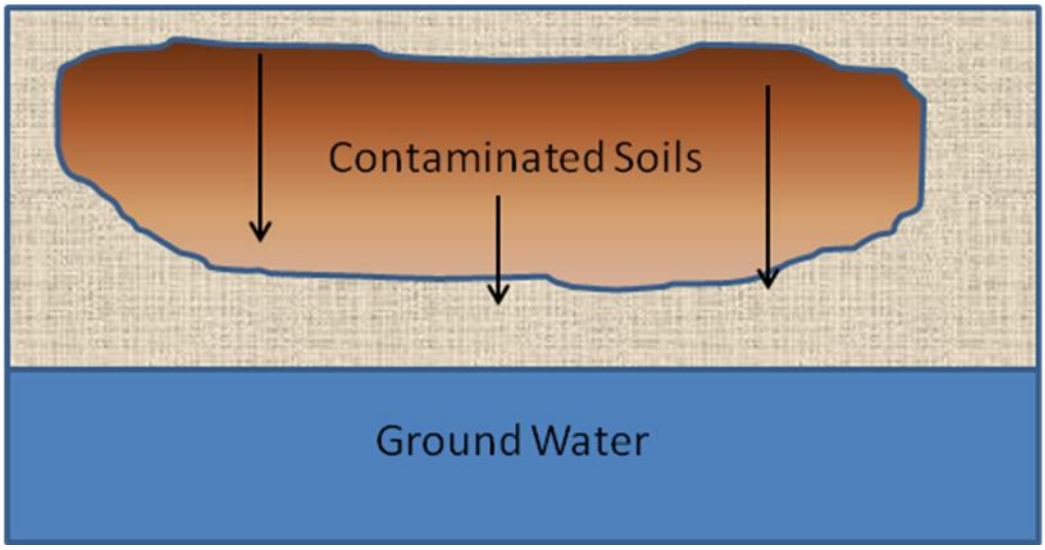
State of Ohio
Environmental Protection Agency

Ohio EPA
Voluntary Action Program
Derived Leach-Based Soil Values

Technical Guidance Document



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Governor : Ted Strickland
Director : Chris Korleski

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(3rd Revision, October 2008)

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

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NOTICE OF CORRECTIONS/CHANGES FROM THE FEBRUARY 2002 (Revision 2).

1. The leach-based values for arsenic, nickel, zinc, phenol, and methyl ethyl ketone were updated based on changes to their respective unrestricted potable use standard (UPUS).

2. Values for ethylbenzene (soil type 2) and cis-1, 2 dichloroethene (soil type 1) were corrected due to typographical errors.

3. The value for leach-based value for hexane was changed. The value for hexane was largely dependant on soil saturation. An incorrect formula was used to calculate soil saturation.

4. Additional leach-based values were derived for antimony, beryllium, lead, selenium, silver, thallium, and vanadium.

Section 1.0 Introduction

The Ohio EPA Voluntary Action Program (VAP) has set forth in administrative rules (Ohio Administrative Code Chapter 3745-300), generic numerical cleanup standards and risk assessment procedures that allow a volunteer or certified professional to adequately and appropriately assess the hazardous substances and petroleum on a voluntary property and determine if the hazardous substances and petroleum meet applicable standards. When hazardous substances and petroleum from the voluntary property are leaching or will leach to the ground water underlying the property and leaching of hazardous substances and petroleum must be controlled in accordance with the VAP Ground Water Rule (Ohio Administrative Code Rule 3745-300-10), the certified professional or volunteer must determine an applicable standard for the leaching pathway. The VAP Risk Assessment Rule (Ohio Administrative Code Rule 3745-300-09) contains data requirements and acceptable mathematical models for assessing the movement of hazardous substances and petroleum through the vadose zone into the ground water. The Risk Assessment Rule also gives the volunteer or certified professional the opportunity to use leach-based soil values derived by Ohio EPA in lieu of performing property-specific fate and transport modeling. These generic leach-based soil values are contained in this guidance document and represent the concentrations of hazardous substances and petroleum that can remain in the soil on a property such that leaching of hazardous substances and petroleum into ground water above generic unrestricted potable use standards is prevented.

This guidance document contains the Ohio EPA derived leach-based soil values for organic chemicals using the vadose zone model RISKPRO SESOIL (Table I) along with the limitations regarding when it is appropriate and when it is inappropriate to apply the leached-based soil values in Table I to a voluntary property (Section 3.0). Table II of this guidance document contains leach-based soil values for inorganic chemicals calculated using the soil/water partitioning equation contained in the guidance document “U.S. EPA. 1996. Soil Screening Guidance: Technical Background Document. Office of Solid Waste and Emergency Response, Washington, D.C. EPA/540/R-95/128". In addition to the leach-based soil values, Ohio EPA derived dilution factors (which may be used with the leach-based soil values for the organic chemicals) and the limitations which apply to the dilution factors are contained in this guidance document (Section 5.0). If a volunteer or certified professional determines that using the Ohio EPA derived dilution factors is inappropriate based on the conditions at the property, property-specific dilution factors for the organic chemicals may be determined. Guidance for deriving property-specific dilution factors is contained in this document (Section 6.0).

General assumptions regarding the development of the Ohio EPA derived leach-based soil values are contained in this guidance document (Section 2.0). For a detailed discussion of the assumptions used in calculating the leach-based values as well as a description of how the values were derived, refer to the Appendix Technical Support Document to this guidance document. Definitions for many of the terms used throughout this guidance document are also contained in the Appendix.

Section 2.0 Assumptions

The Ohio EPA derived leach-based soil values contained in Table I represent the concentrations of hazardous substances or petroleum that may be present in the soils on a property that ensure protection of public health and safety for the reasonable exposure associated with potable groundwater use on and off the property. The leach based soil values for the organic chemicals contained in Table I were derived using SESOIL, an integrated soil compartment model which is designed to simultaneously model water transport, sediment transport and pollutant fate. For additional information concerning the SESOIL model and how it was utilized to derive the leach-based soil values, refer to the Appendix to this guidance document. The leach based soil values for the inorganic chemicals contained in Table II were derived using the soil/water partitioning equation that describes the ability of contaminants to sorb to organic carbon. This equation is contained in the guidance document "U.S. EPA. 1996. Soil Screening Guidance: Technical Background Document. Office of Solid Waste and Emergency Response. Washington, D.C. EPA/540/R-95/128".

The leach-based soil values for the organic chemicals apply to three vadose zone soil types that are characteristic of geological settings common to Ohio. Vadose zone soil types are defined by the quantitative physical property of saturated vertical hydraulic conductivity (K_v) and the qualitative identification of geological setting. The vadose zone soil types are as follows:

Soil Type I

Vadose zone soil type I is characterized by a K_v ranging from 1×10^{-3} to 1×10^{-4} cm/s, a net recharge rate ranging from approximately eight to fourteen inches per year and a mean annual depth to ground water greater than five feet below grade. This soil type may include vertically continuous well-graded sand and gravel, fine sand, silty coarse sands that are typical of glacial outwash, buried valley aquifers, beach ridges and coarse alluvial deposits. This soil type may also include fill material (e.g. non-toxic flyash and non-native soils).

Soil Type II

Vadose zone soil type II is characterized by a K_v ranging from 1×10^{-4} to 1×10^{-5} cm/s, a net recharge ranging from approximately four to eight inches per year and a mean annual depth to ground water greater than five feet below grade. This soil type may include interbedded sand and gravel lenses with silts and clays, silty/clayey sand and gravel, and poorly-graded sands that can be found in some buried valley aquifers, glacial end moraine deposits and alluvial deposits.

Soil Type III

Vadose zone soil type III is characterized by a K_v less than 1×10^{-5} cm/s, a net recharge of less than four inches per year, and a mean annual depth of ground water greater than five feet below grade. This soil type may include silts, clays, silty clays, and silty clayey gravels that can be found in glacial till, lacustrine sediments, flood plain deposits and thick colluvial deposits.

Section 3.0 Applicability

Organics

The Ohio EPA leach-based soil values for the organic chemicals contained in Table I of this document should only be applied to the soils on a voluntary property when all of the following conditions exist:

- The hazardous substances and petroleum are identified in unconsolidated materials (e.g. soil, fill sand and gravel, till and alluvium).
- The depth to groundwater in the uppermost aquifer is equal to or greater than five feet below grade (this excludes the seasonal high water table).
- The saturated vertical hydraulic conductivity of the vadose zone (K_v) is equal to or less than 1×10^{-3} cm/s.

The Ohio EPA leach-based soil values for the organic chemicals contained in Table I of this document should not be applied to the soils on a voluntary property when the soils on the voluntary property exhibit one or more of the following characteristics:

- The saturated vertical hydraulic conductivity of the vadose zone (K_v) is greater than 1×10^{-3} cm/sec.
- The mean annual depth to ground water less than five feet, excluding the seasonal high water table.
- Thin soils (i.e. 5 feet of soil or less) are present over a significant thickness of consolidated bedrock, based on the relative infiltration rate of the vadose zone bedrock.

Inorganics

The generic leach-based values for metals contained in Table II should only be applied when the pH of the soil media is between 5 and 9, and the soil media has ten percent or greater fines. The metal leach-based soil values contained in the Table II assume a dilution-attenuation factor of 10.0 for source areas ½ acre or greater and a dilution-attenuation factor of 20.0 for source areas less than ½ acre.

Section 4.0 Ohio EPA Derived Leach-Based Soil Values

The following tables provide generic leach-based soil values for organics (Table I) and metals (Table II). These values are applicable under the conditions specified in Section 3.0.

Table I: Generic Leach-Based Soil Values for Organic Chemicals

Chemical (Organics)	**Soil Type I*** (mg/kg)	**Soil Type II*** (mg/kg)	**Soil Type III*** (mg/kg)
Benzene	0.017	0.0090	0.015
Toluene	6.8	4.1	7.7
Ethylbenzene	12	7.9	16
Total Xylenes	156	96	191
Styrene	0.46	0.37	0.62
Naphthalene	0.27	0.28	0.36
***n*-Hexane**	121	111	104
Methyl Ethyl Ketone	1.8	1.8	1.8
Phenol	1.1	1.1	1.2
Carbon Tetrachloride	0.25	0.25	0.28
1,2-Dichloroethane	0.0030	0.0020	0.0030
1,1,1-Trichloroethane	1.2	0.74	1.3
Vinyl Chloride	0.0090	0.0050	0.012
1,1-Dichloroethene	0.28	0.10	0.24
***cis*-1,2-Dichloroethene**	0.12	0.070	0.12
***trans*-1,2-Dichloroethene**	0.41	0.23	0.40
Trichloroethene	0.036	0.023	0.048
Tetrachloroethene	0.15	0.11	0.27

* The leach-based soil values contained in Table I assume a dilution factor of 1.0.

Table II: Generic Leach-Based Soil Values for Inorganic Chemicals

Chemical (inorganic)	**Leach-based Value** for sources ≥ ½ acre (mg/kg)	**Leach-based Value** for sources< ½ acre (mg/kg)
Antimony	3.6	7.2
Arsenic	3	6
Barium	56,000	110,000
Beryllium	57	114
Cadmium	21	42
Chromium	56	113
Lead	89	178
Mercury	12	23
Nickel	182	363
Selenium	2.15	4.3
Silver	3120	6240
Thallium	1.5	3.0
Vanadium	130	65
Zinc	44,000	88,000

*Values calculated based on the assumption that chromium is all chromium (VI)

**The leach-based soil values contained in the Table II assume a dilution-attenuation factor of 10.0 for source areas ½ acre or greater and a dilution-attenuation factor of 20.0 for source areas less than ½ acre.

Section 5.0 Ohio EPA Derived Dilution Factors

The leach-based soil values for the organic chemicals that are contained in Table I assume a dilution factor of 1.0. If appropriate, a volunteer or certified professional may apply one of the dilution factors contained in Tables III through V of this document to account for the effect of mixing between water leaching though the vertical zone of contamination and ground water migrating laterally through the aquifer. **The dilution factors contained in Tables III through V may only applied to the leach-based values contained in Table I (organic chemicals).** The leach-based values contained in Table II already assume a dilution-attenuation factor (DAF of 10.0 or 20.0, depending on the size of the source area).

The dilution factors contained in Tables III through V are appropriate to use for properties where the following conditions exist:

- The leach-based soils on the property can be classified into one of the three soil type categories (i.e. soil types I, II or III which are described in the Section 2.0 of this document).

- The ground water upgradient of the property has not been impacted by a release of hazardous substances or petroleum (i.e. the concentrations of hazardous substances or petroleum in the ground water are at background levels or not detectable).

- The horizontal hydraulic conductivity of the aquifer is greater than 1.0×10^{-3} cm/sec.

- The source size is less than 10.0 acres.

If the conditions at the property are not consistent with the above mentioned conditions, a volunteer or certified professional may develop property-specific dilution factors to apply to the leach-based values contained in Table I following the procedure contained in the Section 6.0 of this document.

Section 5.1 Assumptions for the Dilution Factors

The dilution factors contained in Tables III through V are calculated for each of the three soil types (soil types I, II and III), based on the various hydraulic conductivities of the aquifer and the various sizes of the source of contamination. These dilution factors are also based on the following assumptions:

- The ground water upgradient of the property has not been impacted by a release of hazardous substances and petroleum.

  The size of the source of contamination is less than 10 acres. (The generic dilution factors in Tables III through V are based on source area sizes ranging from less than 0.5 acres to up to, but not exceeding 10 acres.)

- The horizontal hydraulic conductivity of the aquifer is greater than 1.0×10^{-3} cm/sec. Dilution factors were determined for aquifers in which the horizontal hydraulic conductivity was greater or equal to 1×10^{-1} cm/sec, less than 1×10^{-1} to 1×10^{-2} cm/sec, and less than 1.0×10^{-2} to 1.0×10^{-3} cm/sec. If the hydraulic conductivity of the aquifer is 9.9×10^{-4} cm/sec or less, then the dilution factor is equal to 1 (i.e., no dilution).

- The source length parallel to flow is taken as the square root of the contaminated area.

  Note: in the event that the upgradient ground water is impacted, the size of the source area is greater than 10 acres or the horizontal hydraulic conductivity of the aquifer is greater than 1×10^{-3} cm/sec, a separate dilution equation, that may be used, is provided in Section 6.1 of this guidance document.

The dilution factors contained in Tables III through V are also based on the following default values:

- A default hydraulic gradient value of 0.002.

- A default mixing zone depth of 10 feet.

- A default recharge rate of: 12.5 in/year for soil type I; 8 in/year for soil type II and 2.5 in/year for soil type III.

Section 5.2 Ohio EPA Derived Dilution Factor Tables

Table III: Dilution Factors for Soil Category 1: Clean Sand and Gravel. (Recharge rate = 12.5)

Hydraulic conductivity of the aquifer (cm/sec)	Size of source area (acres)			
	≤ 0.5	> 0.5 to 1	>1 to 5	> 5 to 10
≥ 1.0×10^{-1}	15	10	5.3	4.0
≥ 1.0×10^{-2} but < 1.0×10^{-1}	2.3	2.0	1.4	1.3
≥ 1.0×10^{-3} but < 1.0×10^{-2}	1.1	1.1	1.0	1.0

Table IV: Dilution Factors for Soil Category 2: Silty Sand. (Recharge rate = 8.0 in/yr)

Hydraulic conductivity of the aquifer (cm/sec)	Size of source area (acres)			
	≤ 0.5	> 0.5 to 1	>1 to 5	> 5 to 10
≥ 1.0×10^{-1}	22	16	7.6	5.7
≥ 1.0×10^{-2} but < 1.0×10^{-1}	3.1	2.5	1.7	1.5
≥ 1.0×10^{-3} but < 1.0×10^{-2}	1.2	1.1	1.1	1.0

Table V: Dilution Factors for Soil Type 3: Till/Clay and Silt. (Recharge rate = 2.5 in/yr)

Hydraulic conductivity of the aquifer (cm/sec)	Size of source area (acres)			
	≤ 0.5	> 0.5 to 1	>1 to 5	> 5 to 10
≥ 1.0×10^{-1}	68	49	22	16
≥ 1.0×10^{-2} but < 1.0×10^{-1}	7.7	5.8	3.1	2.5
≥ 1.0×10^{-3} but < 1.0×10^{-2}	1.7	1.5	1.2	1.1

Section 6.0 Determining Property-Specific Dilution Factors

If the ground water upgradient of the property has been impacted by a release of hazardous substances and petroleum, then the leach based soil values must utilize a dilution factor of 1.0 (i.e. the volunteer or certified professional must use the values that are contained in Table I without applying any dilution factor from Section 5.0) or calculate a property-specific dilution factor using the Summers model described below or other dilution or fate models that incorporate the upgradient concentrations of the hazardous substances or petroleum in the ground water. Also, the volunteer or certified professional may gather information to develop a property-specific dilution factor utilizing Summers Model. **Property-specific dilution factors calculated following the procedures in this section may only be applied to the**

leach-based values for organic chemicals contained in Table I. The leach-based values contained in Table II already assume a dilution-attenuation factor (DAF of 10.0 or 20.0, depending on the size of the source area).

Note: when applying a property-specific dilution factor, an evaluation should be conducted to determine whether the calculated soil-clean value is appropriate (e.g. comparison to the soil saturation limit).

Section 6.1 The Summers Model

Summers model is based on hydrogeologic water-balance relationship and is expressed as:

$$C_{gw} = \frac{(Q_R)(C_p)+(Q_{gw})(C_p)}{Q_{gw}+Q_r}$$

Where:

C_{gw} = concentration of the contaminant in the saturated zone, Φg/ml
Q_R = volumetric flow rate of infiltration (soil water) to the aquifer, cm^3/d (Q_R=rLw)
Q_{gw} = volumetric flow rate of ground water beneath the contaminated area, cm^3/d (Q_{gw} =Kimw)
C_a = upgradient concentration of the pollutant in the aquifer (if any), μg/ml
C_p = contaminant concentration in the soil pore water before entering the ground water zone, μg/ml
r = recharge to the aquifer, cm
L = length of the source parallel to ground water flow, cm
w = length of source area perpendicular to ground water flow, cm
K = horizontal hydraulic conductivity, cm/sec
i = hydraulic gradient
m = mixing zone thickness in the aquifer, cm

Section 6.2 Parameter Determination for Summers Model

The parameters for the above dilution model must be determined in the following manner (default values are provided when appropriate):

Horizontal Hydraulic Conductivity (*K*): Values must be derived from actual field testing. The hydraulic conductivity values can be derived from site-specific field calculations or from other measured values cited in hydrogeologic reports if the volunteer or certified professional can demonstrate continuity between the reported values and the property and that the *K* value typifies the same saturated zone as directly below the leaching zone.

Gradient (*i*): Site-specific information should be used if available and be based on a minimum of three wells. If the site-specific K value is less than or equal to 1×10^{-1} cm/sec, the gradient can default to 0.002. If a site-specific gradient is calculated, it must be demonstrated that the gradient is not under the influence of any pumping wells.

Recharge Rate (*r*): If the site-specific dilution values are to be used with the leaching soil values provided in Table I, then the recharge rates must default to the following values:

Soil Type 1 (clean sand and gravel)	12.5 inches
Soil Type 2 (silty sand)	8.0 inches
Soil type 3 (till/clay)	2.5 inches

(The default values above are consistent with the average recharge rates used in SESOIL to determine the soil leaching values.)

Source Length Parallel to Ground Water Flow (*L*): This parameter requires both the knowledge of ground water flow direction and size of the contaminated area. The length of the source area parallel to flow must be based on results of soil sampling in conjunction with professional judgment. If ground water flow direction is not known then it should default to the square root of the source area.

Mixing zone depth (*m*): The mixing zone depth can default to 10 feet. This is based on the assumption that a residential well would always be at least 10 feet in length. It is believed that this is appropriate even if the mixing zone was less than 10 feet because a pumping well would also draw in uncontaminated water that would dilute the constituent. A volunteer or certified professional may calculate a property-specific mixing zone depth in lieu of the default mixing zone depth of 10 feet, using the following equation and parameter determinations:

$$d = (0.0112L^2)^{0.5} + d_\alpha \left[1 - \exp\left(\frac{-Lr}{Kid_\alpha}\right)\right]$$

Where:

d_α = aquifer thickness (m)
L = source length parallel to ground water flow (m)
r = infiltration rate (meters/year)
K = horizontal hydraulic conductivity (m/yr)
i = hydraulic gradient (m/m)
exp = the inverse of the natural log

The parameters and how they should be determined are the same as defined above for the Summers model. The only additional parameter information needed is guidance is a determination of aquifer thickness. If site specific information can not be reasonably obtained, then an a judgment can be made based on area ODNR well logs, ODNR Ground Water Resource Maps, and other published literature on the hydrogeology of the site/local area. There is a potential that the calculation of the mixing zone could be thicker than the aquifer. If this equation is utilized for determining site-specific mixing zone depth, then the user should default to the aquifer thickness when the equation calculates a mixing zone thickness greater than the aquifer thickness.

Upgradient Water Quality: Hazardous substances and petroleum in the groundwater upgradient of the property must be representative of the zones or depth intervals applicable to the ground water levels underlying the property. Sampling of the ground water should be conducted in accordance with the VAP Phase II rule (Ohio Administrative Code rule 3745-300-07).

Contaminant concentration in the soil pore water before entering the aquifer (C_p): The values in Table VI below represent the SESOIL predicted concentrations for this parameter.

Table VI: SESOIL Predicted Concentrations in the soil pore water before entering the saturated zone (μg/ml).

	SOIL TYPE		
CHEMICAL	**I**	**II**	**III**
Benzene	29.58	54.95	32.47
Toluene	117.34	24.44	12.92
Total Xylenes	6.42	10.44	5.23
Styrene	21.92	27.10	16.19
Naphthalene	26.09	25.10	19.74
n-Hexane	.00036	.000702	.000597
MEK	483.15	497.11	488.64
Phenol	425.34	408.70	309.21
Carbon Tetrachloride	2.00	2.0	1.77
1,2-Dichloroethane	156.25	208.33	151.52
1,1,1-Trichloroethane	16.55	26.95	15.52
Vinyl Chloride	22.47	37.74	16.39
1,1-Dichloroethene	2.54	7.00	2.94
cis-1,2-Dichloroethene	57.24	100.57	61.14
trans-1,2-Dichloroethene	24.59	42.99	24.89
Trichloroethene	13.81	22.12	10.50
Tetrachloroethene	3.27	4.48	1.88

Note: Values are in μg/ml.