Remediation and
Redevelopment Division

Michigan Department of Environmental Quality

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RRD OPERATIONAL MEMORANDUM NO. 1

SUBJECT: **TECHNICAL SUPPORT DOCUMENT - ATTACHMENT 7**
PART 201 GENERIC SOIL INHALATION CRITERIA FOR AMBIENT AIR
PART 213 TIER I SOIL INHALATION RISK-BASED SCREENING LEVELS FOR AMBIENT AIR

Developed under R 299.5726

Key definitions for terms used in this document:

NREPA:	The Natural Resources and Environmental Protection Act, 1994 PA 451, as amended
Part 201:	Part 201, Environmental Remediation, of NREPA
Part 213:	Part 213, Leaking Underground Storage Tanks, of NREPA
MDEQ:	Michigan Department of Environmental Quality
AQD:	Air Quality Division
RRD:	Remediation and Redevelopment Division
CAP/RAP:	Corrective Action Plan pursuant to provisions of Part 213 of NREPA and Remedial Action Plans pursuant to provisions of Part 201 of NREPA
Criteria or Criterion:	Includes the cleanup criteria for Part 201 of the NREPA and Risk-Based Screening Levels as defined in Part 213 of NREPA and R 299.5706a(4)
Facility:	Includes “facility” as defined in Part 201 of the NREPA and “site” as defined in Part 213 of NREPA
SIC:	Soil inhalation criteria for ambient air
Source Area:	The area where concentration exceeds the 1,000 acre source size-adjusted screening value
Source Area Size:	The sum of all source areas for an individual hazardous substance
Generic SIC:	The calculated risk-based SIC that has been adjusted as appropriate using the source area size-based modifier presented in the Modifier Table (R 299.5726(6)). The modified SIC is the generic SIC that must be used for comparison with soil contaminant concentration
PSIC:	Particulate soil inhalation criteria for ambient air
VSIC:	Volatile soil inhalation criteria for ambient air
C_{sat} Value:	The concentration in soil at which the solubility limits of the soil pore water, the vapor phase limits of the soil pore air, and the absorptive limits of the soil particles have been reached
TSD:	Technical Support Document
U.S. EPA:	United States Environmental Protection Agency

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1.0 INTRODUCTION

This TSD provides the methodology for the development of the SIC for ambient air. The SIC represent concentrations of hazardous substances in soil that are not expected to impact ambient air at levels that may cause adverse human health effects. The SIC were developed pursuant to Sections 20120a(1)(a), (b), and (d); 20120(a)(3); and 21304a(1)(2) of NREPA. The method and equations for the SIC are presented in R 299.5726. This TSD supercedes previous MDEQ documents regarding SIC (Environmental Response Division Operational Memorandum No. 18; Generic Soil Inhalation Criteria for Ambient Air: Technical Support Document; and Storage Tank Division Operational Memorandum No. 4 - Attachment 9).

The SIC are presented in the Part 201 Administrative Rules (R 299.5746 and R 299.5748) and Attachment 1 of the RRD Operational Memorandum (Op Memo) No. 1: Part 201 Generic Cleanup Criteria/Part 213 Tier I Risk-Based Screening Levels. The residential and commercial I SIC are presented in columns 15 to 18 of the Soil: Residential and Commercial I Table. The industrial and commercial II, commercial III, and commercial IV SIC are presented in columns 23 to 26 of the Soil: Industrial and Commercial II, III, and IV Table.

2.0 CALCULATION OF THE SOIL INHALATION CRITERIA FOR AMBIENT AIR

Emissions from Part 201 facilities/Part 213 sites are not normally subject to the permit requirements of the Air Toxics Rules of Part 55, Air Pollution Control, of Act 451 (Air Toxics Rules) with the exception of some periods of active remediation. However, compliance with the AQD ambient air screening levels developed under the authority of the Air Toxics Rules has been determined to be one way of demonstrating that soils at Part 201 facilities/Part 213 sites will not result in unacceptable emissions to ambient air. Therefore, the methods used to develop the AQD screening values and the regulations governing application of those values have been considered and employed in the development of SIC for ambient air where appropriate. Some modifications in the AQD methods and applications were made in the development of Part 201 SIC.

The generic VSIC and PSIC have been developed to address inhalation exposures to airborne soil contaminants in ambient air. The VSIC address the migration of volatile hazardous substances in soil to ambient air. The PSIC address the emission and dispersion of contaminated soil particulates into the ambient air. The VSIC and PSIC address the soil to ambient air pathway by incorporating volatilization factors (VF) for volatile contaminants and particulate emission factors (PEF) for particulates, respectively. Both VF and PEF equations require a model that estimates the emission of contaminants from the soil and a dispersion model that simulates the dispersion of the contaminants in ambient air.

The generic SIC are intended to be protective of chronic human health effects that may result from exposure to ambient airborne contaminants. The SIC do not account for and may not be protective of other endpoints such as acute human health effects, odors, ocular irritation, physical hazards (e.g., reactivity, corrosivity, or ignitability), nuisance dust conditions, and/or ecological impacts. The potential occurrence of these effects must be evaluated to determine if more restrictive applicable criteria are needed to ensure protection for these endpoints. Contact the RRD Toxicology Unit for assistance in evaluating the potential for such acute effects.

The soil inhalation pathway for ambient air is relevant for all land uses. The SIC are applicable unless restrictions are placed on the property such that soil contaminants and contaminated soil particles cannot be released or emitted and dispersed into the ambient air. The SIC apply to all soil depths to account for activities that may bring subsurface soils to the surface. The generic VSIC are not protective of indoor air inhalation exposures resulting from the migration of vapors from soil into indoor air spaces. Consult the RRD Op Memo No. 1 - Attachment 5: Part 201 Groundwater and Soil Volatilization to Indoor Air Inhalation Criteria/Part 213 Tier 1 Groundwater and Soil Volatilization to Indoor Air Inhalation Risk-Based Screening Levels TSD (under revision).

If a generic SIC value developed under R 299.5726 is greater than the soil saturation screening concentrations (C_{sat}) for that hazardous substance, then the C_{sat} becomes the generic criterion for this pathway, unless a facility-specific C_{sat} is established using facility-specific soil characteristics (R 299.5718(2)). Refer to the RRD Op Memo No. 1 - Attachment 8: C_{sat} Concentrations TSD (MDEQ, 2007) for details. If the target detection limit (TDL) is greater than the risk-based cleanup criterion for a hazardous substance in a given environmental medium, the TDL is used in place of the risk-based value as the cleanup criterion (R 299.5707). A background concentration may be substituted for the generic cleanup criterion when the cleanup criterion is less than background concentration (R 299.5707, R 299.5706a(5)(b)). Additional guidance on establishing background concentration is available in the RRD Op Memo No. 1 and the MDEQ Sampling Strategies and Statistics Training Materials (S^3TM) (MDEQ, 2002).

The calculated one-half acre source size-based SIC are presented in the Criteria Tables even when the value exceeds 100% (i.e., 1E+09 ppb) to allow for source size modification. *The calculated risk-based SIC values must be appropriately modified before they are used for comparison with facility hazardous substance concentrations using the Modifier Table (R 299.5726(6))*. The modification of the SIC based on source size is discussed in *Application of VSIC for Other Source Area Sizes* (Section 4.9) and *Application of PSIC for Other Source Area Sizes* (Section 5.6).

3.0 GENERIC SIC ALGORITHMS PROTECTIVE OF AMBIENT AIR EXPOSURES

The generic SIC algorithms presented below are consistent with those presented in the U.S. EPA Soil Screening Guidance (EPA SSG): Technical Background Document (U.S. EPA, 1996a). These algorithms yield criteria that represent concentrations of soil contaminants in units of micrograms per kilogram (µg/kg or ppb). A discussion of the generic exposure assumptions for residential and commercial/industrial land uses is found in the RRD Op Memo No. 1 - Attachment 6: Soil Direct Contact Criteria (MDEQ, 2005). Discussion of those parameters which are specific to the ambient air inhalation pathway is presented below.

The inhalation toxicity values are the Initial Threshold Screening Levels (ITSLs) for noncarcinogens and the inhalation unit risk factors (IURFs) for carcinogens. These are utilized in the calculation of the SIC presented in Attachment 1, Table 4 of RRD Op Memo 1. The ITSLs and IURFs are developed by the AQD under the authority of Part 55 of Act 451 and are used for the development of the SIC. The ITSL is the level that is protective of noncarcinogenic effects. The IURF or **unit risk** is based on an assumption of continuous lifetime exposure, which is consistent with the AQD development and application of cancer-based criteria under Rules 225(1) and 225(2). The ITSLs and the IURFs are presented in micrograms per cubic meter of air ($\mu g/m^3$) and $(\mu g/m^3)^{-1}$, respectively. Consult the Air Toxics Rules for information regarding development of the ITSLs and IURFs.

4.0 AMBIENT AIR VSIC

The VSIC address the migration of volatile hazardous substances in soil to ambient air. This section presents the equations including assumptions and default values used to calculate the VSIC. The VSIC algorithm incorporates a VF that accounts for volatilization of a hazardous chemical from soil and a dispersion factor (Q/C) that accounts for subsequent dispersion after the chemical becomes airborne. This section provides guidance on the application of the VSIC including receptor assessment, modification of the VSIC value, closure options, source area size determination, and VSIC modification examples.

4.1 Generic Residential VSIC Algorithms

Carcinogens

$$\mathrm{VSIC} = \frac{\mathrm{TR} \times \mathrm{AT}}{\mathrm{IURF} \times \mathrm{EF} \times \mathrm{ED} \times (1/\mathrm{VF})}$$

where,

VSIC (Volatile soil inhalation criterion) = source size- and chemical-specific, µg/kg or ppb
TR (Target risk level) = 10^{-5}
AT (Averaging time) = 25,550 days (70 years x 365 days/year)
IURF (Inhalation unit risk factor) = chemical-specific, $(\mu g/m^3)^{-1}$
EF (Exposure frequency) = 350 days/year
ED (Exposure duration) = 30 years
VF (Volatilization factor) = chemical-specific, m^3/kg

Noncarcinogens

$$\mathrm{VSIC} = \frac{\mathrm{THQ} \times \mathrm{AT}}{\mathrm{EF} \times \mathrm{ED} \times (1/\mathrm{ITSL} \times 1/\mathrm{VF})}$$

where,

VSIC (Volatile soil inhalation criterion) = source size- and chemical-specific, µg/kg or ppb
THQ (Target hazard quotient) = 1
AT (Averaging time) = 10,950 days (30 years x 365 days/year)
EF (Exposure frequency) = 350 days/year
ED (Exposure duration) = 30 years
ITSL (Initial threshold screening level) = chemical-specific, $\mu g/m^3$
VF (Volatilization factor) = chemical-specific, m^3/kg

4.2 Generic Industrial/Commercial VSIC Algorithms

Carcinogens

$$\mathrm{VSIC} = \frac{\mathrm{TR} \times \mathrm{AT} \times \mathrm{AIR}}{\mathrm{IURF} \times \mathrm{EF} \times \mathrm{ED} \times (1/\mathrm{VF})}$$

where,

VSIC (Volatile soil inhalation criterion) = source size- and chemical-specific, µg/kg or ppb
TR (Target risk level) = 10^{-5}
AT (Averaging time) = 25,550 days (70 years x 365 days/year)
AIR (Adjusted inhalation rate) = (20 m^3/day)/(10 m^3/day)
IURF (Inhalation unit risk factor) = chemical-specific, $(\mu g/m^3)^{-1}$
EF (Exposure frequency) = 245 days/year
ED (Exposure duration) = 21 years
VF (Volatilization factor) = chemical-specific, m^3/kg

Noncarcinogens

$$\text{VSIC} = \frac{\text{THQ} \times \text{AT}}{\text{EF} \times \text{ED} \times (1/\text{ITSL} \times 1/\text{VF})}$$

where,

VSIC (Volatile soil inhalation criterion) = source size- and chemical-specific, µg/kg or ppb
THQ (Target hazard quotient) = 1
AT (Averaging time) = 7,665 days (21 years x 365 days/year)
EF (Exposure frequency) = 245 days/year
ED (Exposure duration) = 21 years
ITSL (Initial threshold screening level) = chemical-specific, $\mu g/m^3$
VF (Volatilization factor) = chemical-specific, m^3/kg

4.3 Soil to Air Volatilization Factor

The soil to air VF defines the relationship between the concentration of a contaminant in soil and the concentration of the volatilized contaminant in ambient air. The VF is determined from two parameters, the average emission flux (J_s^{ave}) of the contaminant in soil and the Q/C of hazardous substance vapors in ambient air. The VF is calculated from the equation below using meteorological data, chemical-specific properties, and default values for soil properties that are representative of conditions for Michigan.

$$\text{VF} = (\text{Q/C}) \times (1/J_s^{ave})$$

J_s^{ave}, using the *Jury infinite source* model (Jury, 1983) is calculated as:

$$J_s^{ave} = \rho_b (4D_A/\pi t)^{1/2} \times 10^4 \, cm^2/m^2$$

The apparent diffusivity (D_A) of a chemical accounts for partitioning of contaminants between phases (liquid, solid, and gas) and is calculated as:

$$D_A = \frac{[(\theta_a^{3.33} D_a (H' \times TAF) + \theta_w^{3.33} D_w)/n^2]}{\rho_b K_d + \theta_w + \theta_a (H' \times TAF)}$$

where,

VF	(Volatilization factor)	=	chemical-specific, m^3/kg
J_s^{ave}	(Normalized average flux from soil)	=	chemical-specific, g/m^2-second
D_A	(Apparent diffusivity)	=	chemical-specific, cm^2/second
Q/C	(Dispersion factor for one-half acre)	=	82.33, g/m^2-second per kg/m^3
t	(Exposure time)	=	seconds (ED x 3.1536E+7 seconds/yr)
θ_a	(Soil air-filled porosity)	=	0.28 L_{air}/L_{soil}
n	(Total soil porosity)	=	0.43 L_{pore}/L_{soil}
θ_w	(Soil water-filled porosity)	=	0.15 L_{water}/L_{soil}
ρ_b	(Dry soil bulk density)	=	1.5 g/cm^3
D_a	(Diffusivity in air)	=	chemical-specific, cm^2/second
D_w	(Diffusivity in water)	=	chemical-specific, cm^2/second
H'	(Dimensionless Henry's Law Constant, where H' = HLC x 41)	=	chemical-specific, unitless
HLC	(Henry's Law Constant at 25º C)	=	chemical-specific, atm-m^3/mol
TAF	(Temperature adjustment factor)	=	0.5
K_d	(Soil-water partition coefficient)	=	chemical-specific, cm^3/g
	For organic compounds	=	K_{oc} (cm^3/g) x f_{oc} (g/g)
	For inorganic compounds	=	chemical-specific, cm^3/g
K_{oc}	(Soil organic carbon partition coefficient)	=	chemical-specific, cm^3/g
f_{oc}	(Organic carbon content of soil)	=	0.006 g/g (0.6%)

Infinite Source VF

The VF equation above is based on the assumption of an infinite source of contamination. It assumes uniform contamination of the soil to an infinite depth, and vapor phase diffusion as the only transport mode. Under these assumptions, exposure to airborne contaminants on the last day of the exposure duration would almost be the same as on the first. If the vertical extent of the contaminant source has not been characterized, the VF must be calculated using the infinite source VF equation (R 299.5726(3)).

Finite Source VF

If the vertical extent of the contaminant source has been adequately characterized throughout the facility, then the VF may be calculated either by the finite source equation or the mass balance equation, whichever yields the highest VSIC (R 299.5726(3)). The finite source model for calculation of the VF incorporates two concepts that are not in the infinite source model. First, the vertical extent of the contamination is assumed to be a discreet, measured thickness. Second, as volatile contaminants are emitted from soil to air, a zone of depletion is assumed to be created at the soil surface. This zone is depleted of contaminants over time and serves to slow down the volatilization of contaminants present at subsurface depths.

The simplified finite source model equation for VF is:

$$VF = (Q/C) \times (C_0 / \rho_b) \times (1/J_s^{ave})$$

and

$$J_s = C_o \left(D_A / \pi t\right)^{1/2} \left[1 - \exp\left(- d_s^2 / 4 D_A t\right)\right]$$

where,

VF	(Volatilization factor)	=	chemical-specific, m^3/kg
Q/C	(Dispersion factor for one-half acre)	=	82.33, g/m^2-second per kg/m^3
C_0	(Uniform contaminant concentration at t=0)	=	1.5 E-6 g/cm^3
ρ_b	(Dry soil bulk density)	=	1.5 g/cm^3
J_s^{ave}	(Normalized average flux from soil)	=	chemical-specific, g/m^2-second
J_s	(Instantaneous flux from soil at time t)	=	chemical-specific, g/m^2-second
D_A	(Apparent diffusivity - see equation above)	=	chemical-specific, cm^2/second
π	(Pi)	=	3.14
t	(Time)	=	seconds
d_s	(Thickness of source)	=	site-specific, meters
exp(p)	(The base of the natural logarithm raised to power (p))	=	e^p

To back calculate a normalized average flux for finite source VSIC, a uniform contaminant concentration at time zero must be assumed. This value is set to 1 part per million (0.001 mg/g) and adjusted using the default dry soil bulk density of 1.5 g/cm^3. This yields a contaminant concentration at time zero of 1.5E-6 g/cm^3 (Jury, 1983).

To calculate J_s^{ave}, the finite equation for J_s is solved iteratively for time dependent volatile emissions and the results are averaged over 30 years for residential land use and 21 years for industrial/commercial land uses. The U.S. EPA Exposure Model for Soil Organic Fate and Transport (EMSOFT) provides an integral solution for these calculations. This model eliminates mass balance violations (discussed below) previously encountered in both the infinite and finite Jury models.

The EMSOFT, with a TAF of 0.5 for the dimensionless Henry's Law Constant, has been used to predict the average flux rates for the 2 and 5 meter finite source VSIC provided in the Part 201 Integrated Tables. Although the EMSOFT program also permits calculation of emission rates from contaminant sources where an overlying layer of clean soil is present or where several soil layers of differing contaminant concentrations are present at a facility, this is not consistent with the algorithms in R 299.5726 and the assumptions used to generate the J_s^{ave} for the finite VSIC. Therefore, facility-specific criteria cannot be developed using such calculations. Application of the finite VSIC is discussed under Section 4.8 *Application of VSIC*. The EMSOFT computer model and user manual may be obtained from the U.S. EPA Office of Research and Development, http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=2862.

The finite VSIC are based upon a limited volume of contaminated soil; therefore, these criteria are generally less restrictive than the infinite source VSIC for the same contaminant. However, for some chemicals that exhibit a combination of low volatility, high affinity for soil particles and/or a molecular weight approaching or greater than 200 g/mol, the finite model may produce VSIC values that are slightly more restrictive (i.e., lower) than the infinite model. This result is a calculation artifact and becomes more probable as the source thickness is increased. Under these circumstances the infinite source VSIC is considered to be protective and is used in place of the finite VSIC.

Mass Balance VF

The Jury model may produce mass balance violations under some conditions, i.e., the model may predict loss from soil of more contaminants than was initially present. To prevent mass balance violations, the VF may be calculated using the mass balance model equation presented below (U.S. EPA, 1996a):

$$\mathrm{VF} = \left(\mathrm{Q/C}\right) \times \frac{\mathrm{AT} \times (3.15 \times 10^{-7}\ \mathrm{seconds/year})}{\rho_b \times d_s \times 10^6\ \mathrm{g/Mg}}$$

where,

VF (Volatilization factor) = chemical-specific, m^3/kg
Q/C (Dispersion factor for one-half acre) = 82.33, g/m^2-second per kg/m^3
AT (Exposure period) = scenario-specific, years
ρ_b (Dry soil bulk density) = 1.5 mg/m^3
d_s (Average source depth) = site-specific, meters

The mass balance model can only be calculated using facility-specific information regarding the vertical extent of contaminated soils, i.e., the thickness of the contaminant source ($\mathbf{d_s}$). A mass balance VSIC greater than the finite source VSIC indicates that the Jury model is over predicting volatile flux from soil. When this occurs, the mass balance VSIC may be used in place of the finite VSIC. As discussed, *finite VSIC generated using the EMSOFT model are not subject to mass balance violations*.

Soil Properties for the VF

The default values for the soil properties used in the VF equations are representative of generic conditions for Michigan. The air-filled soil porosity property has the most significant effect on the modeling of the emission of contaminants from soil and is dependent upon the assumed moisture content of the soil. Effective porosity is the portion of the total soil porosity that is actively involved in the flow and exchange processes. The Jury model adjusts the air-filled (θ_a) and water-filled porosity (θ_w) values to account for the difference between total and effective porosity. The U.S. EPA default values representing total porosity given in the EPA SSG have been used for these soil properties. The U.S. EPA default value of 0.006 g/g or 0.6% for the fraction of organic content (f_{oc}) in the soil is the mean value for the top 0.3 meters of Class B soils (Carsel, 1988). This value is consistent with the range of f_{oc} values for Michigan.

Due to a wide variation in site-specific soil characteristics, it is possible that the generic soil assumptions may not accurately represent the conditions at certain properties. For these cases, facility-specific soil values may be used in place of the generic assumptions and still allow for generic closures under Section 20120a(1). This type of closure is referred to as a "generic facility-specific" closure. Facility-specific measurements of the following parameters may be substituted for the generic assumptions and still allow the facility to satisfy the categorical criteria in Section 20120a(1)(a) to (e) of the Act (R 299.5726(7)):

- Dry soil bulk density (ρ_b)
- Soil water-filled porosity (θ_w)
- Soil air-filled porosity (θ_a)
- Fraction of organic carbon in soil (f_{oc})

Refer to RRD Op Memo No. 2 for methods to measure some of these parameters. For guidance on generating facility-specific f_{oc} and ρ_b, consult RRD Op Memo No. 1 - Attachment 8, Op Memo No. 4, and S^3TM.

Temperature Adjustment Factor (TAF)
Henry's Law Constants are typically reported under the standard temperature of 25º C. The chemical-specific dimensionless Henry's Law Constant (H') is multiplied by the TAF of one half (0.5) to account for reduced volatility of a contaminant under the annual average soil temperatures in Michigan of 10º C (Howe, 1987). This approach is consistent with the use of annual average meteorological data in the development of the VF.

Data to support the calculation of an annual average soil temperature in Michigan was obtained from the Agricultural Weather Office and the Michigan Department of Agriculture/State Climatologist at Michigan State University (MSU) (East Lansing, Michigan). Soil temperatures are routinely gathered at the MSU agricultural station during the Michigan growing season. While no data are available for the colder months, examination of the existing data indicates that soil temperatures parallel air temperatures with a lag time of a few hours. This effect was confirmed by Dr. Fred V. Nurnberger, State Climatologist (Nurnberger, 1997). Therefore, it may be assumed that an annual average air temperature will approximate an annual average *soil* temperature. While air temperatures vary with year and location (i.e., from the Upper Peninsula to the lower parts of Michigan), 10º C is consistent with an average annual air temperature for Michigan as a whole. Therefore, 10º C was chosen to represent an annual average soil temperature for VSIC development.

4.4 Soil Saturation Limit (C_{sat})

The development of C_{sat} is discussed in RRD Operational Memorandum No. 1, Technical Support Document - Attachment 8: C_{sat} Concentrations (MDEQ, 2007). At C_{sat}, the emission flux of volatile contaminants from soil to ambient air reaches a plateau. Under C_{sat} conditions, the Jury model cannot be used to calculate an accurate VSIC because the HLC, which predicts partitioning of chemicals between the soil pore water (liquid) and pore air (gas), is not applicable when free-phase contamination is present. Consequently, generic VSIC less than C_{sat} are applicable soil criteria, whereas VSIC exceeding C_{sat} are not valid criteria. The VSIC for the latter condition, however, are provided in the Criteria Tables to allow for criteria adjustments based on different source area sizes. If the final modified VSIC is greater than C_{sat}, the C_{sat} concentration becomes the criterion unless a facility-specific C_{sat} concentration is established using facility-specific soil parameters (R 299.5718(2)).

When the concentration of a hazardous substance is greater than the C_{sat} values that has become the default criterion, the potential for saturated conditions and its effects must be evaluated (R 299.5706a(2)(a)).

4.5 Chemical-Specific Parameter Values

The EPA SSG provides guidance on the collection and handling of chemical-specific values reported in the scientific literature. Chemical-specific values were derived for the U.S. EPA under contract with Research Triangle Institute (RTI) (U.S. EPA, 1996a). For chemicals not in the EPA SSG, chemical-specific parameter values were obtained through a search of the scientific literature and geometric means were developed following the procedures employed by RTI (MDEQ, 1997).

Reported K_{oc} values were found to vary widely and values are not reported for many chemicals. Therefore, the U.S. EPA applied an alternative method to calculate K_{oc} values (U.S. EPA, 1996a). A regression analysis was used to predict the relationship of K_{oc} to K_{ow} and the resulting formulas were used to develop calculated K_{oc} values. The regression equation is presented below.

$$\log K_{oc\ (L/kg)} = 0.00028 + (0.983 \times \log K_{ow})$$

This equation performs well for most chemicals but consistently over predicts K_{oc} values for volatile organic compounds, chlorinated benzenes, and some chlorinated pesticides. For these compounds, the following equation is used to calculate K_{oc}.

$$\log K_{oc\ (L/kg)} = 0.0784 + (0.7919 \times \log K_{ow})$$

Chemical-physical parameters required for the calculation of VSIC are presented in Table 4 of RRD Op Memo No. 1 - Attachment 1. The VSIC cannot be calculated for some hazardous substances due to the lack of data for the development of one or more chemical parameters. Chemicals that are designated as “ID” (insufficient data) are lacking either chemical-specific data or toxicological data necessary to calculate a criterion. The VSIC for these chemicals will be developed as data become available. R 299.5706(3) requires a person proposing or implementing remedial action to supply the necessary data to establish a VSIC unless the MDEQ determines that it is not required to assure that a remedial action is protective.

4.6 Air Dispersion Factor (Q/C)

The Q/C factor represents dispersion of airborne contaminants. Modeling was conducted to estimate constituent concentrations in air from volatile or particulate emissions from soil. The EPA SSG presents a default value for this parameter that represents the 90th percentile of the distribution of nationally modeled Q/C values from 29 locations from selected states. No Michigan locations were included in these modeling efforts; therefore, air dispersion modeling was used to develop a default dispersion factor for the Michigan Part 201 SIC as discussed in the following.

The VSIC presented in the Criteria Tables are derived using calculated VF based on a one-half acre property model. A one-half acre default source area size for a residential property is consistent with the U.S. EPA recommendations for residential facilities. The generic VSIC algorithm uses a Q/C value of 82.33 g/m^2-s per kg/m^3 for a one-half acre source area size. As the source area size increases, the Q/C value decreases. The generic VSIC value presented in the Criteria Tables must be adjusted based on source area size using the Modifier Table. This modified VSIC value becomes the generic VSIC for the facility. Source area size determination and VSIC modification is discussed under Section 4.9 *Application of VSIC for Other Source Area Sizes*.

Location Selection of Q/C Modeling Data

A *one-half acre source area size* was used for modeling with 15 sets of meteorological data routinely used in Michigan air dispersion modeling. The most recent year of available data for each location was chosen (in most cases this was 1991). Maximum annual average concentrations were obtained using the U.S. EPA's Industrial Source Complex Short-Term Dispersion Model (**ISCST3**). From these results, three meteorological locations were selected and modeled with the most recent five years of data (in all three cases this was 1987-1991). These datasets were selected based on location within an area of the state that is both agricultural and industrial, availability of five years of recent meteorological data, and the conservativeness of the 1991 data. However, the three locations selected do not represent "worst case" meteorological conditions for the state. The five-year analysis was necessary to ensure that the year of data chosen to calculate the Q/C values was representative of general weather conditions for that area (i.e., the year did not represent unusual weather events). The three meteorological locations selected were Midland-Bay City-Saginaw, Grand Rapids, and South Bend (SBN). While SBN does not lie within the geographical boundaries of Michigan, the dataset from this location is considered representative of southwest Michigan and is routinely used in air modeling by the AQD. SBN was chosen as the default location for conducting the air dispersion modeling for the generic SIC. This location represents roughly the 50th percentile of dispersion characteristics for the 15 Michigan meteorological monitoring locations originally modeled.

Air Dispersion Model

The ISCST3 area source model was used with rural dispersion coefficients and several default assumptions (see below) to estimate the generic dispersion of airborne contaminants. For some locations, urban dispersion coefficients may be more appropriate and may be used in the development of generic facility-specific Q/C dispersion factors.

Receptor Height

The emission height in the ISCST3 model was set at zero since contaminants are assumed to be emitted directly from the soil surface. The Source Receptor Analysis Branch of the U.S. EPA, Office of Air Quality Planning Standards has historically recommended a receptor height of zero for air dispersion modeling. The AQD also supports the use of a receptor height of zero to represent a ground level receptor.

Modeled Air Concentration

Dispersion analysis for SIC development requires modeling of predicted air concentrations based on an assumed uniform emission rate from the source area of 1 g/m^2-sec. A receptor grid is imposed on a one-half acre source area and annual average air concentrations are estimated for each discrete receptor location based on meteorological data. The Q/C factor for developing the Part 201 SIC is the 90th percentile of the distribution of modeled annual average air concentrations for all on-property receptor locations.

4.7 Receptors Assessment for the Commercial/Industrial VSIC

Two distinct receptor populations must be considered in the development of VSIC for commercial and industrial facilities: on-property and off-property workers, and nearby residents. Since both Part 201 and Part 55 Rules require compliance with residential criteria at the property boundary of a facility, industrial/commercial VSIC must consider the need to protect off-property receptors if they represent the more highly exposed receptor group.

Off-property Resident: In order to assess which of the two receptor populations would control development of industrial/commercial VSIC, additional dispersion modeling was conducted to predict air impacts to off-property, nearby receptors. Inputs to the ISCST3 model were identical to those used to predict on-property impacts (i.e., the SBN dataset); however, the Q/C values for off-property receptors are based on the 90th percentile of the concentrations predicted by the model for the perimeter of the source area. The VSIC for off-property exposures were developed using the *perimeter Q/C* and the residential default exposure values described previously.

On-property Worker: Calculation of commercial/industrial VSIC for on-property workers relied upon the initial modeling efforts for the generic residential VSIC to predict the Q/C values. To characterize the on-property worker, the ED was adjusted to 21 years and the EF to 245 days.

The default intake rate (i.e., inhalation rate) for adults is assumed to be 20 m^3/day. Because continuous exposure is not representative of worker exposures in commercial and industrial settings, an *adjusted inhalation rate* (**AIR**) factor of **2** [i.e., (20 m^3/day) / (10 m^3/day)] is applied to the VSIC equation for carcinogens. This 2-fold AIR adjustment is consistent with the AQD adjustment of cancer-based criteria for industrial properties and public roadways, which is based on adjustments to the inhalation rate (2-fold) and other exposure factors (Rule 225(3)). The 10 m^3/day intake rate for workers is consistent with both the U.S. EPA and the Occupational Safety and Health Administration standard default values and assumes that a worker engaged in moderate activity will respire more heavily while on the job than during light activity and resting portions of a day.

Comparison of Off-property Resident Versus On-property Worker VSIC: A comparison of VSIC values generated under these two scenarios indicate that the off-property resident scenario generates slightly more restrictive industrial/commercial VSIC than the on-property worker scenario. Since this difference does not appear to be significant, the VSIC for commercial/industrial facilities are based on protection of the on-property worker.

4.8 Application of VSIC

To determine overall compliance with soil cleanup criteria for the soil to ambient air pathway, compliance must be demonstrated for both the VSIC and PSIC for each chemical of concern.

The VSIC are protective of long-term, systemic health effects resulting from ambient air inhalation exposure only. The potential for other effects such as acute toxicity or physical hazards must be considered (R 299.5728). The RAPs/CAPs based on VSIC compliance cannot be approved without a demonstration that all other relevant pathways have been addressed (R 299.5532(7) and Section 21304a).

Closure Options

The VSIC are developed using generic default assumptions for meteorological conditions, soil characteristics, and human exposure parameters. Compliance with the generic or facility-specific generic VSIC for the relevant land use provides for a generic closure under Part 201 Section 20120a(1)(a), (b), and (d) for the soil to ambient air pathway. Other options for compliance with the VSIC include: a limited closure under Part 201 Section 20120a(1)(f), (g), and (i), or a site-specific closure under Part 201 Section 20120a(2).

VSIC Generic Closures

A generic closure is acceptable under Part 201 Section 20120a(1)(a), (b), and (d) for Part 201 facilities/Part 213 sites where concentrations in both surface and subsurface soil do not exceed the generic VSIC. The generic criteria are applicable to the entire soil column since both surface and subsurface soil concentrations may contribute to volatile emissions. Compliance with the generic criteria may be demonstrated by comparing soil sample concentrations to the infinite source VSIC, finite source VSIC, or mass balance VSIC.

Infinite Source VSIC

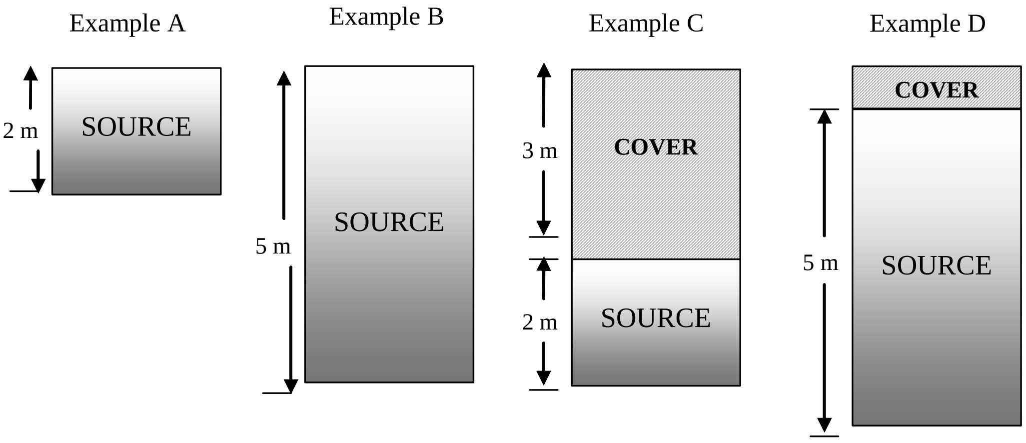
Generic infinite source VSIC may be used as a “first cut” screening tool. These criteria, modified for source area size, may be used as a screen at facilities where the vertical extent of contamination is not well characterized (e.g., Baseline Environmental Assessments, determination of facility status). If contaminant concentrations do not exceed the infinite source VSIC, the soil to ambient air pathway is not a concern for the facility. If contaminant concentrations do exceed the infinite source VSIC, *the vertical extent of contamination must be characterized before either the 2 or 5 meter finite source VSIC values can be applied or the mass balance VSIC equation can be used*.

Finite Source VSIC

Generic one-half acre finite VSIC are provided in the Part 201 Criteria Tables for 2 and 5 meter source thicknesses. These criteria, modified for source area size, may be applied where characterization of the vertical extent of soil contamination is adequate and the vertical extent (i.e., source thickness, d_s) of the contaminant source is no greater than the 2 and 5 meter source thickness assumed for these scenarios. Finite source VSIC may be used to determine the need for a response action to address soil contamination or to verify the adequacy of soil remediation when the soil-to-ambient air pathway is the most restrictive and relevant pathway.

The 2 and 5 meter finite source thickness VSIC presented in the Criteria Tables are calculated utilizing a flux rate (J_s^{ave}) value generated by the EMSOFT program (see *Finite Source VF* under Section 4.3). This flux rate is calculated assuming no cover layer and a contamination source thickness that starts from ground surface to a contamination depth of either 2 or 5 meters. Example A and B exemplify these assumptions. Where an overlying layer of clean soil is present as shown in Example C, the subsurface contamination source thickness of 2 meters is considered the source thickness. The use of the 5 meter finite VSIC is also appropriate for Example D. Consult the RRD Toxicology Unit for further guidance on application of finite VSIC.

Figure 1: Finite Source VSIC and Source Thickness



Mass Balance VSIC

Mass balance VSIC may be calculated where the vertical extent of the contaminant source (d_s) is known. A mass balance VSIC greater than the finite source VSIC indicates that the Jury model is over predicting volatile emissions from soil. In this case, the mass balance VSIC may be used in place of the finite VSIC.

VSIC Facility-Specific Generic Closures

A generic facility-specific closure is acceptable under Part 201 Section 20120a(1)(a), (b), and (d) where local meteorological data is used to develop the Q/C (dispersion factor), Ew (emissions due to wind), or where facility-specific data are substituted for the generic soil characteristics (dry soil bulk density, soil organic carbon content, and soil water-filled and soil air-filled porosity) used to develop the VF (R 299.5726(7)). Refer to Section 4.3 *Soil to Air VF* for guidance on facility-specific determination for these parameters. Consult the RRD for determining the Q/C using local meteorological data.

VSIC Limited Closures

A limited closure is acceptable under Part 201 Section 20120a(1)(f), (g), and (i) if volatilization of soil contaminants to the ambient air is determined by the MDEQ to be prevented by an engineered exposure barrier. A limited closure is also appropriate when emissions from a subsurface source are limited or prevented by an overlying layer of clean soil and has been demonstrated to meet criteria (e.g., using EMSOFT).

The EMSOFT-calculated average flux rates for the generic 2 and 5 meter source thickness VSIC assumed a zero overlying or cover layer and a contamination layer (source) that is located from the surface to a depth of either 2 or 5 meters. The EMSOFT program allows calculation of flux rates from contaminant sources where an overlying layer of clean (i.e., non-detect concentrations) soil is present at a facility. Site-specific criteria may be developed using such calculations. A restrictive covenant is required to ensure that exposure barriers remain in place and that subsurface soils that exceed the applicable VSIC are not brought to the surface.

VSIC Site-Specific Closures

Site-specific criteria may be calculated by substituting site-specific values for the generic assumptions in the SIC equations presented in R 299.5726. Site-specific measurements shall be based on representative characterization. Documentation of all site-specific values shall be provided in the RAP, CAP, or other response action documentation. A site-specific closure is required if site-specific values for exposure parameters (e.g., ED and EF) and contamination or source thickness are substituted for the default values used to develop the generic VSIC. Site-specific closures are provided for in Part 201 Section 20120a(2). A restrictive covenant for the facility must ensure that future exposures will remain consistent with the exposure assumptions used to generate the site-specific VSIC values.

Air Monitoring to Demonstrate Compliance

A person who is implementing a response activity may demonstrate compliance with the generic criteria developed under this rule through the collection and analysis of ambient air samples within the facility boundaries, if the hazardous substance concentration in surficial soil is representative of facility conditions (R 299.5726(8)). Ambient air monitoring proposals may be considered only when the contaminant concentration in surficial soil is representative of facility conditions, i.e., the vertical extent of contamination.

Ambient air monitoring results may be compared to ITSLs for noncarcinogens and Secondary Threshold Screening Levels (SRSL) for carcinogens. The SRSL of a carcinogenic chemical is the target cancer risk adjusted by the unit risk or IURF of the chemical (10^{-5}/IURF). Consult the Air Toxics Rule (R 336.1231) for information regarding development of the SRSLs.

Ambient air monitoring plans must be designed to adequately characterize both current and future facility conditions. For a generic closure, facility conditions during air monitoring must be consistent with the assumptions that are used in the development of the otherwise applicable VSIC for the appropriate land use. In some cases, the use of ambient air monitoring to determine compliance may necessitate a limited rather than a generic closure. For example, if source contamination is subsurface and surface soil exhibits lesser contaminant concentrations, land use restrictions must be required to ensure that the more highly contaminated subsurface soils are not brought to the surface.

Please consult RRD staff for appropriate implementation of the ambient air monitoring alternative to closure.

Chemicals of Concern for the VSIC

Generic VSIC are not presented in the Criteria Tables for some hazardous substances currently regulated under Part 201. Chemicals of concern for the volatilization to the ambient air pathway are generally identified as those having a Henry's Law Constant equal to or greater than 1.0E-5 atm-m^3/mol at a standard temperature and pressure (MDEQ, 2002). Chemicals **not** of concern for this pathway are designated as "NLV" (not likely to volatilize) and compounds lacking sufficient data for VSIC calculation are indicated as "ID" (insufficient data) (R 299.5750(2)). Also refer to Section 4.5 *Chemical-Specific Parameter Values*."

When the C_{sat} value has become the default criterion for the chemicals of concern, documentation must be provided to the MDEQ addressing whether additional response activity is required to control free-phase liquids or to protect against hazards associated with free-phase liquids that are not accounted for in the development of the generic criteria (R 299.5706a(2)(a)).

4.9 Application of VSIC for Other Source Area Sizes

The VSIC presented in the Criteria Tables are derived using calculated VF based on a one-half acre property model. To modify the generic one-half acre VSIC for larger or smaller source area sizes, a set of modifiers shown in Table 1 (see below) was generated using dispersion modeling. Where the source area size falls between the sizes presented in the Source Size Modifier Table, the modifier for the next larger source area size shall be used to multiply the VSIC value presented in the Part 201 Cleanup Criteria Table. *The resulting source size-based VSIC must first be compared to* C_{sat}*. If* C_{sat} *is not exceeded, the soil sample concentrations are compared to the generic VSIC value.* Criteria for a one-half acre source area size have been presented in the Criteria Tables as calculated to allow adjustment for larger or smaller source area sizes.

Table 1: Source Size Modifier Table

Source Area Size (sq. feet or acre)	**Dispersion Factor (Q/C)** (g/m^2-s per kg/m^3)	**Modifier**
400 ft^2	261.26	**3.17**
1,000 ft^2	180.76	**2.2**
2000 ft^2	144.91	**1.76**
½ acre	**82.33**	**1.0**
1 acre	71.74	**0.87**
2 acres	63.51	**0.77**
5 acres	54.62	**0.66**
10 acres	49.13	**0.6**
32 acres	41.55	**0.5**
100 acres	35.66	**0.43**
200 acres	34.98	**0.42**
300 acres	33.25	**0.40**
500 acres	31.23	**0.38**
1,000 acres	28.44	**0.35**

Source Area Size Determination

Source area size may be determined by the property boundaries when property lines are well defined and off-site migration of contaminants is not likely. For unknown and/or large contamination areas, the source area size for contaminated areas may be determined through the following method:

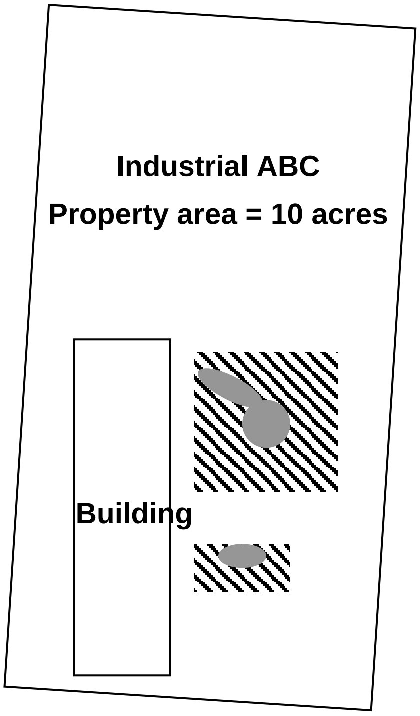
First, establish the screening level (SL) by adjusting the one-half acre residential infinite source VSIC values using the modifier for 1,000 acres, which is 0.35. The 1,000-acre based-adjusted VSIC will serve as the SL. Other SLs may be proposed and considered depending on the appropriate site information. Next, the soil concentrations are compared to the SL to identify the source areas. The source area is the contaminated area with soil concentration(s) exceeding the SL. Third, sum up the identified source areas to determine the source area size. Fourth, utilizing the modifier that corresponds to the source area size (see Source Size Modifier Table), modify the one-half acre infinite source VSIC or finite source VSIC if the facility is well characterized. Compare the source size-based VSIC to the chemical's C_{sat} value. If C_{sat} is exceeded, C_{sat} becomes the criterion. If source size-based VSIC is less than the C_{sat} value, compare the soil concentrations to the source size-based VSIC.

Where the source area size falls between the sizes presented in the Source Size Modifier Table, the one-half acre VSIC shall be multiplied by the modifier for the next larger source area size (R 299.5726(6)). For example, if the source area size is determined to be 50 acres, the one-half acre VSIC is multiplied by the modifier for 100 acres to generate the generic VSIC. Although not included in Rule (R 299.5726(6)), additional modifiers for source area sizes larger than 100 acres up to 1,000 acres have been generated by the AQD. Consult the RRD Toxicology Unit for application of modifiers for source sizes larger than 100 acres that are not represented in the Source Size Modifier Table.

VSIC Application Example

Consider the following example (Figure 2) of an industrial 10-acre facility with trichloroethylene (TCE) contamination that has been adequately characterized.

Figure 2: VSIC Modification Example



Legend:

▨ - Area exceeding SL

● - Area exceeding VSIC

Assumptions:

- The total industrial "property" area is 10 acres.
- Adequate vertical characterization indicates a 5 m finite VSIC is appropriate.
- Property boundaries are defined.
- Potential off-site migration is judged not likely.

Screening Level (SL) Method:

Ex.: Trichloroethylene (TCE).

1) Determine SL for the contaminant.
  a) The industrial one-half acre **infinite VSIC for TCE** is **260,000 µg/kg or ppb**.
  b) The modifier for 1,000-acre source area size is 0.35.
  c) **TCE industrial SL = 91,000 ppb.**

2) Compare soil TCE concentrations to 91,000 ppb. Areas with exceedances are the source areas.

3) Determine source area size. Assume source area size is 0.8 acre. Use the modifier for a 1-acre source size.

4) Modify one-half acre based 5 meter finite VSIC.
  a) The industrial one-half acre **5 meter finite VSIC** for TCE is **440,000 ppb**.
  b) The modifier for 1-acre source size is **0.87.**
  c) **TCE modified 5 meter finite VSIC = 382,800 ppb.**

5) Compare the 1-acre finite source VSIC to the C_{sat}, 500,000 ppb. In this case, TCE VSIC is lower than TCE C_{sat}.

6) Compare soil sample TCE concentrations to the **1-acre VSIC** of **382,800 ppb.**

For non-contiguous source areas, the contamination emitted from each of the source areas is assumed to commingle in ambient air at the “Property” to produce an air concentration greater than that from a single source area. The modified VSIC using a source size based on the sum of all the non-contiguous source areas, will provide a conservative screen since the airborne contaminants emitted from the non-contiguous source areas would likely be more greatly dispersed over the entire source and non-source areas than would be the case if all source areas were contiguous. Professional judgment and information concerning the entire study area or site should be used to determine the extent of sampling required to characterize the areas between source areas.

5.0 AMBIENT AIR PSIC

The generic PSIC addresses the emission and dispersion of contaminated soil particulates into the ambient air. The PSIC calculations are presented below including assumptions and default values used to derive the PSIC value. The PSIC algorithm incorporates a PEF that accounts for emission of particulates from soil as a result of wind erosion (Ew), vehicle emissions, and subsequent dispersion after the particulates became airborne. This section also provides guidance on receptor assessment, closure options, and PSIC modification.

5.1 Generic Residential PSIC Algorithms

Carcinogens

$$\mathrm{PSIC} = \frac{\mathrm{TR} \times \mathrm{AT}}{\mathrm{IURF} \times \mathrm{EF} \times \mathrm{ED} \times (1/\mathrm{PEF})}$$

where,

PSIC (Particulate soil inhalation criterion) = source size- and chemical-specific, µg/kg or ppb
TR (Target risk level) = 10^{-5}
AT (Averaging time) = 25,550 days (70 years x 365 days/year)
IURF (Inhalation unit risk factor) = chemical-specific, $(\mu g/m^3)^{-1}$
EF (Exposure frequency) = 350 days/year
ED (Exposure duration) = 30 years
PEF (Particulate emission factor) = source size-specific, m^3/kg

Noncarcinogens

$$\mathrm{PSIC} = \frac{\mathrm{THQ} \times \mathrm{AT}}{\mathrm{EF} \times \mathrm{ED} \times (1/\mathrm{ITSL} \times 1/\mathrm{PEF})}$$

where,

PSIC (Particulate soil inhalation criterion) = source size- and chemical-specific, µg/kg or ppb
THQ (Target hazard quotient) = 1
AT (Averaging time) = 10,950 days (30 years x 365 days/year)
EF (Exposure frequency) = 350 days/year
ED (Exposure duration) = 30 years

ITSL (Initial threshold screening level) = chemical-specific, µg/m^3
PEF (Particulate emission factor) = source size-specific, m^3/kg

5.2 Generic Industrial/Commercial PSIC Algorithms

Carcinogens

$$\mathrm{PSIC} = \frac{\mathrm{TR} \times \mathrm{AT} \times \mathrm{AIR}}{\mathrm{IURF} \times \mathrm{EF} \times \mathrm{ED} \times (1/\mathrm{PEF})}$$

where,

PSIC (Particulate soil inhalation criterion) = source size- and chemical-specific, µg/kg or ppb
TR (Target risk level) = 10^{-5}
AT (Averaging time) = 25,550 days (70 years x 365 days/year)
AIR (Adjusted inhalation rate) = (20 m^3/day)/(10 m^3/day)
IURF (Inhalation unit risk factor) = chemical-specific, (µg/m^3)$^{-1}$
EF (Exposure frequency) = 245 days/year
ED (Exposure duration) = 21 years
PEF (Particulate emission factor) = source size-specific, m^3/kg

Noncarcinogens

$$\mathrm{PSIC} = \frac{\mathrm{THQ} \times \mathrm{AT}}{\mathrm{EF} \times \mathrm{ED} \times (1/\mathrm{ITSL} \times 1/\mathrm{PEF})}$$

where,

PSIC (Particulate soil inhalation criterion) = source size- and chemical-specific, µg/kg or ppb
THQ (Target hazard quotient) = 1
AT (Averaging time) = 7,665 days (21 years x 365 days/year)
EF (Exposure frequency) = 245 days/year
ED (Exposure duration) = 21 years
ITSL (Initial threshold screening level) = chemical-specific, µg/m^3
PEF (Particulate emission factor) = source size-specific, m^3/kg

The criteria in the R 299.5746 and R 299.5748 tables were calculated using one half of the PEF as shown in the equation below to account for short-term peak particulate levels. See the *Peak Emission and Dispersion of Particulates* under Section 5.3 for details.

$$\mathrm{PSIC} = \frac{\mathrm{THQ} \times \mathrm{AT}}{\mathrm{EF} \times \mathrm{ED} \times (1/\mathrm{ITSL} \times 1/\mathrm{PEF}/2)}$$

5.3 Particulate Emission Factor (PEF)

The soil to air PEF relates the concentration of a particulate contaminant in ambient air to the corresponding concentration of contaminant in soil. The PEF equation incorporates factors that account for emission of particulates from soil due to Ew and Ev and subsequent dispersion (Q/C) after the particulates became airborne. The PEF in the algorithm should be divided by 2 to account for short-term peak particulate levels for noncarcinogenic hazardous substances with ITSLs based on a quarterly, 24-hour, 8-hour, or 1-hour averaging time. Derivation of PEF and default values for PEF parameters are discussed below and in Attachment A.

$$PEF = \left(Q/C\right) \times 1/\left[(Ew \times (1 - V)) + Ev\right]$$

where,

PEF	(Particulate emission factor)	=	source size-specific, m^3/kg
Q/C	(Dispersion factor for 1/2 acre)	=	82.33, g/m^2-second per kg/m^3
Ew	(Emission due to wind)	=	5.50E-7 g/m^2-second
Ev	(Emission due to vehicle traffic)	=	3.68E-7 g/m^2-second (Residential) 1.81E-6 g/m^2-per second (Industrial/Commercial)
V	(Vegetative cover)	=	0.5 (50%), unitless

Air Dispersion Factor (Q/C)

The Q/C represents dispersion of airborne contaminants. The generic PSIC are developed using a Q/C value that is based on a one-half acre (0.5) contamination source area size. Therefore, the generic PSIC value presented in the Criteria Tables must be modified based on source area size using the Modifier Table. This modified PSIC value becomes the generic PSIC for the facility. Source area size determination and PSIC modification is discussed under *Application of PSIC for Other Source Area Sizes*. For explanation on the generation of the Q/C value, refer to Section 4.6 *Air Dispersion Factor (Q/C)*.

Peak Emission and Dispersion of Particulates

The emission and dispersion of particulates are significantly dependent upon meteorological conditions. Day-to-day variations of these conditions are likely to have significant effects on ambient air concentrations of particulates. The equation for PEF represents annual average emission and dispersion of those particulates most relevant to inhalation exposures. The fraction of the total suspended particulate matter that is less than 10 microns in diameter (PM-10) can enter the lung airways and penetrate beyond the terminal bronchioles to the gas exchange region. However, particles larger than 10 microns when inhaled may also present a concern since they can be deposited in the extra-thoracic region of the respiratory track and contribute to exposure.

A dataset of 24-hour PM-10 samples was used to construct a distribution of 24-hour values and associated percentiles. The average PM-10 level from this distribution (equivalent to an annual average) is 20 $\mu g/m^3$ and the 90th percentile is 40 $\mu g/m^3$. This suggests that peak PM-10 concentrations (90th percentile values) for a given 24-hour period are likely to be twice the annual average concentration. A PEF representing annual average emission and dispersion of particulates would not account for the peak concentrations (and greater exposures) observed in the distribution. To account for exposures to peak particulate concentrations, the PEF for all noncarcinogenic hazardous substances with ITSLs based on non-annual (24-hour, 8-hour, or 1-hour) averaging times is divided by a factor of 2.

Particulate Emissions Due to Wind Erosion (Ew)
The Ew represents the emission of a contaminant from soil due to wind erosion. The Ew is derived using parameters that include meteorological factors such as the average annual wind speed and the threshold friction velocity at 7 meters height. Default values for these meteorological factors have been obtained from the dataset selected to model the Q/C dispersion factor discussed under *Air Dispersion Factor* Q/C. The PEF Worksheet-Section B (Attachment A) presents the assumptions and calculations used in developing the generic Ew value.

The Ew may be adjusted to account for vegetative cover at a facility. Data are not available to estimate the distribution of vegetative cover for Michigan. In the absence of data, the mid-range value of 0.5 (50%) was chosen as a central tendency value. If vegetative cover at a facility differs significantly from this value, a facility-specific evaluation of this parameter would be necessary and site-specific criteria developed.

Meteorological characteristics of a specific location may be used to modify the Ew in order to generate facility-specific criteria (R 299.5726(7)). *However, the facility-specific meteorological data used to estimate the Q/C must be used to calculate the Ew parameter for the facility-specific PSIC.* It may not be necessary to generate data for a particular location; rather data from an existing monitoring location may be more appropriate for a facility and may be used in place of the defaults presented in Attachment A. Use of location-specific meteorological data does not preclude closure under a generic land use category.

Particulate Emission Due to Vehicle Traffic (Ev)
The Ev accounts for emission of contaminants from soil due to vehicle traffic. The quantity of particulates generated by vehicular traffic was estimated using Cowherd, et al. (U.S. EPA, 1985). This source of emission was not considered by the U.S. EPA in the EPA SSG; therefore, the Ev emissions equation presented in the U.S. EPA's Compilation of Air Pollution Emission Factors (1995) was used to generate default vehicle emission rates based on a one-half acre source area size. Section C of Attachment A details the default assumptions and equations used to calculate Ev for residential and commercial scenarios. The industrial PSIC values presented in the Criteria Tables are generated using the Ev developed for the commercial scenario, i.e., assumes passenger vehicles only.

Note that the value for Ev is directly proportional to the number of passenger vehicle trips per day assumed for each scenario (e.g., the residential Ev for 10 round trips per day is twice that for 5 round trips per day). The commercial Ev based on 50 round trips per day generated a value that is 4.9 times the Ev for the residential scenario. This difference contributes to a commercial/industrial PSIC value that is more stringent (i.e., lower) than the residential PSIC.

The Ev values assume that vehicles at the facility are passenger automobiles. In addition, the industrial Ev is calculated using the assumptions for the commercial scenario. Therefore, at facilities where trucks and other heavy equipment are expected to be present, a site-specific assessment of Ev and site-specific criteria development are necessary.

5.4 Receptors Assessment for the Commercial/Industrial PSIC

Two distinct receptor populations must be considered in the development of PSIC for industrial and commercial facilities: on-property and off-property workers, and nearby residents. Since both Part 201 and Part 55 Rules require compliance with residential criteria at the property boundary of a facility, industrial/commercial PSIC must consider the need to protect off-property receptors if they represent the more highly exposed receptor group. Also see Section 4.7 *Receptors Assessment for the Commercial/Industrial VSIC* for details relating to assessment of off-property residents and on-property workers.

Adjustments to the PEF for On-property Workers

The PEF is adjusted to account for the greater level of vehicular traffic at industrial or commercial facilities (see Attachment A). The residential default of 50% vegetative cover was retained for commercial or industrial SIC calculation; however, it is anticipated that some industrial facilities may not be as heavily vegetated. Therefore, **the vegetative cover must be evaluated to determine whether it is representative of the specific facility.**

Comparison of Off-property Resident Versus On-property Worker PSIC

A comparison of PSIC generated under these two scenarios indicates that the on-property worker scenario generates more restrictive industrial/commercial PSIC than the off-property resident scenario. Therefore, the PSIC for industrial/commercial sites use the on-property worker scenario.

5.5 Application of PSIC

To determine overall compliance with soil cleanup criteria for the soil to ambient air pathway, compliance must be demonstrated for both VSIC and PSIC for each chemical of concern.

Statistics are applicable for evaluating this exposure pathway. Use of statistics is practical where there are adequate data available on the emission source areas, as appropriate to the facility. The 95% upper confidence level of soil concentrations, calculated using methods described in the S^3TM, may be used to determine compliance if such values are representative of the areas where emissions are likely to occur. Further details are provided in S^3TM.

The PSIC are protective of long-term, systemic health effects resulting from ambient air inhalation exposure only. The potential for other effects such as acute toxicity or physical hazards must be considered (R 299.5728). The RAPs/CAPs based on PSIC compliance cannot be approved without a demonstration that all other relevant pathways have been addressed (R 299.5532(7) and Section 21304a).

Closure Options

Compliance with the generic or facility-specific generic PSIC for the relevant land use provides for a generic closure under Part 201 Section 20120a(1)(a), (b), and (d) for the soil to ambient air pathway. Other options for compliance with the PSIC include: a limited closure under Part 201 Section 20120a(1)(f), (g), and (i), or a site-specific closure under Part 201 Section 20120a(2).

PSIC Generic Closures

A generic closure is acceptable under Part 201 Section 20120a(1)(a), (b), and (d) for sites where concentrations in soil, both surface and subsurface, do not exceed the appropriately modified generic PSIC. For generic closures, the modified generic PSIC will apply to the entire soil column since no restriction prevents subsurface soils from being brought to the surface where they will be subject to emission forces of wind and vehicular traffic.

PSIC Generic Facility-Specific Closures

A generic facility-specific closure is acceptable under Part 201 Section 20120a(1)(a), (b), and

(d) where local meteorological data are used to develop the Q/C and the Ew (see Attachment A for the Q/C and Ew derivation). Since the same dataset is used to develop both these parameters in the PEF equation, it is not appropriate to use a mix of facility-specific data and the default values utilized to develop the generic PSIC.

PSIC Limited Closures
A limited closure is acceptable under Part 201 Section 20120a(1)(f), (g), and (I) if emission of particulate contaminants from soil to the ambient air is determined by the MDEQ to be prevented by an engineered exposure barrier. A limited closure is also appropriate when emissions from a subsurface source are limited or prevented by an overlying layer of clean soils. A restrictive covenant is required to ensure that exposure barriers remain in place and that subsurface soils that exceed the applicable PSIC are not brought to the surface.

PSIC Site-Specific Closures
Site-specific criteria may be calculated by substituting site-specific values for the generic assumptions in the PSIC equations presented in R 299.5726. Site-specific measurements shall be based on representative characterization. Documentation of all site-specific values shall be provided in the RAP, CAP, or other response action documentation. A site-specific closure is required if site-specific values for exposure parameters (e.g., ED and EF), vegetation cover, and Ev are substituted for the default values used to develop the generic SIC. Site-specific closures are provided for in Part 201 Section 20120a(2). A restrictive covenant for the facility must ensure that future exposures will remain consistent with the exposure assumptions used to generate the site-specific PSIC values.

Air Monitoring to Demonstrate Compliance
A person who is implementing a response activity may demonstrate compliance with the generic criteria developed under this rule through the collection and analysis of ambient air samples within the facility boundaries, if the hazardous substance concentration in surficial soil is representative of facility conditions (R 299.5726(8)). Ambient air monitoring proposals may be considered only when the contaminant concentration in surficial soil is representative of facility conditions, i.e., the vertical extent of contamination.

Ambient air monitoring results may be compared to the AQD ITSLs for noncarcinogens and SRSLs for carcinogens. See Section 4.8 under *Air Monitoring to Demonstrate Compliance* for additional details.

Ambient air monitoring plans must be designed to adequately characterize both current and future facility conditions. In some cases, the use of ambient air monitoring to determine compliance may necessitate a limited rather than a generic closure. For example, if source contamination is subsurface and surface soil exhibits lesser contaminant concentrations, land use restrictions must be required to ensure that the more highly contaminated subsurface soils are not brought to the surface.

Consult RRD staff for appropriate implementation of the ambient air monitoring alternative to closure.

Chemicals of Concern for the PSIC

Since all chemicals may be emitted as particulates from soil, PSIC have been calculated for all compounds on the Criteria Tables where sufficient inhalation toxicity and chemical-specific data were available. Those compounds lacking sufficient data are indicated as "ID" on the Criteria Tables.

All PSIC values have been presented as calculated in the Part 201 Criteria Tables to ensure that the one-half acre PSIC is adjusted based on its source area size using the appropriate modifier given in the Source Size Modifier Table.

Vegetative Cover Adjustment

A 50% vegetative cover is assumed for all land uses and is used in the PEF equation to adjust the expected emission of particulates from soil due to Ew. Professional judgment must be used to determine if adjustment of the vegetative cover at a facility is necessary, particularly at industrial facilities where activities may prevent vegetative growth.

Ev Adjustment

Professional judgment must be used in situations where Ev at a facility will be greater than that assumed for the generic scenarios presented in Attachment A (e.g., multiple residential properties with contaminated roadways or truck traffic).

5.6 Application of PSIC for Other Source Area Sizes

The PSIC presented in the Criteria Tables are derived using a PEF that is calculated using a Q/C estimate of a one-half acre source area size (also see Section 4.6 *Air Dispersion Factors (Q/C)*). As seen in the Source Size Modifier Table (refer to Table 1: Source Size Modifier Table under Section 4.9 *Application of VSIC for Other Source Area Sizes*) as the source area size increases, the Q/C value decreases. Modification of the one-half acre PSIC value to reflect the source area size must be applied. To modify the generic one-half acre based-SIC for larger or smaller source area sizes, a set of modifiers was generated using air dispersion modeling. Where the source area size falls between the sizes presented in the Source Size Modifier Table, the modifier for the next larger source area size shall be used to multiply the PSIC value presented in the Part 201 Cleanup Criteria Table (R 299.5726(6)). The resulting source size-based PSIC is the generic PSIC value that must be compared to the soil sample concentration.

Source Area Size Determination

Source area size may be determined by the property boundaries when property lines are well defined and off-site migration of contaminants is not likely. For unknown and/or large contamination areas, the source area size for contaminated areas may be determined through the SL method described below. Background concentrations may be used; however, the background values are generally more stringent than the SL generated for the hazardous substance.

To determine the source area size, first, establish the SL by adjusting the one-half acre residential PSIC values using the modifier for 1,000 acres, which is 0.35. The 1,000-acre based-adjusted PSIC will serve as the SL. Other SLs may be proposed and considered depending on the appropriate site information. Next, the soil concentrations are compared to the SL to identify the source areas. The source area is the contaminated area with soil concentration(s) exceeding the SL. Third, sum up the identified source areas to determine the source area size. Fourth, utilizing the modifier that corresponds to the source area size (see Source Size Modifier Table) modify the one-half acre PSIC. Lastly, compare the soil concentrations to the source size-based PSIC.

Although not included in Rule (R 299.5726(6)), additional modifiers for source area sizes larger than 100 acres up to 1,000 acres have been generated by the AQD. Consult the RRD Toxicology Unit for application of modifiers for source sizes larger than 100 acres that are not represented in the Source Size Modifier Table.

PSIC Application Example

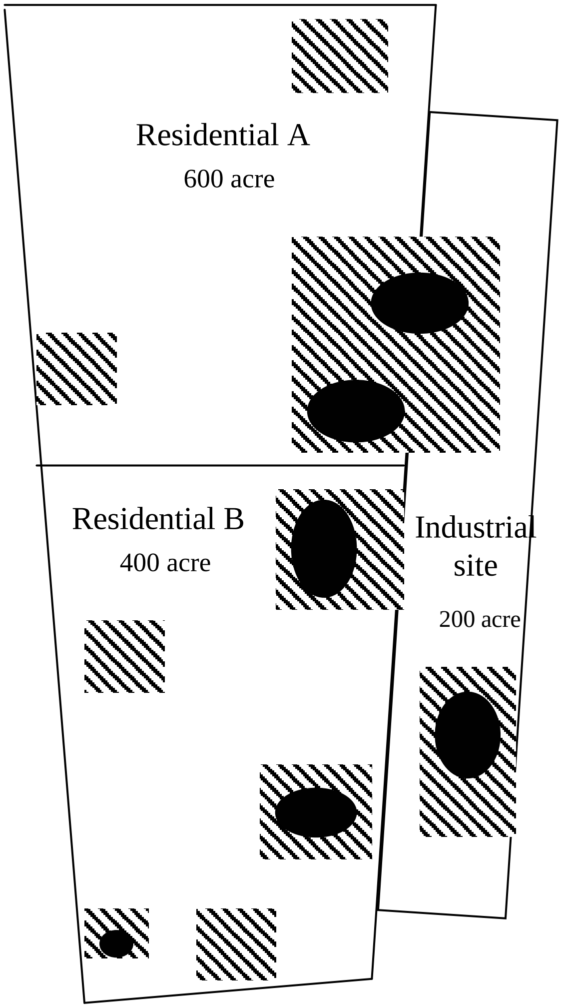
The example shown in Figure 3 presents a manganese contamination site composed of multi-acre residential and industrial properties. In this example, the SL for manganese are 1,155 ppm (residential) and 1,500 ppm (industrial). The five areas with concentrations exceeding the SL (source areas) are added to generate the source area size (e.g., 250 acres). In this example, because the 250-acre source size lies between 200- and 300-acre source sizes in the Source Size Modifier Table, the 300-acre modifier of 0.40 may be used to multiply the one-half acre PSIC value to generate the generic PSIC.

In this example, although the source area size represents residential and industrial source areas, the contaminant concentrations of soil samples from industrial properties must be compared to the modified PSIC for industrial use. Similarly, soil concentrations from residential use properties should be compared to the modified residential PSIC.

For non-contiguous source areas, the concentration in each source area cannot be compared to the PSIC for each source area without considering the combined effect of all source areas. The contamination emitted from all source areas is assumed to commingle in ambient air at the study area to produce an air concentration greater than that from a single source area. The resulting modified PSIC provide a conservative screen since the airborne contaminants emitted from the non-contiguous source areas would likely be more greatly dispersed over the entire source and non-source areas than would be the case if all source areas were contiguous.

Professional judgment and information concerning the entire study area or site should be used to determine the extent of soil sampling required to characterize the areas between source areas. Consult the S^3TM for the appropriate sampling strategy.

Figure 3: PSIC Modification Example



Legend:

▨ - **Area exceeding SL**

● - **Area exceeding 300 acre-based PSIC**

Assumptions:

- Mixed residential (R) and industrial (I) properties.
- Total acreage is 1,200 acres.

Modification Steps:

1) **Determine the SL for manganese** (Mn).
   a) The **one-half acre PSIC for Mn** are:
      3,300 mg/kg or ppm (R)
      1,500 ppm (I).
   b) The modifier for 1,000-acre source area size is 0.35.
   c) **Mn SL = 1,155 ppm (R) and 525 ppm (I).**

2) **Identify the source areas** - Compare soil concentration(s) to **1,155 ppm (R) or 525 ppm (I).** Areas with SL exceedances are the source areas.

3) **Determine source area size** - Source area size is the sum of all residential and industrial source areas. Assume total of all source areas is **250 acres**. The appropriate source area size is **300 acres.**

3) **Modify one-half acre PSIC for Mn** using modifier for source area size of 300 acres.
   a) Modifier for 300 acres is 0.40.
   b) The **300-acre PSIC for Mn** are:
      1,320 ppm (R)
      600 ppm (I)

4) **Compare residential and industrial soil concentrations to 1,320 ppm (R) or 600 ppm (I), respectively.**

This memorandum is intended to provide guidance that will foster consistent application of Part 201 and Part 213 of NREPA and the associated Administrative Rules. This document is not intended to convey any rights to any person nor itself create any duties or responsibilities under law. This document and matters addressed herein are subject to revision.

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ATTACHMENT A: PEF WORKSHEET

A. PEF (for annual averaging time)

$$PEF = (Q/C) \times 1/(Ew((1-V)) + Ev)$$

where,

PEF	(Particulate emission factor of a one-half acre source)	=	1.28E+8 m^3/kg (Residential) 3.95E+7 m^3/kg (Industrial/Commercial)
Q/C	(Dispersion factor)	=	82.33 g/m^2-s per kg/m^3
Ew	(Emissions due to wind erosion)	=	5.50 E-7 g/m^2-s
V	(Assumed fraction of vegetative cover)	=	50% (0.5)
Ev	(Emissions due to vehicle traffic)	=	3.68E-7 g/m^2-s (Residential) 1.81E-6 g/m^2-s (Industrial/Commercial)

The PEF for noncarcinogenic hazardous substances is divided by 2 to account for short-term peak particulate levels for all chemicals that are associated with non-annual (quarterly, 24-hour, 8-hour, or 1-hour) AT under the Air Toxics Rules. See Section 5.3 under *Peak Emission and Dispersion of Particulates* for details.

B. Emissions Due to Wind Erosion (Ew)

$$Ew = 0.036(U_m/Ut_{adj})^3 \times F(x)/3600$$

where,

Ew	(Emissions due to wind erosion at height 7 meters)	=	5.50E-7 g/m^2-s
0.036	(Respirable fraction emission rate)	=	0.036 g/m^2-s
$U_{m(z)}$	(Mean annual windspeed at height z)	=	4.56 m/s at 6.4m diffusion height
$\mathbf{U_m}$	(Um(z) adjusted to 7 m height)	=	Um(z) x (7.0/6.4)$^{.15}$ = 4.62 m/s
z_0	(Roughness height)	=	0.005 m
z	(Height above surface)	=	6.4 m
U*t	(Equivalent threshold friction velocity)	=	0.42 m/s for a 0.35 mm mode soil aggregate size
Ut	(Equivalent threshold friction velocity at 7 m above ground surface)	=	(0.42 / 0.4) x (ln (7.0/0.005)) = 7.61 m/s
$\mathbf{Ut_{adj}}$	(Adjusted threshold friction velocity at 7 m height)	=	7.61 m/s x 1.25 = 9.51 m/s
x	(Ut_{adj}/U_m derived using Cowherd (EPA, 1985))	=	0.886 x (Ut_{adj}/U_m) = 1.824 (unitless)
F(x)	(Function dependent on Um/Ut derived using Cowherd)	=	F(1.824) = 0.48 (unitless)

The Ew is derived using the equation for the “unlimited reservoir” model from Cowherd et al. (EPA, 1985). The Ew is sensitive to the equivalent threshold friction velocity (Ut), which is a function of the mode of the surface soil aggregate size distribution (EPA, 1996b). This surface soil aggregate size determines the wind needed to generate dust at a contaminated area. The default value for the mode aggregate size is 0.350 millimeters, which corresponds to a threshold friction velocity of 7.61 m/s at a height of 7 meters above ground. To account for the presence of non-erodible elements, the threshold friction velocity is adjusted using a default correction factor of 1.25 (EPA, 1996b). This results in an adjusted threshold friction velocity (Ut_{adj}) of 9.51 m/sec at 7 meters above ground surface. The F(x) term is an empirically-based function dependent on Um and Ut.

The meteorological conditions (i.e., the intensity and frequency of wind) affect both the dispersion and emissions of particulate matter. Therefore, the same set of meteorological data must be used to derive the facility-specific Q/C and the mean annual wind speed input to the facility-specific Ew.

C. Emissions Due to Vehicles (Ev)

Ev for Residential Sites

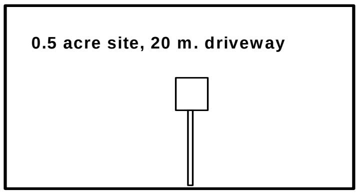
$$E_{10} = k \times 1.7 \times (s/12) \times (S/48) \times (W/2.7)^{0.7} \times (w/4)^{0.5} \times ((365-p)/365)$$

where,

E_{10}	PM_{10} emissions per vehicle-kilometer of travel (VKT)	=	0.163 kg/VKT
k	Particle size multiplier (Number for 10 um is used; Cowherd residential default is 0.36 (EPA, 1985))	=	0.36, unitless
s	Silt content of road surface material (Cowherd shows a range of 5-68%, default *s* is 15%)	=	15%
S	Mean vehicle speed, (km/hr) (Cowherd default for S, 48 km/hr, was not used for this scenario)	=	20 km/hr
W	Mean vehicle weight	=	2 Mg
w	Mean number of wheels	=	4
p	Number of days with at least 0.254 mm (0.01 inch) of precipitation per year (Cowherd - Figure 4-4 (EPA, 1985)).	=	135 days

Assumptions: These parameters may be changed if site-specific information is available.

Size of residential site = 0.5 acre
Size of home = 25 feet per side
Round trips/day = 10 trips away from home/day
Length of driveway = 20 meters (unpaved)
Time period = 350 days



Calculations: Units for annual average vehicle emissions must be in g/m^2-s.

Area of home = 58.06 m^2
Dimension of site = 44.98 m/side
Area of site (excluding area of the house) = 1965 m^2
Distance traveled/day = 0.40 km/d; 140 km/year
Emission per VKT (E_{10}) = 0.163 kg/VKT; 0.065 kg/day
Vehicle emission (at 10 round trips/day) = **22.79 kg/year**
Annual average vehicle emissions (at 10 round trips/day for a 0.5 acre site with one home) = **3.68E-7 g/m^2-s**

NOTE: The emission from the Ev is averaged over the area of the entire site rather than just the area of the driveway (excluding the area of the house).

Ev for a 0.5 acre site with one home at 10 round trips/day:
Ev (residential) = 22.79 kg/yr x 1000 g/kg x (1 yr/3.154E+7sec) x 1/1965 m^2
Ev (residential) = 3.68E-7 g/m^2-s

For comparison:
Ev at 5 round trips per day = 1.84E-7 g/m^2-s
Ev at 2 round trips per day = 7.36E-8 g/m^2-s

Ev for Commercial Sites

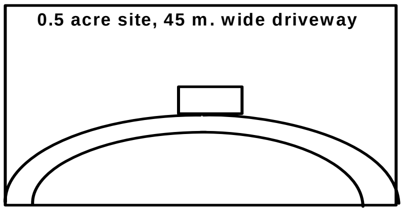
$$E_{10} = k \times 1.7 \times (s/12) \times (S/48) \times (W/2.7)^{0.7} \times (w/4)^{0.5} \times ((365-p)/365)$$

where,

E_{10}	PM_{10} emissions per vehicle-kilometer of travel (VKT)	=	0.163 kg/VKT
k	Particle size multiplier (Number for 10 um is used; Cowherd residential default is 0.36 (EPA, 1985))	=	0.36, unitless
s	Silt content of road surface material (Cowherd shows a range of 5-68%, default ***s*** is 15%)	=	15%
S	Mean vehicle speed, (km/hr) (Cowherd default for ***S***, 48 km/hr, was not used for this scenario)	=	20 km/hr
W	Mean vehicle weight	=	2 Mg
w	Mean number of wheels	=	4
p	Number of days with at least 0.254 mm (0.01 inch) of precipitation per year (Cowherd - Figure 4-4 (EPA, 1985)).	=	135 days

Assumptions: These parameters may be changed if site-specific information is available.

Size of commercial site = 0.5 acre
Size of building = 25 feet per side
Round trips/day = 50 vehicles/day
Length of driveway = 45 meters (unpaved)
Time period = 307 days (6 days/wk.
5 holidays



Calculations: Units for annual average vehicle emissions must be in g/m^2-s.

Area of building = 58.06 m^2
Dimension of site = 44.98 m/side
Area of site = 1965 m^2 (excluding area of the building)
Distance traveled/day = 2.25 km/d; 690.75 km/year
Emission/VKT = 0.163 kg/VKT or kg/km
Vehicle emission (at 50 round trips/day) = **112.45 kg/year**
Annual average vehicle emissions (at 50 round trips/day for a 0.5 acre site with one building) = **1.81E-6 g/m^2-s**

NOTE: The emission from the Ev is averaged over the area of the entire site rather than just the area of the driveway (excluding the area of the building).

Ev for a 0.5 acre commercial site with one building (50 round trips/day):
Ev (commercial) = (112.5 kg/yr x 1000 g/kg) x 1/(3.154E+7sec/yr x 1965 m^2)
Ev (commercial) = 1.81E-6 g/m^2-s