

**APPENDIX B**  
**DEVELOPMENT OF RISK-BASED TARGET LEVELS**

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## A. INTRODUCTION

The procedure used to calculate Tier 1 risk-based target levels (RBTLs) and Tier 2 site-specific target levels (SSTLs) is presented in this appendix. This procedure requires quantitative values of:

- Target risk levels,
- Chemical-specific toxicological factors,
- Physical and chemical properties of the chemicals of concern (COCs),
- Receptor-specific exposure factors,
- Fate and transport parameters, and
- Mathematical models.

Each of these factors is discussed below. Additionally, this appendix discusses the (i) target levels for lead (Section B.8), and (ii) estimation of target levels when LNAPL is present on the groundwater surface (Section B.9).

For Tier 1 risk assessments, MDNR has calculated RBTLs for each of the COCs (refer to Section 5.3.3 and Table 5-1), the receptors (refer to Section 6.1.2), and the commonly encountered routes of exposure (refer to Section 6.1.3) using conservative assumptions applicable to most Missouri sites. The resultant Tier 1 RBTLs are presented in Tables 7-1 through 7-6(c).

For Tier 2 and Tier 3 risk assessments, the risk evaluator will calculate the SSTLs using technically justifiable site-specific data and, for Tier 3, pathway-specific models. For Tier 2 risk assessments, the models used for developing the Tier 1 RBTLs must be used. A Tier 3 risk assessment may include different models, though the model to be used must be approved by MDNR.

### B.1 TARGET RISK LEVELS

A risk-based decision making process requires the specification of a target risk levels for both carcinogenic and non-carcinogenic adverse health effects. For carcinogenic effects, MDNR will use an **individual excess lifetime cancer risk (IELCR) of  $1 \times 10^{-5}$**  as the target risk for both current and future receptors. For non-carcinogenic effects, the acceptable level is a hazard quotient of one (1) for current and future receptors. Due to the limited number of COCs, additivity of risk is not considered.

For evaluating the ingestion of groundwater and protection of groundwater resource pathways, Maximum Contaminant Levels (MCLs) or, where MCLs are not available, health advisories were used as the target concentrations at the point of exposure. For chemicals that do not have such levels, the target concentration at the point of exposure (POE) was estimated assuming ingestion of groundwater, inhalation of vapors from indoor water use, and dermal contact with water under residential conditions.

Potential impacts to streams and other surface water bodies from a release must be evaluated and surface water quality protected as per 10 CSR 20-7.031. Allowable concentrations in surface water for COCs are presented in Table 6-1.

## B.2 QUANTITATIVE TOXICITY FACTORS

Toxicity values for the COCs are presented in Table B-1. MDNR may update the data in Table B-1 as new information becomes available.

Typically, the toxicity values in Table B-1 will also be used for Tier 3 risk assessments, although alternate values may be used at Tier 3 with adequate justification and the approval of MDNR. Current toxicity values were obtained from the *Departmental Missouri Risk-Based Corrective Action Technical Guidance* (MDNR, April 2006) which were extracted from the hierarchy of sources as per “*Human Health Toxicity Values in Superfund Risk Assessments*,” *OSWER directive 9285.7-53, December 5, 2003*. Specifically it included:

1. Tier 1: Integrated Risk Information System (IRIS),
2. Tier 2: Provisional Peer Reviewed Toxicity Values (PPRTVs),
3. Tier 3: Miscellaneous Sources:
  - (i) National Center for Environmental Assessment (NCEA) as listed in USEPA’s Region IX Preliminary Remediation Goal (PRG) Table,
  - (ii) California Office of Environmental Health Hazard Assessments (OEHHAs) chemical database,
  - (iii) Health Effects Assessment Summary Tables (HEAST) as listed in USEPA’s Region IX PRG tables, and
  - (iv) Table for Texas Risk Reduction Program.

Dermal toxicity values are not available in the above sources; therefore the dermal toxicity values were calculated. The assumption underlying the calculation of dermal toxicity values is that the dermal toxicity of the chemical is the same as the oral toxicity values, except that a semi-permeable barrier (the skin) affects absorption. Using oral toxicity values to calculate dermal toxicity values is based on sound toxicological principles, and in the absence of direct measurement of dermal toxicity, considered an acceptable alternative by the USEPA. However, the calculation is complicated due to the fact that different chemicals pass through the skin with different efficiencies. These differing efficiencies are factored into the formulae for dermal toxicity as the term “oral absorption factors ( $RAF_o$ ).”

The formulae for calculation of slope factor ( $SF_d$ ) and reference dose ( $RfD_d$ ) for dermal exposure are as below:

$$SF_d = \frac{SF_o}{RAF_o} \quad (1)$$

$$RfD_d = RfD_o \times RAF_o \quad (2)$$

where,

- $SF_o$  = Slope factor for oral exposure (mg/kg-day)<sup>-1</sup>,  
 $RfD_o$  = Reference dose for oral exposure (mg/kg-day)<sup>-1</sup>, and  
 $RAF_o$  = Oral absorption factor (dimensionless).

The oral absorption factors are not readily available. Conservatively, a value of 1.0 was assigned for all chemicals.

The dermal absorption factors were obtained from the *Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual, Part E Supplemental Guidance for Dermal Risk Assessment* (USEPA, 2004). However, this guidance does not have any recommendations for volatile organic compounds (VOCs), or inorganic compounds. For these compounds, the absorption factors were obtained from the USEPA Region III and RAGS, Volume 1, Part A.

The parameters used for dermal contact pathway are shown in Table B-1 and are discussed below:

### Permeability Coefficient

For organic chemicals, the chemical-specific permeability coefficients in water were obtained from Exhibit B-3 of the *RAGS Volume I, Part E* (USEPA, 2004). For chemicals not listed in Exhibit B-3, the permeability constant,  $K_p$  (cm/hr), was estimated using the following equation as per the *RAGS Volume I, Part E* (USEPA, 2004):

$$\log K_p = -2.80 + 0.66(\log K_{ow}) - 0.0056MW \quad (3)$$

where,

- $K_{ow}$  = Octanol-water partition coefficient (dimensionless), and  
 $MW$  = Molecular weight (g/mole).

Note the  $MW$  and  $K_{ow}$  are presented in Table B-3.

For metals and inorganics, the permeability coefficients were obtained from Exhibit B-4 of the *RAGS Volume I, Part E* (USEPA, 2004). If no value is available, the permeability coefficient of  $1 \times 10^{-3}$  cm/hr is recommended as default value (USEPA, 2004).

### Relative Contribution of Permeability Coefficient

The relative contribution of permeability coefficients for the chemicals was obtained from Exhibit B-3 of the *RAGS Volume I, Part E* (USEPA, 2004). For chemicals not listed in Exhibit B-3, the relative contribution of permeability coefficient,  $B$  (unitless), was estimated using the following equation as per the *RAGS Volume I, Part E* (USEPA, 2004):

$$B = K_p \frac{\sqrt{MW}}{2.6} \quad (4)$$

### Lag Time

The lag times for the chemicals,  $\tau_{event}$  (hr/event), were obtained from Exhibit B-3 of the *RAGS Volume I, Part E* (USEPA, 2004).

As per the *RAGS Volume I, Part E* (USEPA, 2004), the equation to estimate  $\tau_{event}$  is derived as below:

$$\frac{D_{sc}}{l_{sc}} = 10^{(-2.80 - 0.0056MW)} \quad (5)$$

$$\tau_{event} = \frac{l_{sc}^2}{6 \times D_{sc}} \quad (6)$$

where,

- $D_{sc}$  = Effective diffusion coefficient for chemical transfer through the stratum corneum (cm<sup>2</sup>/hr), and  
 $l_{sc}$  = Apparent thickness of stratum corneum (cm).

The lag time is dependent on the effective diffusion coefficient for chemical transfer through the stratum corneum and the apparent thickness of stratum corneum. Assuming  $l_{sc} = 10^{-3}$  cm as a default value for the thickness of the stratum corneum,  $\tau_{event}$  becomes:

$$\tau_{event} = 0.105 \times 10^{(0.0056MW)} t^* = 2.4 \tau_{event} \quad (6)$$

If  $B > 0.6$ ,

$$t^* = 6 \tau_{event} \times \left( b - \sqrt{b^2 - c^2} \right) \quad (7)$$

where  $b$  and  $c$  are correlation coefficient which have been fitted to the data from Flynn, G.L. (1990) and are expressed as below:

$$c = \frac{1 + 3B + 3B^2}{3(1 + B)} \text{ and } b = 2 \times \frac{(1 + B)^2}{\pi} - c.$$

## **Fraction Absorbed**

The fraction absorbed for the chemicals considered were obtained from Exhibit B-3 of the *RAGS Volume I, Part E* (USEPA, 2004). For chemicals not listed in Exhibit B-3, the fraction absorbed water, *FA* (unitless), was estimated from Exhibit A-5 of the *RAGS Volume I, Part E* (USEPA, 2004).

### **B.3 PHYSICAL AND CHEMICAL PROPERTIES OF THE COCs**

Physical and chemical properties of the COCs are listed in Table B-2. These values must be used for all MRBCA evaluations unless there are justifiable reasons to modify these values and MDNR concurs. The use of different values would be allowed only under a Tier 3 risk assessment.

### **B.4 EXPOSURE FACTORS**

A list of the exposure factors and their values that were used to develop the Tier 1 RBTL values is presented in Table B-3. The exposure factors are typically estimated based on literature rather than site-specific measurements. The values listed in Table B-3 are conservative values that are exceeded by about 5% of the population, i.e. they are the upper 95<sup>th</sup> percentile values. For a Tier 3 risk assessment, site-specific exposure factor values may be used with thorough justification and MDNR approval.

A source of exposure factor information is U.S. EPA's *Exposure Factors Handbook Volume 1 – General Factors* (August 1997). Other sources of exposure factor data may be used for Tier 3 risk assessment with approval of MDNR.

### **B.5 FATE AND TRANSPORT PARAMETERS**

Fate and transport parameters are necessary to estimate the target levels for the indirect routes of exposure. These factors characterize the physical site properties such as depth to groundwater, soil porosity, and infiltration rate.

For a Tier 2 risk assessment, a combination of site-specific and default fate and transport values may be used. However, the value of each parameter used, whether site-specific or default, must be justified based on site-specific conditions. Where site-specific conditions are significantly different from the Tier 1 assumptions, site-specific values should be used.

For a Tier 3 risk assessment, the specific fate and transport parameters required to calculate the target levels will depend on the model used.

## **B.6 MATHEMATICAL MODELS**

The input parameters mentioned above are used in two types of models, or equations, to calculate the risk-based target levels. These are the (i) uptake equations and (ii) fate and transport models. For Tier 1 and Tier 2 risk assessments, MDNR has selected the models and equations included in this appendix. These models have been programmed in the MRBCA Computational Software and were used to develop the Tier 1 RBTLs presented in Section 7.0.

For Tier 2 risk assessments, the same equations and models must be used. With the prior approval of MDNR through the submittal of a Tier 3 work plan, a different set of models may be used for Tier 3 risk assessments.

The equations and models used for estimating Tier 1 RBTLs and Tier 2 SSTLs are presented in Section B.10.

## **B.7 RISK-BASED TARGET LEVELS**

The input parameters and models mentioned above are used to calculate RBTLs for each COC and each route of exposure. For certain COCs, the target levels developed for groundwater may exceed the solubility of the COC. In such cases, the values shown in Tables 7-1 through 7-6(c) are the actual calculated values, annotated with an asterisk indicating that the calculated values exceed solubility. Similarly, for certain COCs and pathways, soil target levels may exceed levels at which the soil is saturated by the chemical. As with the groundwater values, in such case, the values shown in Tables 7-1 through 7-6(c) represent the actual calculated values annotated with an asterisk indicating that the calculated value exceeds the soil saturation value. The saturated soil concentrations, effective soil concentrations, effective solubility, and effective soil vapor concentrations are presented in Table B-5.

For both the above cases, the results can be interpreted to mean that the chemical and the pathway do not need any further evaluation and that the site-specific concentrations are protective of the pathway. Further, if concentrations above the solubility level in groundwater and above the soil saturation level are measured in a sample, the implication is that the sample had some free product in it.

## **B.8 TARGET LEVELS FOR LEAD**

Lead has a number of toxic effects, but the main target for lead toxicity is the nervous system. Young children are especially vulnerable from the standpoints of both exposure and toxicity. Certain behaviors, such as crawling and playing on the floor or ground, result in increased exposure, and the central nervous system of a young child is particularly susceptible because it is still developing. Chronic exposure to even low levels of lead that are not overly toxic can result in impaired mental development.

The U.S. EPA has developed the Integrated Exposure Uptake Biokinetic [IEUBK] Model

to predict the risk of elevated blood lead (PbB) in children under the age of seven that are exposed to environmental lead from various sources. The model predicts the probability that a child exposed to lead concentrations in a specified media will have a PbB level greater than 10 micrograms per deciliter (ug/dL), the level associated with adverse health effects (EPA, 1999).

Because of the greater vulnerability of children to lead exposure and toxicity, the primary concern in a residential setting is the risk lead poses to children. In the non-residential scenario, children are not directly exposed, but fetuses carried by female workers can be exposed. The EPA has developed an adult lead methodology (ALM) to assess risk in this scenario (EPA, 1996b). The methodology is limited in terms of exposure media (soil/dust). Specifically, the methodology estimates the PbB concentrations in fetuses carried by women exposed to lead contaminated soils. Research is ongoing to develop a model capable of simulating multimedia exposures over the entire human lifetime. Until this model is developed, MDNR will require the use of the IEUBK model for residential scenarios and ALM for non-residential scenarios.

At petroleum impacted sites, use of the IEUBK or ALM to assess lead risk and determine cleanup goals is not necessary. Based on the above discussion, MDNR will use the following Tier 1 levels for lead (MDNR, 2001):

Residential land use soil (direct contact with soil)	260 mg/kg
Non-residential land use soil (direct contact with soil)	660 mg/kg

The groundwater target level where domestic use of groundwater is a complete pathway is 0.015 mg/L.

## **B.9 TARGET LEVEL CALCULATION FOR LNAPL**

As discussed in Section 6.8, the MRBCA process allows for the calculation of risk and target levels when LNAPL is present. Under this condition, the primary routes of exposure are (i) indoor inhalation for a residential or a non-residential receptor, and, if the domestic use of groundwater pathway is complete or potentially complete, (ii) the protection of a current or potential future point of exposure (POE) groundwater well. For these pathways, the key step is the calculation of the vapor concentration and the dissolved concentration emanating from the LNAPL. Once these concentrations have been estimated, risk and target levels can be determined using the procedures presented in Section B.1 to B.7 above.

Soil Vapor Concentration: The soil vapor concentration in equilibrium with LNAPL is the effective soil vapor concentration. This concentration depends on (i) the chemical-specific saturated soil vapor concentration, and (ii) the mole fraction of the chemical in the LNAPL for which the soil vapor concentration is being calculated. If the mole fraction of a COC is not known, default mole fractions, calculated using the weight fraction of a specific COC in the LNAPL (refer to Table 5-2), may be used. Alternatively, the evaluator may sample the LNAPL for laboratory analysis to determine site-specific values for the weight and mole fractions. The specific equations used to

calculate the effective soil vapor or effective dissolved concentrations are presented in Section B.10.

In the forward model of risk assessment, the effective soil vapor and dissolved concentrations can be used to calculate the risk due to indoor inhalation or to estimate the concentration in the POD and POE wells. In the backward mode of risk assessment, the Tier 1 RBTLs and Tier 2 and 3 SSTLs must be compared with the effective concentrations. The models and equations to be used are presented in Section B.10.