



## Remediation and Redevelopment Division

*Michigan Department of Environmental Quality*

July 2006

### RRD OPERATIONAL MEMORANDUM NO. 1

**SUBJECT: TECHNICAL SUPPORT DOCUMENT - ATTACHMENT 4  
PART 201 GROUNDWATER CONTACT CRITERIA  
PART 213 TIER I GROUNDWATER CONTACT RISK-BASED  
SCREENING LEVELS**

Developed under R 299.5712

Key definitions for terms used in this document:

<b>NREPA:</b>	<a href="#"><u>The Natural Resources and Environmental Protection Act, 1994 PA 451, as amended</u></a>
<b>Part 201:</b>	<a href="#"><u>Part 201, Environmental Remediation, of NREPA</u></a>
<b>Part 213:</b>	<a href="#"><u>Part 213, Leaking Underground Storage Tanks, of NREPA</u></a>
<b>MDEQ:</b>	<a href="#"><u>Michigan Department of Environmental Quality</u></a>
<b>RRD:</b>	<a href="#"><u>Remediation and Redevelopment Division</u></a>
<b>U.S. EPA:</b>	<a href="#"><u>United States Environmental Protection Agency</u></a>
<b>CAP/RAP:</b>	Corrective Action Plan pursuant to provisions of Part 213 of NREPA and Remedial Action Plans pursuant to provisions of Part 201 of NREPA
<b>Criteria or criterion:</b>	Includes the cleanup criteria for Part 201 of NREPA and Risk-Based Screening Levels as defined in Part 213 of NREPA and R 299.5706a(4)
<b>GCC:</b>	Groundwater contact criteria or criterion
<b>Facility:</b>	Includes "facility" as defined by Part 201 of NREPA and "site" as defined by Part 213 of NREPA
<b>TSD:</b>	Technical Support Document

This TSD presents the methodology for development of the GCC. The GCC represent groundwater concentrations that are protective against adverse health effects due to long-term dermal exposure to hazardous substances in groundwater. The GCC were developed pursuant to Sections 20120a(1)(a), (b), and (d); 20120a(3); and 21304a(1)(2) of NREPA. The method and equations for the GCC are presented in R 299.5712. This TSD supercedes previous MDEQ documents regarding the GCC (Environmental Response Division Operational Memorandum No. 18, Technical Support Document – Generic Groundwater Contact Criteria, and Storage Tank Division Operational Memorandum No. 4 – Attachment 5, Utility Worker Groundwater Direct Contact).

The GCC are presented in the Part 201 Administrative Rules (R 299.5744) 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 GCC are presented in column 6 of the groundwater criteria table.

### **IMPLEMENTATION OF THE GROUNDWATER CONTACT CRITERIA**

The GCC were derived to address human health risk from dermal (i.e., skin) exposure to hazardous substances in groundwater. Subsurface utility line repair, maintenance, and installation are the common types of activities that could result in periodic contact with hazardous substances in groundwater for any land use. Therefore, generic GCC have been developed using the utility worker as the target receptor. Utility worker exposure to groundwater contaminants at a facility is likely to occur throughout the duration of their employment, resulting in a higher frequency of contact with contaminants than a construction worker whose exposure is likely to occur over a few months for only one year at a facility.

The groundwater contact pathway is relevant for all land uses where contaminated groundwater is or will be encountered at a depth where construction or maintenance of utilities or other subsurface activities may reasonably be expected to result in persons coming into contact with the groundwater. If utilities are not currently present at a facility, then the location and elevation of contaminated groundwater relative to the location and elevation of surrounding utilities shall be considered in determining whether it is likely that dermal contact with groundwater related to utility construction and maintenance is reasonably likely to occur in the future (R 299.5712(1) and R 299.5532(7)(ii)).

If the pathway is relevant, the GCC are applicable for all land uses where soil excavations to conduct subsurface work can result in groundwater seepage and collection in the excavation. The GCC are applicable at facilities that have existing utilities and at facilities where utilities could be placed in the future. These criteria are not applicable if restrictions are placed on the property to prevent subsurface activities. The GCC are not applicable for ponds and other surface water. The groundwater surface water interface criteria established under R 299.5716(6) shall apply to such surface water bodies unless the MDEQ approves of alternative criteria under R 299.5716(8), R 299.5716(11), or R 299.5712(2). The RAPs/CAPs must identify if the pathway and risks due to hazardous substances in groundwater as a result of dermal contact with that groundwater are relevant (R 299.5532(7)). As a part of the evaluation, RAPs/CAPs must also identify existing utility corridors and their depth in relation to the saturated soils, describe the basis for conclusions regarding the potential depth of future utilities, and describe other subsurface activities that are anticipated to occur at the facility.

Since the GCC are based upon a specific set of exposure assumptions for a utility worker, it is essential that other groundwater exposure pathways be considered to assure that exposures different than the generic GCC exposure assumptions are evaluated. For example, consider a situation where the drinking water use of an aquifer is controlled by land use restrictions, but groundwater may be used for irrigation and recreational activities such as filling small backyard swimming pools. The generic GCC based on exposure assumptions for a utility worker will not protect for these other uses. Therefore, a criterion more restrictive than the GCC may be necessary to protect for the health and ecological risks posed by nondrinking uses of the groundwater.

***Typically, the generic GCC address systemic human health effects (i.e., only those effects that occur as a result of absorption and distribution of the chemical to an***



***organ/tissue that is different than the site of contact) from long-term dermal exposure.***

Assessment of the potential for acute systemic and/or acute non-systemic (point-of-contact) effects may be necessary for some chemicals to determine criteria that are protective for the most sensitive effect (Section 20120a(4)). For example, acute systemic toxicity data were used to generate the soil direct contact criteria (DCC) and the GCC for cyanide. The acute toxicity assessment for cyanide is provided in Appendix A for reference.

For some contaminants and exposure settings, the inhalation exposure route may be significant. The potential for acute inhalation effects due to hazardous substances in groundwater in subsurface excavations must be evaluated using the Acute Inhalation Screening Levels (AISLs) or other information addressing acute inhalation concerns. In addition, excavations greater than 4 feet below ground surface are considered confined spaces under occupational safety regulations (MIOsha Administrative Rule 6402).

The concentrations of hazardous substances in groundwater must also be evaluated for potential acute physical hazards such as flammability and explosivity. Flammability explosivity screening levels (FESLs) have been derived for this purpose.

The FESLs and AISLs, which have been developed for hazardous substances where sufficient chemical-specific information is available, are presented in columns 8 and 9 in Op Memo No. 1, Attachment 1 (Groundwater Criteria Table). Information related to the FESLs and AISLs are presented in the Part 201 Cleanup Criteria Training Material Guidesheet D (R 299.5728(1)(d) and (e)).

If the risk-based GCC is greater than the solubility limit for that specific hazardous substance, then the solubility limit is the cleanup criterion (R 299.5708(2)). Criteria that are based on the solubility limit are identified by the (S) footnote in Op Memo No. 1, Attachment 1 (Groundwater Criteria Table) (R 299.5750(S)).

The generic GCC have been developed to protect workers exposed to contamination in subsurface excavations for less than 20 days/year. Facilities with a dedicated work force for these activities would likely experience higher exposure rates and would need to develop site-specific criteria using appropriate exposure rates.

The GCC algorithm estimates a criterion protective against adverse health effects resulting from dermal exposure to hazardous substances dissolved in groundwater. The presence of dissolved phase contaminant is a key assumption for the GCC methodology. Some hazardous substances strongly adsorb to soil particles and their dissolution in groundwater may be minimal. These contaminants are identified in the criteria tables with the (AA) footnote (R 299.5750). When the groundwater contact pathway is a driver for remediation activities and hazardous substances notated with footnote (AA) exceed the GCC using totals analysis, groundwater samples may be filtered with a 0.45 micron filter for demonstrating compliance with the GCC. This allows for comparison of data representing dissolved phase contaminant to criteria based on dissolved phase contaminant. See RRD Operational Memorandum No. 2, Attachment 5 (page 5) for further details.

**GROUNDWATER CONTACT ALGORITHMS**The GCC are derived from the algorithms presented below except as provided in R 299.5734. The exposure assumptions for calculation



of GCC apply for all land use categories. The series of generic equations presented below are consistent with the U.S. EPA's guidance for dermal risk assessment (U.S. EPA, 2004). Some modifications of the equations are necessary for converting the calculation procedures from one of calculating risk from dermal exposure to a contaminant concentration in water, to that of back-calculating the contaminant concentration in water assuming a fixed "target" risk and acceptable dose. As a result, the *dose absorbed per exposure event* term has been modified to calculate the extent of *skin penetration* (SP) per exposure event. Since only one exposure event is assumed to occur per day under the generic scenario, the SP values are expressed in units of cm/day. Lastly, the *dermal absorbed dose* from forward calculation of risk becomes the acceptable (exposure) dose (i.e., oral cancer slope factor (SF) or oral reference dose (RfD)) for back-calculation of generic GCC.

The algebraically rearranged equations for back-calculating acceptable hazardous substance concentrations in groundwater for dermal contact (i.e., GCC) are shown in equations 1 (carcinogenic) and 2 (non-carcinogenic). Further details regarding the common parameters within the GCC algorithms are presented following the "Derivation of Skin Penetration" section.

**EQUATION FOR CARCINOGENIC EFFECTS:**

$$GCC = \frac{BW \times AT \times TR \times CF_1}{SF \times SA \times SP \times EV \times EF \times ED \times CF_2} \quad (1)$$

where,

GCC	(Groundwater contact criterion)	= chemical-specific (ug/L or ppb)
BW	(Body weight)	= 70 kg
AT	(Averaging time)	= 25,550 days (70 years x 365 days/year)
TR	(Target risk level)	= 10 <sup>-5</sup>
SF	(Oral cancer slope factor)	= chemical-specific (mg/kg-day) <sup>-1</sup>
SA	(Skin surface area – adult)	= 3,300 cm <sup>2</sup>
SP	(Skin penetration per event)	= chemical-specific (cm/event)
EV	(Event frequency)	= 1 event/day
EF	(Exposure frequency)	= 20 days/year
ED	(Exposure duration)	= 21 years
CF <sub>1</sub>	(Conversion factor 1)	= 1E+3 ug/mg
CF <sub>2</sub>	(Conversion factor 2)	= 1E-3 L/cm <sup>3</sup>

**EQUATION FOR NON-CARCINOGENIC EFFECTS:**

$$GCC = \frac{THQ \times RfD \times BW \times AT \times CF_1}{SA \times SP \times EV \times EF \times ED \times CF_2} \quad (2)$$

where,

GCC	(Groundwater contact criterion)	= chemical-specific (ug/L or ppb)
THQ	(Target hazard quotient)	= 1
RfD	(Oral reference dose)	= chemical-specific (mg/kg-day)
BW	(Body weight)	= 70 kg
AT	(Averaging time)	= 7,665 days (21 years x 365 days/year)
SA	(Skin surface area – adult)	= 3,300 cm <sup>2</sup>
SP	(Skin penetration per event)	= chemical-specific (cm/event)
EV	(Event frequency)	= 1 event/day
EF	(Exposure frequency)	= 20 days/year
ED	(Exposure duration)	= 21 years
CF <sub>1</sub>	(Conversion factor 1)	= 1E+3 ug/mg
CF <sub>2</sub>	(Conversion factor 2)	= 1E-3 L/cm <sup>3</sup>

**DERIVATION OF SKIN PENETRATION**

Chemical-specific SP values are a function of the chemical's permeability coefficient (K<sub>p</sub>) and the exposure time (ET). The K<sub>p</sub> is a flux parameter, normalized for concentration, that represents the rate at which the chemical penetrates the skin (cm/hour) (U.S. EPA, 1992). Derivation of chemical-specific SP values is performed differently for inorganic and organic hazardous substances. The traditional steady-state method is used to estimate skin penetration for inorganic hazardous substances (SP<sub>i</sub>) as shown in the following equation:

$$SP_i = K_p \times ET \quad (3)$$

where,

SP <sub>i</sub>	(Skin penetration per event for inorganic substances)	= chemical-specific (cm/event)
K <sub>p</sub>	(Permeability coefficient)	= chemical-specific (cm/hour), or default specified by the MDEQ
ET	(Exposure time)	= 2 hours/event for subsurface worker (hours/event)

If the MDEQ does not specify a K<sub>p</sub> for a particular inorganic hazardous substance, a default value of 0.001 cm/hour shall be used.

A nonsteady-state method is used to calculate skin penetration values for organic hazardous substances (SP<sub>o</sub>) to account for absorption that can occur after the exposure event due to storage of the hazardous substance within skin lipids (U.S. EPA, 1992). Factors such as the tendency for the chemical to partition between lipid and water phases, estimated by the octanol-



water partition coefficient ( $K_{ow}$ ) influence the amount of contaminant absorbed after exposure has ceased.

Chemical-specific  $K_p$  values for organic hazardous substances are estimated using a refined Potts and Guy (1992) correlation equation (U.S. EPA, 2004). The correlation equation is a function of the  $K_{ow}$  and molecular weight (MW) and is based on an experimental database from Flynn (1990) for approximately 90 chemicals. The  $K_p$  values derived from this equation, presented below, were found to correlate reasonably well with experimentally determined  $K_p$  values.

$$\log K_p = - 2.80 + (0.67 \times \log K_{ow}) - (0.0056 \times MW) \quad (4)$$

where,

$K_p$	(Permeability coefficient)	= chemical-specific (cm/hour)
$K_{ow}$	(Octanol-water partition coefficient)	= chemical-specific (unitless)
MW	(Molecular weight)	= chemical-specific (g/mole)

Chemical-specific values for  $K_{ow}$  and MW are specified by the MDEQ and are presented in Op Memo No. 1, Attachment 1, Table 4: Toxicological and Chemical-Physical Data.

Derivation of  $K_p$  values using equation 4 is recommended over experimentally determined values as it provides a consistent methodology across chemicals, including chemicals that do not have an experimental measurement of  $K_p$ . Additionally, replicated experimental measurements have been shown to vary by one to two orders of magnitude (Vecchia, 1997).

An analysis using the Flynn (1990) database was conducted to determine the range of  $K_{ow}$  and MW where equation 4 would be valid for extrapolation to other chemicals. Using Mandel's analysis (Mandel, 1985), the following boundaries of  $K_{ow}$  and MW for equation 4 were determined and are referred to as the effective predictive domain (EPD):

$$- 0.06876 \leq 0.5088 \times 10^{-4} MW + 0.056466 \log K_{ow} \leq 0.5586 \quad (5)$$

$$- 0.30118 \leq 0.5088 \times 10^{-4} MW + 0.056466 \log K_{ow} \leq 0.1453 \quad (6)$$

This analysis indicates that equation 4 would not apply to chemicals with  $\log K_{ow} < -1$  and  $MW < 60$ , and those with  $\log K_{ow} > 4$  and  $150 < MW < 350$ , and  $MW > 600$ . Generally, chemicals with very large and very small  $K_{ow}$  values are outside the EPD of equation 4. There are 38 hazardous substances in the Part 201 criteria tables that lie within these boundaries. Nonetheless, equation 4 was used to develop conservative  $K_p$  values for the purpose of deriving generic GCC. The equations used to estimate  $SP_o$  are as follows:

$$\text{If } ET \leq t^*, \text{ then: } SP_o = 2 \times K_p \times \sqrt{\frac{6 \times \tau \times ET}{\pi}} \quad (7)$$

$$\text{If } ET > t^*, \text{ then: } SP_o = K_p \times \left[ \frac{ET}{1+B} + 2\tau \left( \frac{1+3B+3B^2}{(1+B)^2} \right) \right] \quad (8)$$

where,

$SP_o$	(Skin penetration per event for organic substances)	= chemical-specific (cm/event)
$t^*$	(Time to reach steady-state)	= chemical-specific (hours)
$\tau$	(Lag time)	= chemical-specific (hours)
ET	(Exposure time)	= 2 hours
$\pi$	(pi)	= 3.141592654
B	(Ratio of the $K_p$ of the stratum corneum to the $K_p$ of the viable epidermis)	= chemical-specific (dimensionless)

### Derivation of B, $\tau$ and $t^*$

Chemical-specific values for B,  $\tau$  and  $t^*$  are calculated from the following steps:

Step 1: Calculate B

$$B = K_p \times \left( \frac{\sqrt{MW}}{2.6} \right) \quad (9)$$

where,

B	(Ratio of the $K_p$ of the stratum corneum to the $K_p$ of the viable epidermis)	= chemical-specific (dimensionless)
$K_p$	(Permeability coefficient)	= chemical-specific (cm/hour)
MW	(Molecular weight)	= chemical-specific (g/mole)

Step 2: Calculate the chemical-specific diffusivity across the stratum corneum ( $D_{sc}$ )

$$D_{sc} = 10^{(-2.80-0.0056MW)} \times I_{sc} \quad (10)$$

where,

$D_{sc}$	(Effective diffusivity across stratum corneum)	= chemical-specific (cm <sup>2</sup> /hour)
$I_{sc}$	(Thickness of stratum corneum)	= 0.001 cm

Step 3: Calculate lag time ( $\tau$ ) in hours

$$\tau = \frac{I_{sc}^2}{6 \times D_{sc}} \quad (11)$$



Step 4: Calculate  $t^*$

$$\text{If } B \leq 0.6, \text{ then } t^* = 2.4 \times \tau \quad (12)$$

$$\text{If } B > 0.6, \text{ then } t^* = \left( b - \sqrt{b^2 - c^2} \right) \left( \frac{I_{sc}^2}{D_{sc}} \right) \quad (13)$$

where,

$$b = \frac{2(1+B)^2}{\pi} - c \quad (14)$$

$$c = \frac{1 + 3B + 3B^2}{3(1+B)} \quad (15)$$

### TARGET RISK LEVEL AND TARGET HAZARD QUOTIENT

The GCC are calculated using a TR for carcinogens or a THQ for non-carcinogens. The TR represents the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a carcinogenic hazardous substance. The required level of protection is no greater than 1 additional cancer above the background cancer rate per 100,000 individuals (written as  $1 \times 10^{-5}$  or  $10^{-5}$  or  $1E-5$ ;  $10^{-5}$  is preferentially used in this document). (Section 20120a(4)). A THQ is the ratio of the chronic daily dose of a hazardous substance (reasonable maximum exposure) divided by the chronic reference dose for that substance. The GCC are calculated using a TR of 1 in 100,000 ( $10^{-5}$ ) (Section 20120a(4) and Section 21304a(3) of NREPA) and a THQ of 1 (Section 20120a(4) of NREPA).

### EXPOSURE ASSUMPTIONS

The generic GCC exposure assumptions were developed to characterize a reasonable maximum exposure (RME). The RME represents a “high end” exposure estimate defined as the highest exposure that is reasonably expected to occur at a site but that is still within the range of possible exposures (U.S. EPA, 1989). Dermal contact with groundwater by the RME individual (RMEI) is unlikely to be continuous over an 8-hour workday. It is reasonable to assume that a RMEI will be in contact with groundwater for 25 percent of the 8-hour workday or 2 hours/day (i.e., ET = 2 hours/day). The ET is one of the parameters used to derive the SP. The SP in combination with the other exposure assumptions (including the EF) is incorporated into the GCC equation. In developing the EF default value, consideration was given to the likelihood of multiple utilities being present and the variability in days required for repair and installation of the various utility types. Accidents or natural events (e.g., frost heaving) necessitating utility repairs were also considered in developing the default EF value. Based on this general knowledge, an EF of 20 days/year is used, which represents both the uncertainty and variability in utility work events that can occur across varying types of land uses. The MDEQ recognizes that in practice this value could overestimate or underestimate exposure. The default value of 20 days/year was selected for generic application to all land use categories statewide. Facilities with a dedicated work force for these activities would likely experience higher exposure rates and would need to have site-specific criteria developed with appropriate exposure rates.





An ED default value of 21 years is used since a utility worker is considered to spend as many years on the job as an industrial worker characterized in the generic soil DCC calculations. The SA is not considered to be equivalent to the SA of the industrial worker. It is more probable that half the lower legs, feet, and hands (i.e., SA=3,300 cm<sup>2</sup>; U.S. EPA, 1997) will be the areas of the body routinely in contact with groundwater contaminants for this scenario. The conventional adult BW of 70 kg is used for the RMEI.

### TOXICITY VALUES

Toxicity values specific to dermal contact exposure are not currently available. Ideally, a dermal toxicity factor would consider point-of-contact toxicity as well as dosimetry information on the dose-response relationship for systemic effects via dermal absorption. Toxic responses elicited from oral doses may differ significantly from responses associated with dermal exposure because of differences in the toxicokinetics between the two routes. Given the absence of dermal exposure information, toxicity factors based on oral dose-response relationships, such as the RfD for noncancer assessment and SF for cancer assessment, must be used to calculate the GCC. Oral toxicity factors, without adjustment for absorption efficiency, are used in the development of the GCC. A detailed discussion of the basis for the dermal toxicity factor is presented in Appendix B.

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This memorandum is intended to provide guidance to 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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- MDEQ. 2004. RRD Operational Memorandum No. 1. Part 201 Cleanup Criteria. Part 213 Risk-Based Screening Levels. December 10, 2004.
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## Appendix A

### EXAMPLE ASSESSMENT FOR ACUTE TOXIC EFFECTS

A toxicological evaluation of the acute systemic effects of cyanide (CN) was completed (MDEQ, 1999) and is summarized here. This evaluation is performed pursuant to Section 20120a(4) of the NREPA, which requires that generic cleanup criteria be protective of the most sensitive effect. The evaluation determined that the acute toxicity of CN is the most sensitive effect; therefore, the acute endpoint was used to generate the generic soil DCC and GCC for CN.

The following acute toxicity data are based on CN poisoning in humans (ATSDR, 1995). Estimation of the lethal dose in humans is difficult since most lethal events occur under either accidental or suicidal conditions. Gettler and Baine (1938) applied an analytical methodology first developed under experimental conditions to 4 human suicide cases to estimate both an average and a lowest human lethal dose. Under controlled experimental conditions, lethal doses of CN were administered to dogs through inhalation and stomach intubation and organ tissues were then analyzed to determine the CN content relative to the lethal dose. Expressed per unit of organ weight, CN content was shown to be consistent throughout several organs with slightly higher concentrations in the blood. Since tissue samples are frequently available for only a limited number of organs from human autopsies, the brain and liver were selected to be representative of the CN present in the total body. Experimental results, confirmed by whole body human autopsies, indicate that the absorbed CN dose is approximately 7 times the total concentration of CN in the liver and brain combined. Based on these findings, absorbed CN lethal doses were calculated for 4 suicide victims and an average human lethal dose for CN was estimated at 1.4 mg/kg of body weight. The lowest human lethal absorbed CN dose of 0.54 mg/kg of body weight is selected as the lowest observed adverse effect level (LOAEL) for the lethal endpoint.

An uncertainty factor (UF) of 10 is applied to the LOAEL to account for human differences in sensitivity to the effects of CN. A full value of 10 is justified in part because no data are available for children, one of the subpopulations of interest in this assessment. An additional UF of 10 is applied to account for extrapolation from a LOAEL to a no-observed adverse effect level. A full 10-fold UF is consistent with MDEQ policy and is justified by the significance of the lethal endpoint used for this analysis. Since the LOAEL is based on a lethal dose in a human subject, no UF is necessary to account for interspecies differences.

Application of the total UF of 100 (10 X 10) to the LOAEL of 0.54 mg/kg results in an acute RfD of 5.4E-3 mg/kg for the lethal effects of CN in human subjects. A comparison of the RfD for lethal effects in humans to that of 2.0E-2 mg/kg-day for chronic effects derived from the Howard and Hanzel (1955) study in rats indicates that lethality is the more sensitive effect in human subjects. Therefore, the RfD of 5.4E-3 mg/kg is used to derive Part 201 soil DCC.

Incorporating this oral acute-based RfD into the GCC equation for non-carcinogens along with setting AT, EF, and ED parameters to a value of one for acute calculations, and using a default  $K_p$  of  $10^{-3}$  for inorganics (see main body of TSD for equations) yields a GCC of 57,000 ug/L (ppb).



The GCC for CN is based on an RfD and may not be protective of other routes of exposure. Other toxic effects that need to be evaluated are contact site toxicity and the inhalation of hydrogen cyanide (HCN) gas. Most CN compounds in water will form HCN and then evaporate. Therefore, it is possible that the emission of HCN gas will be significant at concentrations equal to the acute GCC potentially causing adverse health effects through the inhalation route of exposure. These routes of exposure warrant further evaluation. In addition, CN may be more readily absorbed through the skin than indicated by the generic default SP of 0.001 for inorganic chemicals and should be evaluated further.

Although this toxicological assessment may not result in development of a criterion that is protective of all exposure routes and health endpoints, it does emphasize the importance of considering all toxic effects and relevant exposure pathways in establishing final groundwater cleanup criteria. It also demonstrates that in many cases the scientific database is insufficient to address all effects clearly and quantitatively. For some chemicals, it will be necessary to use a limited database, a qualitative approach, and professional judgment to ensure that all effects are addressed in developing a generic GCC.

## REFERENCES

- ATSDR (Agency for Toxic Substances and Disease Registry). 1995. Toxicological Profile for Cyanide. U.S. Department of Health & Human Services, Atlanta, Georgia.
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## Appendix B

**DERMAL TOXICITY FACTOR**

Toxicity values specific to dermal contact exposure are not currently available. Ideally, a dermal toxicity factor would consider point-of-contact toxicity as well as dosimetry information on the dose-response relationship for systemic effects via dermal absorption. Toxic responses elicited from oral doses may differ significantly from responses associated with dermal exposure because of differences in the toxicokinetics (absorption, metabolism, distribution, and elimination) between the two routes. Given the absence of this information, toxicity factors based on oral dose-response relationships, such as the RfD for noncancer assessment and SF for cancer assessment, must be used to calculate the GCC.

Oral toxicity factors are typically based on administered dose whereas exposure estimates for the dermal route yield an absorbed dose. To characterize risk for the dermal exposure pathway, an adjustment of the oral toxicity values to represent an absorbed rather than an administered dose is necessary. The U.S. EPA (1989) general risk assessment guidance and dermal risk assessment guidance (U.S. EPA, 2004) recommend that the toxicity adjustment be based on the gastrointestinal (GI) absorption efficiency of the “critical study” that forms the basis of the RfD or SF. This is not significant to the many organic hazardous substances whose oral absorption in the critical study was complete (i.e., 100 percent; the absorbed dose is equal to the administered dose) and would not require an adjustment to the toxicity value. Toxicity factor adjustments are significant for hazardous substances whose GI absorption is significantly less than 100 percent (i.e., 50 percent). In these cases, the absorbed dose, which is more representative of the systemic dose causing the toxic effect, is much smaller than the administered dose.

The U.S. EPA (2004) proposes that an adjustment to the oral toxicity factor should be made when the following conditions are met: (1) the toxicity value derived from the critical study is based on administered dose (e.g., delivery in diet or by gavage) in the study design; (2) a scientifically defensible database demonstrates that the GI absorption of the chemical from a medium (e.g., water, feed) similar to the one used in the critical study is significantly less than 100 percent (i.e., 50 percent). A cutoff of 50 percent absorption is recommended to represent the intrinsic variability in the analysis of the absorption studies. Applying this cutoff level eliminates the need to make relatively small adjustments in the toxicity value that would otherwise imply a level of accuracy not supported by the scientific literature (U.S. EPA, 2004). In the absence of the chemical-specific data on absorption efficiency, the U.S. EPA recommends 100 percent absorption for organic and inorganic substances.

Concomitant with this recommendation, the U.S. EPA acknowledges that adjusting toxicity values from administered to absorbed doses based on absorption efficiency introduces some uncertainty. A portion of this uncertainty involves important distinctions between “absorption” and “bioavailability.” Absorption refers to the disappearance of a chemical from the GI lumen, while bioavailability is the rate and amount of a chemical that reaches the systemic circulation unchanged. Bioavailability represents both absorption and pre-systemic metabolism. Pre-systemic metabolism includes both gut wall and liver metabolism, with liver metabolism referred to as the “first pass effect,” playing the major role. First pass liver metabolism may be an



activating or detoxifying process, further complicating the route-to-route extrapolation. Ultimately, toxicity is a function of the contaminant concentration at the site of action.

At present, oral toxicity factors, without adjustment for absorption efficiency, are used as the dermal toxicity factor in development of the GCC.

## REFERENCES

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

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