



May 2007 Revision with June 27, 2007 correction

RRD OPERATIONAL MEMORANDUM NO. 1

SUBJECT: TECHNICAL SUPPORT DOCUMENT - ATTACHMENT 8
PART 201 C_{sat} CONCENTRATIONS
PART 213 TIER I C_{sat} CONCENTRATIONS

Developed pursuant to R 299.5718(2)

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
RRD:	Remediation and Redevelopment Division
Criteria or criterion:	Includes the cleanup criteria for Part 201 of NREPA and the Risk-Based Screening Levels as defined in Part 213 of NREPA and R 299.5706a(4)
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. C_{sat} is a theoretical threshold above which a free-phase liquid hazardous substance may exist.
Facility:	Includes "facility" as defined by Part 201 of NREPA and "site" as defined by Part 213 of NREPA
Facility-specific value or criterion:	Means "facility-specific" for Part 201 of NREPA or "site-specific" for Part 213 of NREPA
Free-Phase Liquid:	A substance that is liquid in its natural state, that is not dissolved in water and is at a concentration sufficient to allow it to flow and migrate in the environment separate from the influence of water. Includes free product as defined in Parts 201 and 213.
Response actions:	Includes "response activities" as defined by Part 201 of NREPA and "corrective action" as defined by Part 213 of NREPA
TSD:	Technical Support Document

The objective of this TSD is to describe the technical basis and purpose for developing the generic C_{sat} concentrations. The equation and parameter assumptions used to calculate the C_{sat} concentrations along with guidance for their application are provided in Part 201 and Part 213. This TSD supersedes other MDEQ documents regarding C_{sat} .

R 299.5718(2) states that if a generic soil criterion developed under R 299.5720 to R 299.5726 is greater than the C_{sat} concentration, the C_{sat} concentration becomes the generic criterion for that pathway, unless a facility-specific C_{sat} concentration is established using facility-specific soil characteristics. R 299.5706a(2)(a) states that if a criterion is greater than C_{sat} , 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. The generic C_{sat} concentrations are presented in the RRD Operational Memorandum No. 1, Attachment 1: Part 201 Cleanup Criteria; Part 213 Risk-Based Screening Levels. They are located in column 20 of the soil criteria table. C_{sat} concentrations have been substituted for those criteria which exceed C_{sat} in the criteria tables except for the volatile and particulate soil inhalation criteria (VSIC and PSIC) for ambient air. The actual calculated VSIC and PSIC are presented in the criteria tables even if C_{sat} has been exceeded to allow for source size modifications. An underlying assumption of the generic soil inhalation criteria (SIC) is that the area of soil contamination is equal to a half-acre. In order to adapt the generic SIC for a half-acre source to larger and smaller source sizes, air dispersion modeling was used to provide a set of modifiers to adjust the criteria presented in the criteria tables (see RRD Operational Memorandum No. 1, Attachment 7).

C_{sat} is an estimate of the concentration at which the soil pore water, pore air, and surface sorption sites are saturated with a particular hazardous substance, based upon the properties of the soil and hazardous substances. Above this theoretical threshold concentration, the hazardous substance may be present in free-phase within the soil matrix - as nonaqueous phase liquids (NAPLs) for substances that are liquid at ambient soil temperatures, and pure solid phases for compounds that are solids at ambient soil temperatures (EPA, 1996). Because C_{sat} is a theoretical value, concentrations greater than C_{sat} are not definitive evidence of a saturated soil condition or the presence of free-phase liquids. Instead, they are conservative estimates of when saturation conditions may occur. Concentrations at or near saturation may require response actions as a matter of source control or to address unacceptable risks not accounted for in the development of generic criteria.

C_{sat} concentrations are not risk-based values. The purpose of a C_{sat} value is to identify an upper limit to the applicability of generic risk-based soil criteria since certain assumptions and models used in the generic algorithms are not applicable when free-phase contamination is present in soil. In addition, soil concentrations greater than C_{sat} raise concerns relative to physical hazards, such as corrosivity and flammability, contact-site toxicity, aesthetic impacts, and/or ecological impacts which are not incorporated into the development of generic soil criteria. These factors must be considered in determining final soil criteria at a facility.

Soil saturation is not equivalent to free-phase liquid conditions. The term saturation refers to the soil pore water, soil pore air, and soil sorption sites that are **saturated** or contain the maximum amount of hazardous substance within each of these soil compartments. It is not a visible condition. Concentrations greater than C_{sat} may exhibit the characteristics of free-phase liquids or NAPL. The absence of free-phase liquids should not be construed to mean that C_{sat} conditions do not exist.

C_{sat} concentrations do not account for the effects of multiple contaminants and their interactions in soil. The presence of multiple contaminants is common at many facilities. It is probable that chemical-specific C_{sat} concentrations would be lower when present with other organic liquid contaminants in the soil. Since soil organic carbon water partition coefficient (K_{oc}) are determined for a contaminant in the presence of one solvent (i.e., water), multiple contaminants at a facility may cause free-phase contamination even when single chemical C_{sat} values are not exceeded.

An explanation of the importance for using C_{sat} as a limit for certain exposure pathway-specific soil criteria is discussed below:

Direct Contact Criteria for Soil

The result of human exposure to free-phase contaminants in soil is expected to be significantly different than that characterized by the generic soil direct contact equation. This is because certain exposure parameters in the generic soil direct contact equation, such as ingestion and dermal absorption efficiencies and soil adherence, characterize desorption and absorption (i.e., bioavailability) of a contaminant that is sorbed or “bound” to soil particles. The default values for these parameters are not applicable for a contaminant that is “unbound” to soil, as would be the case with free-phase contamination in soil. Pure substances, particularly those existing as liquids (i.e., NAPLs), unbound to a solid, may be completely absorbed through skin (EPA, 1992a) and absorbed to a greater extent across the gastrointestinal tract. The bioavailability of NAPL in soil may significantly exceed that represented in the soil direct contact equation.

Soil Volatilization to Indoor Air Inhalation Criteria (SVIIC)

The Johnson and Ettinger (1991) model (JEM) is used for the development of generic soil criteria protective of indoor air inhalation health risks from vapor migration into buildings. The initial step in the JEM involves vapor equilibrium modeling to determine the vapor concentration ratio in the soil to the initial unit mass concentration in the source. Vapor equilibrium modeling is only applicable at concentrations less than free-phase, where the chemical is sorbed to organic carbon in the soil, dissolved in soil moisture, and present as a gas in the air-filled pore spaces of the soil.

Ambient Air SIC

At C_{sat} , the emission flux of volatile contaminants from soil to ambient air reaches a plateau. Volatile emissions will not increase above C_{sat} , given the soil porosity assumptions inherent to the C_{sat} and volatilization factor equations, even if more chemical is added to the soil. C_{sat} concentrations, therefore, correspond to maximum volatile emissions from soil. Under C_{sat} conditions, the Jury model (RRD Operational Memorandum No. 1, Attachment 7) cannot be used to calculate an accurate SIC because the Henry's Law Constant (HLC), which predicts partitioning of chemical between the soil pore water (liquid) and pore air (gas), is not applicable when free-phase contamination is present (see discussion in the section titled “Equation Assumptions” for more information on the application of HLC). 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 modification based on different source area sizes.

Soil Criteria for Groundwater Protection (all pathways)

When C_{sat} concentrations are exceeded at facilities, there is an increased potential for contaminant migration from soil to groundwater. Generally, the mobility of liquid phase contaminants will increase as soil concentrations approach and exceed the C_{sat} concentration; contaminants will migrate downward more rapidly simply by advection and gravity. Modeling soil contaminant migration to groundwater using the EPA (1996) soil-water partition (SWP) equation is invalid when C_{sat} conditions are present (for more information on the SWP equation, see the SWP criteria TSD (RRD Operational Memorandum No. 1, Attachment 9)). The concept of three-phase chemical equilibrium partitioning, a fundamental component of the SWP equation, is invalid under C_{sat} conditions because once the three phases reach capacity (i.e., C_{sat}), multiphase (NAPL and dissolved) flow of contaminants to groundwater is possible (see the discussion in the section titled “Equation Assumptions” for more information on three-phase equilibrium partitioning). Therefore, if a chemical-specific C_{sat} value is less than the calculated groundwater protection value, the C_{sat} value becomes the criterion unless a facility-specific C_{sat}

concentration is established using facility-specific soil characteristics (R 299.5722). If a facility-specific C_{sat} is calculated, it is necessary to evaluate if additional response activity is necessary to protect against hazards unaccounted for in the development of that facility-specific criterion.

EQUATION ASSUMPTIONS

The C_{sat} equation illustrates that soil saturation is a function of several soil- and chemical-specific factors. The equation is presented below:

SOIL SATURATION (C_{sat}) CONCENTRATION EQUATION:

$$C_{sat} = \frac{S}{\rho_b} [(K_d \times \rho_b) + \theta_w + (H' \times TAF \times \theta_a)]$$

where,

C_{sat}	Soil saturation concentration	= ug/kg (ppb), chemical-specific
S	Chemical-specific solubility in water	= ug/L
ρ_b	Dry soil bulk density	= 1.5 kg/L
K_d	Soil-water distribution coefficient, where, $K_d = K_{oc} \times f_{oc}$	= L/kg, chemical-specific
K_{oc}	Soil organic carbon water partition coefficient	= L/kg, chemical-specific
f_{oc}	Fraction organic carbon in soil	= 0.002 (i.e., 0.2% - subsurface soil)
θ_w	Soil water-filled porosity	= 0.16 L_{water}/L_{air}
HLC	HLC	= atm-m ³ /mol, chemical-specific
H'	Dimensionless HLC, where $H' = HLC \times 41$	= unitless, chemical-specific
TAF	Temperature adjustment factor	= 0.5 (H') adjusted to Michigan annual average soil temperature of 10° Celsius
θ_a	Soil air-filled porosity	= 0.09 L_{air}/L_{soil}

The C_{sat} equation models a contaminant's equilibrium partitioning into three phases in soil - the amount dissolved in the soil pore water, the amount in the vapor phase of the soil pore air, and the amount sorbed to soil particles. These three phases are represented by the chemical-specific properties, water solubility (S), the HLC , and the soil-water distribution coefficient (K_d), respectively. For example, at C_{sat} the concentration of a hazardous substance in the soil pore water is equal to the chemical's S , the concentration in the pore air space is equal to its saturated vapor concentration estimated by the chemical's HLC , and the concentration of the substance sorbed to organic carbon in the soil is at its maximum based on the chemical's K_d . Therefore, C_{sat} corresponds to the soil concentration at which the solubility limits of the soil pore water, the vapor phase limits of the soil pore air, and the adsorptive limits of the soil particles have been reached. Free-phase liquid or solid may occur above C_{sat} , depending on the contaminant's physical state at ambient soil temperature. The conceptual application of C_{sat} has been modified to represent subsurface soil characteristics instead of surface soil assumptions as used by the EPA. This was necessary to establish consistency with default soil assumptions used to develop SWP criteria and SVIIC. As a result, the fraction of organic carbon default

value was reduced from 0.6 to 0.2 percent. Similarly, the water- and air-filled soil porosity default values in the equation, θ_w and θ_a , respectively, were modified to account for “effective porosity” instead of total porosity. Effective porosity is defined as the portion of the total soil porosity that is actively involved in the flow and exchange processes. Therefore, use of effective porosity will better reflect that portion of the total soil pore volume that could become saturated with a hazardous substance.

Effective porosity values of 25 to 33 percent are common for sand and silty sand. However, Michigan soils are composed of more than sand and silty sand, and there are also several areas throughout the state where clay soil predominates. Effective porosities for clay soil can be lower than 25 percent. Therefore, a default effective porosity value of 25 percent was chosen as a low-end estimate for applicability statewide. The recommended default values for the water- and air-filled soil porosity are $0.16 L_{\text{water}}/L_{\text{air}}$ and $0.09 L_{\text{air}}/L_{\text{soil}}$, respectively, which equate to an effective porosity of 25 percent. Further guidance for estimation of effective porosity in various soil types can be obtained from Russell (1977).

The chemical-specific dimensionless H' are multiplied by one-half (0.5) to account for reduced volatility of the chemical under lower annual average soil temperatures of 10° Celsius in Michigan, relative to the measured HLC reported at 25° Celsius. Justification for this application is available in Howe et al., (1987). The EPA (1996) provides background information for the remaining parameters and their default assumptions used in the C_{sat} equation. Facility-specific soil parameter data may be used in place of the default values and are discussed later in the application and implementation section of this document.

Development of chemical-specific C_{sat} concentrations is limited since the equation requires data on each chemical's soil organic carbon water partition coefficient (K_{oc} for calculation of K_d), S , and HLC . C_{sat} concentrations are presented in the cleanup criteria tables for substances that are liquid at standard temperature and pressure. Interpretation and implementation of the C_{sat} concentrations for solids is more complex. The average C_{sat} concentration for chemical liquids presented in the cleanup criteria tables is $2.8\text{E}+7$ parts per billion (ppb) which equals 2.8 percent. Based on these results, $1.0\text{E}+7$ ppb, or 1.0 percent is chosen as a reasonable default C_{sat} concentration for chemical liquids that have insufficient data for calculating their C_{sat} value. Qualitatively, soil concentrations greater than 1 percent or 10,000 mg/kg (ppm) are generally considered to indicate the likely presence of NAPL (Feenstra et al., 1991).

APPLICATION AND IMPLEMENTATION

Since free-phase liquids may be present at concentrations greater than C_{sat} , consideration should be given to whether Section 20114(1)(f) or Section 21307(2) of NREPA is applicable. This section describes obligations to address free-phase liquids and free product.

Soil sampling locations with concentrations at or above C_{sat} may represent contaminant source areas and/or hot spots as defined in the Sampling Strategies and Statistics Training Materials for Part 201 Cleanup Criteria (S3TM). The S3TM states:

“It is not appropriate to combine samples from Hot Spot areas with samples from other areas of a property for statistical analysis. This is necessary to avoid averaging or diluting the samples that represent Hot Spots. Hot Spots must be addressed separately.”

This is particularly important when conducting a statistical evaluation of soil data for comparison to C_{sat} concentrations. Care must be exercised not to mask potential source areas. Hot spots and/or potential source areas must be evaluated separately. This assures identification of soils that may serve as continuing sources of contamination to groundwater and air.

Facility-Specific

Facility-specific C_{sat} values can be developed only for those facilities where a single contaminant is present in the soil. In addition, facility-specific C_{sat} cannot be developed where free product is present or where free-phase contamination has been observed. See Appendix 2 for further details and direction on the circumstances under which developing a facility-specific C_{sat} concentration is appropriate. Information on the development of facility-specific C_{sat} values for soils where only one contaminant is present follows below.

A person conducting the evaluation has the option to develop facility-specific C_{sat} concentrations by modifying either dry soil bulk density (ρ_b) or fraction organic carbon in soil (f_{oc}) (R299.5718(2)). Methods for determining dry soil bulk density and fraction organic carbon in soil are specified in the RRD Operational Memorandum No. 2.

Properly calculated facility-specific C_{sat} concentrations allow for a generic or unrestricted closure if the generic or calculated facility-specific criteria are not exceeded. The facility-specific parameters must be based upon representative sampling. A single measurement is not an acceptable representation given the variability of these soil parameters for different soil conditions. Adequate site characterization is necessary to establish appropriate soil types and uncontaminated areas. General guidelines for conducting representative sampling for this option are presented below (S3TM, RRD Operational Memorandum No. 4, Site Characterization and Remediation Verification).

- Soil samples must be taken from uncontaminated areas; the samples need to represent native soil conditions unaffected by any release.
- Soil samples must be collected from the same soil type associated with the contamination but not from the contaminated area.
- Soil samples must include a chemical analysis to assure that the sample area is not contaminated.
- The appropriate analytical method must be used as described above.
- A minimum of 4 samples from each soil type must be analyzed.
 - If fewer than 9 samples are collected for f_{oc} , the lowest value from each soil type should be used in calculating the facility/site-specific f_{oc} . If a minimum of 9 samples from each soil type is analyzed, a 95 percent lower confidence limit (LCL) for the mean may be used to determine the facility/site-specific f_{oc} . If an LCL for the mean is calculated, a random sampling strategy should be used to collect the samples from the appropriate soil type (i.e., the same soil type as that associated with the release) from uncontaminated areas. Methods for calculating LCLs for the mean will be provided as an addendum to the S3TM document.
 - If fewer than 9 samples are collected for soil dry bulk density analysis, the highest value from each soil type should be used in calculating the facility/site-specific soil dry bulk density. If a minimum of 9 samples from each soil type is

analyzed, a 95 percent upper confidence limit (UCL) may be used to determine the facility/site-specific soil dry bulk density. If a UCL for the mean is calculated, a random sampling strategy should be used to collect the samples from the appropriate soil type (i.e., the same soil type as that associated with the release) from uncontaminated areas. Tabbed section 7 of the S3TM should be referred to for guidance on calculating the 95 percent UCL for the mean concentration.

Prior to relying upon an appropriately calculated facility-specific C_{sat} concentration as a criterion, it must be compared to the risk-based value. Appendix 1 consists of a table of generic risk-based soil values for the various exposure pathways that are greater than the generic C_{sat} concentrations. The lower of the appropriately calculated facility-specific C_{sat} concentration and the risk-based value is the applicable facility-specific criterion. If facility-specific, risk-based values are calculated for any pathway, the same soil parameter values must be used as are used for the facility-specific C_{sat} calculations.

This memorandum is intended to provide guidance to foster consistent application of Part 201, Part 213, and 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.



REFERENCES

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RRD Operational Memorandum No. 1, Attachment 8, Appendix 1:

Generic Soil Saturation Concentrations (C_{sat}) and Calculated Risk-based Soil Values Greater than the Generic C_{sat}

Hazardous Substance	Generic C_{sat} Concentration (ug/kg)	Risk-based Values Greater than C_{sat} (ug/kg or ppb)								
		Residential Drinking Water Protection	Industrial and Commercial Drinking Water Protection	Ground- water Contact Protection	Residential & Commercial I Soil Volatilization to Indoor Air Inhalation	Industrial & Commercial II III IV Soil Volatilization to Indoor Air Inhalation	Residential & Commercial I Direct Contact	Industrial & Commercial II Direct Contact	Commercial III Direct Contact	Commercial IV Direct Contact
Acetaldehyde (l)	1.1E+08			8.4E+08					1.3E+08	
Acetic acid	6.5E+08			3.6E+09						
Acetone (l)	1.1E+08			6.2E+08	2.9E+08	5.4E+08				
Acetonitrile	2.2E+07			1.1E+08						
Acetophenone	1.1E+06			1.2E+08	1.2E+08	2.1E+08	4.7E+07	1.5E+08	2.1E+08	1.8E+08
Acrolein (l)	2.3E+07			6.8E+07						
t-Amyl methyl ether (TAME)	4.4E+05			6.0E+07			2.9E+07	9.5E+07	1.3E+08	1.1E+08
Benzene (l)	4.0E+05							8.4E+05	1.2E+06	9.9E+05
Benzyl alcohol	5.8E+06			8.8E+08			3.2E+08	1.0E+09	1.4E+09	1.2E+09
Benzyl chloride	2.3E+05								3.1E+05	2.6E+05
bis(2-Ethylhexyl)phthalate	1.0E+07							1.2E+07	2.1E+07	1.5E+07
Bromobenzene (l)	7.6E+05							1.7E+06	2.5E+06	2.1E+06
Bromoform	8.7E+05			2.8E+06				3.8E+06	5.3E+06	4.5E+06
n-Butanol (l)	8.7E+06			1.8E+08			2.9E+07	9.5E+07	1.3E+08	1.1E+08
2-Butanone (MEK) (l)	2.7E+07			4.8E+09	5.4E+07	9.9E+07	1.2E+08	7.0E+08	1.1E+09	8.6E+08
n-Butyl acetate	1.1E+06			3.6E+07	5.6E+07	1.0E+08	1.7E+07	5.5E+07	7.8E+07	6.5E+07
t-Butyl alcohol	1.1E+08			1.6E+09	3.1E+08	5.7E+08	1.2E+08	3.9E+08	5.5E+08	4.6E+08
Butyl benzyl phthalate	3.1E+05	2.2E+06	5.0E+06	5.0E+06			3.6E+07	1.2E+08	1.6E+08	1.4E+08



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		Residential Drinking Water Protection	Industrial and Commercial Drinking Water Protection	Ground- water Contact Protection	Residential & Commercial I Soil Volatilization to Indoor Air Inhalation	Industrial & Commercial II III IV Soil Volatilization to Indoor Air Inhalation	Residential & Commercial I Direct Contact	Industrial & Commercial II Direct Contact	Commercial III Direct Contact	Commercial IV Direct Contact
n-Butylbenzene	1.0E+07								1.1E+07	
sec-Butylbenzene	1.0E+07								1.1E+07	
tert-Butylbenzene (l)	1.0E+07								1.1E+07	
Carbon disulfide (l,R)	2.8E+05			2.4E+07			7.2E+06	4.3E+07	6.6E+07	5.3E+07
Carbon tetrachloride	3.9E+05							4.4E+05	6.2E+05	5.2E+05
Chlorobenzene (l)	2.6E+05			1.7E+06			4.3E+06	1.4E+07	1.9E+07	1.6E+07
1-Chloro-1,1-difluoroethane	9.6E+05			7.8E+07	2.9E+06	5.4E+06	4.7E+08	1.5E+09	2.1E+09	1.8E+09
Chloroethane	9.5E+05			8.8E+06	2.9E+06	5.3E+06	2.6E+06	1.2E+07	1.7E+07	1.4E+07
Chloroform	1.5E+06			3.0E+06				5.5E+06	7.7E+06	6.5E+06
Chloromethane (l)	1.1E+06			9.8E+06			1.6E+06	7.4E+06	1.0E+07	8.7E+06
o-Chlorotoluene (l)	5.0E+05			9.8E+05		5.0E+05	4.5E+06	1.5E+07	2.0E+07	1.7E+07
Cyclohexanone	2.2E+08			3.6E+09			1.0E+09	3.3E+09	4.6E+09	3.9E+09
Dalapon	5.9E+07			2.4E+08				6.2E+07	8.7E+07	7.3E+07
Di-n-butyl phthalate	7.6E+05	9.6E+05	2.7E+06	1.2E+07			2.7E+07	8.7E+07	1.2E+08	1.0E+08
Di(2-ethylhexyl) adipate	9.6E+05	1.3E+07	1.3E+07	1.5E+07			1.5E+07	6.3E+07	1.1E+08	8.2E+07
Di-n-octyl phthalate	1.4E+08		2.9E+08	3.1E+08						
Dibromochloromethane	6.1E+05								6.9E+05	
Dibromochloropropane	1,200			7,800	11,000	20,000	4,400	20,000	28,000	24,000



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Hazardous Substance	Generic C_{sat} Concentration (ug/kg)	Risk-based Values Greater than C_{sat} (ug/kg or ppb)								
		Residential Drinking Water Protection	Industrial and Commercial Drinking Water Protection	Ground- water Contact Protection	Residential & Commercial I Soil Volatilization to Indoor Air Inhalation	Industrial & Commercial II III IV Soil Volatilization to Indoor Air Inhalation	Residential & Commercial I Direct Contact	Industrial & Commercial II Direct Contact	Commercial III Direct Contact	Commercial IV Direct Contact
Dibromomethane	2.0E+06			1.1E+07			2.5E+06	8.0E+06	1.1E+07	9.4E+06
1,2-Dichlorobenzene	2.1E+05			3.6E+06	1.1E+07	2.0E+07	1.9E+07	6.3E+07	8.8E+07	7.4E+07
1,3-Dichlorobenzene	1.7E+05						2.0E+05	6.6E+05	9.2E+05	7.7E+05
Dichlorodifluoromethane	1.0E+06			1.7E+07			5.2E+07	1.7E+08	2.3E+08	2.0E+08
1,1-Dichloroethane	8.9E+05			4.8E+07			2.7E+07	8.7E+07	1.2E+08	1.0E+08
1,1-Dichloroethylene (I)	5.7E+05							6.6E+05	9.2E+05	7.7E+05
cis-1,2-Dichloroethylene	6.4E+05			4.0E+06			2.5E+06	8.0E+06	1.1E+07	9.4E+06
trans-1,2-Dichloroethylene	1.4E+06			4.4E+06			3.8E+06	1.2E+07	1.7E+07	1.5E+07
2,4-Dichlorophenol	1.8E+06							3.9E+06	6.0E+06	4.8E+06
1,2-Dichloropropane (I)	5.5E+05							6.6E+05	9.2E+05	7.7E+05
Diethyl ether	7.4E+06			7.0E+08	2.8E+07	5.2E+07	1.1E+08	3.6E+08	5.1E+08	4.3E+08
Diethyl phthalate	7.4E+05			2.2E+07			1.7E+08	5.5E+08	7.7E+08	6.4E+08
Diisopropyl ether	1,300		1,700	1.6E+05	6.7E+05	1.2E+06	9.2E+05	3.0E+06	4.2E+06	3.5E+06
Dimethyl phthalate	7.9E+05	1.5E+06	4.2E+06	8.4E+07			2.3E+09	7.3E+09	1.0E+10	8.6E+09
Dinoseb	1.4E+05			3.0E+05				3.9E+05	6.0E+05	4.8E+05
Ethanol (I)	1.1E+08			2.0E+10			4.1E+09	2.4E+10	3.7E+10	3.0E+10
Ethyl-tert-butyl ether (ETBE)	6.5E+05					1.0E+06				
Ethylbenzene (I)	1.4E+05			3.4E+06		4.6E+05	2.2E+07	7.1E+07	9.9E+07	8.3E+07
Ethylene glycol	1.1E+08			2.0E+10			4.5E+08	1.5E+09	2.0E+09	1.7E+09



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Generic Soil Saturation Concentrations (C_{sat}) and Calculated Risk-based Soil Values Greater than the Generic C_{sat}

Hazardous Substance	Generic C_{sat} Concentration (ug/kg)	Risk-based Values Greater than C_{sat} (ug/kg or ppb)								
		Residential Drinking Water Protection	Industrial and Commercial Drinking Water Protection	Ground-water Contact Protection	Residential & Commercial I Soil Volatilization to Indoor Air Inhalation	Industrial & Commercial II III IV Soil Volatilization to Indoor Air Inhalation	Residential & Commercial I Direct Contact	Industrial & Commercial II Direct Contact	Commercial III Direct Contact	Commercial IV Direct Contact
Formaldehyde	6.0E+07			6.0E+08				1.3E+08	1.8E+08	1.5E+08
Formic acid (I,U)	1.1E+08			1.2E+10			3.2E+08	1.0E+09	1.4E+09	1.2E+09
Hexachlorobutadiene (C-46)	3.5E+05			6.9E+05		7.1E+05		4.7E+05	6.5E+05	5.5E+05
Hexachlorocyclopentadiene (C-56)	7.2E+05			1.0E+07			2.3E+06	6.7E+06	1.2E+07	8.7E+06
2-Hexanone	2.5E+06			1.0E+08			3.2E+07	1.0E+08	1.4E+08	1.2E+08
Isobutyl alcohol (I)	8.9E+06			5.0E+08	2.3E+08	4.3E+08	7.2E+07	2.3E+08	3.3E+08	2.7E+08
Isophorone	2.4E+06			2.0E+07			4.8E+06	2.2E+07	3.1E+07	2.6E+07
Isopropyl alcohol (I)	1.1E+08			2.6E+08						
Isopropyl benzene	3.9E+05			6.4E+06	4.0E+05	7.3E+05	2.5E+07	8.0E+07	1.1E+08	9.4E+07
Methanol	3.1E+06			5.8E+08	3.6E+07	6.7E+07	1.1E+08	3.6E+08	5.1E+08	4.3E+08
4-Methyl-2-pentanone (MIBK) (I)	2.7E+06			2.6E+08	3.7E+07	6.9E+07	5.6E+07	1.8E+08	2.6E+08	2.1E+08
Methyl-tert-butyl ether (MTBE)	5.9E+06			1.2E+07	9.9E+06	1.8E+07		7.1E+06	1.0E+07	8.4E+06
Methylene chloride	2.3E+06			4.4E+06				5.8E+06	8.1E+06	6.8E+06
Metolachlor	4.4E+05			1.8E+06			1.5E+06	6.9E+06	9.7E+06	8.2E+06
Pentachlorobenzene	1.9E+05			1.1E+06			3.2E+05	9.3E+05	1.7E+06	1.2E+06
Pentane	2.4E+05				9.5E+05					
Phenol	1.2E+07			5.8E+08			4.0E+07	2.3E+08	3.6E+08	2.9E+08
Phthalic anhydride	1.1E+06			1.2E+08			4.7E+08	1.5E+09	2.1E+09	1.8E+09



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Generic Soil Saturation Concentrations (C_{sat}) and Calculated Risk-based Soil Values Greater than the Generic C_{sat}

Hazardous Substance	Generic C_{sat} Concentration (ug/kg)	Risk-based Values Greater than C_{sat} (ug/kg or ppb)								
		Residential Drinking Water Protection	Industrial and Commercial Drinking Water Protection	Ground- water Contact Protection	Residential & Commercial I Soil Volatilization to Indoor Air Inhalation	Industrial & Commercial II III IV Soil Volatilization to Indoor Air Inhalation	Residential & Commercial I Direct Contact	Industrial & Commercial II Direct Contact	Commercial III Direct Contact	Commercial IV Direct Contact
Propionic acid	1.1E+08			5.6E+09			3.8E+08	1.2E+09	1.7E+09	1.5E+09
n-Propylbenzene (l)	1.0E+07								1.1E+07	
Propylene glycol	1.1E+08			2.0E+10			4.5E+09	1.5E+10	2.0E+10	1.7E+10
Pyridine (l)	37,000			1.9E+06			2.3E+05	7.3E+05	1.0E+06	8.6E+05
Styrene	5.2E+05					1.3E+06		1.9E+06	2.6E+06	2.2E+06
1,1,1,2-Tetrachloroethane	4.4E+05			6.0E+05			4.8E+05	2.2E+06	3.1E+06	2.6E+06
Tetrachloroethylene	88,000			2.4E+05			2.0E+05	9.3E+05	1.3E+06	1.1E+06
Toluene (l)	2.5E+05			1.1E+07	3.3E+05	6.1E+05	5.0E+07	1.6E+08	2.2E+08	1.9E+08
Triallate	2.5E+05		2.7E+05	4.0E+06			2.9E+06	9.5E+06	1.3E+07	1.1E+07
1,2,4-Trichlorobenzene	1.1E+06				9.6E+06	1.8E+07		5.8E+06	9.0E+06	7.2E+06
1,1,1-Trichloroethane	4.6E+05			2.6E+07			5.0E+08	1.6E+09	2.2E+09	1.9E+09
1,1,2-Trichloroethane	9.2E+05								1.2E+06	9.9E+05
Trichloroethylene	5.0E+05						5.3E+05	6.6E+05	1.0E+06	8.1E+05
Trichlorofluoromethane	5.6E+05			2.2E+07	2.8E+06	5.2E+06	7.9E+07	2.6E+08	3.6E+08	3.0E+08
1,2,3-Trichloropropane	8.3E+05			1.7E+06			1.3E+06	4.2E+06	5.8E+06	4.9E+06
1,1,2-Trichloro-1,2,2-trifluoroethane	5.5E+05	9.0E+06	9.0E+06	9.0E+06	5.1E+06	9.3E+06	6.1E+09	2.0E+10	2.8E+10	2.3E+10
Triethylene glycol	1.1E+05	2.0E+05	2.4E+05	2.0E+07			3.9E+07	2.3E+08	3.6E+08	2.8E+08
1,2,4-Trimethylbenzene (l)	1.1E+05			1.9E+06	4.3E+06	7.9E+06	3.2E+07	1.0E+08	1.4E+08	1.2E+08
1,3,5-Trimethylbenzene (l)	94,000			1.5E+06	2.6E+06	4.8E+06	3.2E+07	1.0E+08	1.4E+08	1.2E+08



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Generic Soil Saturation Concentrations (C_{sat}) and Calculated Risk-based Soil Values Greater than the Generic C_{sat}

Hazardous Substance	Generic C_{sat} Concentration (ug/kg)	Risk-based Values Greater than C_{sat} (ug/kg or ppb)								
		Residential Drinking Water Protection	Industrial and Commercial Drinking Water Protection	Ground- water Contact Protection	Residential & Commercial I Soil Volatilization to Indoor Air Inhalation	Industrial & Commercial II III IV Soil Volatilization to Indoor Air Inhalation	Residential & Commercial I Direct Contact	Industrial & Commercial II Direct Contact	Commercial III Direct Contact	Commercial IV Direct Contact
Triphenyl phosphate	1.1E+05	1.5E+06	1.8E+06	1.8E+06			3.6E+07	1.2E+08	1.6E+08	1.4E+08
tris(2,3- Dibromopropyl)phosphate	27,000			1.9E+05	81,000	4.3E+05			28,000	
Vinyl acetate (I)	2.4E+06			1.6E+08			5.8E+06	3.4E+07	5.3E+07	4.2E+07
Xylenes (I)	1.5E+05			3.8E+06	6.3E+06	1.2E+07	4.1E+08	1.3E+09	1.8E+09	1.5E+09

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Facility-Specific C_{sat}

Under limited circumstances there is an opportunity to establish a facility-specific C_{sat} concentration using facility-specific soil characteristics. The following provides additional guidance to determine when establishing a facility-specific C_{sat} concentration is appropriate.

Even in the absence of *observable* free-phase contamination, free-phase contamination can be present within the soil matrix when contaminant concentrations approach or reach their individual C_{sat} concentrations. The C_{sat} model assumes only one contaminant is present in the soil. The individual C_{sat} values presented in the criteria tables (and the equation used to develop the values) do not account for the effects on saturation resulting from the presence of multiple contaminants in the soils. The presence of multiple contaminants has the effect of lowering the concentration at which saturation of any one compound might occur. The presence of multiple contaminants can cause free-phase contamination to form, even when individual chemical C_{sat} values have not been exceeded. A facility-specific C_{sat} value can be developed only for those facilities where a single contaminant has been released; the single contaminant must have adequate chemical-specific information to allow for calculation of a C_{sat} value. (Note: most metals do not have C_{sat} values.) The analysis of soil contaminants must be appropriate to the site and must be for all hazardous substances which may have been released at the site. Analytical data must document the presence of only a single contaminant with a C_{sat} value, unless other contaminants are at such low concentrations that they will not significantly affect the saturation value of the prevailing contaminant. The Remediation and Redevelopment Division's Toxicology Unit should be consulted if there is a question regarding the effect of specific mixtures of contaminants.

Facility-specific C_{sat} values cannot be used to overcome the presence of observable free-phase contamination or free product. Therefore, facility-specific C_{sat} values are not useful to develop for soil where there is, or has been, observable free-phase contamination or free product. It may be appropriate to develop a facility-specific C_{sat} value for an area demonstrated to be physically separate from the areas on the site where free-phase contamination or free product has been observed. This facility-specific C_{sat} value can only be compared to the soil contaminant concentrations in the spatially distinct area where no observable free-phase contamination or free product has occurred.

It must be demonstrated that all known and potential source areas have been adequately investigated and that the maximum contaminant concentrations have been detected prior to developing a facility-specific C_{sat} value and/or comparing a facility-specific C_{sat} value to site data to determine compliance. This includes the collection of soil samples from the location of the release(s) (if known) and from likely source or release areas, including beneath product piping, dispensers, and within underground storage tank cavities.