.2.5-2 of AP-42 (USEPA 1998a).

Equation for Calculating the Friction Velocity:

$$u^* = 0.053 \times u_{10}^{+}$$

Equation 24

u* = Friction velocity (m/s)
u^{+}_{10} = Fastest Mile Wind at 10 meters (m/s)

Equation to Correct the Fastest Wind Mile ($u^{6.1}$) to a Reference Height of 10 meters:

$$u_{10}^{+} = u^{6.1} \times \frac{\ln(10m/0.005)}{\ln(z/0.005)}$$

Equation 25

u^{+}_{10} = Fastest Mile Wind at 10 meters (m/s)
$u^{6.1}$ = Fastest Mile Wind at standard anemometer height (m/s)
z = Anemometer height (m)

Fastest Mile Wind Speed of 55 miles per hour (24.58 m/s) found in "Local Climatological Data Annual Summary for Newark, New Jersey" (NOAA 2002b). Value is fastest mile wind speed among climatological records for stations at Allentown and Philadelphia, Pennsylvania, Wilmington, Delaware, Atlantic City, New Jersey, and Central Park, New York.

D. Non-residential Default Input Parameters

The inputs used by the Department in the above equations are either USEPA default inputs, New Jersey-specific values developed by the Department, or by Boile (2006; reproduced as Appendix J of this document). Table 5 shows the input values and sources used to calculate the non-residential InhSRS. Sensitivity analyses for a number of the inputs were done; Appendix F details the findings.

Table 5
Non-residential Exposure Parameters

Parameters		Input Value	Source
A_s	Site size	2 acres	This document Appendix G
s	Silt content	11%	USEPA (1998a)
W	Mean vehicle weight	6,886 pounds (3.1 Mg)	BOILE (2006)
M	Surface material moisture content	0.2 %	USEPA (1998a)
p	Number of days with > 0.01 inch of precipitation	121.3 days	NOAA (2002b)
TC	Daily traffic count	33 vehicles	BOILE (2006)
D	Average distance traveled	0.09 km	This document Section IV.D
TF	Frequency of traffic	225 days	USEPA (2001)
IR	Inhalation rate	20 m^3/day	USEPA (1997b)
EF	Exposure frequency	225 days	USEPA (2001)
ED	Exposure duration	25 years	USEPA (2001)
BW	Body weight	70 kg	USEPA (2001)
AT	Averaging time	Carcinogen: 70 years	USEPA (2001)
		Noncarcinogen: 25 years	

Site size is a major factor affecting the dispersion modeling results. Currently, the Department considers a site size of two acres for non-residential exposure. The larger the site, the less stringent the Inh_pSRS, assuming that the number of vehicles and distance traveled are unchanged. In other words, when a source of emissions is dispersed over a larger area, the average concentration of contaminated dust in the air is smaller. Conversely, if a greater number of vehicles travel the site, or distance traveled increases, then the Inh_pSRS become more stringent. Other factors influencing emissions are the silt content and soil moisture content of the soil. The mean silt content of 11% used is USEPA's value for publicly accessible unpaved dirt roads (1998a). The 121.3 days with more than 0.254 mm (0.01 inch) of measurable precipitation represents Newark's thirty-year average of precipitation days in a year.

The particulate emission factor is calculated with the ISCST3 dispersion model, utilizing the particulate emission rate, $ER_{traffic}$, and the average annual concentration of resuspended particulates. For the modeling, a normalized concentration of one gram per second was assumed for the entire square site that is two-acres (8093.6 m^2) in size, which is the assumed average size for a non-residential site. The annual average concentration calculated assumes the number of possible hours (5,400 hours) with activity at the site (this is the equivalent of 225 days). Meteorological observations from Newark International Airport were used to account for the site-specific wind intensity and frequency in New Jersey. The exposure of a common worker is then estimated by applying a ratio of 8/24 to the particulate emission factor.

In calculating $ER_{traffic}$ (in Equation 20), it was assumed that a worker at a non-residential site would be exposed to particulate emissions for a maximum of eight hours per day. An inhalation rate of 20 cubic meters over the eight hours is assumed (USEPA 1991b). This value reflects an inhalation rate of 2.5 cubic meters per hour for heavy activity by an outdoor worker (USEPA 1997b). As for all lifetime or long-term (i.e., 25 years) exposure estimates, an average body weight of 70 kg was assumed (USEPA 1991b).

The default mean vehicle weight is 6,886 pounds (Boile, 2006). The average distance of 0.09 km traveled represents the distance of one side of a square two-acre site or alternatively the travel distance to and from the center of the site.

In the initial draft Basis and Background document, the Department had tried to evaluate traffic count data provided by NJDOT. In response to comments made, the Department revisited this evaluation and determined that errors had been made and/or that there were flaws in the analysis. Consequently, the Department has withdrawn that particular evaluation from this document.

Commenters also suggested that the entire approach be revamped and that measured emissions data be used instead. A literature search was performed to see if there was an appropriate default value available. Such a value was not found. To establish a site-specific basis for a number would require long term monitoring under the assumed conditions. Because of the difficulty involved, this option is felt to be impractical and is not being proposed by the Department at this time.

To address this issue, the Department has funded a study by Rutgers University, aimed at determining the average number of trucks that visit an industrial facility each day. The study provided the Department with estimates of the number of truck trips per establishment for each industry category for each county in New Jersey. Various levels of aggregation were then used to produce the average number of trucks visiting a 'typical' non-residential site in the state. This number was then used as input into the equations used by the Department to determine the appropriate standard for the inhalation exposure pathway for each contaminant. The study used publicly available data sources and truck trip generation techniques that have been established in the literature to estimate the number of trucks visiting non-residential sites. Sources used to determine trip generation rates for different facility types included the Institute of Transportation Engineers (ITE) Trip Generation Handbook (TGH) published in 2003 and the Federal Highway Administration (FHWA) Quick Response Freight Manual (QRFM) published in 1996.

Based on the results of this study, the average number of vehicles visiting a typical non-residential site is the state of New Jersey is determined to be 33 vehicles, and the average weight is calculated to be 6,886 pounds. The default weight is calculated based on the weighted average of the curb weight plus half the payload weight of each given vehicle class. This weighting is based on the percent that each vehicle class represents of the total number of vehicles. The half loaded vehicle weight is selected because it recognizes that the vehicles will not be fully loaded at all times.

V. Inhalation Soil Remediation Standards

A. Calculation Results

For residential and non-residential exposure scenarios, InhSRS were calculated for each contaminant for both particulate and volatile phases using existing carcinogenic and noncarcinogenic health endpoint toxicity data where applicable. Inorganic contaminants with negligible vapor pressure have no Henry's law constant and exhibit no vapor phase behavior. For these contaminants, only the particulate phase pathway was calculated. The volatile pathway was calculated using Equations 1 through 9, and the particulate pathway was calculated using Equations 10 through 25.

It is obvious that the particulate approach applies to metals (except for mercury) and other solid contaminants. However, because conceptually volatile contaminants could adhere to the surface of existing nuclei, the particulate approach is relevant, as well. Specific to volatile contaminants, smaller particles, called fines, can be formed from gases. The smallest particles, less than 0.1 µm, can be formed from nucleation, which is the condensation of low vapor pressure substances at high-temperature vaporization. Particles formed by nucleation can then grow by either coagulation, which is the combination of two or more particles to form a larger particle, or by the condensation of gas or vapor molecules on the surface of existing particles. Similarly, because semi-volatile contaminants could also adhere to the surface of existing nuclei, this same approach for calculating remediation standards was applied to semi-volatile contaminants.

The results of these calculations are provided in Appendix H1 (volatile) and Appendix H2 (particulate). Note that the values in Appendix H1 and Appendix H2 are the raw results and have not been modified to conform to the significant figure and rounding rules established for this document. The lowest calculated standard for each given contaminant for the different exposure scenarios is highlighted in these tables. This value would be the most protective standard irrespective of whether the health endpoint was carcinogenic or noncarcinogenic. Two different exposure scenarios are represented in the tables. One is the typical residential exposure scenario; the other is the non-residential exposure scenario. For ease of use Table 6 summarizes the Appendix H1 and Appendix H2 values by presenting the proposed standard for each of the three inhalation exposure scenarios. These values are the lowest and therefore most protective of the calculated standards within a given exposure scenario and are irrespective of the relevant phase of investigation (i.e., site investigation, remedial investigation) or health endpoint type. The values in Table 6 have been rounded and are to the appropriate number of significant figures.

Contaminants for which the volatile pathway yielded the lowest criterion are regulated as volatile organic contaminants. Those for which the particulate pathway yielded the lowest criterion are regulated as particulate phase contaminants.

B. Calculated Values

Within the inhalation exposure pathway and for all the chemicals considered, the standards for the volatile organic compounds typically are more likely to be lower than the standards developed for particulate contamination. For the residential exposure scenario, of the total 136 chemicals for which standards were derived, 60 were volatile based and 25 were particulate based. The remaining 51 were not regulated or had no available toxicity data to derive an appropriate InhSRS. For the non-residential exposure scenario, 55 were volatile based and 43 were particulate based. The remaining 38 were not regulated or had no available toxicity data to derive an appropriate InhSRS.

The increase in the particulate based standards compared to volatile based standards under the non-residential exposure scenario is in part attributable to how Csat was addressed, as well as the inclusion of vehicular traffic impacts under the non-residential exposure scenario. Vehicular traffic produces much higher airborne particulate concentrations compared to just wind alone generated particulate concentrations. Consequently, the non-residential exposure scenario InhSRS is much lower than the residential exposure scenario InhSRS. The implication of this is that the unrestricted remediation level for these particulate-based InhSRS is determined by the non-residential exposure scenario InhSRS. This differs from the typical situation in which residential standards are lower then non-residential standards.

The calculated values derived for a carcinogenic health endpoint are similarly more critical to a remedial investigation than the corresponding noncarcinogenic health endpoint values. For the residential exposure scenario, of the 85 regulated chemicals, 66 were associated with a carcinogenic health endpoint; two of these are determined to be carcinogenic under the Departments C-Carcinogen policy. For the 98 regulated chemicals under the non-residential exposure scenario, 75 were associated with a carcinogenic health endpoint; two of these are determined to be carcinogenic under the Departments C-Carcinogen policy.

C. Soil Remediation Standards for the Inhalation Exposure Pathway

Listed in Table 6 are the InhSRS below which the Department has no regulatory concern relative to the inhalation exposure pathway for the respective residential and non-residential exposure scenarios. Notes are provided to identify if the standard is derived from a carcinogenic or noncarcinogenic health endpoint, as well as whether or not the chemical was evaluated as a volatile or a particulate. The values listed in Table 6 have been rounded using currently accepted rounding rules.

Practical quantitation levels

Part of an effective regulatory program involves the ability of analytical laboratories to reliably measure the concentration of a contaminant in environmental media. A Practical Quantitation Limit (PQL) is the lowest quantitation level of a given analyte that can be reliably achieved among laboratories within the specified limits of precision and accuracy of a given analytical method during routine laboratory operating conditions. Therefore, the Department determined compound-specific PQL values and has provided these values in the remediation standards tables. The remediation standard is set at the less stringent of either the health-based criteria or the PQL for each contaminant.

Analytical methods generally provide PQLs or equivalent values. USEPA SW-846 methods refer to these values as "Estimated Quantitation Limits (EQLs). The USEPA Contract Laboratory Program Statements of Work (SOWs) use the term Contract Required Quantitation Limits (CRQLs) for organic target compounds and inorganic target analytes. The PQL values are predominately based on CRQLs. For those few analytes not included in the USEPA SOW, either the Department used EQLs cited in conventional laboratory methods, a random sample of actual method detection limit (MDL) values on file with the Department’s Office of Quality Assurance, and/or MDL values submitted to the Department in actual site-specific data packages as a basis to develop compound specific PQL values. The Department multiplied the MDL by 5 for organic analytes to produce the PQL, which is an accepted practice and convention. The Department did not adjust the MDLs for inorganic analytes because instrument detection limits cited in the methods are below the MDLs. The Department has evaluated each PQL with regard to its "reasonableness" and has determined that the values given are "routinely attainable by the laboratories" based on the Department’s professional judgement and historical observations of laboratory analyses.

PQLs for Contaminants in Soil

The Department used the CRQLs from the USEPA Contract Laboratory Statement of Work for Organic Analysis, Multi-Media, Multi-Concentration (SOMO1.1) to determine PQLs for volatile organic compounds in soil (except acrolein, acrylonitrile and tertiary butyl alcohol); PQLs for semi-volatile organic compounds in soil (except benzidine, 1,2-diphenylhydrazine and n-nitrosodimethylamine) and PQLs for Pesticide Compounds in soil (including PCBs).

PQLs for the exceptions noted above were determined as follows: for tertiary butyl alcohol an average value of actual laboratory MDLs was multiplied by 5; for acrolein and Acrylonitrile the PQLs were obtained from the generic EQL default values noted in USEPA SW-846 Method 8260B; for benzidine, 1,2-diphenylhydrazine and n-nitrosodimethylamine PQLs were obtained from the generic EQL default values noted in USEPA SW-846 Method 8270C (USEPA, 1998b).

The Department used the Contract Required Quantitation Limits from the USEPA Contract Laboratory Statement of Work for Inorganic Analysis, Multi-Media, Multi-Concentration (ILM05.2) to determine PQLs for metals in soil.

Appendix H1 and Appendix H2 contain all the calculated standards, regardless of whether they are the soil remediation standards (the most conservative value for a given exposure scenario). Appendix H1 and Appendix H2 are provided in order to facilitate potential alternative remediation standard development. The alternative remediation standard analysis may occur both within and between pathways. Consequently, it may be necessary to evaluate more than just the standards. By providing all the calculated values, maximum flexibility is provided. Appendix H1 is for volatiles, and Appendix H2 is for particulates. The values in Appendix H1 and Appendix H2 are truncated for presentation purposes; it should not be assumed that the values are rounded correctly.

Table 6. Lowest Soil Remediation Standards for the Inhalation Exposure Pathway						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Acenaphthene (PAH)	83-32-9	0.2	NR[1]	A[2], B[3]	300,000	C[4], P[5]
Acenaphthylene (PAH)	208-96-8	0.2	NR	A, B	300,000	C, P
Acetone (2-Propanone)	67-64-1	0.01	NR	A, B, D[6]	NR	A, B, D
Acetophenone	98-86-2	0.2	2	NC[7], V[8]	5	NC, V
Acrolein	107-02-8	0.5	0.5	NC, V	1	NC, V
Acrylonitrile	107-13-1	0.5	0.9	C, V	3	C, V
Aldrin	309-00-2	0.002	5	C, V	14	C, V
Aluminum	7429-90-5	20	NR	B, NV[9]	NR	B, NV
Anthracene (PAH)	120-12-7	0.2	380,000	C, P	30,000	C, P
Antimony	7440-36-0	6	360,000	NC, P	23,000	NC, P
Arsenic	7440-38-2	1	980	C, P	76	C, P
Atrazine + (11)	1912-24-9	0.2	NR	A, B	NR	A, B
Barium	7440-39-3	20	910,000	NC, P	59,000	NC, P
Benzaldehyde	100-52-7	0.2	NR	A, B	NR	A, B
Benzene	71-43-2	0.005	2	C, V	5	C, V
Benzidine	92-87-5	0.7	(0.004)[10]	C, V	(0.01)	C, V
Benzo(a)anthracene (1,2-Benzanthracene) (PAH)	56-55-3	0.2	38,000	C, P	3,000	C, P
Benzo(a)pyrene (PAH)	50-32-8	0.2	3,800	C, P	300	C, P

Table 6. Lowest Soil Remediation Standards for the Inhalation Exposure Pathway						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Benzo(b)fluoranthene (3,4-Benzofluoranthene) (PAH)	205-99-2	0.2	3,8000	C, P	3,000	C, P
Benzo(ghi)perylene (PAH)	191-24-2	0.2	380,000	C, P	30,000	C, P
Benzo(k)fluoranthene (PAH)	207-08-9	0.2	38,000	C, P	3,000	C, P
Beryllium	7440-41-7	0.5	1,800	C, P	140	C, P
1,1'-Biphenyl	92-52-4	0.2	NR	A, B	NR	A, B
Bis(2-chloroethyl)ether	111-44-4	0.2	0.6	C, V	2	C, V
Bis(2-chloroisopropyl)ether	108-60-1	0.2	23	C, V	67	C, V
Bis(2-ethylhexyl) phthalate	117-81-7	0.2	NR	A, B	140,000	C, P
Bromodichloromethane (Dichlorobromomethane)	75-27-4	0.005	1	C, V	3	C, V
Bromoform	75-25-2	0.005	98	C, V	280	C, V
Bromomethane (Methyl bromide)	74-83-9	0.005	25	NC, V	59	NC, V
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	0.01	NR	A, B	NR	A, B
Butyl benzyl phthalate $^+$	85-68-7	0.2	NR	A, B	NR	A, B
Cadmium	7440-43-9	0.5	1000	C, P	78	C, P
Caprolactam	105-60-2	0.2	NR	A, B	NR	A, B
Carbazole	86-74-8	0.2	740,000	C, P	58,000	C, P
Carbon disulfide	75-15-0	0.5	NR	A, B	NR	A, B

Table 6. Lowest Soil Remediation Standards for the Inhalation Exposure Pathway						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
Carbon tetrachloride	56-23-5	0.005	0.6	C, V	2	C, V
Chlordane (alpha and gamma)	57-74-9	0.002	42,000	C, P	3,300	C, P
Chlorobenzene	108-90-7	0.005	NR	A, B	NR	A, B
Chloroethane (Ethyl chloride)	75-00-3	0.005	NR	A, B	NR	A, B
Chloroform	67-66-3	0.005	0.6	C, V	2	C, V
Chloromethane (Methyl chloride)	74-87-3	0.005	4	C, V	12	C, V
2-Chlorophenol (o-Chlorophenol)	95-57-8	0.2	910	NC, V	2,200	NC, V
Chrysene (PAH)	218-01-9	0.2	380,000	C, P	30,000	C, P
Cobalt	7440-48-4	5	9,100	NC, P	590	NC, P
Copper	7440-50-8	3	NR	B	280,000	NC, P
Cyanide	57-12-5	3	NR	B, NV	NR	B, NV
4,4'-DDD	72-54-8	0.003	61,000	C, P	4,800	C, P
4,4'-DDE	72-55-9	0.003	670	C, V	3,400	C, P
4,4'-DDT	50-29-3	0.003	44,000	C, P	3,400	C, P
Dibenz(a,h)anthracene (PAH)	53-70-3	0.2	3,500	C, P	270	C, P
Dibromochloromethane (Chlorodibromomethane) +	124-48-1	0.005	3	C, V	8	C, V
1,2-Dibromo-3-chloropropane	96-12-8	0.005	0.08	C, V	0.2	C, V
1,2-Dibromoethane	106-93-4	0.005	0.1	C, V	0.3	C, V

Table 6. Lowest Soil Remediation Standards for the Inhalation Exposure Pathway						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	0.005	NR	A, B	NR	A, B
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	0.005	NR	A, B	NR	A, B
1,4-Dichlorobenzene (p-Dichlorobenzene) $^+$	106-46-7	0.005	5	C, V	13	C, V
3,3'-Dichlorobenzidine	91-94-1	0.2	3	C, V	960	C, P
Dichlorodifluoromethane	75-71-8	0.005	490	NC, V	NR	A, B
1,1-Dichloroethane	75-34-3	0.005	8	C, V	24	C, V
1,2-Dichloroethane	107-06-2	0.005	0.9	C, V	3	C, V
1,1-Dichloroethene $^+$	75-35-4	0.005	61	NC, V	150	NC, V
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	0.005	230	NC, V	560	NC, V
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	0.005	300	NC, V	720	NC, V
2,4-Dichlorophenol	120-83-2	0.2	NR	A, B	NR	A, B
1,2-Dichloropropane	78-87-5	0.005	2	C, V	5	C, V
1,3-Dichloropropene (cis and trans)	542-75-6	0.005	2	C, V	7	C, V
Dieldrin	60-57-1	0.003	1	C, V	3	C, V
Diethyl phthalate	84-66-2	0.2	NR	A, B	NR	A, B, D
2,4-Dimethyl phenol	105-67-9	0.2	NR	A, B	NR	A, B
Di-n-butyl phthalate	84-74-2	0.2	NR	A, B, D	NR	A, B, D

Table 6. Lowest Soil Remediation Standards for the Inhalation Exposure Pathway						
Chemical	**CAS No.**	**Practical Quantitation Limit (PQL)**	**Residential Standards**		**Non-residential Standards**	
			Mg/kg	**Notes**	**mg/kg**	**Notes**
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)	534-52-1	0.3	730,000	NC, P	47,000	NC, P
2,4-Dinitrophenol	51-28-5	0.3	NR	A, B	820,000	NC, P
2,4-Dinitrotoluene	121-14-2	0.2	6	C, V	16	C, V
2,6-Dinitrotoluene	606-20-2	0.2	2	C, V	7	C, V
2,4-Dinitrotoluene/2,6-Dinitrotoluene (mixture)	25321-14-6	NE (12)	NE	NE	NE	NE
Di-n-octyl phthalate	117-84-0	0.2	NR	A, B, D	NR	A, B, D
1,2-Diphenylhydrazine	122-66-7	0.7	5	C, V	13	C, V
Endosulfan I and Endosulfan II (alpha and beta)	115-29-7	0.003	NR	A, B	NR	A, B
Endosulfan sulfate	1031-07-8	0.003	NR	A, B	NR	A, B
Endrin	72-20-8	0.003	NR	A, B	120,000	NC, P
Ethyl benzene	100-41-4	0.005	NR	A, B	NR	A, B
Fluoranthene (PAH)	206-44-0	0.2	NR	A, B	300,000	C, P
Fluorene (PAH)	86-73-7	0.2	NR	A, B	300,000	C, P
alpha-HCH (alpha-BHC)	319-84-6	0.002	0.7	C, V	2	C, V
beta-HCH (beta-BHC) $^{+}$	319-85-7	0.002	8,000	C, P	620	C, P
Heptachlor	76-44-8	0.002	6	C, V	18	C, V
Heptachlor epoxide	1024-57-3	0.002	5	C, V	13	C, V

Table 6. Lowest Soil Remediation Standards for the Inhalation Exposure Pathway

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Non-residential Standards	
			Mg/kg	Notes	mg/kg	Notes
Hexachlorobenzene	118-74-1	0.2	1	C, V	4	C, V
Hexachloro-1,3-butadiene +	87-68-3	0.2	12	C, V	35	C, V
Hexachlorocyclopentadiene	77-47-4	0.2	45	NC, V	110	NC, V
Hexachloroethane +	67-72-1	0.2	83	C, V	82,000	C, P
Indeno(1,2,3-cd)pyrene (PAH)	193-39-5	0.2	38,000	C, P	3000	C, P
Isophorone +	78-59-1	0.2	NR	A, B	NR	A, B
Lead	7439-92-1	1	44,000	NC, P	12,000	NC, P
Lindane (gamma-HCH) (gamma-BHC)	58-89-9	0.002	3	C, V	10	C, V
Manganese	7439-96-5	2	91,000	NC, P	5,900	NC, P
Mercury	7439-97-6	0.1	27	NC, V	65	NC, V
Methoxychlor	72-43-5	0.02	NR	A, B	NR	A, B
Methyl acetate	79-20-9	0.005	NR	A, B	NR	A, B
Methylene chloride (Dichloromethane)	75-09-2	0.005	34	C, V	97	C, V
2-Methylnaphthalene	91-57-6	0.17	NR	A, B	300,000	C, P
2-Methylphenol (o-Creosol) +	95-48-7	0.2	NR	A, B	NR	A, B
4-Methylphenol (p-Creosol) +	106-44-5	0.2	NR	A, B	NR	A, B
Methyl tert-butyl ether (MTBE) +	1634-04-4	0.005	110	C, V	320	C, V
Naphthalene +	91-20-3	0.2	6	C, V	17	C, V

Table 6. Lowest Soil Remediation Standards for the Inhalation Exposure Pathway

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Non-residential Standards	
			Mg/kg	Notes	mg/kg	Notes
Nickel (Soluble salts)	7440-02-0	4	360,000	NC, P	23,000	NC, P
2-Nitroaniline	88-74-4	0.3	39	NC, V	23,000	NC, P
Nitrobenzene	98-95-3	0.2	160	NC, V	390	NC, V
N-Nitrosodimethylamine	62-75-9	0.7	(0.02)	C, V	(0.05)	C, V
N-Nitrosodi-n-propylamine	621-64-7	0.2	0.2	C, V	0.5	C, V
N-Nitrosodiphenylamine	86-30-6	0.2	NR	A, B	130,000	C, P
Pentachlorophenol	87-86-5	0.3	590	C, V	1,700	C, V
Phenanthrene (PAH)	85-01-8	0.2	NR	A, B	300,000	C, P
Phenol	108-95-2	0.2	NR	A, B	NR	A, B
Polychlorinated biphenyls (PCBs)	1336-36-3	0.03	20	C, V	57	C, V
Pyrene (PAH)	129-00-0	0.2	NR	A, B	300,000	C, P
Selenium	7782-49-2	4	NR	B, NV	NR	B, NV
Silver	7440-22-4	1	NR	B, NV	NR	B, NV
Styrene	100-42-5	0.005	90	C, V	260	C, V
Tertiary butyl alcohol (TBA) $^{+}$	75-65-0	0.1	4,800	NC, V	11,000	NC, V
1,1,2,2-Tetrachloroethane $^{+}$	79-34-5	0.005	1	C, V	3	C, V
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	0.005	2	C, V	5	C, V
Thallium	7440-28-0	3	360,000	NC, P	23,000	NC, P

Table 6. Lowest Soil Remediation Standards for the Inhalation Exposure Pathway

Chemical	CAS No.	Practical Quantitation Limit (PQL)	Residential Standards		Non-residential Standards	
			Mg/kg	Notes	mg/kg	Notes
Toluene	108-88-3	0.005	NR	A, B	NR	A, B
Toxaphene	8001-35-2	0.2	70	C, V	200	C, V
1,2,4-Trichlorobenzene	120-82-1	0.005	NR	A, B	NR	A, B
1,1,1-Trichloroethane $^{+}$	71-55-6	0.005	NR	A, B	NR	A, B
1,1,2-Trichloroethane	79-00-5	0.005	2	C, V	6	C, V
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	0.005	7	C, V	20	C, V
Trichlorofluoromethane	75-69-4	0.005	NR	A, B	NR	A, B
2,4,5-Trichlorophenol	95-95-4	0.2	NR	A, B	NR	A, B
2,4,6-Trichlorophenol	88-06-2	0.2	340	C, V	960	C, V
Vanadium	7440-62-2	5	NR	B, NV	470,000	NC, P
Vinyl chloride	75-01-4	0.005	0.7	C, V	2	C, V
Xylenes	1330-20-7	0.005	NR	A, B	NR	A, B
Zinc	7440-66-6	6	NR	B, NV	110,000	NC, P

(1) NR means the chemical is not regulated by the Department for the inhalation exposure pathway and for the specified exposure scenario. The reasons are identified in the "Notes" in the adjacent column.

(2) A means the health based soil remediation standard for a volatile compound exceeds Csat.

(3) B means that the calculated health based soil remediation standard for a compound in a particulate phase exceeds one million parts per million.

(4) C means the chemical was evaluated as a carcinogen.

(5) P means the chemical was evaluated as a particulate.

(6) D means that the calculated health based soil remediation standard for a volatile compound exceeds one million parts per million.

(7) NC means the chemical was evaluated as a noncarcinogen.

(8) V means the chemical was evaluated as a volatile.

(9) NV means the chemical is nonvolatile.

(10) Values within parentheses denote standards that defer to the PQLs.

(11) + = Compound evaluated under Department C-Carcinogen policy.

(12) NE = Mixture of 2,4-Dinitrotoluene/2,6-Dinitrotoluene not evaluated for inhalation exposure pathway. Instead, two contaminants evaluated individually.

VI. Methodology for Developing Alternative Remediation Standards

A. Overview

The Brownfield and Contaminated Site Remediation Act (N.J.S.A. 58:10B-1 et seq.) requires the New Jersey Department of Environmental Protection (Department) to consider site-specific factors in determining alternative remediation standards (ARS). These site-specific factors may vary from those used by the Department in the development of the adopted soil remediation standards pursuant to this section. ARSs for the inhalation exposure pathway are to be developed pursuant to N.J.A.C. 7:26D-7.

In addition, the Department has developed a spreadsheet calculator that will allow the input of site-specific conditions that will calculate an appropriate ARS. This Inhalation Exposure Pathway Alternative Remediation Standard Calculator may be found at http://www.nj.gov/dep/srp/guidance/rs.

The Department will also review other proposed approaches incorporating different models, assumptions, and information on a case by case basis. If the Department approves of their use, these may then be used to develop an acceptable ARS. However, the Department reserves the right to unilaterally determine the acceptability of these proposals.

Be advised that the Department will continue to evaluate other factors for potential use in the ARS process. The Department will also monitor those variables it currently allows to be used to develop ARS and will, if appropriate, preclude their future use.

An acceptable ARS will effectively function as the InhSRS that it replaces for that particular site. Specifically, such an ARS would be used in determining whether an area is contaminated. The ARS would be used in the compliance process just as an InhSRS would be.

B. Methods to Develop ARSs for Volatile Contaminants - variables which can be changed

For volatile contaminants, only a limited number of variables are allowed to be changed to accommodate site-specific conditions. These are described below.

1. Depth Range of Contamination – The EPA SSG methodology (USEPA, 1996a) used to develop remediation standards assumes an infinite depth of contamination. If the depth of contamination is known, this may be incorporated into development of alternative remediation standards. An assumption of finite depth range will reduce the mass of contaminant in the soil, which will reduce the average volatilization flux. This in turn will result in a greater remediation standard. Use the following procedure:

   (1) Determine the actual depth range of contamination by sampling conducted pursuant to the Technical Requirements for Site Remediation, N.J.A.C. 7:26E-4.

   (2) Use the actual depth range of contamination in the Jury model that is included in the EMSOFT software package to derive a site-specific volatilization factor (VF) following the methodology in Appendix I.

   (3) Substitute the derived site-specific volatilization factor into Equations 1 and 2 to calculate an alternative inhalation remediation standard.

   (4) The Department will not require the use of an institutional control pursuant to N.J.A.C. 7:26E-8 for an ARS based on depth range of contamination.

2. Organic Carbon (f_{oc}) - The organic carbon content of the soil is used with a contaminant's K_{oc} value to determine the extent the contaminant is adsorbed to soil. In general, the soil remediation standard is linearly related to the organic carbon content (for example, a doubling of the organic carbon content of the soil will double the calculated remediation standard, making it greater). Use the following procedure:

(1) Collect a minimum of 3 samples from different locations at the site that are representative of each area of concern including soil type(s) and sample depth equivalent to the location of contamination. Samples may not be collected from areas with high levels of organic contamination (greater than 1,000 ppm), since they will contribute to an artificially high organic carbon content. Additional soil samples should be collected and submitted for testing to calculate a refined site-specific remediation standard if further investigation reveals a contaminated area significantly larger than the original area investigated during the earlier phases of case processing. The number of samples should be based on the size of the area of concern pursuant to the Technical Requirements for Site Remediation, N.J.A.C. 7:26E.

(2) Analyze samples for soil organic carbon content using the Lloyd Kahn method (USEPA, 1988).

(3) Use the average soil organic content as f_{oc} in the soil-water partition coefficient equation (Equation 5) to develop a site-specific K_d value. If f_{oc} values at a given area of concern vary by more than an order of magnitude, they may not be averaged to calculate a site-specific K_d value. In this case, the lowest f_{oc} value must be used to determine the K_d value for the soil in the area of concern.

(4) Use the site-specific K_d value in Equation 4 to calculate a site-specific value for apparent diffusivity, D_A.

(5) Use the site-specific value for apparent diffusivity, D_A, in Equation 3 to calculate a site-specific volatilization factor, VF.

(6) Substitute the site-specific volatilization factor into Equations 1 and 2 to calculate an alternative inhalation remediation standard.

(7) The Department will not require the use of an institutional control pursuant to N.J.A.C. 7:26E-8 for an ARS based on soil organic carbon content.

C. Volatiles - variables which cannot be changed

For volatile contaminants, the following variables can **not** be changed to develop an ARS:

1. Total Soil Porosity (n) – The Department uses 0.41 because it is the value for sandy loam soil, which is the default soil texture for New Jersey. The USEPA uses a default of 0.43 for loam soil. Site-specific porosity values are difficult to obtain in the field, and laboratory measurements of this parameter are not advised since the integrity of the soil structure is lost during sampling unless special techniques are used.

2. Water-filled & Air-filled Soil Porosity (Volumetric soil water content) (θ_w & θ_a) – Experimentally determining site-specific air and water contents of a soil at a particular site is difficult, because of long-term and short-term variations in soil moisture. Long-term variations occur due to seasonal changes and short-term variations occur due to weather events. For this reason the SSG User's guide does not recommend using field results to adjust these parameters. Therefore, adjustment of these parameters will not be allowed without consultation with and approval by the Department. The value for air-filled porosity (θ_a) is 0.18 L_{air}/L_{soil}, and the value for water-filled porosity (θ_w) is 0.23 L_{water}/L_{soil}.

3. Dry Soil Bulk Density (ρ_b) - Dry soil bulk densities vary over a relatively small range, from about 1.3 to 1.8 g/cc (Carsel et al., 1988). The USEPA default value of 1.5 g/cm^3 was used because it agrees with the value listed for a sandy loam soil texture. Remediation standards are only slightly affected by the value for this parameter.

4. Averaging time - The averaging time for contaminants that are known carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 30 years. Both of these values are USEPA default values (1996a).

5. Exposure frequency - The exposure frequency of 350 days assumes year-round exposure and is a USEPA default value (1996a).

6. Exposure duration - The exposure duration for residential sites is 30 years and is a USEPA default value (1996a).

D. Methods to Develop ARSs for Particulate Contaminants - variables which can be changed

For particulate contaminants, a limited number of variables are allowed to be changed to accommodate site-specific conditions. These are described below.

Residential Scenario

1. Vegetative Cover - For the residential exposure scenario, the default of 50% vegetative cover is employed because it represents a reasonable compromise between no cover and a totally vegetated site. This parameter can be varied to reflect a site-specific condition and an appropriate ARS subsequently calculated. Use the following procedure:

   (1) Measure the actual amount of vegetative cover to determine the fraction of vegetative cover (V) on the site. An example of an acceptable vegetative cover would be areas of continuous grass where there is no bare ground.

   (2) Use the measured fraction of vegetative cover (V) in Equation 11 to calculate the particulate emission factor (PEF).

   (3) Use the calculated particulate emission factor (PEF) in Equation 9 or 10 to calculate the particulate contaminant carcinogenic (Inh_pSRS_c) or noncarcinogenic (Inh_pSRS_n) soil remediation standard for the inhalation exposure pathway, respectively.

(4) The Department will require the use of an institutional control pursuant to N.J.A.C. 7:26E-8 for an ARS based on an actual amount of vegetative cover to ensure that the basis for the ARS is maintained.

Non-residential Scenario

1. Number of Vehicle Trips per Day For Non-residential Sites - A number different than 33 vehicle trips per day can be used, but must reflect the current or expected vehicle activity level at a given site, whichever is greater. For future use, the entire site is assumed to be unpaved. Use the following procedure:

(1) Determine the daily traffic count for an unpaved area (TC). The number of vehicle trips per day will be calculated by dividing the weekly total by the number of days of site operation for that week.

(2) Use the measured daily traffic count for an unpaved area (TC) in Equation 20 to calculate the particulate emission rate for site traffic ($ER_{traffic}$).

(3) Use the calculated particulate soil remediation standards ($ER_{traffic}$) in Equation 19 to calculate the particulate emission factor from site activity (PEFs).

(4) Use the calculated particulate emission factor from site activity (PEF_s) in Equation 18 to calculate the exposure dose calculation (DOSE).

(5) Use the calculated exposure dose calculation (DOSE) in Equation 14 or 15 to calculate the particulate contaminant carcinogenic (InhpSRSc) or the particulate contaminant noncarcinogenic (Inh_pSRS_n) soil remediation standard for the inhalation exposure pathway, respectively.

(6) The Department will require the use of an institutional control pursuant to N.J.A.C. 7:26E-8 for an ARS based on actual vehicle activity to ensure that the basis for the ARS is maintained.

E. Particulates – variables which cannot be changed

For particulate contaminants, the following variables can **not** be changed to develop an ARS. Many of the variables are used as defaults in other Federal and State calculations. Those variables that are not calculation-defaults would require widespread technical support.

Residential Scenarios

1. Averaging time - The averaging time for contaminants that are known carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 30 years. Both of these values are USEPA default values (1996a).

2. Exposure frequency - The exposure frequency of 350 days assumes year-round exposure and is a USEPA default value (1996a).

3. Exposure duration - The exposure duration for residential sites is 30 years and is a USEPA default value (1996a).

4. Inhalation rate - The Department default inhalation rate for an industrial scenario is 20 cubic meters per day (USEPA 1997b). This is based on the recommended inhalation rate of 2.5 m^3/hr for an outdoor worker undergoing heavy activities (USEPA 2001).

5. Body weight - The default body weight for an industrial scenario is 70 kg (USEPA 2001).

Non-residential Scenarios

1. Surface material moisture content - The default surface material moisture content from AP-42 (USEPA 1998a) is 0.2%. It may not be adjusted because of the difficulty in determining a representative measure for the entire site.

2. Mean vehicle weight - The default mean vehicle weight assumed is 6,886 pounds (3.1 metric tons (Mg)). This is based on the study conducted by Boile (2006). A site-specific vehicle weight value is too variable and will not be readily amendable to enforcement.

3. Number of days with greater than 0.01 inches of precipitation - The Department used 121.3 days with 0.01 inch (0.254 mm) of measurable precipitation as its default. This value represents Newark's 30-year average of precipitation days annually. The average number of precipitation days for Atlantic City and Philadelphia are 111.5 and 115.4 days, respectively, over the same 30-year period. The number of precipitation days with 0.01 inch or greater were taken from the National Oceanic and Atmospheric Administration's (NOAA) Local Climatological Data Summaries (NOAA, 2002a; NOAA, 2002b; NOAA, 2002c). There is no point in changing the number of days with precipitation or other meteorological data because the Newark meteorological data produces the least conservative soil standard. Newark meteorological data was used in all of the InhSRS to offset some of the conservatism inherent in the air dispersion modeling.

4. Frequency of traffic - The frequency of traffic is the number of days per year that vehicular traffic occurs at a site. A value of 225 days assumes that on-site traffic occurs five days a week, 50 weeks per year. Traffic is assumed not to occur on weekends or during holidays (10 days/year), and poor weather days.

5. Averaging time - The averaging time for contaminants that are carcinogens is 70 years, and the averaging time for non-carcinogenic contaminants is 25 years. These are USEPA default values (USEPA 2001).

6. Exposure frequency - The exposure frequency also assumes 225 days per year. A value of 225 days assumes a five-day work week for 50 weeks per year. Furthermore, exposure is assumed not to occur during holidays, vacation, and sick time, accounting for another 25 days during the year. These are USEPA default values (USEPA 2001).

7. Exposure duration - The exposure duration for non-residential sites is 25 years. This is a USEPA default value (USEPA 2001).

8. Inhalation rate - The Department default inhalation rate for an industrial scenario is 20 cubic meters per day (USEPA 1997b). This is based on the recommended inhalation rate of 2.5 m^3/hr for an outdoor worker undergoing heavy activities (USEPA 2001).

9. Body weight - The default body weight for an industrial scenario is 70 kg (USEPA 2001).

F. Alternative Remediation Standards Based on Recreational Land Use

An alternative remediation standard for both volatile and/or particulate contaminants may be based on use of the site for recreational purposes. Recreational purposes are site-specific uses that do not reflect either a residential or non-residential land use scenario. Alternative standards may be based on site-specific land use scenarios that effect the amount of time that people are likely to spend at a site that is designated for recreational use. There are two basic types of recreational land use scenarios, active and passive, that may be considered. Examples of active recreational land use are sports playing fields and playgrounds. Examples of passive recreational land use are walking or bike trails. The approval of an alternative remediation standard for recreational land use will be contingent on the use of proper institutional controls to ensure the continued use of the site for the proposed recreational use.

VII. References

Agency for Toxic Substances and Disease Registry (ATSDR). (2003). Minimal Risk Levels (MRLs) for Hazardous Substances. URL address: http://www.atsdr.cdc.gov/mrls.html.

Boile, M. (2006). Estimation of the Average Number of Trucks Visiting Non-Residential Sites in New Jersey. Center for Advanced Infrastructure and Transportation, Rutgers, The State University of New Jersey. 76 p.

California Air Resources Board (CARB). (2002). Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values, updated 10/05/2006. URL address: http://www.arb.ca.gov/toxics/healthval/healthval.htm.

California Environmental Protection Agency (CEPA). (1998). Determination of Chronic Toxicity Reference Exposure Levels (Draft).

California Environmental Protection Agency (CEPA). (2002). Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II – Technical Support Document for Describing Available Cancer Potency Factors.

California Environmental Protection Agency (CEPA). (2003). Toxicity Criteria Database. URL address: http://www.oehha.ca.gov/risk/ChemicalDB/index.asp.

California Office of Environmental Health Hazard Assessment (OEHHA). (2002). All Chronic Reference Exposure Levels Adopted by OEHHA as of February 2005. URL address: http://www.oehha.ca.gov/air/chronic_rels/AllChrels.html.

Carsel, R.F. and Parrish, R.S. (1988). Developing joint probability distributions of soil water retention characteristics. *Water Resour. Res.* **24**(5):755-769.

Carsel, R.F., Parrish, R.S., Jones, J.L., and Lamb, R.L. (1988). Characterizing the uncertainty of pesticide leaching in agricultural soils. *J. Contam. Hydrol.* 2:111-124.

Cowherd, C., Muleski, G. , Englehart, P. , and Gillette, D. (1985). Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination. U.S. Environmental Protection Agency, Office of Health and Environmental Assessments. EPA/600/8-85/002. Washington, D.C. 160 p.

Foth, H.D. (1984). Fundamentals of Soil Science, 7th ed. John Wiley and Sons: New York.

Jury, W.A., Farmer, W.J., and Spencer, W.F. (1984). Behavior assessment model for trace organics in soil: II. Chemical classification and parameter sensitivity. *J. Environ. Qual.* **13**(4):567-572.

National Oceanic and Atmospheric Administration (NOAA). (2002a). Local Climatological Data for Atlantic City, New Jersey, ISSN 0275-1763.

National Oceanic and Atmospheric Administration (NOAA). (2002b). Local Climatological Data for Newark, New Jersey, ISSN 0198-3431.

National Oceanic and Atmospheric Administration (NOAA). (2002c). Local Climatological Data for Philadelphia, Pennsylvania, ISSN 0198-4535.

New Jersey Department of Environmental Protection, Bureau of Air Quality Evaluation (NJDEP/BAQEv, 2003). Site-Specific Calculations Following USEPA 1996a.

New Jersey Department of Environmental Protection. (2005). Vapor Intrusion Guidance. Trenton, New Jersey. 282 p.

New Jersey Drinking Water Quality Institute (NJDWQI). (1987). Maximum Contaminant Level Recommendation for Hazardous Contaminants in Drinking Water. Appendix B - Health-Based Maximum Contaminant Level Support Documents.

New Jersey Drinking Water Quality Institute (NJDWQI). (1994). Maximum Contaminant Level Recommendation for Hazardous Contaminants in Drinking Water. Appendix A - Health-Based Maximum Contaminant Level Support Documents and Addenda.

Nisbet, I.C.T and LaGoy, P.K. (1992). Toxic equivalency factors for polycyclic aromatic hydrocarbons. *Reg. Toxicol. Pharmacol*. **16**:290-300.

Sanders, P.F. and Talimcioglu, N.M. (1997). Soil-to-Indoor Air Exposure Models for Volatile Organic Compounds: The Effect of Soil Moisture. *Environ. Toxicol. Chem.* **16**(12): 2597-2604.

Tedrow, J.F. (1986). Soils of New Jersey. R.E. Krieger: Malabar, Florida. 512 p.

Toxicology Excellence for Risk Assessment (TERA). (1999). Toxicological Review of Soluble Nickel Salts.

United States Environmental Protection Agency (USEPA). (1988). Determination of Total Organic Carbon in Sediment (Lloyd Kahn Method). U.S. Environmental Protection Agency, Region II, Edison New Jersey. Available at URL address: http://www.epa.gov/region02/desa/hsw/sops.htm.

United States Environmental Protection Agency (USEPA). (1991b). Supplemental Guidance: Standard Default Exposure Factors. Office of Emergency and Remedial Response, Toxics Integration Branch. Washington, D.C.

United States Environmental Protection Agency (USEPA). (1991c). Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals) Interim. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. Publication 9385.7-01B. Washington, D.C.

United States Environmental Protection Agency (USEPA). (1992a). User's Guide for the Fugitive Dust Model (FDM) (revised) Volume I: User's Instructions. U.S. Environmental Protection Agency, Region 10. EPA-910/9-88-202R. Seattle Washington..

United States Environmental Protection Agency (USEPA). (1993). Provisional Guidance for the Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons (Table 8: Estimated Order of Potential Potency). U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/R-93/089. Washington, D.C.

United States Environmental Protection Agency (USEPA). (1994a). CHEMDAT8 User's Guide, November 1994. Office of Air Quality Planning and Standards: Research Triangle Park, NC, EPA-453/C-94-080B.

United States Environmental Protection Agency (USEPA). (1994b). User's Guide for Wastewater Treatment Compound Property Processor and Emissions Estimator (WATER8), November 1994. Office of Air Quality Planning and Standards: Research Triangle Park, NC, EPA-453/C-94-080C.

United States Environmental Protection Agency (USEPA). (1995). User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. EPA-454/B-95-003A and EPA-454/B-95-003B. Research Triangle Park, North Carolina.

United States Environmental Protection Agency (USEPA). (1996a). Soil Screening Guidance: Technical Background Document. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/R-95/128. Washington, D.C.

United States Environmental Protection Agency (USEPA). (1996b). Soil Screening Guidance: User's Guide. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/R-96/018. Washington, D.C.

United States Environmental Protection Agency (USEPA). (1996c). Superfund Chemical Data Matrix, June 1996. Office of Emergency and Remedial Response: Washington, DC, EPA/540/R-96/028, (http://www.epa.gov/oerrpage/superfund/resources/scdm/index.htm, cited Oct. 18, 2000).

United States Environmental Protection Agency (USEPA). (1997a). Health Effects Assessment Summary Tables, FY-1997 Update. U.S. Environmental Protection Agency, Office of Research and Development, Office of Emergency and Remedial Response. Washington, D.C.

United States Environmental Protection Agency (USEPA). (1997b). Exposure Factors Handbook. U.S. Environmental Protection Agency, Office of Research and Development. EPA/600/P-95/002Fa. Washington, D.C.

United States Environmental Protection Agency (USEPA). (1998a). Compilation of Air Pollutant Emission Factors Volume I: Stationary Point and the Area Source, 5th Edition. NTIS PB86-124906. Washington D.C.

United States Environmental Protection Agency (USEPA). (1998b). Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, 3^{rd} ed., Draft IVA. U.S. Environmental Protection Agency, Office of Solid Waste. Washington, D.C.

United States Environmental Protection Agency (USEPA). (2001). Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. Washington, D.C.

United States Environmental Protection Agency (USEPA). (2002). Addendum to the User's Guide for the Industrial Source Complex (ISC3) Dispersion Models, September 1995. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina.

United States Environmental Protection Agency (USEPA). (2003a). Integrated Risk Information System. URL address: http://www.epa.gov/iris.

United States Environmental Protection Agency (USEPA). (2003b). National Center for Environmental Assessment (NCEA).

Appendices

Appendix A - Inhalation Toxicity Factors

			Unit Risk Factor		Reference Concentration	
	CAS No.	**CHEMICAL**	**(ug/m^3)$^{-1}$**	**Reference**	**ug/m^3**	**Reference**
1	83-32-9	Acenaphthene (PAH)	1.10E-06	N&L TEF		
2	208-96-8	Acenaphthalene (PAH)	1.10E-06	N&L TEF		
3	67-64-1	Acetone			31000	ATSDR 04
4	98-86-2	Acetophenone			0.02	HEAST 92
5	107-02-8	Acrolein			0.02	IRIS
6	107-13-1	Acrylonitrile	6.80E-05	IRIS	2	IRIS
7	309-00-2	Aldrin	4.90E-03	IRIS		
8	7429-90-5	Aluminum (total)			3500	NCEAoral
9	120-12-7	Anthracene (PAH)	1.10E-05	N&L TEF		
10	7440-36-0	Antimony (total)			0.2	IRIS
11	7440-38-2	Arsenic (total)	4.30E-03	IRIS	0.03	Cal 05a
12	1912-24-9	Atrazine			12	IRISoral
13	7440-39-3	Barium (total)			0.5	HEAST 97
14	100-52-7	Benzaldehyde			350	IRISoral
15	71-43-2	Benzene	7.80E-06	IRIS	30	IRIS
16	92-87-5	Benzidine	6.70E-02	IRIS		
17	56-55-3	Benz(a)anthracene (PAH)	1.10E-04	Cal 02		
18	50-32-8	Benzo(a)pyrene	1.10E-03	Cal 02		
19	205-99-2	Benzo(b)fluoranthene (PAH)	1.10E-04	Cal 02		
20	191-24-2	Benzo(g,h,i)perylene (PAH)	1.10E-05	N&L TEF		
21	207-08-9	Benzo(k)fluoranthene (PAH)	1.10E-04	Cal 02		
22	7440-41-7	Beryllium	2.40E-03	IRIS	0.02	IRIS
23	92-52-4	1,1-Biphenyl			175	IRISoral
24	111-44-4	Bis(2-chloroethyl)ether	3.30E-04	IRIS		
25	108-60-1	Bis(2-chloroisopropyl)ether	1.00E-05	HEAST 97		
26	117-81-7	Bis(2-ethylhexyl)phthalate	2.40E-06	Cal 02	70	Cal 05a
27	75-27-4	Bromodichloromethane	3.70E-05	Cal 04		
28	75-25-2	Bromoform	1.10E-06	IRIS		
29	74-83-9	Bromomethane (Methyl bromide)			5	IRIS
30	78-93-3	2-Butanone (Methyl ethyl ketone)			5000	IRIS
31	85-68-7	Butylbenzyl phthalate			70	IRISoral
32	7440-43-9	Cadmium	4.20E-03	Cal 02	0.02	Cal 05a
33	105-60-2	Caprolactam			1750	IRISoral
34	86-74-8	Carbazole	5.70E-06	HEASToral		
35	75-15-0	Carbon disulfide			700	IRIS

Appendix A - Inhalation Toxicity Factors

			Unit Risk Factor		**Reference Concentration**	
	CAS No.	**CHEMICAL**	**(ug/m^3)$^{-1}$**	**Reference**	**ug/m^3**	**Reference**
36	56-23-5	Carbon tetrachloride	1.50E-05	IRIS	40	Cal 05a
37	57-74-9	Chlordane (alpha + gamma)	1.00E-04	IRIS	0.7	IRIS
38	108-90-7	Chlorobenzene			1000	Cal 05a
39	75-00-3	Chloroethane (Ethyl chloride)			10000	IRIS
40	67-66-3	Chloroform	2.30E-05	IRIS	300	Cal 05a
41	74-87-3	Chloromethane (Methyl chloride)	1.80E-06	HEAST 97	90	IRIS
42	95-57-8	2-Chlorophenol			18	IRISoral
43	218-01-9	Chrysene (PAH)	1.10E-05	Cal 02		
44	7440-48-4	Cobalt (total)			0.005	Cal 97
45	7440-50-8	Copper (total)			2.4	Cal 05b
46	57-12-5	Cyanide			70	IRISoral
47	72-54-8	DDD	6.90E-05	Cal 04		
48	72-55-9	DDE	9.70E-05	Cal 04		
49	50-29-3	DDT	9.70E-05	IRIS		
50	53-70-3	Dibenz(a,h)anthracene (PAH)	1.20E-03	Cal 02		
51	124-48-1	Dibromochloromethane	2.70E-05	Cal 04		
52	96-12-8	1,2-Dibromo-3-chloropropane	2.00E-03	Cal 02	0.2	IRIS
53	106-93-4	1,2-Dibromoethane	6.00E-04	IRIS	0.8	Cal 05a
54	95-50-1	1,2-Dichlorobenzene (o-)			200	HEAST 97
55	541-73-1	1,3-Dichlorobenzene (m-)			301	A280oral
56	106-46-7	1,4-Dichlorobenzene (p-)	1.10E-05	Cal 02	*80*	*IRIS/10*
57	91-94-1	3,3'-Dichlorobenzidine	3.40E-04	Cal 02		
58	75-71-8	Dichlorodifluoromethane			200	HEAST 97
59	75-34-3	1,1-Dichloroethane	1.60E-06	Cal 02	500	HEAST 97
60	107-06-2	1,2-Dichloroethane	2.60E-05	IRIS	400	Cal 05a
61	75-35-4	1,1-Dichloroethylene (vinylidene chloride)			*20*	*IRIS/10*
62	156-59-2	cis-1,2-Dichloroethylene			35	A280oral
63	156-60-5	trans-1,2-Dichloroethylene			60	A280oral
64	120-83-2	2,4-Dichlorophenol			11	IRISoral
65	78-87-5	1,2-Dichloropropane	1.00E-05	Cal 04	4	IRIS
66	542-75-6	1,3-Dichloropropene	4.00E-06	IRIS	20	IRIS
67	60-57-1	Dieldrin	4.60E-03	IRIS		
68	84-66-2	Diethylphthalate			2800	IRISoral
69	105-67-9	2,4-Dimethyl phenol			70	IRISoral
70	84-74-2	Di-n-butyl phthalate			350	IRISoral

Appendix A - Inhalation Toxicity Factors

			Unit Risk Factor		**Reference Concentration**	
	CAS No.	**CHEMICAL**	**(ug/m^3)$^{-1}$**	**Reference**	**ug/m^3**	**Reference**
71	534-52-1	4,6-Dinitro-2-methylphenol			0.4	NCEAoral
72	51-28-5	2,4-Dinitrophenol			7	IRISoral
73	121-14-2	2,4-Dinitrotoluene	8.90E-05	Cal 02		
74	606-20-2	2,6-Dinitrotoluene	1.9E-04	IRISoral	4	HEASToral
75	25321-14-6	2,4-Dinitrotoluene/2,6-Dinitrotoluene (mixture)	NE		NE	
76	117-84-0	Di-n-octyl-phthalate	1.30E-07	USEPA 85		
77	122-66-7	1,2-Diphenylhydrazine	2.20E-04	IRIS		
78	115-29-7	Endosulfan I & II (a- & b-summed)			21	IRISoral
79	1031-07-8	Endosulfan sulfate			21	IRISoral
80	72-20-8	Endrin			1	IRISoral
81	100-41-4	Ethylbenzene			1000	IRIS
82	206-44-0	Fluoranthene (PAH)	1.10E-06	N&L TEF		
83	86-73-7	Fluorene (PAH)	1.10E-06	N&L TEF		
84	319-84-6	a-HCH	1.80E-03	IRIS		
85	319-85-7	b-HCH	5.30E-04	IRIS		
86	76-44-8	Heptachlor	1.30E-03	IRIS		
87	1024-57-3	Heptachlor epoxide	2.60E-03	IRIS		
88	118-74-1	Hexachlorobenzene	4.60E-04	IRIS		
89	87-68-3	Hexachloro-1,3-butadiene	2.20E-05	IRIS		
90	77-47-4	Hexachlorocyclopentadiene			0.2	IRIS
91	67-72-1	Hexachloroethane	4.00E-06	IRIS		
92	193-39-5	Indeno(1,2,3-cd)pyrene (PAH)	1.10E-04	Cal 02		
93	78-59-1	Isophorone			*200*	*Cal 05b/10*
94	7439-92-1	Lead (total)	1.20E-05	Cal 02	0.1	DEP BAQEv 91
95	58-89-9	Lindane (g-HCH)	3.10E-04	Cal 02		
96	7439-96-5	Manganese (total)			0.05	IRIS
97	7439-97-6	Mercury (total)			0.3	IRIS
98	72-43-5	Methoxychlor			18	IRISoral
99	79-20-9	Methyl acetate			3500	HEASToral
100	75-09-2	Methylene chloride	4.70E-07	IRIS	400	Cal 05a
101	91-57-6	2-Methylnaphthalene	1.10E-06	N&L TEF		
102	95-48-7	2-Methylphenol (o-cresol)			*60*	*Cal 05a/10*
103	106-44-5	4-Methylphenol (p-cresol)			*60*	*Cal 05a/10*
104	1634-04-4	Methyl tert butyl ether	2.60E-07	Cal 02	*300*	*IRIS/10*
105	91-20-3	Naphthalene	3.40E-05	Cal 04a	*0.3*	*IRIS/10*
106	7440-02-0	Nickel (soluble salts)			0.2	TERA 99

Appendix A - Inhalation Toxicity Factors

			Unit Risk Factor		Reference Concentration	
	CAS No.	CHEMICAL	$(ug/m^3)^{-1}$	Reference	ug/m^3	Reference
107	88-74-4	o-Nitroaniline (2-nitroaniline)			0.2	HEAST 97
108	98-95-3	Nitrobenzene	1.20E-07	USEPA 85	2	Cal 05b
109	62-75-9	N-Nitrosodimethylamine	1.40E-02	IRIS		
110	621-64-7	N-Nitrosodi-n-propylamine	2.00E-03	Cal 02		
111	86-30-6	N-Nitrosodiphenylamine	2.60E-06	Cal 02		
112	1336-36-3	PCBs (Polychlorinated biphenyls)	1.00E-04	IRIS		
113	87-86-5	Pentachlorophenol	5.10E-06	Cal 02		
114	85-01-8	Phenanthrene (PAH)	1.10E-06	N&L TEF		
115	108-95-2	Phenol			200	Cal 05a
116	129-00-0	Pyrene (PAH)	1.10E-06	N&L TEF		
117	7782-49-2	Selenium (total)			20	Cal 05a
118	7440-22-4	Silver (total)			18	IRISoral
119	100-42-5	Styrene	5.70E-07	HEAST 91	1000	IRIS
120	75-65-0	Tertiary butyl alcohol			63	DEPoral
121	79-34-5	1,1,2,2-Tetrachloroethane	5.80E-05	IRIS		
122	127-18-4	Tetrachloroethylene	5.90E-06	Cal 02	35	Cal 05a
123	7440-28-0	Thallium (total)			0.2	RBC 2005oral
124	108-88-3	Toluene			5000	IRIS
125	8001-35-2	Toxaphene	3.20E-04	IRIS		
126	120-82-1	1,2,4-Trichlorobenzene			200	HEAST 97
127	71-55-6	1,1,1-Trichloroethane (methyl chloroform)			1000	Cal 05a
128	79-00-5	1,1,2-Trichloroethane	1.60E-05	IRIS		
129	79-01-6	Trichloroethylene	2.00E-06	Cal 02	600	Cal 05a
130	75-69-4	Trichlorofluoromethane			700	Cal 05b
131	95-95-4	2,4,5-Trichlorophenol			350	IRISoral
132	88-06-2	2,4,6-Trichlorophenol	3.10E-06	IRIS		
133	7440-62-2	Vanadium (total)			4	RBC 2005oral
134	75-01-4	Vinyl chloride	8.80E-06	IRIS	100	IRIS
135	1330-20-7	Xylenes (total)			100	IRIS
135	7440-66-6	Zinc (total)			0.9	Cal 97

References

A280 New Jersey Drinking Water Quality Institute (submitted to NJDEP).
Maximum Contaminant Level Recommendation for Hazardous Contaminants

	in Drinking Water. Appendix B - Health-Based Maximum Contaminant Level Support Documents (3/26/87). Appendix A - Health-Based Maximum Contaminant Level Support Documents and Addenda (9/26/94).
ATSDR 03	Agency for Toxic Substances and Disease Registry, "Minimal Risk Levels (MRLs) for Hazardous Substances," January 2003 (www.atsdr.cdc.gov/mrls.html).
Cal 97	California Environmental Protection Agency, Determination of Chronic Toxicity Reference Exposure Levels (Draft), October 1998.
Cal 02	California Environmental Protection Agency, Air Toxics Hot Spots Program Risk Assessment Guidelines, Part II – Technical Support Document for Describing Available Cancer Potency Factors, December 2002.
Cal 04	Cal/EPA Toxicity Criteria Database (www.oehha.ca.gov/risk/ChemicalDB/index.asp), updated 9/24/2004.
Cal 04a	See notice at www.oehha.ca.gov/air/hot_spots/naphth.html (posted 8/3/2004)
Cal 05a	California Office of Environmental Health Hazard Assessment (OEHHA), "All Chronic Reference Exposure Levels Adopted by OEHHA as of February 2005" (www.oehha.ca.gov/air/chronic_rels/AllChrels.html).
Cal 05b	California Air Resources Board (ARB), "Consolidated Table of OEHHA/ARB Approved Risk Assessment Health Values," updated 4/25/05; (www.arb.ca.gov/toxics/healthval/healthval.htm)
DEP BAQEv 91	Derived by NJDEP Bureau of Air Quality Evaluation, based on USEPA's LEAD5 Model (Lead Uptake/Biokinetic Model) Version 5.
HEAST 91	U.S. Environmental Protection Agency (USEPA), Health Effects Assessment Summary Tables, Annual FY-1991, Jan. 1991.
HEAST 92	USEPA Health Effects Assessment Summary Tables, Annual Update 1992, March 1992.
HEAST 97	USEPA, Health Effects Assessment Summary Tables, FY-1997 Update, July 1997.
IRIS	USEPA, Integrated Risk Information System, current; www.epa.gov/iris; current.

N&L TEF	Nisbet, I.C.T, and P.K. LaGoy, 1992, Toxic equivalency factors for polycyclic aromatic hydrocarbons, Reg. Toxicol. Pharmacol. 16:290-300. See Table 4, page 296.
NCEA	USEPA National Center for Environmental Assessment.
RBC 2005	USEPA Region 3 Risk Based Concentration Table, April 2005 (www.epa.gov/reg3hwmd/risk/human/index.htm)
TERA 99	Toxicology Excellence for Risk Assessment, Toxicological Review of Soluble Nickel Salts, March 1999.
USEPA 85	USEPA, The Air Toxics Problem in the United States: An Analysis of Cancer Risks for Selected Pollutants, Office of Air and Radiation, Washington, D.C., 1985, EPA-450/1-85-001. See Attachment A, Summary Table.

Comments

References with an "oral" subscript use converted oral toxicity data in the absence of inhalation data.

RfCs in italics are RfCs divided by 10, because they are Class C carcinogens.

For C carcinogens with RfCs based on RfDs, the RfDs are already divided by 10.

DEP C carcinogen - not classified as such by EPA, but by NJDEP.

For N&L TEFs, this is the toxicity equivalency factor applied to the URF for benzo(a)pyrene (BAP).

Chemicals Using Converted Oral Toxicity Data in the Absence of Inhalation Toxicity Data		
1	7429-90-5	Aluminum (total)
2	1912-24-9	Atrazine
3	100-52-7	Benzaldehyde
4	92-52-4	1,1-Biphenyl
5	85-68-7	Butylbenzyl phthalate
6	105-60-2	Caprolactam
7	86-74-8	Carbazole
8	95-57-8	2-Chlorophenol
9	57-12-5	Cyanide
10	541-73-1	1,3-Dichlorobenzene (m-)
11	156-59-2	cis-1,2-Dichloroethene
12	156-60-5	trans-1,2-Dichloroethene
13	120-83-2	2,4-Dichlorophenol
14	84-66-2	Diethylphthalate
15	105-67-9	2,4-Dimethyl phenol
16	84-74-2	Di-n-butyl phthalate
17	534-52-1	4,6-Dinitro-2-methylphenol
18	51-28-5	2,4-Dinitrophenol
19	606-20-2	2,6-Dinitrotoluene
20	115-29-7	Endosulfan I & II (a- & b- summed)
21	1031-07-8	Endosulfan sulfate
22	72-20-8	Endrin
23	72-43-5	Methoxychlor
24	79-20-9	Methyl acetate
25	7440-22-4	Silver (total)
26	75-65-0	Tertiary butyl alcohol (TBA)
27	7440-28-0	Thallium (total)
28	95-95-4	2,4,5-Trichlorophenol
29	7440-62-2	Vanadium (total)

The following equations were used to convert oral toxicity data to inhalation values.

Conversion of Reference Dose to Reference Concentration

$$RfC = RfD * \frac{1}{IR} * BW * 1000 \frac{\mu g}{mg}$$

Where:

RfC = reference concentration in $\mu g/m^3$

RfD = reference dose in mg/kg/day

IR = inhalation rate of 20 m^3/day

BW = body weight of 70 kg

Conversion of Cancer Slope Factor (CSF) to Unit Risk Factor (URF) in $(\mu g/m^3)^{-1}$:

$$URF = CSF * \frac{1}{BW} * IR * \frac{1mg}{1000 \mu g}$$

Where:

URF = unit risk factor in $(\mu g/m^3)^{-1}$

CSF = cancer slope factor in $(mg/kg\text{-}day)^{-1}$

BW = body weight of 70 kg

IR = inhalation rate of 20 m^3/day

Appendix B - Inhalation Class C Carcinogen Compounds

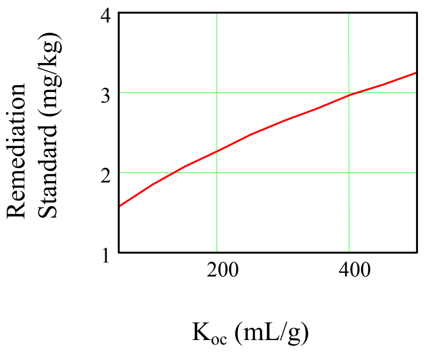
Chemical	CAS Number
Atrazine	1912-24-9
Butylbenzyl phthalate	85-68-7
Dibromochloromethane	124-48-1
1,4 Dichlorobenzene	106-46-7
1,1 Dichloroethene	75-35-4
b- HCH	319-85-7
Hexachloro-1,3-butadiene	87-68-3
Hexachloroethane	67-72-1
Isophorone	78-59-1
2 Methylphenol	95-48-7
4 Methylphenol	106-44-5
Methyl tertiary butyl ether (MTBE)	1634-04-4
Naphthalene	91-20-3
Tertiary butyl alcohol (TBA)	75-65-0
1,1,2,2 Tetrachloroethane	79-34-5
1,1,2 Trichloroethane	79-00-5

Appendix C - Sensitivity Analysis – Volatile Organic Compounds

For this analysis, only one variable was modified at a time, with the other chemical and environmental values being held at their generic New Jersey values. Soil and chemical properties were varied within their normal ranges. Results below are shown for benzene, but observed sensitivities are similar for all volatile organic compounds.

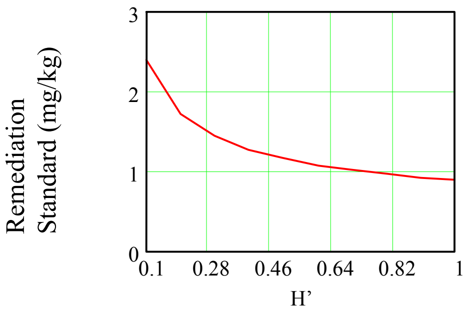
1. Sensitivity of the remediation standard to the organic carbon partition coefficient (K_{oc}). Sensitivity to this parameter is small, due to the weak adsorption of all these chemicals to soil. A ten-fold variation in the Koc value affected the calculated standard by less than a factor of two.

K_{oc} (cm^3/g)	Remediation Std. (mg/kg)
50	1.568
100	1.847
150	2.075
200	2.281
250	2.469
300	2.645
350	2.809
400	2.964
450	3.111
500	3.252



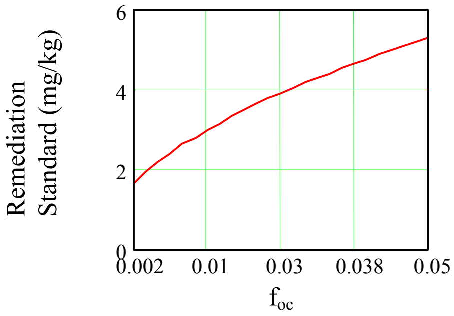
2. Sensitivity of the remediation standard to the Henry's law constant (H'). Dimensionless Henry's law constants for volatile organic chemicals are usually in the range of 0.1 to 1. This variation in the value of H' has a relatively small effect on the calculated remediation standard, which varied by less than a factor of three.

H'	Remediation Std. (mg/kg)
0.1	2.403
0.2	1.736
0.3	1.446
0.4	1.277
0.5	1.163
0.6	1.081
0.7	1.018
0.8	0.969
0.9	0.928
1	0.894



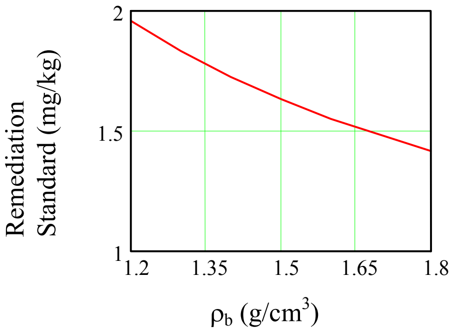
3. Sensitivity of the remediation standard to soil organic carbon (f_{oc}). The fraction of organic carbon in soils generally ranges from about 0.002 to 0.05. This variation in organic carbon has a relatively small effect on calculated remediation standards, which varied by a factor of three.

foc	Remediation Std. (mg/kg)
0.002	1.635
0.006	2.187
0.01	2.626
0.014	3.001
0.018	3.334
0.022	3.637
0.026	3.916
0.03	4.177
0.034	4.423
0.038	4.655
0.042	4.877
0.046	5.088
0.05	5.292



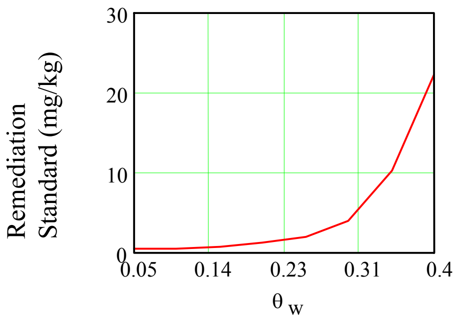
4. Sensitivity of remediation standard to soil bulk density (ρ_b). Soil bulk densities vary over a relatively narrow range, from about 1.2 to 1.8. This causes only small variations in the calculated remediation standard.

ρ_b (g/cm^3)	Remediation Std. (mg/kg)
1.2	1.962
1.3	1.837
1.4	1.729
1.5	1.635
1.6	1.553
1.7	1.48
1.8	1.415



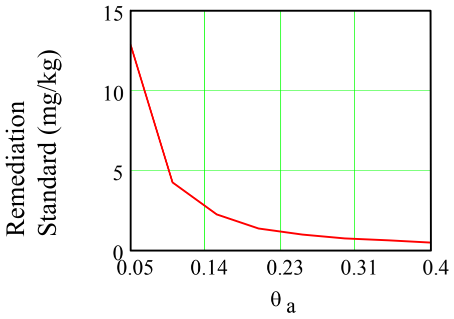
5. Sensitivity of remediation standard to soil moisture (θ_w). Soil moisture has a substantial effect on calculated remediation standards. This parameter may range from about 0.05 (v/v) to saturation volume (about 0.4 (v/v)). At higher moisture levels, small changes result in significant increases in the remediation standard. This is due to the exponential behavior of the model with respect to soil moisture. The generic soil moisture is 0.23 (v/v), which is not on the most sensitive portion of the curve.

θ_w	Remediation Std. (mg/kg)
0.05	0.428
0.1	0.582
0.15	0.823
0.2	1.232
0.25	2.023
0.3	3.909
0.35	10.35
0.4	22.143



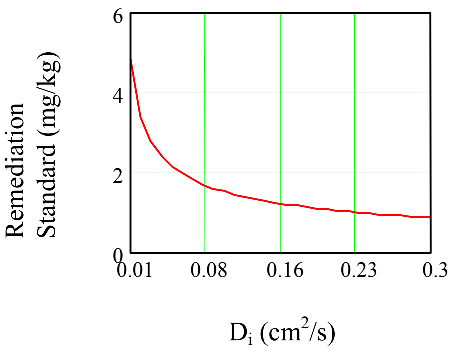
6. Sensitivity of remediation standard to soil air content (θ_a). This parameter is inversely related to soil moisture, and shows a similar, but mirrored sensitivity behavior. At low soil air content levels (corresponding to high soil moisture contents), small changes in this parameter have a large effect on the remediation standard. The generic soil air content is 0.18 (v/v), which is in the midrange of the curve, where the sensitivity is lower.

θa	Remediation Std. (mg/kg)
0.05	12.871
0.1	4.252
0.15	2.198
0.2	1.379
0.25	0.963
0.3	0.719
0.35	0.563
0.4	0.456



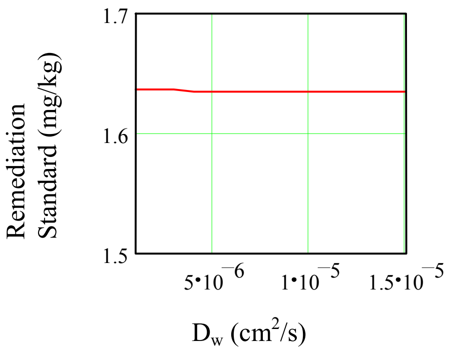
7. Sensitivity of remediation standard to diffusion coefficient in air, (D_i). The remediation standard is inversely related to D_i, but the sensitivity is relatively low. For most volatiles, D_i varies from about 0.07 to 0.1 cm^2/sec, and this range has little effect on the calculated standard.

D_i (cm^2/s)	Remediation Std. (mg/kg)
0.01	4.83
0.05	2.169
0.1	1.534
0.15	1.253
0.2	1.085
0.25	0.971
0.3	0.886



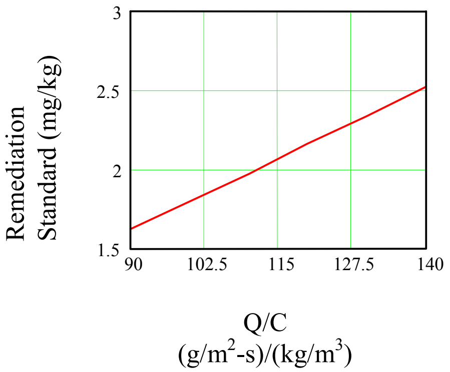
8. Sensitivity of remediation standard to the diffusion coefficient in water, (D_w). The normal range of this parameter for volatiles is 10^{-5} to 10^{-6} cm^2/sec. It has virtually no effect on the calculated remediation standard.

D_w (cm^2/s)	Remediation Std. (mg/kg)
0.000001	1.636
0.000004	1.636
0.000008	1.635
0.000012	1.635
0.000015	1.635



9. Sensitivity of remediation standard to Q/C. The Q/C value determines the dispersion and dilution of a contaminant as it leaves the soil surface and enters the atmosphere. The remediation standard is linearly related to the value of this parameter.

Q/C ((g/m^2-s)/(kg/m^3))	Remediation Std. (mg/kg)
90	1.6
100	1.8
110	2.0
120	2.2
130	2.3
140	2.5



Summary of Sensitivity Analyses: Volatile Organic Chemicals	
Parameter	***Sensitivity***
Organic Carbon Partition Coefficient, K_{oc}	Low
Henry's law constant, H'	Moderate
Fraction organic carbon, f_{oc}	Moderate
Soil bulk density, ρ_b	Low
Soil moisture, θ_w	High
Soil air content, θ_a	High
Diffusion coefficient in air, D_i	Low
Diffusion coefficient in water, D_w	None
Q/C	Linear

Appendix D - Generic Soil Moisture Content -Volatile Organic Compounds

The soil moisture has a large effect on the inhalation remediation standards for volatiles. An average annual soil moisture of 0.23 (v/v) was calculated for New Jersey sandy loam soil using a simple relationship described in the USEPA Soil Screening Level User's Guide (USEPA 1996):

$$\theta_w = n(I / K_s)^{1/(2b+3)}$$

Equation 1

where n is the total soil porosity, I is the soil moisture infiltration rate (m/yr), K_s is the saturated hydraulic conductivity of the soil (m/yr), and the factor 1/(2b+3) is determined by the soil type and is provided in a lookup table in the User's Guide. Rather than estimating soil porosity as described in the User's Guide it was preferred to use a value of 0.41 for sandy loam soil that was statistically derived from the extensive soil database of Carsel and Parrish (1988). This reference is one of EPA's data sources for soil properties for the USEPA SSL document. Additionally, a K_s value of 387 m/yr for sandy loam soil (from Carsel and Parrish, 1988) was used instead of the lookup value of 230 m/yr provided in the user's guide because it is a more recent evaluation.

The final parameter for Equation 1 above is the infiltration rate, I. Infiltration rates for New Jersey soils were determined using a New Jersey-specific tool available from the New Jersey Geological Survey. The New Jersey Geological Survey has published a method for determining infiltration rates for New Jersey as a function of location, soil type and land use (Hoffman, 1999; Charles et al., 1996). Using several of the most commonly occurring soils in New Jersey (Tedrow, 1986), infiltration rates were calculated for each soil in each county where the soil had a significant presence (Table 1). For each calculation, data from a climate station from a municipality located in the area where the soil would occur was used. Three land uses were selected for each calculation: landscaped, bare soil, and agricultural soil. All three of these soil types assume 100% of the surface area is permeable. All sandy loam soils with significant acreage in the state (as mapped by Tedrow, 1986) were used, since this soil texture has been targeted as the default soil texture for New Jersey standards (see main body of this document). In addition, other soil textures with a large presence in the state (as mapped by Tedrow, 1986) were also studied, in order to determine the overall variation of infiltration rates in the state, and to verify that sandy loam soil was appropriate as a default soil texture. A limitation of this method is that the infiltration calculated (below the root zone) is assumed to be equal to groundwater recharge (Charles et al., 1996).

Table 1. Recharge rates for various soils, locations and land uses in New Jersey

			Recharge (in/yr)		
Soil Name	*Primary Counties of Occurrence*	*Representative Municipality*	*Landscaped Open Space*	*Unvegetated*	*General Agriculture*
Sassafras sandy loam	Mercer	Washington Twp.	13.2	8.8	11.6
Sassafras sandy loam	Middlesex	South River Boro	14.2	9.3	12.5
Sassafras sandy loam	Burlington	Delran Twp.	12.8	8.5	11.3
Sassafras sandy loam	Salem	Alloway Twp.	11.6	7.9	10.2
Sassafras sandy loam	Cumberland	Bridgeton City	11	7.6	9.7
Freehold sandy loam	Monmouth	Millstone Twp.	13.1	8.6	11.5
Freehold sandy loam	Burlington	Chesterfield Twp.	13.1	8.6	11.5
Freehold sandy loam	Camden	Runnemede Boro	11.7	7.8	10.2
Freehold sandy loam	Gloucester	Swedesboro Boro	11.5	7.7	10.1
Collington sandy loam	Monmouth	Holmdel Twp.	13.4	8.5	11.7
Colts Neck sandy loam	Monmouth	Colts Neck Twp.	13.2	8.7	11.9
Westphalia sandy loam	Camden	Lindenwold Boro	11.6	7.3	10.1
Westphalia sandy loam	Gloucester	Harrison Twp.	11.4	7.3	9.9
Aura sandy loam	Gloucester	Elk Twp.	11.9	8.1	10.5
Aura sandy loam	Salem	Pittsgrove Twp.	11.7	8	10.4
Aura sandy loam	Cumberland	Upper Deerfield Twp.	11.5	7.9	10.2
Dunnellen sandy loam	Bergen	Oradell Boro	16.4	10.3	14.4
Dunnellen sandy loam	Union	Plainfield City	15.6	9.9	13.8
Dunnellen sandy loam	Middlesex	Piscataway Twp.	15.1	9.7	13.3
Galestown sand	Mercer	Trenton City	15.1	13	14.3
Galestown sand	Burlington	Burlington City	14.9	12.8	14.1
Lakewood sand	Monmouth	Neptune Twp.	17.5	14.7	16.6
Lakewood sand	Ocean	Manchester Twp.	17.2	14.4	16.3
Lakewood sand	Burlington	Pemberton Twp.	15.5	13.3	14.7
Downer loamy sand	Monmouth	Neptune Twp.	16.2	10.8	14.6
Downer loamy sand	Ocean	Manchester Twp.	15.9	10.6	14.2

Table 1. Recharge rates for various soils, locations and land uses in New Jersey

			Recharge (in/yr)		
Soil Name	*Primary Counties of Occurrence*	*Representative Municipality*	*Landscaped Open Space*	*Unvegetated*	*General Agriculture*
Downer loamy sand	Burlington	Pemberton Twp.	14.4	9.7	12.9
Downer loamy sand	Atlantic	Galloway Twp.	11.5	7.9	10.2
Downer loamy sand	Cumberland	Vineland City	12.3	8.5	11
Hammonton loamy sand	Atlantic	Estelle Manor City	12.1	8.5	10.7
Hammonton loamy sand	Cumberland	Hopewell Twp.	12.1	8.5	10.7
Hammonton loamy sand	Cape May	Lower Twp.	10.2	7.4	8.9
Boonton loam	Passaic	Hawthorne Boro	13.9	6.4	11.6
Boonton loam	Hudson	Harrison Town	10.1	4.7	8.5
Boonton loam	Essex	Newark City	10.1	4.7	8.5
Boonton loam	Union	Roselle Park	10.1	4.7	8.5
Boonton loam	Middlesex	Perth Amboy City	13.1	6	10.9
Boonton loam	Bergen	Ramsey Boro	13.9	6.4	11.6
Rockaway loam	Passaic	Ringwood Boro	17.2	8.6	14.6
Rockaway loam	Morris	Rockaway Twp.	16.5	8.3	14
Rockaway loam	Sussex	Franklin Boro	15.2	7.7	13
Annandale loam	Morris	Chester Twp.	16.9	8.4	13.9
Annandale loam	Warren	Pohatcong Twp.	12.4	6.7	10.2
Annandale loam	Hunterdon	Tewksbury Twp.	16.3	8.2	13.5
Penn silt loam	Somerset	Hillsborough Twp.	12.6	5.6	10.5
Penn silt loam	Hunterdon	Delaware Twp.	12	5.3	10

Table 2: Summary of infiltration rates of New Jersey Soils

	Average infiltration rates (in./yr)			
Soil Texture	*Landscaped*	*Unvegetated*	*Agriculture*	*Overall*
Sandy loam	12.8	8.4	11.3	10.9
Sand	16	13.6	15.2	15
Loamy sand	13.1	9	11.6	11.2
Loam	13.8	6.7	11.6	10.7
Silt loam	12.3	5.4	10.2	9.3
All soils	13.5	8.5	11.8	11.3

Table 2 indicates that an 11 inches/yr (0.28 m/yr) infiltration is representative, on average, for sandy loam, loamy sand, and loam soils. Silt loam soils have slightly lower infiltration rates, while sand soils yield rates a few inches higher. As discussed in the main body of the text of this document, it was decided to use sandy loam soil texture as the generic soil type for New Jersey, as it was felt that use of a sand soil would be conservative for much of the state. The results above confirm that assuming an infiltration rate of 11 inches/yr (0.28 m/yr) is adequately protective for sandy loam soil and most other soil textures.

Using Equation 1 and all input parameters discussed above, the average soil moisture for sandy loam was determined to be 0.23 (v/v).

References

Carsel, R.F. and Parrish, R.S. (1988). Developing joint probability distributions of soil water retention characteristics. *Water Resour. Res.* **24**(5):755-769.

Charles, E.G., Behroozi, C., Schooley, J. and Hoffman, J.L. (1996). GSR-32: A Method for Evaluating Ground-Water-Recharge Areas in New Jersey. New Jersey Geological Survey, New Jersey Dept. of Environmental Protection: Trenton, New Jersey. 95 p.

Hoffman, J.L. (1999). DGS 99-2: Microsoft Excel Workbook Implementing the New Jersey Geological Survey's Ground-Water Recharge Methodology. New Jersey Geological Survey, New Jersey Dept. of Environmental Protection: Trenton, New Jersey.

Tedrow, J.F. (1986). Soils of New Jersey. R.E. Krieger: Malabar, Florida. 512 p.

United States Environmental Protection Agency (USEPA). (1996). Soil Screening Guidance: Technical Background Document. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/R-95/128. Washington, D.C.

Appendix E - Chemical Properties

	Chemical	CAS Number	Henry's law constant (atm-m^3/mol)		Henry's law constant (dimensionless)		Water solubility mg/L		Diffusion coefficient in air, (cm^2/s)		Diffusion coefficient in water, (cm^2/s)		K_{oc} or K_d (L/kg)[a]	
1	Acenaphthene	83-32-9	1.55E-04	b	6.36E-03	b	4.24E+00	b	4.21E-02	b	7.69E-06	b	7.08E+03	b
2	Acenaphthylene	208-96-8	1.11E-04	h	4.51E-03	h	1.60E+01	h	4.40E-02	j	7.50E-06	j	2.76E+03	k
3	Acetone (2-propanone)	67-64-1	3.88E-05	b	1.59E-03	b	1.00E+06	b	1.24E-01	b	1.14E-05	b	5.75E-01	b
4	Acetophenone	98-86-2	1.10E-05	h	4.51E-04	h	6.10E+03	h	6.00E-02	o	8.70E-06	o	3.70E+01	k
5	Acrolein	107-02-8	1.20E-04	h	4.92E-03	h	2.10E+05	h	1.05E-01	o	1.20E-05	o	1.00E+00	k
6	Acrylonitrile	107-13-1	1.00E-04	h	4.10E-03	h	7.40E+04	h	1.22E-01	o	1.30E-05	o	2.00E+00	k
7	Aldrin	309-00-2	1.70E-04	b	6.97E-03	b	1.80E-01	b	1.32E-02	b	4.86E-06	b	2.45E+06	b
8	Aluminum (total)	7429-90-5	-	f	-	f	-		-		-		*1.50E+03*	h
9	Anthracene	120-12-7	6.50E-05	b	2.67E-03	b	4.34E-02	b	3.24E-02	b	7.74E-06	b	2.95E+04	b
10	Antimony (total)	7440-36-0	-	f	-	f	-		-		-		*4.50E+01*	b
11	Arsenic (total)	7440-38-2	-	f	-	f	-		-		-		*2.60E+01*	c,g
12	Atrazine	1912-24-9	2.96E-09	i	1.21E-07	i	7.00E+01	h	2.60E-02	j	6.70E-06	j	3.60E+02	k
13	Barium (total)	7440-39-3	-	f	-	f	-		-		-		*1.70E+01*	c,g
14	Benzaldehyde	100-52-7	2.67E-05	i	1.09E-03	i	3.00E+03	i	7.30E-02	j	9.10E-06	j	2.90E+01	k,m
15	Benzene	71-43-2	5.55E-03	b	2.28E-01	b	1.75E+03	b	8.80E-02	b	9.80E-06	b	5.89E+01	b
16	Benzidine	92-87-5	3.90E-11	h	1.60E-09	h	5.00E+02	h	3.40E-02	o	1.50E-05	o	4.70E+01	k
17	Benzo(a)anthracene (1,2-Benzanthracene)	56-55-3	3.35E-06	b	1.37E-04	b	9.40E-03	b	5.10E-02	b	9.00E-06	b	3.98E+05	b
18	Benzo(a)pyrene	50-32-8	1.13E-06	b	4.63E-05	b	1.62E-03	b	4.30E-02	b	9.00E-06	b	1.02E+06	b
19	Benzo(b)fluoranthene (3,4-Benzofluoranthene)	205-99-2	1.11E-04	b	4.55E-03	b	1.50E-03	b	2.26E-02	b	5.56E-06	b	1.23E+06	b
20	Benzo(ghi)perylene	191-24-2	1.40E-07	h	5.74E-06	h	2.60E-04	h	2.01E-02	j	5.30E-06	j	3.86E+06	k
21	Benzo(k)fluoranthene	207-08-9	8.29E-07	b	3.40E-05	b	8.00E-04	b	2.26E-02	b	5.56E-06	b	1.23E+06	b
22	Beryllium	7440-41-7	-	f	-	f	-		-		-		*3.50E+01*	c,g
23	1,1'-Biphenyl	92-52-4	3.00E-04	h	1.23E-02	h	6.00E+00	h	4.04E-02	o	8.20E-06	o	8.56E+03	k
24	Bis(2-chloroethyl)ether	111-44-4	1.80E-05	b	7.38E-04	b	1.72E+04	b	6.92E-02	b	7.53E-06	b	1.55E+01	b
25	Bis(2-chloroisopropyl)ether (2,2'-oxybis(1-chloropropane))	108-60-1	7.40E-05	i	3.03E-03	i	1.30E+03	h	6.02E-02	o	6.40E-06	m	3.60E+02	k
26	Bis(2-ethylhexyl)phthalate	117-81-7	1.02E-07	b	4.18E-06	b	3.40E-01	b	3.51E-02	b	3.66E-06	b	1.51E+07	b
27	Bromodichloromethane (Dichlorobromomethane)	75-27-4	1.60E-03	b	6.56E-02	b	6.74E+03	b	2.98E-02	b	1.06E-05	b	5.50E+01	b
28	Bromoform	75-25-2	5.35E-04	b	2.19E-02	b	3.10E+03	b	1.49E-02	b	1.03E-05	b	8.71E+01	b
29	Bromomethane (Methyl bromide)	74-83-9	6.24E-03	b	2.56E-01	b	1.52E+04	b	7.28E-02	b	1.21E-05	b	1.05E+01	b
30	2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3	5.60E-05	h	2.30E-03	h	2.20E+05	h	8.08E-02	o	9.80E-06	o	1.00E+00	k
31	Butylbenzyl phthalate	85-68-7	1.26E-06	b	5.17E-05	b	2.69E+00	b	1.74E-02	b	4.83E-06	b	5.75E+04	b
32	Cadmium	7440-43-9	-	f	-	f	-		-		-		*2.30E+01*	c,g
33	Caprolactam	105-60-2	3.66E-09	h	1.50E-07	h	3.01E+05	j	6.50E-02	j	9.00E-06	j	6.00E+00	k,n
34	Carbazole	86-74-8	1.53E-08	b	6.27E-07	b	7.48E+00	b	3.90E-02	b	7.03E-06	b	3.39E+03	b
35	Carbon disulfide	75-15-0	3.03E-02	b	1.24E+00	b	1.19E+03	b	1.04E-01	b	1.00E-05	b	4.57E+01	b
36	Carbon tetrachloride	56-23-5	3.04E+02	b	1.25E+00	b	7.93E+02	b	7.80E-02	b	8.80E-06	b	1.74E+02	b
37	Chlordane (alpha and gamma forms summed)	57-74-9	4.86E-05	b	1.99E-03	b	5.60E-02	b	1.18E-02	b	4.37E-06	b	1.20E+05	b
38	Chlorobenzene	108-90-7	3.70E-03	b	1.52E-01	b	4.72E+02	b	7.30E-02	b	8.70E-06	b	2.19E+02	b
39	Chloroethane	75-00-3	8.80E-03	h	3.61E-01	h	5.70E+03	h	2.71E-01	o	1.10E-05	o	1.50E+01	l
40	Chloroform	67-66-3	3.67E-03	b	1.50E-01	b	7.92E+03	b	1.04E-01	b	1.00E-05	b	3.98E+01	b
41	Chloromethane (Methyl chloride)	74-87-3	8.80E-03	h	3.61E-01	h	5.30E+03	h	1.26E-01	o	6.50E-06	o	6.00E+00	l
42	2-Chlorophenol (o-Chlorophenol)	95-57-8	3.91E-04	b	1.60E-02	b	2.20E+04	b	5.01E-02	b	9.46E-06	b	3.98E+02	c,g

Appendix E - Chemical Properties

	Chemical	CAS Number	Henry's law constant (atm-m^3/mol)		Henry's law constant (dimensionless)		Water solubility mg/L		Diffusion coefficient in air, (cm^2/s)		Diffusion coefficient in water, (cm^2/s)		K_{oc} or K_d (L/kg)[a]	
43	Chrysene	218-01-9	9.46E-05	b	3.88E-03	b	1.60E-03	b	2.48E-02	b	6.21E-06	b	3.98E+05	b
44	Cobalt (total)	7440-48-4	-	f	-	f	-		-		-		*4.50E+01*	h
45	Copper (total)	7440-50-8	-	f	-	f	-		-		-		*4.30E+02*	h
46	Cyanide	57-12-5	-	f	-	f	-		-		-		*9.90E+00*	b
47	4,4'-DDD (p,p'-TDE)	72-54-8	4.00E-06	b	1.64E-04	b	9.00E-02	b	1.69E-02	b	4.76E-06	b	1.00E+06	b
48	4,4'-DDE (p,p'-DDX)	72-55-9	2.10E-05	b	8.61E-04	b	1.20E-01	b	1.44E-02	b	5.87E-06	b	4.47E+06	b
49	4,4'-DDT	50-29-3	8.10E-06	b	3.32E-04	b	2.50E-02	b	1.37E-02	b	4.95E-06	b	2.63E+06	b
50	Dibenz(a,h)anthracene	53-70-3	1.47E-08	b	6.03E-07	b	2.49E-03	b	2.02E-02	b	5.18E-06	b	3.80E+06	b
51	Dibromochloromethane (Chlorodibromomethane)	124-48-1	7.83E-04	b	3.21E-02	b	2.60E+03	b	1.96E-02	b	1.05E-05	b	6.31E+01	b
52	1,2-Dibromo-3-chloropropane	96-12-8	1.50E-04	h	6.15E-03	h	1.20E+03	h	2.12E-02	j	7.00E-06	j	7.90E+01	l
53	1,2-Dibromoethane	106-93-4	7.40E-04	h	3.03E-02	h	4.20E+03	h	2.87E-02	j	8.10E-06	j	4.60E+01	l
54	1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1	1.90E-03	b	7.79E-02	b	1.56E+02	b	6.90E-02	b	7.90E-06	b	6.17E+02	b
55	1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1	3.10E-03	h	1.27E-01	h	1.30E+02	h	6.92E-02	o	7.90E-06	o	7.08E+02	l
56	1,4-Dichlorobenzene (p-Dichlorobenzene)	106-46-7	2.43E-03	b	9.96E-02	b	7.38E+01	b	6.90E-02	b	7.90E-06	b	6.17E+02	b
57	3,3'-Dichlorobenzidine	91-94-1	4.00E-09	b	1.64E-07	b	3.11E+00	b	1.94E-02	b	6.74E-06	b	7.24E+02	b
58	Dichlorodifluoromethane	75-71-8	3.40E-01	h	1.39E+01	h	2.80E+02	h	5.20E-02	j	1.00E-05	j	6.60E+01	l
59	1,1-Dichloroethane	75-34-3	5.62E-03	b	2.30E-01	b	5.06E+03	b	7.42E-02	b	1.05E-05	b	3.16E+01	b
60	1,2-Dichloroethane	107-06-2	9.79E-04	b	4.01E-02	b	8.52E+03	b	1.04E-01	b	9.90E-06	b	1.74E+01	b
61	1,1-Dichloroethene (1,1-Dichloroethylene)	75-35-4	2.61E-02	b	1.07E+00	b	2.25E+03	b	9.00E-02	b	1.04E-05	b	5.89E+01	b
62	1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	4.08E-03	b	1.67E-01	b	3.50E+03	b	7.36E-02	b	1.13E-05	b	3.55E+01	b
63	1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	9.38E-03	b	3.85E-01	b	6.30E+03	b	7.07E-02	b	1.19E-05	b	5.25E+01	b
64	2,4-Dichlorophenol	120-83-2	3.16E-06	b	1.30E-04	b	4.50E+03	b	3.46E-02	b	8.77E-06	b	1.59E+02	c,g
65	1,2-Dichloropropane	78-87-5	2.80E-03	b	1.15E-01	b	2.80E+03	b	7.80E-02	b	8.73E-06	b	4.37E+01	b
66	1,3-Dichloropropene (cis and trans) (summed)	542-75-6	1.77E-02	b	7.26E-01	b	2.80E+03	b	6.26E-02	b	1.00E-05	b	4.57E+01	b
67	Dieldrin	60-57-1	1.51E-05	b	6.19E-04	b	1.95E-01	b	1.25E-02	b	4.74E-06	b	2.14E+04	b
68	Diethylphthalate	84-66-2	4.50E-07	b	1.85E-05	b	1.08E+03	b	2.56E-02	b	6.35E-06	b	2.88E+02	b
69	2,4-Dimethylphenol	105-67-9	2.00E-06	b	8.20E-05	b	7.87E+03	b	5.84E-02	b	8.69E-06	b	2.09E+02	b
70	Di-n-butyl phthalate	84-74-2	9.38E-10	b	3.85E-08	b	1.12E+01	b	4.38E-02	b	7.86E-06	b	3.39E+04	b
71	4,6-Dinitro-2-methylphenol	534-52-1	4.30E-07	h	1.76E-05	h	2.00E+02	h	2.93E-02	j	6.90E-06	j	1.16E+02	k
72	2,4-Dinitrophenol	51-28-5	4.43E-07	b	1.82E-05	b	2.79E+03	b	2.73E-02	b	9.06E-06	b	1.78E-02	c,g
73	2,4-Dinitrotoluene	121-14-2	9.26E-08	b	3.80E-06	b	2.70E+02	b	2.03E-01	b	7.06E-06	b	9.55E+01	b
74	2,6-Dinitrotoluene	606-20-2	7.47E-07	b	3.06E-05	b	1.82E+02	b	3.27E-02	b	7.26E-06	b	6.92E+01	b
75	2,4-Dinitrotoluene/2,6-Dinitrotoluene (mixture)	25321-14-6	q											
76	Di-n-octyl phthalate	117-84-0	6.68E-05	b	2.74E-03	b	2.00E-02	b	1.51E-02	b	3.58E-06	b	8.32E+07	b
77	1,2-Diphenylhydrazine	122-66-7	1.50E-06	h	6.15E-05	h	6.80E+01	h	3.17E-02	j	7.40E-06	j	7.10E+02	k
78	Endosulfan I and Endosulfan II (alpha and beta) (summed)	115-29-7	1.12E-05	b	4.59E-04	b	5.10E-01	b	1.15E-02	b	4.55E-06	b	2.14E+03	b
79	Endosulfan sulfate	1031-07-8	2.10E-03	h	8.61E-02	h	6.40E+00	h	1.10E-02	j	4.40E-06	j	1.02E+03	l
80	Endrin	72-20-8	7.52E-06	b	3.08E-04	b	2.50E-01	b	1.25E-02	b	4.74E-06	b	1.23E+04	b
81	Ethylbenzene	100-41-4	7.88E-03	b	3.23E-01	b	1.69E+02	b	7.50E-02	b	7.80E-06	b	3.63E+02	b
82	Fluoranthene	206-44-0	1.61E-05	b	6.60E-04	b	2.06E-01	b	3.02E-02	b	6.35E-06	b	1.07E+05	b
83	Fluorene	86-73-7	6.36E-05	b	2.61E-03	b	1.98E+00	b	3.63E-02	b	7.88E-06	b	1.38E+04	b
84	alpha-HCH (alpha-BHC)	319-84-6	1.06E-05	b	4.35E-04	b	2.00E+00	b	1.42E-02	b	7.34E-06	b	1.23E+03	b

Appendix E - Chemical Properties

	Chemical	*CAS Number*	*Henry's law constant (atm-m^3/mol)*		*Henry's law constant (dimensionless)*		*Water solubility mg/L*		*Diffusion coefficient in air, (cm^2/s)*		*Diffusion coefficient in water, (cm^2/s)*		*K_{oc} or K_d (L/kg)*[a]	
85	beta-HCH (beta-BHC)	319-85-7	7.43E-07	b	3.05E-05	b	2.40E-01	b	1.42E-02	b	7.34E-06	b	1.26E+03	b
86	Heptachlor	76-44-8	1.09E-03	d	4.47E-02	d	1.80E-01	b	1.12E-02	b	5.69E-06	b	1.41E+06	b
87	Heptachlor epoxide	1024-57-3	9.50E-06	b	3.90E-04	b	2.00E-01	b	1.32E-02	b	4.23E-06	b	8.32E+04	b
88	Hexachlorobenzene	118-74-1	1.32E-03	b	5.41E-02	b	6.20E+00	b	5.42E-02	b	5.91E-06	b	5.50E+04	b
89	Hexachloro-1,3-butadiene	87-68-3	8.15E-03	b	3.34E-01	b	3.23E+00	b	5.61E-02	b	6.16E-06	b	5.37E+04	b
90	Hexachlorocyclopentadiene	77-47-4	2.70E-02	b	1.11E+00	b	1.80E+00	b	1.61E-02	b	7.21E-06	b	2.00E+05	b
91	Hexachloroethane	67-72-1	3.89E-03	b	1.59E-01	b	5.00E+01	b	2.50E-03	b	6.80E-06	b	1.78E+03	b
92	Indeno(1,2,3-cd)pyrene	193-39-5	1.60E-06	b	6.56E-05	b	2.20E-05	b	1.90E-02	b	5.66E-06	b	3.47E+06	b
93	Isophorone	78-59-1	6.64E-06	b	2.72E-04	b	1.20E+04	b	6.23E-02	b	6.76E-06	b	4.68E+01	b
94	Lead (total)	7439-92-1	-	f	-	f	-		-		-		*9.00E+02*	h
95	Lindane (gamma-HCH) (gamma-BHC)	58-89-9	1.40E-05	b	5.74E-04	b	6.80E+00	b	1.42E-02	b	7.34E-06	b	1.07E+03	b
96	Manganese (total)	7439-96-5	-	f	-	f	-		-		-		*6.50E+01*	h
97	Mercury (total)	7439-97-6	-		-		-		-		-		*5.30E+01*	c,g
98	Methoxychlor	72-43-5	1.58E-05	b	6.48E-04	b	4.50E-02	b	1.56E-02	b	4.46E-06	b	9.77E+04	b
99	Methyl acetate	79-20-9	1.15E-04	i	4.72E-03	i	2.40E+05	i	1.04E-01	o	1.00E-05	o	2.00E+00	k,m
100	Methylene chloride (Dichloromethane)	75-09-2	2.19E-03	b	8.98E-02	b	1.30E+04	b	1.01E-01	b	1.17E-05	b	1.17E+01	b
101	2-Methylnaphthalene	91-57-6	5.20E-04	h	2.13E-02	h	2.50E+01	h	5.22E-02	p	7.75E-06	p	6.82E+03	k
102	2-Methylphenol (o-cresol)	95-48-7	1.20E-06	b	4.92E-05	b	2.60E+04	b	7.40E-02	b	8.30E-06	b	9.12E+01	b
103	4-Methylphenol (p-cresol)	106-44-5	7.90E-07	h	3.24E-05	h	2.20E+04	h	7.40E-02	o	1.00E-05	o	7.40E+01	k
104	MTBE (tert-butyl methyl ether)	1634-04-4	5.87E-04	i	2.40E-02	i	4.80E+04	i	1.02E-01	o	1.00E-05	o	8.00E+00	k,m
105	Naphthalene	91-20-3	4.83E-04	b	1.98E-02	b	3.10E+01	b	5.90E-02	b	7.50E-06	b	2.00E+03	b
106	Nickel (total)	7440-02-0	-	f	-	f	-		-		-		*2.40E+01*	c,g
107	2-Nitroaniline	88-74-4	1.81E-08	i	7.42E-07	i	2.90E+02	h	7.30E-02	o	8.00E-06	o	7.40E+01	k
108	Nitrobenzene	98-95-3	2.40E-05	b	9.84E-04	b	2.09E+03	b	7.60E-02	b	8.60E-06	b	6.46E+01	b
109	N-Nitrosodimethylamine	62-75-9	1.20E-06	h	4.92E-05	h	1.00E+06	h	1.13E-01	j	1.20E-05	j	3.00E-01	k
110	N-Nitrosodi-n-propylamine	621-64-7	2.25E-06	b	9.23E-05	b	9.89E+03	b	5.45E-02	b	8.17E-06	b	2.40E+01	b
111	N-Nitrosodiphenylamine	86-30-6	5.00E-06	b	2.05E-04	b	3.51E+01	a	3.12E-02	b	6.35E-06	b	1.29E+03	b
112	PCBs (Polychlorinated biphenyls) (summed)	1336-36-3	2.60E-03	h	1.07E-01	h	7.00E-01	c	1.75E-02	o	8.00E-06	o	3.09E+05	c
113	Pentachlorophenol	87-86-5	2.44E-08	b	1.00E-06	b	1.95E+03	b	5.60E-02	b	6.10E-06	b	5.10E+03	c,g
114	Phenanthrene	85-01-8	2.30E-05	h	9.43E-04	h	1.10E+00	h	3.33E-02	j	7.50E-06	j	2.65E+04	k
115	Phenol	108-95-2	3.97E-07	b	1.63E-05	b	8.28E+04	b	8.20E-02	b	9.10E-06	b	2.88E+01	b
116	Pyrene	129-00-0	1.10E-05	b	4.51E-04	b	1.35E-01	b	2.72E-02	b	7.24E-06	b	1.05E+05	b
117	Selenium (total)	7782-49-2	-	f	-	f	-		-		-		*1.40E+01*	c,g
118	Silver (total)	7440-22-4	-	f	-	f	-		-		-		*2.60E-01*	c,g
119	Styrene	100-42-5	2.75E-05	b	1.13E-01	b	3.10E+02	b	7.10E-02	b	8.00E-06	b	7.76E+02	b
120	Tertiary butyl alcohol (TBA)	75-65-0	9.05E-06	i	3.71E-04	i	1.00E+06	i	9.85E-02	j	1.14E-05	j	2.00E+00	k,m
121	1,1,2,2-Tetrachloroethane	79-34-5	3.45E-04	b	1.41E-02	b	2.97E+03	b	7.10E-02	b	7.90E-06	b	9.33E+01	b
122	Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	1.84E-02	b	7.54E-01	b	2.00E+02	b	7.20E-02	b	8.20E-06	b	1.55E+02	b
123	Thallium (total)	7440-28-0	-	f	-	f	-		-		-		*4.80E+01*	c,g
124	Toluene	108-88-3	6.64E-03	b	2.72E-01	b	5.26E+02	b	8.70E-02	b	8.60E-06	b	1.82E+02	b
125	Toxaphene	8001-35-2	6.00E-06	b	2.46E-04	b	7.40E-01	b	1.16E-02	b	4.34E-06	b	2.57E+05	b
126	1,2,4-Trichlorobenzene	120-82-1	1.42E-03	b	5.82E-02	b	3.00E+02	b	3.00E-02	b	8.23E-06	b	1.78E+03	b
127	1,1,1-Trichloroethane	71-55-6	1.72E-02	b	7.05E-01	b	1.33E+03	b	7.80E-02	b	8.80E-06	b	1.10E+02	b

Appendix E - Chemical Properties

	Chemical	CAS Number	Henry's law constant (atm-m^3/mol)		Henry's law constant (dimensionless)		Water solubility mg/L		Diffusion coefficient in air, (cm^2/s)		Diffusion coefficient in water, (cm^2/s)		K_{oc} or K_d (L/kg)[a]	
128	1,1,2-Trichloroethane	79-00-5	9.13E-04	b	3.74E-02	b	4.42E+03	b	7.80E-02	b	8.80E-06	b	5.01E+01	b
129	Trichloroethene (TCE) (Trichloroethylene)	79-01-6	1.03E-02	b	4.22E-01	b	1.10E+03	b	7.90E-02	b	9.10E-06	b	1.66E+02	b
130	Trichlorofluoromethane	75-69-4	9.70E-02	h	3.98E+00	h	1.10E+03	h	4.26E-02	j	1.00E-05	j	1.14E+02	l
131	2,4,5-Trichlorophenol	95-95-4	4.33E-06	b	1.78E-04	b	1.20E+03	b	2.91E-02	b	7.03E-06	b	2.34E+03	c,g
132	2,4,6-Trichlorophenol	88-06-2	7.79E-06	b	3.19E-04	b	8.00E+02	b	3.18E-02	b	6.25E-06	b	9.99E+02	c,g
133	Vanadium (total)	7440-62-2	-	f	-	f	-		-		-		*1.00E+03*	b
134	Vinyl chloride	75-01-4	2.70E-02	b	1.11E+00	b	2.76E+03	b	1.06E-01	b	1.23E-06	b	1.86E+01	b
135	Xylenes (total)	1330-20-7	6.73E-03	b,e	2.76E-01	b,e	1.75E+02	b,e	7.69E-02	b	8.44E-06	b	3.86E+02	b,e
136	Zinc (total)	7440-66-6	-	f	-	f	-		-		-		*2.30E+01*	c,g

a. Values in italics are Kd values

b. Soil Screening Guidance: Technical Background Document. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, EPA/540/R-95/128 (1996)

c. Soil Screening Guidance: User's Guide. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, EPA/540/R-96/018 (1996)

d. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites – Peer Review Draft, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC, OSWER 9355.4-24 (2001)

e. Values for the 3 xylene isomers were averaged

f. Compound is not volatile

g. pH 5.3

h. Superfund Chemical Data Matrix. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC, EPA/540/R-96/028 (1996). URL: http://www.epa.gov/oerrpage/superfund/resources/scdm/index.htm

i. Hazardous Substances Data Bank. National Library of Medicine: Bethesda, MD (1999). URL: http://toxnet.nlm.nih.gov/servlets/simple-search

j. Calculated using WATER8. See User's Guide for Wastewater Treatment Compound Property Processor and Air Emissions Estimator (WATER8). U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards Research, Research Triangle Park, NC, EPA-453/C-94-80C (1994).

k. Calculated from Kow using Equation No. 70 in USEPA Soil Screening Guidance: Technical Background Document. Kow from Superfund Chemical Data Matrix unless otherwise noted

l. Calculated from K_{ow} using Equation No. 71 in USEPA Soil Screening Guidance: Technical Background Document. Kow from Superfund Chemical Data Matrix unless otherwise noted

m. Kow from Hazardous Substances Databank (1999)

n. Kow calculated using WATER8.

o. From CHEMDAT8 User's Guide, U.S. Environmental Protection Agency, Office of Air Planning and Standards: Research Triangle Park, NC, EPA-453/C-94-080B (1994).

p. From WATER9

q. Mixture of 2,4-Dinitrotoluene/2,6-Dinitrotoluene not evaluated for inhalation exposure pathway. Instead, two contaminants evaluated individually.

Appendix F - Sensitivity Analysis - Particulates

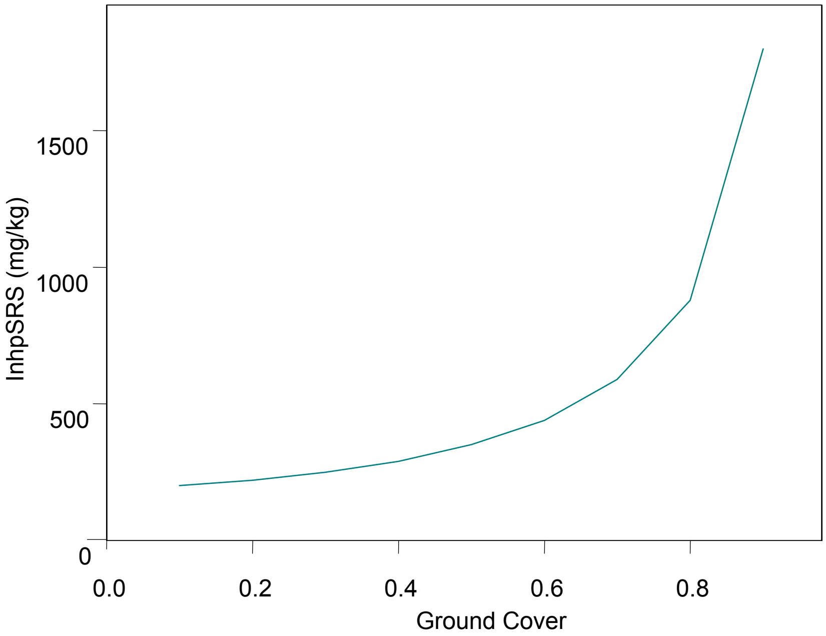
For this sensitivity analysis, only one variable was modified at a time as the other variables are held at their USEPA default or generic New Jersey value. In most cases, the parameters were varied by documented values. This analysis was conducted for both types of land use: residential and non-residential. For residential use, the ground cover and wind speed variables in the particulate emission factor taken from USEPA's *Soil Screening Guidance: Technical Background Document* (1996) were evaluated. For non-residential use, variables included in the USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites: Peer Review Draft* (2001) were evaluated.

Residential

1. Sensitivity of the Inh_pSRS to the amount of ground cover

The amount of vegetative cover assumed for wind erosion effects was 50% as a reasonable compromise between no vegetation and complete cover. The 50% vegetative cover was also assumed as default by USEPA. Vegetative cover has a significant effect.

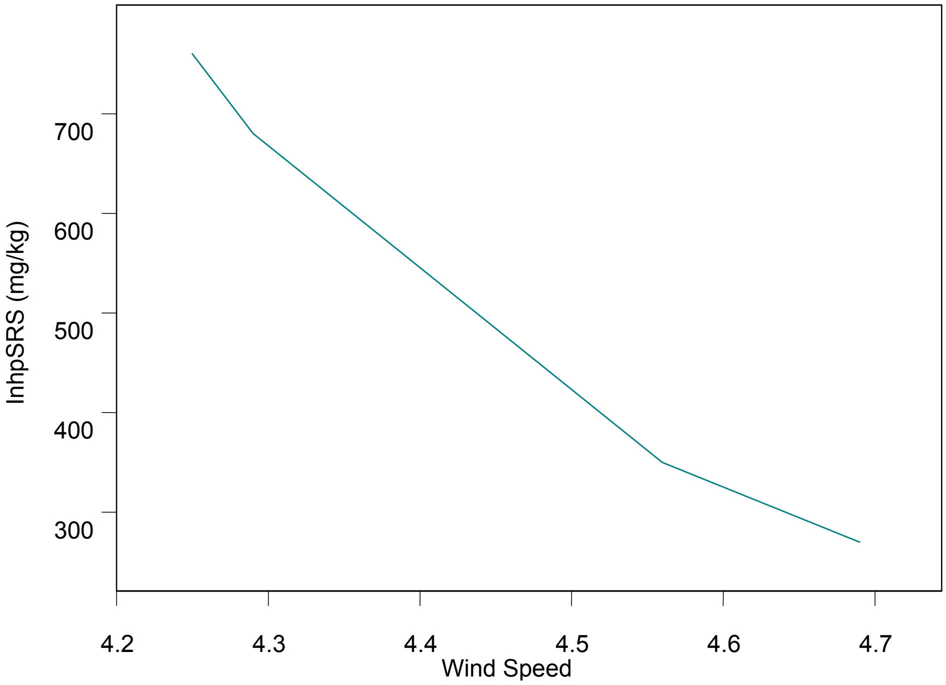
Ground Cover	Inh_pSRS (mg/kg)
0.1	200
0.2	220
0.3	250
0.4	290
0.5	350
0.6	440
0.7	590
0.8	880
0.9	1,800



2. Sensitivity of the Inh_pSRS to mean wind speed

The mean annual wind speed (4.69 m/s) and equivalent threshold wind speed value used in the Department's calculations are default values were taken from *USEPA's Soil Screening Guidance: Technical Background Document* (1996). The other mean wind speeds shown are site-specific values for Philadelphia (4.29 m/s), Atlantic City (4.25 m/s), and Newark (4.56 m/s). These mean wind speeds are 30-year (24-year for Atlantic City) normals statistically calculated by the National Oceanic and Atmospheric Administration (NOAA) (2003a, 2003b, 2003c). The effect of mean wind speed is significant.

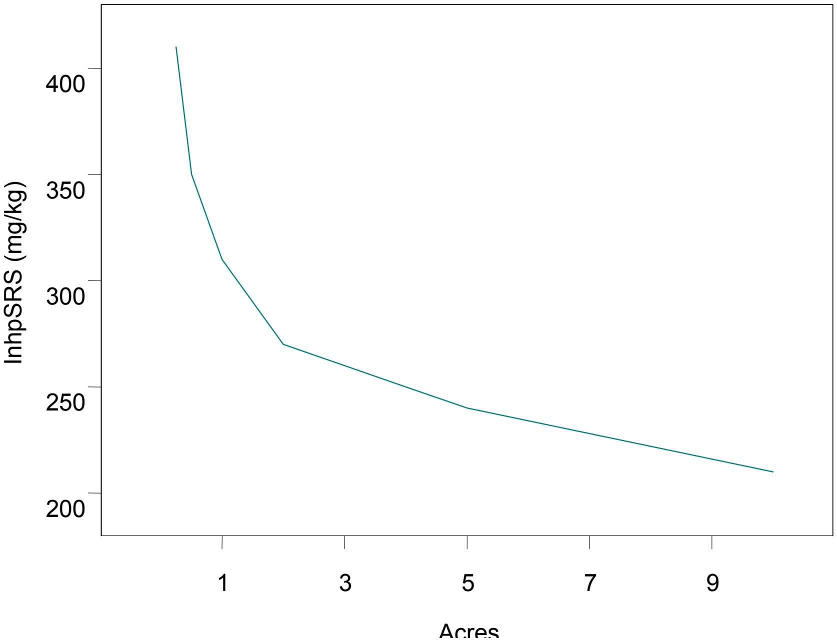
Mean Wind Speed (m/s)	Inh_pSRS (mg/kg)
4.25	760
4.29	680
4.56	350
4.69	270



3. Sensitivity of the Inh_pSRS to residential site size

A large number of comments on USEPA's December 1994 Soil Screening Guidance suggest that most contaminated soil sources are 0.5 acres or less. The USEPA's Office of Emergency and Remedial Response (OERR) conducted an analysis of the effects of changing the default source area from 30 acres to 0.5 acre. The results of the analysis indicated that the Inh_pSRS are sensitive to varying the source area. The reduction in the source area from 30 acres to 0.5 acre increases the Inh_pSRS for the inhalation exposure pathway by about a factor of 2 (USEPA 1996). The effect of site size on the Inh_pSRS is significant.

Site Size (Acres)	Inh_pSRS (mg/kg)
0.25	410
0.5	350
1	310
2	270
3	260
4	250
5	240
10	210



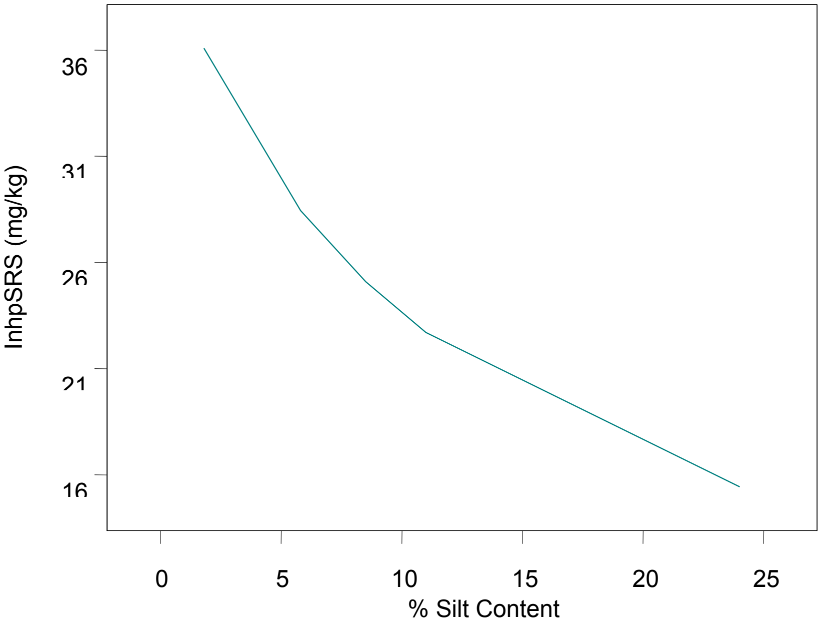
Non-Residential

The factors evaluated for sensitivity in regard to the non-residential scenario are mostly related to vehicular traffic over a site. It is assumed that vehicles can travel anywhere on the site, and that the site is unpaved. Another factor that significantly influences the non-residential scenario is the amount of time a worker is exposed to dust generated by vehicle travel and other activities at the site.

4. Sensitivity of the Inh_pSRS to silt content

Silt is defined by USEPA as particles smaller than 75 micrometers (um) in diameter (USEPA, 1998). The range of documented silt contents is 5.8% to 23.3%. The silt content of 5.8% is the composite of 63 soil samples collected from soil contaminated with chromium ore processing residue at Liberty State Park (Kitsa, et al. 1992). These soil samples were collected from 0 to 2 cm A value of 10.3% is the mean silt content measured at a tractor/trailer parking facility in Hudson County (Scott et al. 1997). Eight surface soil samples (0 to 1 cm) from this site were collected and analyzed. The silt contents for these soil samples ranged from 1.9 to 23.3%. The default silt content used to calculate the generic soil screening level is 11%. This value is from USEPA (1998) for dirt roads (i.e., local material compacted, bladed, and crowned) and determined from 24 samples taken at eight sites. Department approval is required prior to varying the silt content variable as a means of calculating an ARS. The Department is currently evaluating the feasibility of substituting site-specific values for soil type. However, until such data are available in a statistically large enough data set, the USEPA defaults will continue to be used. The effect of silt content on the Inh_pSRS is significant.

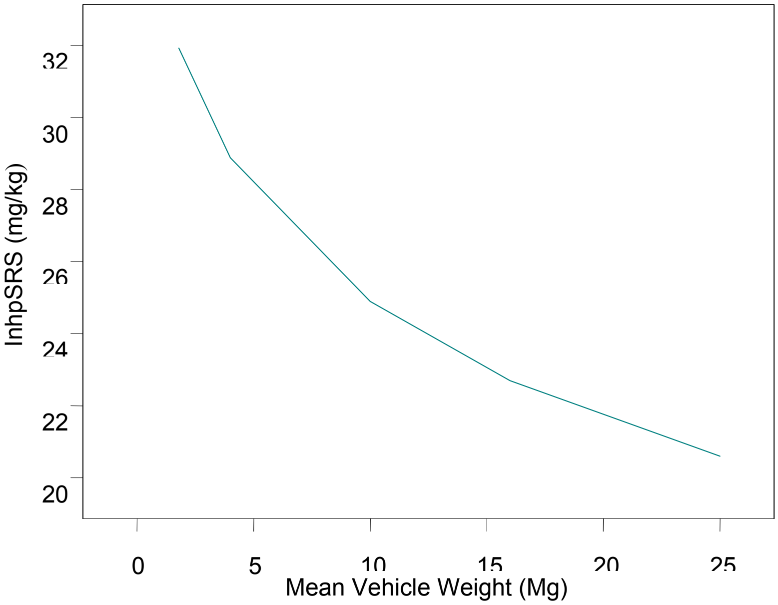
% Silt Content	Inh_pSRS (mg/kg)
1.8	36.08
5.8	28.45
8.5	25.1
11	22.7
24	15.44



5. Sensitivity of the Inh_pSRS to mean vehicle weight

Sensitivity of the mean vehicle weight assumed is 3.4 short tons, or 3.1 Metric Tons (Mg). This is based on the study conducted by Boile (2006). The Inh_pSRS are not particularly sensitive to the average weight of the vehicle.

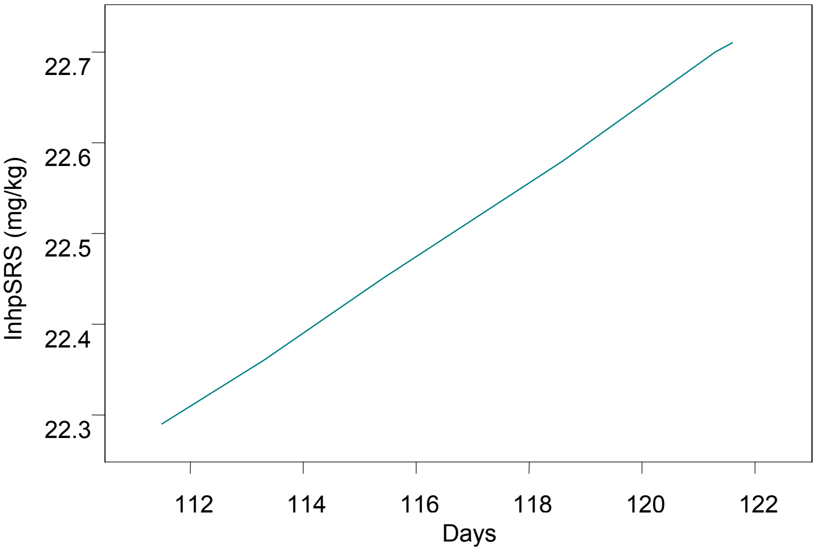
Mean Vehicle Weight (Mg)	Mean Vehicle Weight (Tons)	Inh_pSRS (mg/kg)
1.8	2	31.92
4	4.4	28.88
10	11	24.89
16	17.6	22.7
25	27.6	20.6



6. Sensitivity of the Inh_pSRS to days with greater than 0.01 inches of precipitation

The Department used 115.4 days with 0.01 inch (0.254 mm) of measurable precipitation as its default. This value represents Philadelphia's 30-year average of precipitation days annually. The average number of precipitation days for Atlantic City and Newark are 111.5 and 121.3 days, respectively, over the same 30-year period. The number of precipitation days with 0.01 inch or greater were taken from the National Oceanic and Atmospheric Administration's (NOAA) Local Climatological Data Summaries (1999a, 1999b, 1999c). Adjusting this variable has very little effect on the Inh_pSRS.

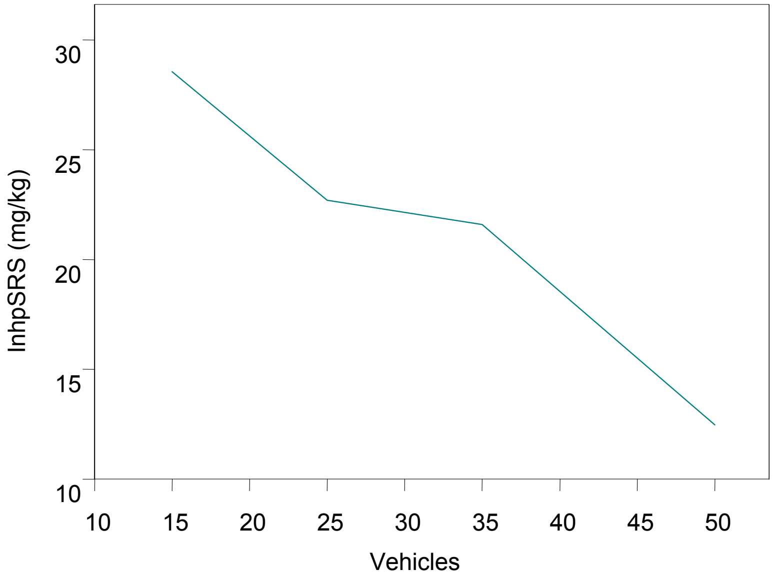
Days w/ > 0.01" Precip.	Inh_pSRS (mg/kg)
111.5	22.29
113.3	22.36
115.4	22.45
118.6	22.58
121.3	22.7
121.6	22.71



7. Sensitivity of the Inh_pSRS to number of vehicle trips per day

The default vehicle count assumed for a two-acre site is 33 vehicle trips per day, based on the study conducted by Boile (2006). This is a moderate assumption, as this variable can vary significantly by industrial use and site size. For example, Scott et al. (1997) assumed a total of 40 vehicle trips per day for a non-residential half-acre site. The number of vehicle trips significantly effects the Inh_pSRS.

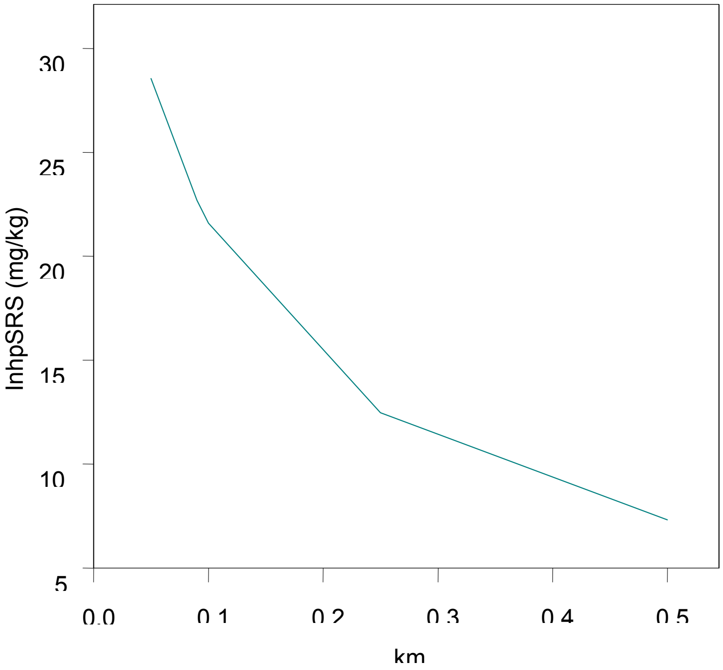
Number of Vehicle Trips/Day	Inh_pSRS (mg/kg)
15	27.84
25	22.7
35	19.16
50	15.53



8. Sensitivity of the Inh_pSRS to distance each vehicle travels

The average distance a vehicle travels through an unpaved area is also closely-related to site size. A reasonable estimate as a travel distance is using the square root of the site area in meters. For this sensitivity analysis, however, the site size of two acres was unchanged. See the following sensitivity data for more information on site area and distance traveled. Vehicle distance travelled can have a significant effect on the InhSRS.

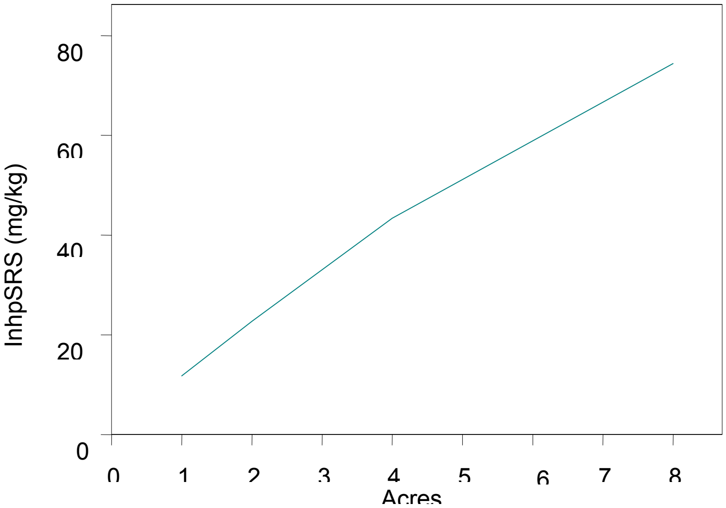
Distance each Vehicle Travels (km)	Inh_pSRS (mg/kg)
0.05	28.55
0.09	22.7
0.1	21.59
0.25	12.47
0.5	7.32



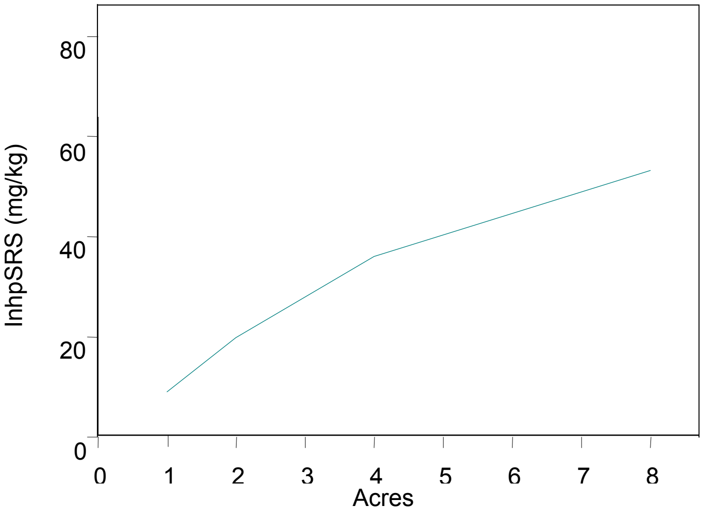
9. Sensitivity of the Inh_pSRS to non-residential site size

Overall, the Inh_pSRS increases as site size increases. By itself, site size has a significant effect on the Inh_pSRS. When only the site size is changed, the equations assess the same amount of traffic and resuspension of fugitive dust into the air, but diffuse it over the area of the site. Thus, the Inh_pSRS becomes less stringent as the site area is increased. The first set of data show the sensitivity of only changing the site size; the distance traveled remains at 0.09 km for all of the site areas. However, if the distance traveled is adjusted with the site size, the effect of site size is less significant. The second set of data show this correlation.

Data Set 1 (only change site size)	Site Size (acres)	Inh_pSRS (mg/kg)
	1	11.76
	2	22.7
	4	43.36
	8	74.41



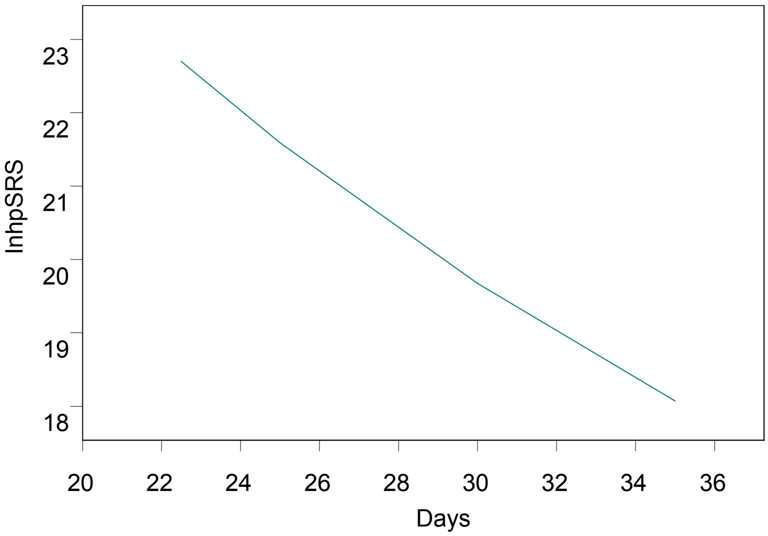
Data Set 2 (change site size and distance traveled)	Site Size (acres)	Distance Traveled (km)	Inh_pSRS (mg/kg)
	1	0.064	13.57
	2	0.09	22.7
	4	0.13	36.44
	8	0.18	50.92



10. Sensitivity of the Inh$_p$SRS to exposure frequency in days per year

The USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (Peer Review Draft)* (USEPA, 2001) recommends an exposure frequency of 225 days per year for the outdoor worker, 250 days per year for an indoor worker, and 350 days per year for residential exposure. Exposure frequency has very little effect on the Inh$_p$SRS.

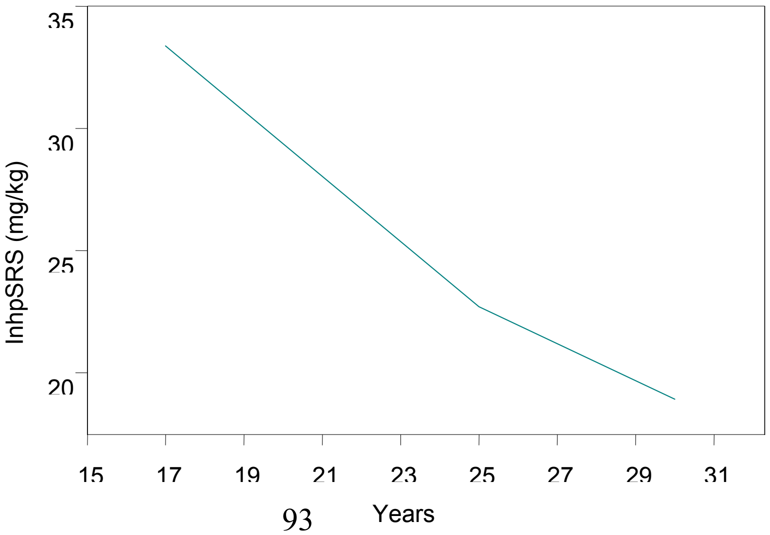
Days/Year	Inh$_p$SRS (mg/kg)
225	22.7
250	21.59
300	19.67
350	18.07



11. Sensitivity of the Inh$_p$SRS to exposure duration in years

The USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (Peer Review Draft)* (USEPA, 2001) recommends an exposure duration of 25 years for the non-residential scenario worker and a duration of 30 years for residential exposure. Exposure duration has a slightly greater effect on the Inh$_p$SRS than the exposure frequency.

Years	Inh$_p$SRS (mg/kg)
17	33.38
25	22.7
30	18.92



Summary of Sensitivity Analyses: Particulates	
Residential	
Parameter	***Sensitivity***
Ground cover	High
Mean wind speed	High
Residential site size	High
Non-residential	
Parameter	***Sensitivity***
Silt content	High
Mean vehicle weight	Low
Days with greater than 0.01 inches of precipitation	Low
Number of vehicle trips per day	High
Distance each vehicle travels	High
Non-residential site size	High
Exposure frequency in days per year	Low
Exposure duration in years	Low

REFERENCES

Boile, M. (2006). Estimation of the Average Number of Trucks Visiting Non-Residential Sites in New Jersey. Center for Advanced Infrastructure and Transportation, Rutgers, The State University of New Jersey. 76 p.

Kitsa, V., Lioy, P.J., Chow, J.C., Watson, J.G., Shupack, S., Howell, T., and Sanders, P. (1992). Particle-size distribution of chromium: total and hexavalent chromium in inspirable, thoracic, and respirable soil particles from contaminated sites in New Jersey. *Aerosol Science Technology*. **17**(3):213-229.

National Oceanic and Atmospheric Administration (NOAA). (1999a). Local Climatological Data for Atlantic City, New Jersey, ISSN 0275-1763.

National Oceanic and Atmospheric Administration (NOAA). (1999b). Local Climatological Data for Newark, New Jersey, ISSN 0198-3431.

National Oceanic and Atmospheric Administration (NOAA). (1999c). Local Climatological Data for Philadelphia, Pennsylvania, ISSN 0198-4535.

National Oceanic and Atmospheric Administration (NOAA). (2003a). Local Climatological Data for Atlantic City, New Jersey, ISSN 0275-1763.

National Oceanic and Atmospheric Administration (NOAA). (2003b). Local Climatological Data for Newark, New Jersey, ISSN 0198-3431.

National Oceanic and Atmospheric Administration (NOAA). (2003c). Local Climatological Data for Philadelphia, Pennsylvania, ISSN 0198-4535.

Scott, P., Finley, B., Sung, H., Schulze, R., and Turner, D.B. (1997). Identification of an Accurate Soil Suspension/Dispersion Modeling Method for Use in Estimating Health-Based Soil Cleanup Levels of Hexavalent Chromium in Chromite Ore Processing Residues, ISSN 1047-3289, *Journal of Air & Waste Management Association*, **47**(7):753-765.

United States Environmental Protection Agency (USEPA). (1996). Soil Screening Guidance: Technical Background Document. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/R-95/128. Washington, D.C.

United States Environmental Protection Agency (USEPA). (1998). Compilation of Air Pollutant Emission Factors Volume I: Stationary Point and the Area Source, 5th Edition. NTIS PB86-124906. Washington D.C.

United States Environmental Protection Agency (USEPA). (2001). Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER 9355.4-24. Washington, D.C.

Appendix G - Site Size Justification

Non-residential Exposure Scenario:

To calculate an inhalation exposure pathway, soil remediation standard for a non-residential exposure scenario, it is necessary to determine a default value for the size of a non-residential site. This information on a statewide basis is not readily available. Two sources of data regarding site size were examined and eventually used to develop a number. The Department fully recognizes the implications of using databases of limited size, but this was the best available option for developing a New Jersey specific value.

One source originates from the Department's program overseeing the remediation of facilities subject to the Industrial Site Recovery Act. Site size information was provided for 154 individual sites. The site sizes ranged from 0.11 acres to 13.16 acres with a median of 1 acre and an upper 95% confidence limit of the median equal to 1.9 acres. The 25th percentile value is 1 acre and the 75th percentile is 3.13 acres. The interquartile range (the range between the 25th and 75th percentile) is 2.13 acres. A strict arithmetic mean equals 2.58 acres; however, the population itself appears to be lognormal in nature. Taking this into account, the 95% upper confidence limit of the mean is 3.10 acres. Examination of the inputs yielded a qualitative judgement that this data set would be biased towards small sites since smaller sites would be more numerous in the data set.

The other source originates from the Site Remediation and Waste Management Program conducting remediation using public funds. Specifically, the site data in the Publicly Funded Cleanups Site Status Report for the years 1995 to 2002 was examined. Excluded were landfills, parks, and regional ground water or radiation remediations. Site sizes on 138 sites were obtained. The site sizes range from 0.07 acres to 640 acres with a median of 1.6 acres and an upper 95% confidence limit of the median equal to 2 acres. The 25th percentile value is 0.5 acre and the 75th percentile is 8.8 acres. The interquartile range (the range between the 25th and 75th percentile) is 8.3 acres. A strict arithmetic mean equals 16.06 acres; however, the population itself appears to be lognormal in nature. Taking this into account, the 95% upper confidence limit of the mean is 17.86 acres.

It is recognized that the largest sites were excluded from the evaluation in the case of the second set of data. However, as an offset to this, data under the purview of the underground storage tank program were also not included. This type of site, which is extremely numerous, would have a tendency to be smaller in size and consequently would likely reduce the average site size. The Department views these impacts as offsetting in nature.

The evaluation of the two data sets above yielded the following conclusion. The available data are lognormal distributions and there is a bias towards the inclusion of smaller sites. The median of these populations provides a better measure of the central tendency than the geometric mean. Because a true mean would necessarily be larger than the median in such a distribution, as well as in consideration of the data bias towards smaller sites, an upper bound of the median could serve as a better measure of central tendency. The upper 95% confidence limits of the two populations are 2 and 3 acres, respectively. The lower 95% confidence limits of the two populations are both 1 acre. It is concluded on this basis that 2 acres represents a reasonable estimate of the average site size of a non-residential type site because it is centrally located within the bounded ranges for the medians of both data sets.

Residential Exposure Scenario:

In the SSG, the USEPA assumes a residential lot is 0.5 acres in size. Because New Jersey is a small state, but more importantly, because it is the most densely populated state in the United States, an adjustment in lot size was deemed appropriate. Consequently, applying an arbitrary factor of 2, the New Jersey default residential lot size was determined to be 0.25 acres in the initial draft Basis and Background document.

Because of comments on the draft Basis and Background document, a reevaluation of the assumed residential site size was done. This effort consisted of tabulating site size data for 3,000 single family residences in each of the 21 counties of New Jersey. A real estate database provided the input data (Win2Data). Potential erroneous entries and those with zero or no area value entered were excluded from the data collected. Also excluded were lot sizes greater than

20 acres, which were usually large forested, farmed, or open space areas. The number of sites excluded in this manner was minimal.

A strict averaging (no weighting or filtering) of the 63,000 single family residence site size data points yielded a statewide mean of 0.475 acres. The larger average lot sizes in Atlantic, Hunterdon, and Salem Counties did influence the result. A mean value excluding the data from these counties would have resulted in an average lot size of 0.302 acres. However, because the purpose of the soil remediation standard effort is to develop a statewide standard, the mean derived from all the data is the more appropriate choice. Consequently, the assumed lot size for a residential exposure scenario will be 0.475 acres, which when rounded is 0.5 acres. This selection of 0.5 acres as the default residential lot size again returns the Department to consistency with the current USEPA assumption.

Appendix H1 - Table of Inhalation Soil Remediation Standards Based on Volatile Inhalation						
Chemical	**CAS Number**	**Csat mg/kg**	**Residential Standards**		**Non-residential Standards**	
			Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
Acenaphthene (PAH)*	83-32-9	6.07E+01	7.14E+02		2.04E+03	
Acenaphthylene (PAH)*	208-96-8	9.07E+01	5.17E+02		1.48E+03	
Acetone (2-Propanone)*	67-64-1	1.55E+05		*1.23E+06*		*2.93E+06*
Acetophenone	98-86-2	1.39E+03		2.09E+00		5.00E+00
Acrolein	107-02-8	3.27E+04		5.09E-01		1.21E+00
Acrylonitrile	107-13-1	1.17E+04	8.90E-01	5.19E+01	2.55E+00	1.24E+02
Aldrin	309-00-2	8.82E+02	4.93E+00		1.41E+01	
Anthracene (PAH)*	120-12-7	2.57E+00	2.40E+02		6.88E+02	
Atrazine*$^{+}$	1912-24-9	6.11E+01		4.32E+03		1.03E+04
Benzaldehyde*	100-52-7	6.34E+02		2.42E+04		5.76E+04
Benzene	71-43-2	5.22E+02	1.73E+00	1.74E+02	4.96E+00	4.15E+02
Benzidine	92-87-5	1.24E+02	4.46E-03		1.28E-02	
Benzo(a)anthracene (1,2-Benzanthracene) (PAH)*	56-55-3	7.48E+00	1.72E+02		4.92E+02	
Benzo(a)pyrene (PAH)*	50-32-8	3.31E+00	3.04E+01		8.71E+01	
Benzo(b)fluoranthene (3,4-Benzofluoranthene) (PAH)*	205-99-2	3.69E+00	1.47E+02		4.21E+02	
Benzo(ghi)perylene (PAH)*	191-24-2	2.01E+00	8.04E+03		2.30E+04	
Benzo(k)fluoranthene (PAH)*	207-08-9	1.97E+00	4.32E+02		1.24E+03	

Appendix H1 - Table of Inhalation Soil Remediation Standards Based on Volatile Inhalation						
Chemical	**CAS Number**	**Csat mg/kg**	**Residential Standards**		**Non-residential Standards**	
			Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
1,1'-Biphenyl*	92-52-4	1.04E+02		4.81E+04		1.15E+05
Bis(2-chloroethyl)ether	111-44-4	3.17E+03	5.53E-01		1.58E+00	
Bis(2-chloroisopropyl)ether	108-60-1	1.14E+03	2.33E+01		6.69E+01	
Bis(2-ethylhexyl) phthalate*	117-81-7	1.03E+04	8.74E+04	*6.29E+06*	2.50E+05	*1.50E+07*
Bromodichloromethane (Dichlorobromomethane)	75-27-4	1.83E+03	1.11E+00		3.18E+00	
Bromoform	75-25-2	1.02E+03	9.79E+01		2.80E+02	
Bromomethane (Methyl bromide)	74-83-9	3.12E+03		2.49E+01		5.94E+01
2-Butanone (Methyl ethyl ketone) (MEK)*	78-93-3	3.42E+04		2.06E+05		4.91E+05
Butyl benzyl phthalate* $^{+}$	85-68-7	3.10E+02		3.28E+05		7.83E+05
Caprolactam*	105-60-2	4.98E+04		2.37E+05		5.65E+05
Carbazole*	86-74-8	5.19E+01	4.05E+02		1.16E+03	
Carbon disulfide*	75-15-0	4.68E+02		1.84E+03		4.38E+03
Carbon tetrachloride	56-23-5	5.17E+02	6.04E-01	1.55E+02	1.73E+00	3.71E+02
Chlordane (alpha and gamma)*	57-74-9	1.34E+01	9.40E+01	2.82E+03	2.69E+02	6.73E+03
Chlorobenzene*	108-90-7	2.88E+02		1.11E+04		2.65E+04
Chloroethane (Ethyl chloride)*	75-00-3	1.29E+03		2.29E+04		5.46E+04
Chloroform	67-66-3	1.99E+03	6.11E-01	1.81E+03	1.75E+00	4.31E+03

Appendix H1 - Table of Inhalation Soil Remediation Standards Based on Volatile Inhalation

Chemical	CAS Number	Csat mg/kg	Residential Standards		Non-residential Standards	
			Carcinogenic mg/kg	Noncarcinogenic mg/kg	Carcinogenic mg/kg	Noncarcinogenic mg/kg
Chloromethane (Methyl chloride)	74-87-3	1.11E+03	4.17E+00	2.90E+02	1.19E+01	6.91E+02
2-Chlorophenol (o-Chlorophenol)	95-57-8	2.05E+04		9.09E+02		2.17E+03
Chrysene (PAH)*	218-01-9	1.27E+00	8.56E+02		2.45E+03	
4,4'-DDD*	72-54-8	1.80E+02	6.17E+02		1.77E+03	
4,4'-DDE #	72-55-9	1.07E+03	6.74E+02		1.93E+03	
4,4'-DDT*	50-29-3	1.32E+02	6.60E+02		1.89E+03	
Dibenz(a,h)anthracene (PAH)*	53-70-3	1.89E+01	7.43E+01		2.13E+02	
Dibromochloromethane (Chlorodibromomethane) +	124-48-1	7.37E+02	2.70E+00		7.74E+00	
1,2-Dibromo-3-chloropropane	96-12-8	3.74E+02	8.09E-02	1.39E+01	2.32E-01	3.31E+01
1,2-Dibromoethane	106-93-4	1.05E+03	9.77E-02	2.01E+01	2.80E-01	4.80E+01
1,2-Dichlorobenzene (o-Dichlorobenzene)*	95-50-1	2.18E+02		4.83E+03		1.15E+04
1,3-Dichlorobenzene (m-Dichlorobenzene)*	541-73-1	2.06E+02		6.06E+03		1.45E+04
1,4-Dichlorobenzene (p-Dichlorobenzene) +	106-46-7	1.03E+02	4.54E+00	1.71E+03	1.30E+01	4.09E+03
3,3'-Dichlorobenzidine #	91-94-1	4.98E+00	3.34E+00		9.56E+00	
Dichlorodifluoromethane	75-71-8	5.48E+02		4.94E+02		1.18E+03
1,1-Dichloroethane	75-34-3	1.24E+03	8.28E+00	2.84E+03	2.37E+01	6.77E+03
1,2-Dichloroethane	107-06-2	1.64E+03	9.14E-01	4.08E+03	2.62E+00	9.73E+03

Appendix H1 - Table of Inhalation Soil Remediation Standards Based on Volatile Inhalation						
Chemical	**CAS Number**	**Csat mg/kg**	**Residential Standards**		**Non-residential Standards**	
			Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
1,1-Dichloroethene (1,1-Dichloroethylene) $^{+}$	75-35-4	8.99E+02		6.12E+01		1.46E+02
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2	8.55E+02		2.34E+02		5.59E+02
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5	1.92E+03		3.01E+02		7.19E+02
2,4-Dichlorophenol*	120-83-2	2.12E+03		2.30E+03		5.49E+03
1,2-Dichloropropane	78-87-5	7.13E+02	1.86E+00	3.20E+01	5.34E+00	7.63E+01
1,3-Dichloropropene (cis and trans)	542-75-6	9.29E+02	2.37E+00	8.11E+01	6.78E+00	1.94E+02
Dieldrin	60-57-1	8.38E+00	1.16E+00		3.33E+00	
Diethyl phthalate*	84-66-2	7.88E+02		9.32E+05		*2.22E+06*
2,4-Dimethyl phenol*	105-67-9	4.50E+03		1.61E+04		3.83E+04
Di-n-butyl phthalate*	84-74-2	7.61E+02		*1.03E+06*		*2.45E+06*
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)*	534-52-1	7.71E+01		9.28E+01		2.22E+02
2,4-Dinitrophenol*	51-28-5	4.28E+02		8.98E+02		2.14E+03
2,4-Dinitrotoluene	121-14-2	9.30E+01	5.64E+00		1.62E+01	
2,6-Dinitrotoluene	606-20-2	5.31E+01	2.39E+00	7.77E+02	6.83E+00	1.85E+03
2,4-Dinitrotoluene/2,6-Dinitrotoluene (mixture)	25321-14-6	$				
Di-n-octyl phthalate*	117-84-0	3.33E+03	*1.56E+06*		*4.48E+06*	

Appendix H1 - Table of Inhalation Soil Remediation Standards Based on Volatile Inhalation						
Chemical	**CAS Number**	**Csat mg/kg**	**Residential Standards**		**Non-residential Standards**	
			Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
1,2-Diphenylhydrazine	122-66-7	1.07E+02	4.62E+00		1.32E+01	
Endosulfan I and Endosulfan II (alpha and beta)*	115-29-7	2.26E+00		1.68E+04		4.02E+04
Endosulfan sulfate*	1031-07-8	1.41E+01		1.51E+03		3.61E+03
Endrin*	72-20-8	6.19E+00		1.96E+03		4.67E+03
Ethyl benzene*	100-41-4	1.55E+02		9.24E+03		2.21E+04
Fluoranthene (PAH)*	206-44-0	4.41E+01	7.96E+03		2.28E+04	
Fluorene (PAH)*	86-73-7	5.50E+01	1.58E+03		4.53E+03	
alpha-HCH (alpha-BHC)	319-84-6	5.23E+00	6.59E-01		1.89E+00	
beta-HCH (beta-BHC)* +	319-85-7	6.42E-01	2.62E+00		7.50E+00	
Heptachlor	76-44-8	5.08E+02	6.32E+00		1.81E+01	
Heptachlor epoxide	1024-57-3	3.33E+01	4.53E+00		1.30E+01	
Hexachlorobenzene	118-74-1	6.83E+02	1.47E+00		4.22E+00	
Hexachloro-1,3-butadiene +	87-68-3	3.48E+02	1.21E+01		3.46E+01	
Hexachlorocyclopentadiene	77-47-4	7.21E+02		4.49E+01		1.07E+02
Hexachloroethane +	67-72-1	1.87E+02	8.33E+01		2.39E+02	
Indeno(1,2,3-cd)pyrene (PAH)*	193-39-5	1.53E-01	7.08E+02		2.03E+03	
Isophorone* +	78-59-1	2.96E+03		2.63E+04		6.27E+04

Appendix H1 - Table of Inhalation Soil Remediation Standards Based on Volatile Inhalation

Chemical	**CAS Number**	**Csat mg/kg**	**Residential Standards**		**Non-residential Standards**	
			Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
Lindane (gamma-HCH) (gamma-BHC)	58-89-9	1.56E+01	3.44E+00		9.85E+00	
Mercury	7439-97-6	1.00E+06		2.74E+01		6.55E+01
Methoxychlor*	72-43-5	8.80E+00		8.41E+04		2.01E+05
Methyl acetate*	79-20-9	3.79E+04		9.22E+04		2.20E+05
Methylene chloride (Dichloromethane)	75-09-2	2.44E+03	3.39E+01	2.73E+03	9.70E+01	6.51E+03
2-Methylnaphthalene*	91-57-6	3.45E+02	3.52E+02		1.01E+03	
2-Methylphenol (o-Creosol)* $^{+}$	95-48-7	8.73E+03		1.10E+04		2.63E+04
4-Methylphenol (p-Creosol)* $^{+}$	106-44-5	6.63E+03		9.89E+03		2.36E+04
Methyl tert-butyl ether (MTBE) $^{+}$	1634-04-4	8.27E+03	1.12E+02	3.75E+03	3.22E+02	8.96E+03
Naphthalene $^{+}$	91-20-3	1.29E+02	6.10E+00	2.67E+01	1.75E+01	6.37E+01
2-Nitroaniline	88-74-4	8.74E+01		3.87E+01		9.23E+01
Nitrobenzene	98-95-3	5.91E+02	1.60E+03	1.64E+02	4.58E+03	3.93E+02
N-Nitrosodimethylamine	62-75-9	1.54E+05	1.72E-02		4.92E-02	
N-Nitrosodi-n-propylamine	621-64-7	1.99E+03	1.62E-01		4.64E-01	
N-Nitrosodiphenylamine*	86-30-6	9.59E+01	4.89E+02		1.40E+03	
Pentachlorophenol	87-86-5	2.02E+04	5.94E+02		1.70E+03	
Phenanthrene (PAH)*	85-01-8	5.85E+01	3.34E+03		9.57E+03	
Phenol*	108-95-2	1.75E+04		2.95E+04		7.03E+04

Appendix H1 - Table of Inhalation Soil Remediation Standards Based on Volatile Inhalation

Chemical	CAS Number	Csat mg/kg	Residential Standards		Non-residential Standards	
			Carcinogenic mg/kg	Noncarcinogenic mg/kg	Carcinogenic mg/kg	Noncarcinogenic mg/kg
Polychlorinated biphenyls (PCBs)	1336-36-3	4.33E+02	2.01E+01		5.75E+01	
Pyrene (PAH)*	129-00-0	2.84E+01	8.63E+03		2.47E+04	
Styrene	100-42-5	5.33E+02	8.99E+01	2.20E+04	2.57E+02	5.24E+04
Tertiary butyl alcohol (TBA) $^{+}$	75-65-0	1.57E+05		4.75E+03		1.13E+04
1,1,2,2-Tetrachloroethane $^{+}$	79-34-5	1.01E+03	1.11E+00		3.17E+00	
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	1.11E+02	1.90E+00	1.68E+02	5.43E+00	4.01E+02
Toluene*	108-88-3	2.89E+02		3.62E+04		8.64E+04
Toxaphene	8001-35-2	3.80E+02	6.97E+01		2.00E+02	
1,2,4-Trichlorobenzene*	120-82-1	1.12E+03		1.38E+04		3.29E+04
1,1,1-Trichloroethane*	71-55-6	6.09E+02		4.33E+03		1.03E+04
1,1,2-Trichloroethane $^{+}$	79-00-5	1.14E+03	2.05E+00		5.88E+00	
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	5.90E+02	7.02E+00	3.61E+03	2.01E+01	8.62E+03
Trichlorofluoromethane*	75-69-4	9.44E+02		2.37E+03		5.65E+03
2,4,5-Trichlorophenol*	95-95-4	5.80E+03		2.52E+05		6.01E+05
2,4,6-Trichlorophenol	88-06-2	1.72E+03	3.36E+02		9.63E+02	
Vinyl chloride	75-01-4	8.94E+02	6.61E-01	2.49E+02	1.89E+00	5.95E+02
Xylenes*	1330-20-7	1.68E+02		1.01E+03		2.41E+03

Please note that concentrations shaded are critical values for each chemical and exposure scenario within the inhalation exposure pathway.

Please note that concentrations italicized and shaded are greater than one million parts per million.

Numbers are truncated for presentation purposes; do not assume numbers are rounded correctly.

* Chemical is not regulated because the Csat value for this compound precludes achieving the calculated contaminant concentration in air that would cause an adverse health impact via the inhalation of volatiles.

Chemical is partially not regulated because the Csat value for this compound precludes in part achieving the calculated contaminant concentration in air that would cause an adverse health impact.

+ Compound evaluated under Department C-Carcinogen policy.

$ Mixture of 2,4-Dinitrotoluene/2,6-Dinitrotoluene not evaluated for inhalation exposure pathway. Instead, two contaminants evaluated individually.

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation

Chemical	**CAS Number**	**Residential Standards**		**Non-residential Standards**	
		Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
Acenaphthene (PAH)	83-32-9	*3.85E+06*		2.98E+05	
Acenaphthylene (PAH)	208-96-8	*3.85E+06*		2.98E+05	
Acetone (2-Propanone)	67-64-1		*5.62E+10*		*3.63E+09*
Acetophenone	98-86-2		3.63E+04		2.34E+03
Acrolein	107-02-8		3.63E+04		2.34E+03
Acrylonitrile	107-13-1	6.22E+04	*3.63E+06*	4.82E+03	2.34E+05
Aldrin	309-00-2	8.64E+02		6.69E+01	
Aluminum	7429-90-5		*6.35E+09*		*4.10E+08*
Anthracene (PAH)	120-12-7	3.85E+05		2.98E+04	
Antimony	7440-36-0		3.63E+05		2.34E+04
Arsenic	7440-38-2	9.84E+02	5.44E+04	7.63E+01	3.51E+03
Atrazine $^{+}$	1912-24-9		*2.18E+07*		*1.41E+06*
Barium	7440-39-3		9.07E+05		5.86E+04
Benzaldehyde	100-52-7		*6.35E+08*		*4.10E+07*
Benzene	71-43-2	5.43E+05	*5.44E+07*	4.20E+04	*3.51E+06*
Benzidine	92-87-5	6.32E+01		4.89E+00	
Benzo(a)anthracene (1,2-Benzanthracene) (PAH)	56-55-3	3.85E+04		2.98E+03	

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation					
Chemical	**CAS Number**	**Residential Standards**		**Non-residential Standards**	
		Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
Benzo(a)pyrene (PAH)	50-32-8	3.85E+03		2.98E+02	
Benzo(b)fluoranthene (3,4-Benzofluoranthene) (PAH)	205-99-2	3.85E+04		2.98E+03	
Benzo(ghi)perylene (PAH)	191-24-2	3.85E+05		2.98E+04	
Benzo(k)fluoranthene (PAH)	207-08-9	3.85E+04		2.98E+03	
Beryllium	7440-41-7	1.76E+03	3.63E+04	1.37E+02	2.34E+03
1,1'-Biphenyl	92-52-4		*3.17E+08*		*2.05E+07*
Bis(2-chloroethyl)ether	111-44-4	1.28E+04		9.94E+02	
Bis(2-chloroisopropyl)ether	108-60-1	4.23E+05		3.28E+04	
Bis(2-ethylhexyl) phthalate	117-81-7	*1.76E+06*	*1.27E+08*	1.37E+05	*8.20E+06*
Bromodichloromethane (Dichlorobromomethane)	75-27-4	1.14E+05		8.86E+03	
Bromoform	75-25-2	*3.85E+06*		2.98E+05	
Bromomethane (Methyl bromide)	74-83-9		*9.07E+06*		5.86E+05
2-Butanone (Methyl ethyl ketone) (MEK)	78-93-3		*9.07E+09*		*5.86E+08*
Butyl benzyl phthalate +	85-68-7		*1.27E+08*		*8.20E+06*
Cadmium	7440-43-9	1.01E+03	3.63E+04	7.81E+01	2.34E+03
Caprolactam	105-60-2		*3.17E+09*		*2.05E+08*
Carbazole	86-74-8	7.43E+05		5.75E+04	

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation					
Chemical	**CAS Number**	**Residential Standards**		**Non-residential Standards**	
		Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
Carbon disulfide	75-15-0		*1.27E+09*		*8.20E+07*
Carbon tetrachloride	56-23-5	2.82E+05	*7.26E+07*	2.19E+04	*4.68E+06*
Chlordane (alpha and gamma)	57-74-9	4.23E+04	*1.27E+06*	3.28E+03	8.20E+04
Chlorobenzene	108-90-7		*1.81E+09*		*1.17E+08*
Chloroethane (Ethyl chloride)	75-00-3		*1.81E+10*		*1.17E+09*
Chloroform	67-66-3	1.84E+05	*5.44E+08*	1.43E+04	*3.51E+07*
Chloromethane (Methyl chloride)	74-87-3	*2.35E+06*	*1.63E+08*	1.82E+05	*1.05E+07*
2-Chlorophenol (o-Chlorophenol)	95-57-8		*3.27E+07*		*2.11E+06*
Chrysene (PAH)	218-01-9	3.85E+05		2.98E+04	
Cobalt	7440-48-4		9.07E+03		5.86E+02
Copper	7440-50-8		*4.35E+06*		2.81E+05
Cyanide	57-12-5		*1.27E+08*		*8.20E+06*
4,4'-DDD	72-54-8	6.13E+04		4.75E+03	
4,4'-DDE	72-55-9	4.36E+04		3.38E+03	
4,4'-DDT	50-29-3	4.36E+04		3.38E+03	
Dibenz(a,h)anthracene (PAH)	53-70-3	3.53E+03		2.73E+02	
Dibromochloromethane (Chlorodibromomethane) $^{+}$	124-48-1	1.57E+05		1.21E+04	

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation					
Chemical	**CAS Number**	**Residential Standards**		**Non-residential Standards**	
		Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
1,2-Dibromo-3-chloropropane	96-12-8	2.12E+03	3.63E+05	1.64E+02	2.34E+04
1,2-Dibromoethane	106-93-4	7.05E+03	*1.45E+06*	5.47E+02	9.37E+04
1,2-Dichlorobenzene (o-Dichlorobenzene)	95-50-1		*3.63E+08*		*2.34E+07*
1,3-Dichlorobenzene (m-Dichlorobenzene)	541-73-1		*5.46E+08*		*3.53E+07*
1,4-Dichlorobenzene (p-Dichlorobenzene) $^+$	106-46-7	3.85E+05	*1.45E+08*	2.98E+04	*9.37E+06*
3,3'-Dichlorobenzidine	91-94-1	1.24E+04		9.65E+02	
Dichlorodifluoromethane	75-71-8		*3.63E+08*		*2.34E+07*
1,1-Dichloroethane	75-34-3	*2.65E+06*	*9.07E+08*	2.05E+05	*5.86E+07*
1,2-Dichloroethane	107-06-2	1.63E+05	*7.26E+08*	1.26E+04	*4.68E+07*
1,1-Dichloroethene $^+$	75-35-4		*3.63E+07*		*2.34E+06*
1,2-Dichloroethene (cis) (c-1,2-Dichloroethylene)	156-59-2		*6.35E+07*		*4.10E+06*
1,2-Dichloroethene (trans) (t-1,2-Dichloroethylene)	156-60-5		*1.09E+08*		*7.03E+06*
2,4-Dichlorophenol	120-83-2		*2.00E+07*		*1.29E+06*
1,2-Dichloropropane	78-87-5	4.23E+05	*7.26E+06*	3.28E+04	4.68E+05
1,3-Dichloropropene (cis and trans)	542-75-6	*1.06E+06*	*3.63E+07*	8.20E+04	*2.34E+06*
Dieldrin	60-57-1	9.20E+02		7.13E+01	

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation

Chemical	CAS Number	Residential Standards		Non-residential Standards	
		Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
Diethyl phthalate	84-66-2		*5.08E+09*		*3.28E+08*
2,4-Dimethyl phenol	105-67-9		*1.27E+08*		*8.20E+06*
Di-n-butyl phthalate	84-74-2		*6.35E+08*		*4.10E+07*
4,6-Dinitro-2-methylphenol (4,6-Dinitro-o-cresol)	534-52-1		7.26E+05		4.68E+04
2,4-Dinitrophenol	51-28-5		*1.27E+07*		8.20E+05
2,4-Dinitrotoluene	121-14-2	4.76E+04		3.68E+03	
2,6-Dinitrotoluene	606-20-2	2.18E+04	*7.26E+06*	1.69E+03	4.68E+05
2,4-Dinitrotoluene/2,6-Dinitrotoluene (mixture)	25321-14-6	$			
Di-n-octyl phthalate	117-84-0	*3.26E+07*		*2.52E+06*	
1,2-Diphenylhydrazine	122-66-7	1.92E+04		1.49E+03	
Endosulfan I and Endosulfan II (alpha and beta)	115-29-7		*3.81E+07*		*2.46E+06*
Endosulfan sulfate	1031-07-8		*3.81E+07*		*2.46E+06*
Endrin	72-20-8		*1.81E+06*		1.17E+05
Ethyl benzene	100-41-4		*1.81E+09*		*1.17E+08*
Fluoranthene (PAH)	206-44-0	*3.85E+06*		2.98E+05	
Fluorene (PAH)	86-73-7	*3.85E+06*		2.98E+05	
alpha-HCH (alpha-BHC)	319-84-6	2.35E+03		1.82E+02	

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation					
Chemical	**CAS Number**	**Residential Standards**		**Non-residential Standards**	
		Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
beta-HCH (beta-BHC) $^{+}$	319-85-7	7.99E+03		6.19E+02	
Heptachlor	76-44-8	3.26E+03		2.52E+02	
Heptachlor epoxide	1024-57-3	1.63E+03		1.26E+02	
Hexachlorobenzene	118-74-1	9.20E+03		7.13E+02	
Hexachloro-1,3-butadiene $^{+}$	87-68-3	1.92E+05		1.49E+04	
Hexachlorocyclopentadiene	77-47-4		3.63E+05		2.34E+04
Hexachloroethane $^{+}$	67-72-1	*1.06E+06*		8.20E+04	
Indeno(1,2,3-cd)pyrene (PAH)	193-39-5	3.85E+04		2.98E+03	
Isophorone $^{+}$	78-59-1		*3.63E+08*		*2.34E+07*
Lead	7439-92-1	3.53E+05	4.37E+04	2.73E+04	1.17E+04
Lindane (gamma-HCH) (gamma-BHC)	58-89-9	1.37E+04		1.06E+03	
Manganese	7439-96-5		9.07E+04		5.86E+03
Mercury	7439-97-6		5.44E+05		3.51E+04
Methoxychlor	72-43-5		*3.27E+07*		*2.11E+06*
Methyl acetate	79-20-9		*6.35E+09*		*4.10E+08*
Methylene chloride (Dichloromethane)	75-09-2	*9.01E+06*	*7.26E+08*	6.98E+05	*4.68E+07*
2-Methylnaphthalene	91-57-6	*3.85E+06*		2.98E+05	

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation					
Chemical	**CAS Number**	**Residential Standards**		**Non-residential Standards**	
		Carcinogenic mg/kg	**Noncarcinogenic mg/kg**	**Carcinogenic mg/kg**	**Noncarcinogenic mg/kg**
2-Methylphenol (o-Creosol) [+]	95-48-7		*1.09E+08*		*7.03E+06*
4-Methylphenol (p-Creosol) [+]	106-44-5		*1.09E+08*		*7.03E+06*
Methyl tert-butyl ether (MTBE) [+]	1634-04-4	*1.63E+07*	*5.44E+08*	*1.26E+06*	*3.51E+07*
Naphthalene [+]	91-20-3	1.24E+05	5.44E+05	9.65E+03	3.51E+04
Nickel (Soluble salts)	7440-02-0		3.63E+05		2.34E+04
2-Nitroaniline	88-74-4		3.63E+05		2.34E+04
Nitrobenzene	98-95-3	*3.53E+07*	*3.63E+06*	*2.73E+06*	2.34E+05
N-Nitrosodimethylamine	62-75-9	3.02E+02		2.34E+01	
N-Nitrosodi-n-propylamine	621-64-7	2.12E+03		1.64E+02	
N-Nitrosodiphenylamine	86-30-6	*1.63E+06*		1.26E+05	
Pentachlorophenol	85-01-8	8.30E+05		6.43E+04	
Phenanthrene (PAH)	108-95-2	*3.85E+06*		2.98E+05	
Phenol	1336-36-3		*3.63E+08*		*2.34E+07*
Polychlorinated biphenyls (PCBs)	87-86-5	4.23E+04		3.28E+03	
Pyrene (PAH)	129-00-0	*3.85E+06*		2.98E+05	
Selenium	7782-49-2		*3.63E+07*		*2.34E+06*
Silver	7440-22-4		*3.27E+07*		*2.11E+06*

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation

Chemical	CAS Number	Residential Standards		Non-residential Standards	
		Carcinogenic mg/kg	Noncarcinogenic mg/kg	Carcinogenic mg/kg	Noncarcinogenic mg/kg
Styrene	100-42-5	*7.43E+06*	*1.81E+09*	5.75E+05	*1.17E+08*
Tertiary butyl alcohol (TBA) +	75-65-0		*1.14E+08*		*7.38E+06*
1,1,2,2-Tetrachloroethane +	79-34-5	7.30E+04		5.65E+03	
Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4	7.17E+05	*6.35E+07*	5.56E+04	*4.10E+06*
Thallium	7440-28-0		3.63E+05		2.34E+04
Toluene	108-88-3		*9.07E+09*		*5.86E+08*
Toxaphene	8001-35-2	1.32E+04		1.02E+03	
1,2,4-Trichlorobenzene	120-82-1		*3.63E+08*		*2.34E+07*
1,1,1-Trichloroethane	71-55-6		*1.81E+09*		*1.17E+08*
1,1,2-Trichloroethane +	79-00-5	2.65E+05		2.05E+04	
Trichloroethene (TCE) (Trichloroethylene)	79-01-6	*2.12E+06*	*1.09E+09*	1.64E+05	*7.03E+07*
Trichlorofluoromethane	75-69-4		*1.27E+09*		*8.20E+07*
2,4,5-Trichlorophenol	95-95-4		*6.35E+08*		*4.10E+07*
2,4,6-Trichlorophenol	88-06-2	*1.37E+06*		1.06E+05	
Vanadium	7440-62-2		*7.26E+06*		4.68E+05
Vinyl chloride	75-01-4	4.81E+05	*1.81E+08*	3.73E+04	*1.17E+07*
Xylenes	1330-20-7		*1.81E+08*		*1.17E+07*

Appendix H2 - Table of Inhalation Soil Remediation Standards Based on Particulate Inhalation

Chemical	CAS Number	Residential Standards		Non-residential Standards	
		Carcinogenic mg/kg	Noncarcinogenic mg/kg	Carcinogenic mg/kg	Noncarcinogenic mg/kg
Zinc	7440-66-6		*1.63E+06*		1.05E+05

Please note that concentrations shaded are critical values for each chemical and exposure scenario within the inhalation exposure pathway.

Please note that concentrations italicized and shaded are greater than one million parts per million.

Numbers are truncated for presentation purposes; do not assume numbers are rounded correctly.

\+ Compound evaluated under Department C-Carcinogen policy.

$ Mixture of 2,4-Dinitrotoluene/2,6-Dinitrotoluene not evaluated for inhalation exposure pathway. Instead, two contaminants evaluated individually.

Appendix I - Calculation of an Alternative Remediation Standard using the EMSOFT Model and a Finite Contamination Thickness

Introduction

The generic remediation guidance uses a simplified form of the model of Jury et al. (1990), which assumes an infinite depth of contamination. The full version of this model allows for a finite depth range to be specified (Jury et al., 1990). Assuming a finite depth range will reduce the mass of contaminant in the soil, which will reduce the average volatilization flux. This in turn will result in a higher remediation standard. Calculation of an Alternative Remediation Standard using the Jury model is likely to be worthwhile (result in a higher criteria) if the thickness of the contaminated zone is not extensive. To calculate this site-specific standard, the EMSOFT software package is recommended. The package is available on the Internet from USEPA's National Center for Environmental Assessment (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2862). Software documentation (in PDF format) may also downloaded from the site.

Theoretical basis

For volatile organic chemicals (dimensionless Henry's law constant >> 2.5×10^{-5}), volatilization from the soil surface is limited only by the diffusion rate through the soil, with no restriction imposed by the stagnant air layer at the soil surface (Jury et al., 1984). If soil moisture advection is not considered, and if a chemical is assumed to be present from the soil surface to an infinite depth, the volatilization flux equation can be expressed as follows (Jury et al., 1984):

$$J = C_0 (D_A / \pi \times t)^{1/2} \tag{1}$$

where J is the volatilization flux (mg/cm^2/day) as a function of time t (days), C_0 is the concentration of contaminant at time zero on a volume basis (mg/cm3), and D_A is the soil diffusion coefficient (cm^2/day, from Equation 6 of the EPA SSG document). An average volatilization flux may be calculated by integrating Equation 1 from time 0 to time t, to give cumulative flux, and dividing by the time interval:

$$\frac{\int_0^t C_0 (D_A / \pi \times t)^{1/2}}{t} \qquad (2)$$

The solution to this equation is

$$2C_0 \sqrt{D_A / \pi \times t} \qquad (3)$$

If Equation 3 is normalized for concentration by dividing C_0 (which has units of mg/cm^3) by the initial concentration on a weight basis (C_S , which has units of mg/g), the equation is transformed to

$$2\rho_b \sqrt{D_A / \pi \times t} \tag{4}$$

where Equation 4 now represents the average volatilization flux per unit concentration of contaminant on a weight basis, and ρ_b is the bulk density of the soil as described in the EPA SSG document (g/cm^3). Note that Equation 4 is equivalent to the inverse of the second factor of Equation 6 in the EPA SSG document. Thus, the average volatilization flux using the Jury model can be used along with the inverse of the mean concentration at the center of a square source (g/m^2/s per kg/m^3 – see Q/C factor of Equation 6 in the EPA SSG document) to calculate the volatilization factor.

While the above derivation was carried out using a simplified form of the Jury model, the average volatilization flux from the full Jury model can be used in the same manner. The full version of the Jury model (Jury et al., 1990) considers a finite source of contaminant located in a depth range of L to $L + W$, where L is the depth of the top of the contamination, and W is the thickness of the contamination. Advection of soil moisture, due to precipitation infiltration, may also be considered, as well as degradation of the contaminant. These additional features in the full version of the model may result in a significantly lower average volatilization flux, and in turn, a higher calculated remediation standard. The full version of the Jury model may be evaluated using the EMSOFT program, available without charge on the Internet (USEPA, 1997).

Calculation of Alternative Remediation Standard using EMSOFT

Calculating an alternative inhalation soil remediation standard for volatile organic chemicals requires three steps:

1. Calculation of the time-averaged volatilization flux of contaminant from the soil using the model of Jury et al.

2. Calculation of the Volatilization Factor (VF) from the time-averaged volatilization flux.

3. Calculation of the soil remediation criteria using the exposure assumptions assumed during calculation of the remediation standards.

Step 1: Running the Jury model (using the EMSOFT software package) to obtain the time-averaged volatilization flux.

Several types of output are available from the program. For purposes of the NJDEP remediation criteria, the time-averaged flux output is all that is necessary. The program should be run for the exposure period of interest (30 years, or 10,958 days). Chemical degradation is not allowed for these calculations. A 1 mg/kg concentration of contaminant must be used, in order to correctly calculate the volatilization factor.

1. Begin execution of the EMSOFT program by double-clicking on EMSOFT.BAT

2. A title screen comes up. Click on the OK button.

3. If you have previously saved a chemical input file (*.CHM) or a complete input scenario (*.DAT) file that you wish to use, click on the appropriate selection box and the desired file name, and then click on OK. If you will be entering new data, simply click on OK.

4. Select the time-averaged flux box by clicking on it. Then click on the Time period for averaging.... box and enter 10,958 days. For depths D1 and D2, first click on the data entry box, then enter the depth to groundwater, in cm. Then click on OK. If depth to groundwater is not known, enter a depth below the location of the contamination.

5. Enter the chemical data by clicking on each selection box and entering the appropriate values (see following table). If you wish to save this chemical data in a file for future use, click on the selection box, click on the name entry box (leave the .CHM part alone), and enter the name. Then click on OK.

Parameter	Value
Organic carbon partition coefficient (mL/g, or L/kg)	Chemical specific[a]
Henry's law constant (dimensionless)	Chemical specific[a]
Air diffusion coefficient (cm^2/day)	Chemical specific[a,b]
Aqueous diffusion coefficient (cm^2/day)	Chemical specific[a,b]
Half-life (days)	1,000,000[c]
Number of contaminant layers	1[c]

[a] Use values from Appendix E.

[b] Multiply the DEP values (cm^2/s) by 86,400 s/day to obtain units of cm^2/day.

[c] This parameter value may not be changed.

6. Enter the soil properties and physical constants, using the following table as guidance, then click on OK:

Parameter	Value
Fraction organic carbon	0.002[d]
Porosity (v/v, dimensionless)	0.41[e]
Water content (v/v, dimensionless)	0.23[e]
Bulk density (g/cm^3)	1.5[e]
Porewater flux (cm/day)	0.08[f]
Boundary layer thickness (cm)	0.5[e]

[d] This may be adjusted using site-specific measurements (see text).

[e] This parameter value may not be changed.

[f] This parameter value may not be changed without consultation with the Department. Corresponds to New Jersey annual infiltration rate (see Appendix D).

7. Enter layer properties using the following table, then click on OK:

Parameter	Value
Cover thickness (cm)	Site-specific[g]
Layer thickness (cm)	Site-specific[h]
Contaminant concentration (mg/kg)	1[i]

[g] Enter the shallowest depth at which contamination is observed (cm). If contamination extends to the soil surface, enter 0.

[h] Enter the thickness, in cm, of the contaminated soil. This is the lowest depth at which contamination is observed minus the shallowest depth at which contamination is observed.

[i] This value may not be changed.

8. If you wish to save the entire input scenario and/or the output data in a file, check the appropriate box, click on the name entry box, and enter the desired name (leave the .DAT and .OUT part of the name intact). Then click on OK.

9. The program then calculates the time-averaged volatilization flux (average surface flux). Write down the value shown. Then click on OK.

Step 2: Calculate the Volatilization Factor (VF)

1. Convert the time-averaged volatilization flux (mg/cm^2/day) to units of gm/m^2/sec. To do this, multiply by 10,000 cm^2/m^2, divide by 86,400 sec/day, and divide by 1,000 mg/g.

2. Divide the converted value by 10^{-6} to give the normalized volume-based flux, J (gm/m^2/sec).

3. Calculate the VF as follows:

$$VF = \frac{Q / C}{J}$$

where Q/C is either 90.4 (g/m^2/sec)/(kg/m^3) (residential sites) or 138.7 (g/m^2/sec)/(kg/m^3) (non-residential sites), and VF is the volatilization factor (m^3/kg).

Step 3: Calculate the site-specific soil remediation criteria using the above VF value

Use Equation 1 or 2 from the main guidance for this exposure pathway.

REFERENCES

Jury, W.A., Farmer, W.J. and Spencer, W.F. (1984). Behavior Assessment Model for Trace Organics in Soil: II Chemical Classification and Parameter Sensitivity. *J. Environ. Qual.*, **13**(4):567-572.

Jury, W.A., Russo, D., Streile, G., and Abd, H.E. (1990). Evaluation of Volatilization by Organic Chemicals Residing Below the Soil Surface. *Water Resour. Res*. **26**(1):13-20.

United States Environmental Protection Agency (USEPA). (1997). EMSOFT User's Guide. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, NCEA-W-0073. 105 p.

Appendix J - Estimation of the Average Number of Trucks Visiting Non-Residential Sites in New Jersey

Go to the following web page to link to the Rutgers study:

http://www.nj.gov/dep/srp/regs/rs