Technical Support Memorandum:

Development of Migration to Groundwater Cleanup Levels

This memo supplements Fact Sheet #12 and describes the methods used to develop migration to groundwater cleanup levels for the VRP.

Development of Migration to Groundwater Cleanup Levels:

I. Introduction

Voluntary Remediation Program (VRP) Fact Sheet 12 and the Cleanup Level Lookup Table (Lookup Table) provide a simple, easy-to-use method to evaluate whether site soil contamination is present at a level that may require further evaluation and/or remediation for protection of human health. The soil portion of the Cleanup Level Lookup Table is a list of chemicals with pre-calculated screening levels based on: (1) direct contact with soil (residential cleanup levels), which includes ingestion, skin contact, and inhalation) and, (2) the potential for soil contamination to migrate to groundwater. The residential soil cleanup levels are derived from EPA Region 9 Regional Screening Levels (RSLs). The parameters and equations used to develop the VRP migration to groundwater (MGW) default cleanup levels are described below. This Technical Support Memorandum will focus solely on the development of the MGW cleanup levels. For an in-depth discussion and additional guidance for investigation and remediation of soil contamination, please see Fact Sheets 8, 12 & 21.

The equations the VRP has chosen for calculating potential site-specific impacts to groundwater are provided in Section III below. The equations are based on two well-known and widely accepted references: the USEPA (1996a), (1996b) Soil Screening Level Guidance, and the Soil Attenuation Model, (Connor et al, 1997). Both references back-calculate a concentration in soil from an acceptable groundwater concentration for a given chemical. The VRP has provided Fact Sheet 12 and the Lookup Table that include both the residential soil cleanup levels, and the migration to groundwater cleanup levels. The migration to groundwater equations use conservative default site conditions and assumptions. The default levels provided in the Lookup Table are appropriate for use at sites where no site-specific data such as organic carbon content of the soil, water & air-filled soil porosities or dry soil bulk density are available.

Although this methodology can be used for all contaminants, it is not recommended for metals unless a site-specific soil-water partitioning coefficient (Kd) has been developed. The speciation of a metal greatly influences its adsorptive capacity, or Kd, and therefore its mobility. Because the soil-water equation methodology does not take speciation into account, the methodology may result in a more conservative cleanup level than is appropriate for the site. The Lookup Table provides such default cleanup levels. Volunteers are encouraged to collect appropriate site-specific data that may enable a more representative calculation for migration to groundwater to be performed. The VRP has made available a Fate and Transport spreadsheet (Fact Sheet 25, http://deq.wyoming.gov/shwd/voluntary-remediation-program/resources/fact-sheets/) to quickly and easily generate site-specific cleanup levels that are protective of groundwater.

II. Soil Cleanup Level Partitioning Equation Assumptions

The USEPA Soil Cleanup Level Soil-Water Partition equation makes the following conservative assumptions for calculating migration to groundwater cleanup levels:

- The source is infinite,
- Contaminants are uniformly distributed throughout the zone of contamination,
- Soil contamination extends from the surface to the water table,
- There is no chemical or biological degradation in the unsaturated zone,
- Equilibrium soil/water partitioning is instantaneous and linear in the contaminated zone,
- The receptor well is at the edge of the source (i.e., there is no dilution from recharge downgradient of the site) and is screened within the plume,
- The aquifer is unconsolidated and unconfined,
- Aquifer properties are homogenous and isotropic
- There is no attenuation (i.e., adsorption or degradation) of contaminants in the aquifer; and,
- NAPLs are not present at the site.

In the absence of site-specific data, conservative assumptions are used, such as infinite source and a dilution attenuation factor of 1, to provide a level of assurance that the resulting default cleanup level calculated is appropriate for use in an unrestricted land use scenario. Equation A calculates the total amount of an organic contaminant that may remain in soil without causing an unacceptable concentration of the contaminant in groundwater.

III. Equations for calculating Migration to Groundwater Cleanup Levels

Equation A for organic contaminants: $$C_t = C_w \left\{ \left(K_{oc} \; f_{oc} \right) + \frac{\theta_w + \theta_a \; H'}{\rho_b} \right\}$$

Equation A Parameters Used for Migration to Groundwater Calculations (Organic Contaminants)				
Parameter	Definition	Default value	Units	Source
C_t	Migration to groundwater cleanup level	----------	mg/kg	Calculated using Eq. A
C_w	Non-zero MCL, DWEL, ADWEL	----------	mg/L	VRP Fact sheet 13
K_{oc}	Soil-organic carbon-water partitioning coefficient	Chemical-specific	L/kg	EPA Soil Screening Guidance (1996a); EPI Suite *
f_{oc}	Organic carbon content of the soil (specific to Wyoming soils)	.001 (0.01%)	----------	Carel et al., 1988
θ_w	Water-filled soil porosity	.003 (0.03%)	L_{water}/L_{soil}	
θ_a	Air-filled soil porosity	.13	L_{air}/L_{soil}	
H'	Henry's Law constant (dimensionless)	Chemical-specific	----------	EPA Soil Screening Guidance (1996a); EPI Suite *
ρ_b	Dry soil bulk density	1.5	kg/L	EPA 1991

Equation B for inorganic contaminants: $$C_t = C_w \left\{ (K_d) + \frac{\theta_w + \theta_a H'}{\rho_b} \right\}$$

Equation B Parameters Used for Migration to Groundwater Calculations (Inorganic Contaminants)				
Parameter	Definition	Default value	Units	Source
C_t	Migration to groundwater cleanup level	----------	mg/kg	Calculated using Eq. B
C_w	Non-zero MCL, DWEL, ADWEL	----------	mg/L	Fact sheet 13
K_d	Soil- water partitioning coefficient	Chemical-specific	L/kg	EPA Soil Screening Guidance (1996a); EPI Suite *
θ_w	Water-filled soil porosity	.003 (0.03%)	L_{water}/L_{soil}	
θ_a	Air-filled soil porosity	.13	L_{air}/L_{soil}	
H'	Henry's Law constant (dimensionless), and assumed to be zero for inorganics (except mercury)	0	----------	EPA Soil Screening Guidance (1996a); EPI Suite *
ρ_b	Dry soil bulk density	1.5	kg/L	EPA 1991

* K_{oc} and Henry's dimensionless constants (for use in the MGW equation) were taken from EPA's Soil Screening Guidance (http://www.epa.gov/superfund/health/conmedia/soil/pdfs/ssg496.pdf), where available, or from EPA's EPI Suite (http://www.epa.gov/opptintr/exposure/pubs/episuite.htm)

IV. Drinking Water Equivalent Levels (DWEL) and Alternative Drinking Water Levels (ADWEL) used to calculate Migration to Groundwater Cleanup Levels (Equations A and B)

When MCL or WQD Chapter 8 drinking water concentrations were available, those values were used to calculate a MGW value; however, if none were available, the equations below were used to calculate an **acceptable drinking water concentration for use as a C_w value in the equations**.

DWELs for non-carcinogenic substances and ADWELs for carcinogenic substances were calculated using the following equations, as found in WDEQ Chapter 17 WQD Rules and Regulations:

$$DWEL = \frac{(RfD_o)(ABW)(HQ)}{(DWI)(AB)(FOE)}$$

Non-carcinogenic substances

$$ADWL = \frac{(RISK)(ABW)(LIFE)}{(CPF_O)(DWI)(AB)(FOE)(DUR)}$$

Carcinogenic substances

DWEL= Drinking water equivalent level (mg/L)
ADWL= Acceptable Drinking Water Levels (mg/L)
RfDo= Oral reference dose (mg/kg-day); chemical specific

ABW= Average adult body weight over exposure period (80 kg)
HQ= Hazard Quotient (1)
DWI= Adult drinking water intake, 2.5 L/day
AB= Gastrointestinal absorption rate (1.0)
FOE= Frequency of exposure (350 days/365days = 0.96)
DUR= Duration of exposure (26 years)
RISK= Cancer risk for drinking water, (1×10^{-6})
LIFE= Lifetime (70 years)
CFPo= Oral cancer potency factor $(mg/kg\text{-}day)^{-1}$, chemical specific

Toxicity values for use in the DWEL and ADWL equations were researched and updated using the following hierarchy:

1. EPA's Integrated Risk Information System (IRIS) (http://www.epa.gov/IRIS/)
2. The Provisional Peer Reviewed Toxicity Values (PPRTVs) derived by EPA's Superfund Health Risk Technical Support Center (STSC) for the EPA Superfund program (http://hhpprtv.ornl.gov/index.html)
3. The Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs) (http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls_march_2013.pdf)
4. The California Environmental Protection Agency (OEHHA) Office of Environmental Health Hazard Assessment's Chronic Reference Exposure Levels (RELS) (http://www.oehha.org/tcdb/index.asp)
5. Screening toxicity values in an appendix to certain PPRTV assessments (see the User's Guide at http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm for additional information on this toxicity values resource).
6. The EPA Superfund program's Health Effects Assessment Summary (HEAST) (http://epa-heast.ornl.gov/)

V. For sites with site-specific information

A site-specific migration to groundwater value may be calculated using site-specific information. Certain input parameters in the equations lend themselves to site-specific modification. The use of site data to modify default input parameters in the soil-water partition equation may generate a higher remediation standard that is still protective and appropriate for a given site. Some input parameters will have a greater effect on increasing a cleanup level than others. In particular, higher values for soil organic carbon content, depth to ground water and thickness of the contaminated zone will have the greatest effect on increasing the cleanup level. Please see Fact Sheet 25 and the associated spreadsheet (which uses Equation 1 or Equation 2, as appropriate) for more information.

VI. Summary

Using the referenced values and equations above, MGW values were calculated using updated toxicity and drinking water values and inserted into the 2013 Lookup Table. Over 150 Chemicals of Concern (COCs) default values can be found in the lookup table. These chemicals were chosen as they are the most common COCs found at VRP sites. If the volunteer encounters a chemical not listed on the lookup table, please use the formulas in the above referenced documents to calculate site specific cleanup levels or contact a VRP project manager for further guidance.

References

Hawai'i Department of Health. April 2007. Use of Laboratory Batch Tests to Evaluate Potential Leaching of Containments from Soil. Hazard Evaluation and Emergency Response.

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Michigan Department of Environmental Quality, October 2004. RRP Operational Memorandum No. 2, Sampling and Analysis – Attachment 2, Soil Leaching Methods. Remediation and Redevelopment Division.

New Jersey Department of Environmental Protection, December 2008a. Guidance Document, Development of Site-Specific Impact to Ground Water Soil Remediation Standards Using the Soil-Water Partition Equation; Revised.

USEPA (1988). Determination of Total Organic Carbon in Sediment (Lloyd Khan Method). U.S. Environmental Protection Agency, Region II, Edison, New Jersey. Available at http://www.epa.gov/region02/qa/documents.htm

USEPA (1996a). Soil Screening Guidance: User's Guide, April 1996. Office of Solid Waste and Emergency Response: Washington, DC, EPA/540/R-96/018.

USEPA (1996b). Soil Screening Guidance: Technical Background Document, May 1996. U.S. Environmental Protection Agency, Office of Emergency Response: Washington, DC, EPA/540/R-95/128 PB96-963502.