PROTOCOL FOR VCP REMEDIATION GOAL LOOKUP TABLES
NEBRASKA VOLUNTARY CLEANUP PROGRAM

1.0 WHAT'S NEW – SEPTEMBER 2012

The September 2011 version of this Protocol has revised chemical-specific and media-specific remediation goals (RGs) for direct contact exposures from soils and groundwater from the August 2006 Protocol based on review of any updated chemical-specific toxicological and/or other risk assessment information since 2006. The NDEQ also introduces new RGs based on potential intrusion of vapors into enclosed structures for volatile contaminants in soil gas and groundwater. The rationale used to develop these vapor intrusion (VI) RGs is presented in Attachment D of this Protocol.

2.0 INTRODUCTION

This guidance describes the protocol employed by Nebraska Department of Environmental Quality (NDEQ) to establish chemical-specific and media-specific remediation goals (RGs) for soil and ground water that are protective of human health and the environment. NDEQ created this document to support a consistent and streamlined decision-making process for sites being managed under the Nebraska Voluntary Cleanup Program (VCP). The goal is to use this guidance as one tool to identify RGs for a site in the VCP. This document generally refers to RGs as "VCP RGs."

The protocol described in this guidance reflects approaches and procedures for establishing RGs that NDEQ, other state agencies, and the U.S. Environmental Protection Agency (U.S. EPA) use in existing programs to assess potential human health risks posed by potential exposure to environmental contamination. The bases of this approach are the U.S. EPA guidance and directives established to support the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). In addition, this document relies on Nebraska standards promulgated under Title 117—Nebraska Surface Water Quality Standards (NDEQ 2009) and Title 118—Ground Water Quality Standards and Use Classification (NDEQ 2006). This protocol resulted from discussions between NDEQ and the Nebraska Department of Health and Human Services (NDHHS) Risk Assessment Program. Please note that the VCP RGs developed in this document are not static, but "living" benchmarks that will be periodically revised as significant new exposure and toxicological information becomes available.

Complexities of contaminated sites vary widely in physical and contaminant characteristics, exposure factors, and resultant risks and hazards. This protocol aims to provide an acceptable level of protectiveness and flexibility that will promote high-quality, effective, and efficient cleanups by:

- Streamlining decision-making
- Framing a consistent approach
- Ensuring remedial action that protects human health and the environment
- Providing flexibility either to use risk-based lookup tables or to develop site-specific risk-based cleanup goals
- Considering land use
- Maintaining consistency with NDEQ and U.S. EPA guidance.

The remaining sections of this guidance provide an overview the protocol (Section 3.0); describe the tiered approach for establishing VCP RGs (Section 4.0), specify procedures for developing the VCP RG lookup tables (Section 5.0); furnish a guide to interpreting the VCP RG lookup tables (Section 6.0); discuss the technical documentation supporting the VCP RG lookup tables, including assumptions used to calculate the VCP RGs (Section 7.0) and summarize the document (Section 8.0).

3.0 OVERVIEW

The following sections describe various aspects of the VCP RG protocol approach, including the three tiers of the VCP RG approach, as discussed in Section 3.1. This protocol focuses on Tier 2 values, referred to as VCP RGs, but also presents the Tier 1 and Tier 3 options. Section 3.2 outlines the assessment of noncancer hazards and carcinogenic risks associated with exposure to site-related contaminants, including the assessment of exposure to multiple contaminants undergoing a Tier 2 evaluation. Section 3.3 discusses the requirements for determining the assessment of risk for ecological receptors.

3.1 VCP REMEDIATION GOAL PROTOCOL

The VCP RG protocol is based on a three-tiered approach: (1) determine if contamination identified on site is greater than background levels (Tier 1); (2) use a set of VCP RG lookup tables (Tier 2); and (3) develop site-specific VCP RGs (Tier 3). The Tier 2 approach is similar to methodologies followed to develop RGs by U.S. EPA in “Regional Screening Levels” (RSLs) (U.S. EPA 2010); many other state

voluntary cleanup programs that use risk-based lookup tables; and the Tier 1 lookup tables in NDEQ's Risk-Based Corrective Action (RBCA) at Petroleum Release Sites: Tier 1/Tier 2 Assessments (NDEQ 2009). The Tier 3 approach is similar to other approaches under existing U.S. EPA and NDEQ guidance. These approaches range from: (1) completing a baseline risk assessment in accordance with U.S. EPA's *Risk Assessment Guidance for Superfund (RAGS)*…."Part B…". (U.S. EPA 1991a), to (2) modifying only certain exposure pathways and assumptions to reflect site-specific conditions, to (3) using site-specific values for fate and transport parameters consistent with the Tier 2 approach in NDEQ's RBCA at Petroleum Release Sites (NDEQ 2009).

3.2 NONCARCINOGENIC HAZARDS AND CARCINOGENIC RISKS

The VCP RGs were developed to assess both adverse noncarcinogenic health effects and carcinogenic risks that may be associated with chronic (i.e., long-term) exposure to site-related contaminants. In cases where a contaminant is both a carcinogen and may also be associated with adverse noncarcinogenic effects, the VCP RG provided is based on the lower (more conservative) of these two values.

For noncarcinogenic effects, protective mechanisms in the body are believed to exist that must be overcome before the adverse effect is manifested. As a result, exposure to a contaminant can be tolerated without expression of adverse effects up to a threshold level. This threshold level is referred to as the reference dose (RfD) for oral exposure or reference concentration (RfC) for inhalation exposure. The general assumption is that exposure below the RfD or RfC will pose no appreciable risk of adverse effects on human health, including the health of sensitive populations during a lifetime. The ratio between the RfD or RfC and the exposure is known as the Hazard Quotient (HQ). For residential exposure to site-related contaminants that may be associated with adverse noncarcinogenic effects, the VCP RGs are set at a Hazard Quotient of 0.25. This conservative assumption is believed to be protective of not only sensitive populations but considers potential exposure to more than one contaminant. For workplace exposure, industrial VCP RGs are set at a Hazard Quotient of 1.0. When an individual is exposed to multiple noncarcinogenic contaminants, the sum of HQs calculated for an exposure pathway (the way a contaminant comes in contact with an individual—e.g., ingestion, inhalation) is referred to as the Hazard Index (HI). For both residential and industrial VCP RGs, a target organ-specific HI exceeding 1.0 is not to be exceeded. See Section 5.3 for further information on HQs and HIs.

For carcinogens, results of clinical studies are used to estimate the probability of increasing potential for developing cancer due to chronic exposure to contaminated media. The chemical-specific oral slope

factor (SF) or inhalation unit risk factor (URF) represents the carcinogenic risk factor: the higher the SF or URF, the greater the potential for that contaminant to cause a cancer over a lifetime. This SF (along with an estimated dose) or URF is used to calculate a probability of excess cancers occurring over a lifetime. The probability is expressed as an excess probability of an *individual* (not a population) developing cancer over a lifetime as a result of exposure to the carcinogen. This incremental or excess individual lifetime cancer risk exceeds the background cancer risk (for example, it is expressed as one excess cancer incidence per 1,000,000 population [1 in 1,000,000] or 1×10^{-6}). U.S. EPA's National Contingency Plan (NCP) has established 1×10^{-6} as a point of departure for determining remediation decisions when applicable, relevant, and appropriate regulations are not available. For the residential VCP RGs a point of departure of 1×10^{-6} has also been selected, therefore VCP RGs that are based on carcinogenic risk were set at an excess cancer risk level of 1×10^{-6}. U.S. EPA guidance indicates that action at a site is generally warranted when the cumulative carcinogenic risk from exposure to one or more carcinogens is greater than $1 \text{ X } 10^{-4}$ (1 in 10,000) (U.S. EPA 1991). For residential VCP RGs, a combined cumulative cancer risk level of 1×10^{-5} (1 in 100,000) should not be exceeded. For workplace exposure the industrial VCP RGs are based on an excess cancer risk level of 1×10^{-5} and a combined cumulative cancer risk level of 1×10^{-4} should not be exceeded.

3.3 ECOLOGICAL RECEPTORS

The VCP RG lookup tables used in Tier 2 are not designed to protect ecological receptors. U.S. EPA and other agencies have not yet developed a comprehensive set of lookup tables for ecological screening levels because ecological settings are so complex. Development of VCP RGs for ecological receptors therefore first requires reasonable support for assuming a complete exposure pathway exists for these receptors. Under the VCP, the participant is required to answer a series of questions about significant ecological receptors at or adjacent to the site. These questions address the site's proximity to sensitive habitats, known ecological receptors in the area, presence of threatened or endangered species near the site, and other information on ecological receptors. These questions are listed below:

- If contamination is present at the site, is all soil contamination below 15 feet?
- Is less than 0.25 acre of contiguous undeveloped land on or within 500 feet of any area of the site?

- Are any of the following contaminants present: chlorinated dioxins or furans, polychlorinated biphenyl mixtures, dichlorodiphenyltrichloroethane, dichlorodiphenyldichloroethene, dichlorodiphenyldichloroethane, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, toxaphene, hexachlorobenzene, pentachlorophenol, or pentachlorobenzene?

- For sites that do not contain any contaminants listed above, are more than 1.5 acres of contiguous undeveloped land on or within 500 feet of any area of the site?

- Does the site have any features that would obviously eliminate specific exposure pathways, such as paving or other permanent barriers?

- Does the site contain or is it likely to contain special status species or habitats?

- Does ground water from the site discharge to a water body or wetland?

The VCP participant should provide answers to these questions to NDEQ, which reviews them with assistance from other appropriate state or federal agencies. If a site is found to have a viable ecological population and a chemical of potential ecological concern (COPEC) is present, the participant should conduct an ecological risk assessment at the site in accordance with U.S. EPA's *Ecological Risk Assessment Guidance for Superfund*…." (U.S. EPA 1997b). The risk assessment is then used to establish VCP RGs under direction of NDEQ. Site-specific ecological VCP RGs then will be developed using the exposure assumptions from this assessment. For surface water, the VCP RGs should be consistent with Title 117—Nebraska Surface Water Quality Standards, Chapter 4, Section 003, Aquatic Life (NDEQ 2009).

4.0 TIERED APPROACH

The following sections describe the three-tiered approach to establishing VCP RGs for contaminated sites. The protocol assumes that before the tiered approach is applied to any VCP site, the site has been thoroughly characterized according to information outlined in VCP guidance. This site characterization includes identifying the nature and extent of contamination, defining the land use (current and future), determining ground water use, and identifying potential receptors. Development of a conceptual site model that clearly identifies all contaminant sources and their migration pathways as well as potentially exposed individuals (i.e., residents, industrial workers) is also necessary. Note that for simplicity, this document and the VCP RG lookup tables refer to industrial-commercial workers and the industrial-commercial land use scenario as "industrial" instead of industrial-commercial.

4.1 TIER 1

The Tier 1 evaluation compares contaminants identified on site with site-specific background levels for those contaminants that may also be naturally occurring. Background samples furnish a baseline measurement to assess the degree of contamination at a site. Whether background samples are truly uncontaminated should be determined—if COPCs are detected in the background samples, assessment should proceed as to whether they are anthropogenic (man-made) in origin and not site-related, present at naturally occurring levels, or actual site contaminants. Anthropogenic contaminant concentrations result from man-made sources (e.g., automobile traffic).

A basic assumption for Tier 1 is that contaminants found at a site are related to site activities and are not considered background. The background evaluation focuses on inorganic contaminants, as most organic compounds found at contaminated sites are not naturally occurring (although they may be ubiquitous) and may also include certain contaminants naturally enriched in various environments. As part of the site investigation, site-specific background levels for soil and ground water should be established. Analytical results for site soil should be compared to soils of similar soil type, and analytical results for site ground water should be compared to ground water from the same water-bearing unit.

NDEQ recognizes that a number of naturally occurring inorganic contaminants are present at sites in varying concentrations. These contaminants may include metals (lead, arsenic, chromium, and others) and other inorganics (such as chloride and natural nitrate). In addition, other organic contaminants may be present due to their widespread human uses and could be considered as anthropogenic (man-made) contamination. Tier 1 is designed to address primarily background contaminant situations; anthropogenic concentrations should not be screened out at Tier 1 and need to be carried through Tier 2. An assessment should be made as to whether contaminants are present at the site as naturally occurring soil or groundwater compounds or represent contamination associated with past site activities.

The VCP participant should evaluate analytical results of contaminant concentrations found at the site to determine if they are within the range of background conditions. Any contaminant found at or below inorganic background levels is not considered a chemical of potential concern (COPC) and does not need to be included in the remedial action plan for the site. To determine whether a contaminant is above background, the participant should follow the procedures outlined in U.S. EPA's *Guidance for Comparing Background and Chemical Concentrations in Soil at Superfund Sites* (U.S. EPA 2001b), American Society for Testing and Materials (ASTM) D6312-98 "Standard Guide for Developing

Appropriate Statistical Approaches for Groundwater Detection Monitoring Programs" (ASTM 1998), or a functional equivalent. A contaminant found above inorganic background levels, determined either by direct comparison or appropriate statistics, is a COPC. VCP RGs are required for all COPCs.

4.2 TIER 2

The Tier 2 evaluation compares concentrations of COPCs found on site with VCP RGs in lookup tables to determine if concentrations in soils, soil gas, or groundwater are above the VCP RGs. The user may select the maximum concentration of a COPC or calculate the upper confidence limit of the arithmetic mean for each COPC and use this value to compare with the appropriate VCP RG. This calculation may be completed using U.S. EPA's ProUCL Software, available at http://www.epa.gov/esd/tsc/software.htm . If the maximum concentration or the upper confidence limit of the arithmetic mean for contaminant concentrations is found at concentrations above the VCP RGs, the participant has two alternatives: either remediate the site to the values in the VCP RG lookup tables or develop a site-specific VCP RG under Tier 3. If a COPC is not on the VCP RG lookup tables, the participant should contact NDEQ to determine an appropriate VCP RG.

For each organic COPC, the soil's saturation concentration should be calculated (equations to calculate saturation concentrations are provided in Attachment C). At the soil saturation concentration, the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the contaminant may be present as a pure liquid phase (if the contaminant is liquid at ambient soil temperatures) or pure solid phase (if the contaminant is solid at ambient soil temperatures). If the soil saturation concentration is lower than the risk-based VCP RG, the saturation concentration is used as the VCP RG.

VCP RGs are risk-based values designed to be protective of human health and the environment.

- For residential land use scenarios, the VCP RG in soil and soil gas is set at an excess cancer risk level of 1×10^{-6} for individual carcinogens and a cancer risk level of 1×10^{-5} for the cumulative carcinogenic effects of multiple carcinogenic COPCs. For noncarcinogens, the VCP RG in soil is set at a HQ value of 0.25 and a target organ-specific HI for the combined effects of noncarcinogens of 1.0. The required cancer risk levels are further discussed in Section 5.2 and the required HQ and HI are further discussed in Section 5.3. Note that where the background concentration for a COPC exceeds an excess cancer risk level of 1×10^{-6} or a HQ value of 0.25, the background concentration becomes the VCP RG.

- For industrial land use scenarios, the VCP RG in soil and soil gas is set at an excess cancer risk level of 1×10^{-5} for individual carcinogens and a cancer risk level of 1×10^{-4} for the

cumulative carcinogenic effects of multiple carcinogenic COPCs. The participant should contact NDEQ if more than 10 carcinogenic COPCs are present, which would exceed the target risk level of 1×10^{-4}. For noncarcinogens, the VCP RG is set at a HQ value of 1.0 and a target organ-specific HI for the combined effects of noncarcinogens of 1.0. The required cancer risk levels are further discussed in Section 5.2, and the required HQ and HI are further discussed in Section 5.3. Note that where the background concentration for a COPC exceeds an excess cancer risk level of 1×10^{-5} or a HQ value of 1.0, the background concentration becomes the VCP RG. If the participant decides to use the VCP RG for an industrial worker, the site should have an institutional control in place to ensure that future land uses remain only industrial.

- For direct contact exposures to groundwater (i.e., ingestion of groundwater), NDEQ has chosen to use promulgated Maximum Contaminant Levels (MCLs), where available, as the VCP RG. For COPCs not having an MCL, the VCP RG is set at an excess cancer risk level of 1×10^{-6} for individual carcinogens. For noncarcinogens with no MCL, the VCP RG is set at an HQ value of 1.0.

- For indirect exposure to groundwater (i.e., vapor intrusion from contaminated groundwater), VCP RGs are based on the appropriate land use scenario. For residential land use scenarios, the VCP RG is set at an excess cancer risk level of 1×10^{-6} for a carcinogen and an HQ value of 0,25 for noncarcinogens. For industrial land use scenarios, the VCP RG is set at an excess cancer risk level of 1×10^{-5} for carcinogens and an HQ value if 1.0 for noncarcinogens.

The VCP RG lookup tables are for protection of human health only, not for ecological receptors. Parameter values for all exposure assumptions are discussed in more detail in Section 6.0.

4.3 TIER 3

Tier 3 requires NDEQ's oversight of the entire process. Under Tier 3, the participant can develop site-specific, risk-based VCP RGs that are protective of human health. This site-specific approach may consist of a complete baseline risk assessment; modification of certain exposure pathways and assumptions to reflect site-specific conditions; or use of site-specific values for fate and transport parameters consistent with the Tier 2 approach in NDEQ's RBCA at Petroleum Release Sites (NDEQ 2009).

Tier 3 provides the participant an option to determine VCP RGs using models, formulas, risk and exposure assessment methods, and approaches other than those specified under Tier 2. Tier 3 can involve considerably more effort than Tiers 1 and 2, since the evaluation can be more complex. Performing a Tier 3 analysis may necessitate expanding the site investigation and the risk assessment, or including sophisticated contaminant fate and transport modeling. The following is a list of information that may be required to support a Tier 3 VCP RG:

- Additional geologic or hydrogeologic data
- Data required to support the accuracy of predictive fate and transport models
- Data to support alternative assumptions for exposure pathways and receptor models
- Data to support an alternative exposure point or point of compliance
- Data required to support alternative future land uses.

The approach to developing Tier 3 VCP RGs should be consistent with U.S. EPA's *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual* ("Part B, Development of Risk-based Preliminary Remediation Goals") (U.S. EPA1991a) and other relevant U.S. EPA and NDEQ guidance (such as NDEQ's RBCA at Petroleum Release Sites: Tier 1/Tier 2 Assessments [NDEQ 2002]).

5.0 DEVELOPMENT OF VCP REMEDIATION GOAL LOOKUP TABLES

The exposure assumptions for the VCP RG lookup tables area are largely based on default values, as outlined in U.S. EPA's current risk assessment guidance and NDEQ guidance:

- Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (U.S. EPA 2002a)
- *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual* (*HHEM*), "Part B, Development of Risk-Based Preliminary Remediation Goals" (U.S. EPA 1991a)
- RBCA at Petroleum Release Sites: Tier 1/Tier 2 Assessments – Appendixes D and E (NDEQ 2009)
- "Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils…" (U.S. EPA 2002b).
- RAGS, Volume 1 – Human Health Evaluation Manual Part E, Supplemental Guidance for Dermal Risk Assessment. Final. Office of Superfund Remediation and Technology Innovation. EPA/540/R/99/005. July. On-Line Address: http://www.epa.gov/oswer/riskassessment/ragse/index.htm (U.S. EPA 2004)
- Child-Specific Exposure Factors Handbook. National Center for Environmental Assessment. Washington, DC. Final. EPA/600/R-06/096F. On-line Address: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=199243 (U.S. EPA 2008)
- RAGS, Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment). Office of Superfund Remediation and Technology Innovation. EPA-540-R-070-002. January. (U.S. EPA 2009)

However, to be consistent with current NDEQ guidance and policies, and to reflect current conditions in Nebraska, some assumptions in the guidance above should be modified. For ease of discussion, these assumptions have been differentiated into groups.

The remainder of this section specifies and justifies the assumptions for developing human health VCP RG lookup tables under Tier 2 for the VCP.

5.1 EXPOSED POPULATIONS

Soil, soil gas, and groundwater related to vapor intrusion VCP RGs are developed for two exposure populations based on land use: (1) residents and (2) industrial workers. These two groups are most likely to be exposed to contamination released from a site in the VCP. Moreover, children are included in the residential population, thereby assuring protection of sensitive receptors and complying with the Safe Drinking Water Act. Other populations were considered, such as trespassers, recreationalists, or construction workers. However, the resident or industrial worker is exposed for a longer duration than these other populations and therefore is at higher risk of COPC exposure. Also, RAGS Part A (U.S. EPA 1989) identifies residential, commercial/industrial, and recreational land use as the land use categories most often applicable at Superfund sites. As mentioned above, recreationalists have less exposure than residents, so the receptors chosen for the VCP RG lookup tables include residents (children and adults) and industrial workers.

Groundwater (as drinking water) VCP RGs are based on Title 118—Ground Water Quality Standards and Use Classification—Appendix A, which considers exposure to residents (the most sensitive population group) (NDEQ 2006).

Exposure pathways considered in the VCP RG lookup tables are as shown in Table 1.

TABLE 1.
RECEPTORS AND EXPOSURE PATHWAYS CONSIDERED IN THE VCP REMEDIATION GOAL LOOKUP TABLES

Exposure Medium	Exposure Pathway	Land Use	Receptor
Soil	Incidental ingestion	Residential	Age-adjusted – carcinogens Child – noncarcinogens
	Inhalation of volatiles and particulates	Residential	Adult – carcinogens Adult – noncarcinogens
	Dermal contact	Residential	Age-adjusted – carcinogens Child – noncarcinogens
	Incidental ingestion	Industrial	Worker
	Inhalation of volatiles and particulates	Industrial	Worker
	Dermal contact	Industrial	Worker
	Soil-to-ground water	Residential	Age-adjusted – carcinogens Adult – noncarcinogens
Soil Gas	Inhalation	Residential	Adult – carcinogens Adult - noncarcinogens
		Industrial	Worker
Ground water	Ingestion	Residential	Age-adjusted – carcinogens Adult – noncarcinogens
	Inhalation	Residential	Adult – carcinogens Adult – noncarcinogens
		Industrial	Worker

5.2 TARGET CANCER RISK

The target cancer risk, a probability of an excess cancer over a lifetime, is set at different levels for soils, soil gas, and vapor intrusion from groundwater exposures based on two distinct populations: residential and industrial workers. The residential population is assumed to include sensitive populations such as elderly residents and children. To protect the most sensitive residential exposure groups, the target cancer risk for exposure to individual COPCs is set at 1 excess cancer in 1,000,000 population, or 1×10^{-6}. The target cancer risk level for the cumulative effects of multiple carcinogens is 1×10^{-5} for residential land use. If more than 10 carcinogenic COPCs are present for residential land use scenarios, NDEQ should be contacted to determine how to best adjust the VCP RGs so the 1×10^{-5} goal is met. Note that even if the cumulative risk level of 1×10^{-5} is met, each COPC must still meet a 1×10^{-6} risk level.

Since the industrial worker population is not anticipated to include the elderly and children, its target cancer risk is set at 1 in 100,000 (1×10^{-5}). The target cancer risk level for the cumulative effects of multiple carcinogens is 1×10^{-4} for industrial land use. If more than 10 carcinogenic COPCs are present for industrial land use scenarios, NDEQ should be contacted to determine how to best adjust the VCP

RGs so the 1 x 10^{-4} goal is met. Note that even if the cumulative risk level of 1 x 10^{-4} is met, each COPC must still meet a 1 x 10^{-5} risk level. As discussed earlier, if a participant decides to use the VCP RG for an industrial worker, the site should have an institutional control in place to ensure that future land uses remain only industrial.

VCP RGs for exposure to ground water will be identified consistent with the approach outlined in Title 118—Ground Water Standards and Use Classification—Appendix A (NDEQ 2006). The receptor is assumed an adult resident and the target cancer risk for those compounds without Title 118 numerical standards is 1 x 10^{-6}. Absent a standard, however, VCP RGs are calculated in a manner similar to that for soils (e.g., children are evaluated as receptors as well). This is discussed in more detail in Section 5.6.

5.3 TARGET HAZARD INDEX

The target HQ (established for individual noncarcinogens) and the HI (sum of the HQs for combined effects of noncarcinogens) are set at different levels for soils, soil gas, and vapor intrusion from groundwater based on two distinct populations: residential and industrial workers. The residential population is assumed to include sensitive populations such as elderly residents and children. The selected receptor-specific target HQs and HIs provide a high level of protection for the most sensitive populations that would be exposed almost exclusively in a residential setting. In addition, calculating a VCP RG for residential exposures to noncarcinogenic COPCs assumes a child as the receptor (this ensures the VCP RG is protective, since a child is more sensitive than an adult). Importantly, U.S. EPA's NCP identifies a target HI of 1.0 as the goal for combined effects of noncarcinogenic contaminants.

To protect the residential exposure groups, the HQ for exposure to individual COPCs in soils, soil gas, and groundwater related to potential vapor intrusion is set at 0.25. An HQ of 0.25 for exposure to soils provides a level of conservatism for sites with multiple noncarcinogenic contaminants. The target organ-specific HI for the cumulative effects of multiple noncarcinogens is 1.0 for residential land use. If more than four noncarcinogenic COPCs are present for residential land use scenarios, the participant should refer to Attachment E of this document, "Target Organs for Noncarcinogenic Effects of Various Contaminants." The number of contaminants affecting each target organ should be determined. If more than four COPCs affect a single target organ or multiple target organs (thereby exceeding the target organ-specific HI of 1.0), NDEQ should be contacted to determine how to best adjust the VCP RGs so the 1.0 goal is met. Note that even if the cumulative HI of 1.0 is met, each individual COPC must still each meet an HQ of 0.25. If a COPC is present but not listed in the VCP RG lookup tables (and not on the list

presented in Attachment E), the participant should contact NDEQ to determine if target organ effects are applicable for the contaminant.

For industrial land use scenarios, the VCP RG in soil is set to a target HQ of 1.0. This value is less conservative than the residential target, but still considered protective of industrial workers. The target organ-specific HI for the cumulative effects of multiple noncarcinogens is 1.0 for industrial land use. If more than one noncarcinogenic COPC is present for industrial land use scenarios, the participant should refer to Attachment E of this document, "Target Organs for Noncarcinogenic Effects of Various Contaminants." The number of contaminants affecting each target organ should be determined. If more than one COPC affects a single target organ or multiple target organs (thereby exceeding the target organ-specific HI of 1.0), NDEQ should be contacted to determine how to best adjust the VCP RGs so the 1.0 goal is met. As discussed earlier, if a participant decides to use the VCP RG for an industrial worker, the site should have an institutional control in place to ensure that future land uses remain only industrial. If a COPC is present but not listed in the VCP RG lookup tables (and not on the list presented in Attachment E), the participant should contact NDEQ to determine if target organ effects are applicable for the contaminant.

As with the target cancer risk discussed above, VCP RGs for exposure to groundwater (as drinking water) will be identified consistent with the approach outlined in Title 118—Ground Water Standards and Use Classification—Appendix A (NDEQ 2006). The receptor is assumed an adult resident and a target HQ of 0.25 will be used for those compounds without Title 118 numerical standards. This HQ value will correspond to a concentration expected to result in no adverse health effect for longer-term or lifetime exposure, as discussed in Title 118, Appendix A. Absent a standard, however, VCP RGs are calculated in a manner similar to that for soils (e.g., childhood exposures are considered). This is discussed in more detail in Section 5.6.

5.4 SURFACE WATER

All surface water values for human exposure will be consistent with Title 117—Nebraska Surface Water Quality Standards, Chapter 4, Section 004—Water Supply (NDEQ 2009). Note that values protective of ecological receptors will be determined separately.

5.5 SOIL EXPOSURE

Multiple exposure pathways are considered when establishing a VCP RG for soil. VCP RGs for soil are based on three major pathways: incidental ingestion, dermal contact, and inhalation. The incidental ingestion pathway assumes a higher incidental ingestion rate of soil for children than adults, and estimates protective concentrations in soil considering these ingestion rates combined with toxicity factors, risk levels/hazard indices, and other exposure factors (e.g., duration of exposure).

The dermal contact pathway takes into account receptor-specific contact rates and the same considerations used for incidental soil ingestion. In addition, chemical-specific absorption fractions and chemical-specific modifications of oral toxicity factors for dermally absorbed contaminant doses are used.

The soil inhalation pathway takes into account either inhalation of COPCs volatilizing from the soils (volatile compounds only) or inhalation of airborne particulates or dusts. Chemical-specific volatilization factors from soil (VF_s) are used to estimate exposure from volatile COPCs, defined as contaminants with a Henry's law constant greater than 1×10^{-5} atmosphere-cubic meter per mole (atm-m^3 / mole) and a molecular weight (MW) less than 200 grams per mole (g/mole). For the purposes of the VCP RG tables, only volatile organic compounds (VOC) are considered "volatile"; inorganics are not. To estimate the inhalation of particulates from nonvolatile COPCs, a particle emission factor (PEF) is used. U.S. EPA's "Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites" (U.S. EPA 2002a) provides a procedure to calculate PEFs for various locations. To calculate a default PEF for Nebraska, specific data provided for Lincoln, Nebraska, were used.

As discussed earlier, the soil's saturation concentration is also calculated for each COPC. If the soil saturation concentration is lower than the above risk-based VCP RG, the saturation concentration is used as the VCP RG.

5.6 GROUNDWATER EXPOSURE

Groundwater (for direct contact exposure pathways) exposure values are set consistent with Title 118—Ground Water Standards and Use Classification—Appendix A (NDEQ 2006), which establishes a groundwater classification process to protect groundwater for appropriate uses. For groundwater pollution occurrences, Title 118 identifies three remedial action classes (RAC): RAC-1, RAC-2, and RAC-3—defined in Appendix A as:

- RAC-1— This category includes groundwaters of Class GA and a portion of Class GB, a 500-foot radius around all private drinking water supply wells. In addition, RAC-1 shall be assigned automatically when a public or private drinking water supply well has been contaminated. RAC-1 shall receive the most extensive remedial action measures.

- RAC-2— This category includes groundwaters of Class GB (except for the portion of Class GB placed in RAC-1) and Class GC(R).

- RAC-3—This category includes, but is not limited to, groundwaters of Class GC, except for Class GC(R) that were placed in RAC-2. RAC-3 shall receive the least extensive remedial action measures.

Definitions of the groundwater classes GA, GB, and GC are provided in Chapter 7 of Title 118. Under Title 118, Appendix A, the VCP RGs for RAC-1 and RAC-2 are set at the maximum contaminant levels (MCLs) in Chapter 4. Absent an established MCL, U.S. EPA's Ambient Water Quality Criteria, Health Advisories, and other documents are used to set the VCP RG.

For COPCs without a regulatory standard, the level is set at one of the following under Title 118: the concentration estimated to result in an excess lifetime cancer risk of 1×10^{-6}; a concentration expected to result in no adverse health effect for longer term (i.e., 30 years) or lifetime exposures; or a laboratory detection limit (if higher and within an acceptable range). For RAC-3, cleanup of readily removable contaminants (e.g., free product) is required, other impacts to beneficial use may be considered (e.g., wetland systems), and monitoring may also be necessary.

Note that the VCP RG protocol modifies the approach taken under Title 118, Appendix A. Instead of using only the ingestion pathway to determine the risk-based value, it also includes the inhalation pathway (as related to direct contact with groundwater, i.e., showering) for volatile COPCs and uses an HQ of 0.25 for noncarcinogenic COPCs; procedures to calculate this risk-based value follow those provided in the supporting documentation for U.S. EPA Regional Screening Levels (RSLs) and are described in more detail in Section 7.6. Note that VCP RGs based on dermal exposure to ground water are not derived, as ground water ingestion and inhalation, which are evaluated, are expected to contribute much more to ground water risk and hazard than would dermal exposure.

5.7 SOIL-TO-GROUNDWATER

Calculation of the VCP RGs for the soil-to-groundwater exposure pathway assumes that contaminants are leached from the soil, migrate to the groundwater, and eventually enter a receptor well. For RAC-1 and RAC-2 sites, the receptor is assumed at the source area. For RAC-3 sites, the VCP RG should ensure no

free product development on the groundwater table or no soil saturation.

The calculations follow the recommendations outlined in U.S. EPA's soil screening guidance (U.S. EPA 1996a, 1996b, and 2002a) and assume a dilution attenuation factor (DAF) of 20. DAF represents the reduction in concentration that occurs as soil leachate moves through soil and groundwater, as a result of adsorption, degradation, and dilution by clean groundwater. DAF is defined as the ratio of soil leachate concentration to receptor point concentration. A DAF of 20, as used here, assumes a 20-fold reduction in contaminant concentration between the soil sampling location and the receptor well location. This DAF value is based on the assumption of a 0.5-acre source and is applicable to most sites in the VCP program. In addition, a DAF of 20 is considered protective since NDEQ assumes the receptor to be at the source area, while in most cases actual receptors will be off site.

5.8 SOIL DEPTH

Soil VCP RGs for exposure through direct contact pathways apply to soil depths to which a receptor will likely be exposed at the site. For a residential receptor, this is the upper 10 feet—the assumption being that potential basement construction may bring soil from this depth to the surface. For an industrial receptor, this is the upper 15 feet—assuming that construction or maintenance of a utility line could occur at this depth and exposure then would occur.

5.9 INDOOR AIR

Intrusion of volatile contaminants from the subsurface into buildings is a pathway of concern that has received increased scrutiny from U.S. EPA and state remedial programs, including NDEQ. Previous versions of the Nebraska VCP guidance have referenced use of U.S. EPA draft vapor intrusion guidance "Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils" (U.S. EPA 2002b) to address VCP sites where vapor intrusion into buildings may have been an issue. This most recent revision to the RG Protocol establishes RGs for soil gas and groundwater related to the vapor intrusion pathway. The basis for the vapor intrusion RGs is provided in this document as a separate subprotocol (Attachment D). This protocol is consistent with the recent draft U.S. EPA vapor intrusion guidance. Intrusion of volatile contaminants may be of concern at sites meeting the following criteria:

- Volatile COPCs (as defined in Attachment D) are identified at the site
- Volatile COPCs are located 100 feet below ground level (bgl) or less.

- Volatile COPCs are located in proximity to existing or future buildings (within 100 feet horizontally).

If these criteria are met, the participant should use the lookup tables presented in Attachment D to determine if the site could pose a risk to human health from vapor intrusion to indoor air.

6.0 READING THE VCP REMEDIATION GOAL LOOKUP TABLES

This section provides an overview of the VCP RG lookup tables. Since the approach taken to develop these tables was similar to the approach taken by U.S. EPA in developing their RSLs, large portions of the text in the following two sections are taken from the U.S. EPA RSL supporting documentation (U.S. EPA 2010). The VCP RG lookup tables are presented in Attachment A and the supporting tables are presented in Attachment B.

6.1 GENERAL CONSIDERATIONS

With the exceptions described below, VCP RGs are contaminant concentrations that correspond to fixed levels of risk and hazard in soil, soil gas, and groundwater—cancer risk of either 1×10^{-6} for residential or 1×10^{-5} for industrial, or a noncarcinogenic HQ of either 0.25 for residential or 1.0 for industrial. For most cases in which a contaminant causes both cancer and noncancer effects, the cancer risk estimate will call for more stringent criteria, and consequently this value appears in the printed copy of the VCP RG lookup tables. VCP RG values that are based on adverse noncarcinogenic effects are indicated by "ca." VCP RG concentrations that equate to the calculated HQ for noncarcinogenic concerns are indicated by "nc." Note that for groundwater and soil-to-groundwater RGs, a “m” designation indicates that the value is based on a MCL from Title 118.

In general, concentrations in the VCP RG lookup tables are risk-based, but two important exceptions for soil exist: (1) for some contaminants, VCP RGs are based on the soil saturation equation ("sat") and (2) for relatively less toxic inorganic and semivolatile contaminants, a non-risk-based "ceiling limit" concentration is given as $1 \times 10^{+5}$ milligram per kilogram (mg/kg) ("max"). The risk-based values for these same contaminants are also available along with the VCP RGs if the participant wants to view the risk-based concentrations before applying “sat” or “max.” For more information on why the “sat” value and not a risk-based value is presented for several volatile contaminants in the VCP RG lookup tables, see Section 7.5.

Applying a "ceiling limit" to contaminants for reasons other than exceeding the saturation limit is not universally accepted. It has been argued that all values should be risk-based to allow for scaling (for example, if the risk-based VCP RG is set at HQ = 1.0, and the participant would like to set the HQ to 0.1 to take into account multiple contaminants, this is as simple as multiplying the risk-based VCP RG by 1/10th). If scaling is necessary, VCP RG participants can make this adjustment by referring to the VCP RG lookup tables where risk-based soil concentrations are presented for all contaminants (see soil calculations, "combined" pathways column). Participants should contact NDEQ prior to conducting any scaling.

Though applying a ceiling limit is not universally accepted, NDEQ has opted to continue applying a "max" soil concentration to the VCP RG lookup tables for the following reasons:

- Risk-based VCP RGs for some contaminants in soil exceed unity (>1,000,000 mg/kg), which is not possible.
- The ceiling limit of $1 \times 10^{+5}$ mg/kg is equivalent to a contaminant representing 10% by weight of the soil sample. At this contaminant concentration (and higher), the assumptions for soil contact may not be accurate due to presence of the foreign contaminant itself (e.g., soil adherence, windborne dispersion may have changed).
- VCP RGs currently do not address short-term exposures (e.g., pica children [children who ingest unusually large amounts of non-food items, e.g., soil] and construction workers). Though extremely high soil VCP RGs are likely to represent relatively non-toxic contaminants, such high values might not be justified if more toxicological data were available for evaluating short-term and/or acute exposures. In other words, if more data regarding the acute toxicity of various compounds were available and considered, extremely high soil concentrations (e.g., > $1 \times 10^{+5}$ mg/kg) may be found unprotective. Therefore, application of the "max" soil concentration is intended to address this issue.

6.2 TOXICITY VALUES

Several issues impact toxicity values used to establish VCP RGs discussed in this section. A variety of sources are available for toxicity values, and this section identifies the toxicity source hierarchy used.

<u>Hierarchy of Toxicity Values</u>

Toxicity values, known as noncarcinogenic RfDs and RfCs, and carcinogenic SFs and URFs, were obtained from the following hierarchy of sources:

- Level 1: U.S. EPA's Integrated Risk Information System (IRIS) (U.S. EPA 2010) values—indicated by "i" in the VCP RG lookup tables.

- Level 2: U.S. EPA's National Center for Environmental Assessment (NCEA) provisional peer-reviewed toxicity values (PPRTV) (U.S. EPA 2004d)—indicated by "p" in the VCP RG lookup tables. Other NCEA values follow the PPTRVs in the hierarchy and are indicated by "n" in the VCP RG lookup tables.

- Level 3: U.S. EPA's Health Effects Assessment Summary Tables (HEAST) (U.S. EPA 1997a)—indicated by "h" in the VCP RG lookup tables—and other sources. Values withdrawn from IRIS or HEAST and under review are indicated by "x"; values obtained from other sources are indicated by "o."

Note that the toxicity factor hierarchy prescribed above reflects the U.S. EPA hierarchy (U.S. EPA 2003).

Inhalation Toxicity Factors

Consistent with current U.S. EPA methodology, the VCP RG inhalation equations use RfCs and IURs instead of inhalation RfDs and SFs. Due to the uncertainties involved in making the surface area and/or pharmacokinetic adjustments required to estimate an internal dose (e.g., inhalation RfD), and considering possible route-of-entry effects of various contaminants, route-to-route extrapolations are not performed for the toxicity factors in the VCP RG lookup tables. Therefore, the VCP RG lookup tables do not contain any inhalation values obtained using route-to-route extrapolation methods.

Dermal Toxicity Factors

Consistent with current U.S. EPA methodology, the VCP RG dermal equations use modified oral toxicity values to assess dermal risk. The approach taken to modify the toxicity factors for dermal exposure was consistent with U.S. EPA dermal guidance (U.S. EPA 2004).

6.3 CHEMICAL/PHYSICAL PARAMETERS

Chemical/physical parameters used to calculate the VCP RGs are presented in Attachment B, Table B-1 and were taken directly from the chemical/physical properties table listed in the U.S. EPA RSL table.

Since groundwater-to-soil VCP RGs are calculated in the VCP RG lookup tables, additional chemical/physical data (Soil-water partition coefficient [K_d], Soil-organic carbon-water partition coefficient [K_{oc}], and Henry's Law Constant [H]) were necessary and were obtained from U.S. EPA's "Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites, Appendix C" (U.S. EPA 2002a). K_d/K_{oc} and H values for organics were obtained from Exhibit C-1 of this document; K_d values for inorganics (assuming a pH of 6.8) were obtained from Exhibit C-4 of this document. As

H values for inorganics were not available in this 2002 Supplemental Guidance document, the Texas Risk Reduction Program Rule chemical/physical properties (Texas Commission on Environmental Quality [TCEQ] 2004) were reviewed to ensure that all inorganics listed in Exhibit C-4 of the 2002 soil screening Supplemental Guidance document had a H value of zero. This was true for all inorganics listed except mercury (mercury has a H value listed in Exhibit C-1 of the U.S. EPA "Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites"; this H value for mercury was used in the VCP RG lookup tables).

6.4 VCP REMEDIATION GOALS DERIVED WITH SPECIAL CONSIDERATIONS

Most VCP RGs are readily derived via the various equations contained herein. However, for some contaminants the standard equations do not apply and/or adjustments to the toxicity values are recommended. These special case contaminants are discussed below. Note that each of these special considerations, with the exception of ammonia, is consistent with the approaches taken by the U.S. EPA in deriving the RSLs for these contaminants (U.S. EPA 2010). Ammonia is considered here based on information derived from consultation with other NDEQ programs.

Ammonia

Ammonia use as a fertilizer is common in Nebraska. In the subsurface, ammonia is generally converted to nitrites via biological oxidation, and then to nitrates in the chemical nitrification process. No MCL has been established for ammonia. As established by Nebraska Title 118, the MCL for nitrite (as N) is 1 mg/L and for nitrate is 10 mg/L. By NDEQ policy decision, the VCP RG for ammonia in groundwater is provided as 10,000 µg/L (10mg/L) total combined ammonia (as N), nitrite (as N), and nitrate (as N). For the migration to groundwater exposure pathway, the soil RG for ammonia is provided as 40 mg/kg (parts per million) combined ammonia/nitrite/nitrate.

Cadmium

The VCP RGs for cadmium are based on the oral RfD for water for exposure to that medium and the RfD for food for exposure to soil. This is consistent with current U.S. EPA guidance (U.S. EPA 2010).

Chromium VI

For chromium VI, IRIS shows an URF of 1.2 x 10^{-2} microgram per cubic meter $(\mu g/m^3)^{-1}$. However, the supporting documentation in the IRIS file states that these toxicity values are based on an assumed 1:6 ratio of chromium VI:chromium III. Because of this assumption, these cancer toxicity values were presented in the VCP RG lookup tables as "total chromium" numbers. In the VCP RG lookup tables, chromium VI-specific values are also included. These are derived by multiplying the "total chromium" value by 7, yielding a unit risk factor of 8.4 x 10^{-2} $(\mu g/m^3)^{-1}$.

Lead

Derivations of residential VCP RGs for lead are based on pharmacokinetic models. U.S. EPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model is designed to predict the probable blood lead concentrations for children 0 to 84 months old who have been exposed to lead through various sources (air, water, soil, dust, diet and *in utero* contributions from the mother) (U.S. EPA 1994a, 1994b). Consistent with U.S. EPA guidance, this model is run in reverse to derive a VCP RG for lead.

Manganese

The IRIS RfD (0.14 mg/kg-day) includes manganese from all sources, including diet. The author of the IRIS assessment for manganese recommends subtracting the dietary contribution from the normal U.S. diet (an upper limit of 5 mg/day) when evaluating non-food (e.g., drinking water or soil) exposures to manganese, leading to a RfD of 0.071 mg/kg-day for non-food items. The explanatory text in IRIS further recommends using a modifying factor of 3 when calculating hazards associated with non-food sources due to a number of uncertainties discussed in the IRIS file for manganese, leading to a RfD of 0.024 mg/kg-day. This modified RfD is applied in the derivation of the VCP RGs for soil and ground water.

Mutagens

Some of the cancer-causing analytes in the lookup tables operate by a mutagenic mode of action for carcinogenesis. There is reason to surmise that some chemicals with a mutagenic mode of action, which would be expected to cause irreversible changes to DNA, would exhibit a greater effect in early-life versus later-life exposure. Cancer risk to children in the context of the U.S. Environmental Protection Agency's cancer guidelines (U.S. EPA 2005) includes both early-life exposures that may result in the

occurrence of cancer during childhood and early-life exposures that may contribute to cancers later in life. In keeping with this guidance, separate cancer risk equations are presented for mutagens. The following compounds included in the lookup tables are identified as mutagens – benzidine, benzo(a)pyrene, dibenz[a,h]anthracene, 1,2,3-trichloropropane, trichloroethylene, vinyl chloride, coke oven emissions, and 1,2-dibromo-3-chloropropane. The mutagen vinyl chloride has a unique set of equations.

Vanadium and compounds

The oral RfD toxicity value for vanadium used in calculating the VCP RG is derived from the IRIS oral RfD for vanadium pentoxide by factoring out the molecular weight of the oxide ion. Vanadium pentoxide (V205) has a molecular weight of 181.88. The two atoms of vanadium contribute 56% of the molecular weight. Vanadium pentoxide's oral RfD of 9E-03 multiplied by 56% gives a vanadium oral RfD of 5.04E-03; the RfD listed in the U.S. EPA RSL table is 5.0 E-03 (U.S. EPA 2010)..

6.5 SOIL-TO-GROUNDWATER APPROACH

The soil-to-groundwater RGs were developed using a default DAF of 20 to account for natural processes that reduce contaminant concentrations in the subsurface. In general, if VCP RGs are not exceeded for the migration to groundwater pathway, this pathway may be eliminated from further investigation.

6.6 MISCELLANEOUS

VOCs are indicated by "1" in the VOC column of the VCP RG lookup tables and are defined in Section 5.5 of this document. Three borderline contaminants (dibromochloromethane, 1,2-dibromochloropropane, and pyrene) that do not strictly meet these criteria of volatility have also been included based on professional judgment.

VOCs are evaluated for potential volatilization from soil and water to air but not for dermal exposure to soil per U.S. EPA guidance. Chemical-specific dermal absorption values for contaminants in soil and dust are presented for arsenic, cadmium, chlordane, 2,4-dichlorophenoxyacetic acid (2,4-D), 4,4′- dichlorodiphenyldichloroethane (DDD), 4,4′- dichlorodiphenyldichloroethene (DDE), and 4,4′- dichlorodiphenyltrichloroethane (DDT) , hexachlorocyclohexane (HCH), tetrachlorodibenxo-p-dioxin (TCDD), polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and pentachlorophenols as recommended in the *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* (“Part E, Supplemental Guidance for Dermal

Risk Assessment") Interim Guidance" (U.S. EPA 2001a). Otherwise, default dermal absorption fractions are assumed 0.10 for semivolatile organic compounds (SVOC).

7.0 TECHNICAL SUPPORT DOCUMENTATION

VCP RGs are chemical- and media-specific goals for soil, soil gas, and groundwater that are designed to be protective of human health and the environment. The following section describes the approach taken to calculate exposure to soils via incidental ingestion, dermal contact, inhalation, soil to groundwater; and exposures to groundwater via ingestion and inhalation. The results of the calculations for each pathway are presented in Attachment B, Tables B-2 through B-4. The approach taken to calculate potential exposure to vapors in indoor air via the intrusion of contaminant vapors from soil gas and groundwater are described in Attachment D. The results of the calculations for the vapor intrusion pathway are presented in Tables 3-1 through 3-5 in Attachment D.

7.1 SOILS - INCIDENTAL INGESTION

Calculation of risk-based VCP RGs for incidental ingestion of soil is based on methods presented in RAGS (U.S. EPA 1991a) and soil screening guidance (U.S. EPA 1996a, 1996b, 2001a). Briefly, these methods involve calculating a soil concentration of a contaminant, an RG that is associated with the selected target cancer risk or, for adverse noncarcinogenic effects, the selected Hazard Index.

A number of studies have shown that inadvertent ingestion of soil is common among children six years old and younger (Calabrese and others 1989; Davis and others 1990; Van Wijnen, Clausing, and Brunekreef 1990). To take into account the higher soil intake rate for children, two different approaches are used to estimate soil VCP RGs, depending on whether the adverse health effect is cancer or some effect other than cancer. For carcinogens, the method for calculating soil VCP RGs uses an age-adjusted soil ingestion factor that considers the difference in daily soil ingestion rates, body weights, and exposure duration for children from 0 to 6 years old and for individuals from 7 to 30 years old. This health-protective approach is chosen to take into account the higher daily rates of soil ingestion in younger children, as well as the longer duration of exposure anticipated for an adult resident. For more on this method, see RAGS (U.S. EPA 1991a).

For the assessment of noncarcinogenic effects, childhood exposure is evaluated separately from adult exposure. An age-adjustment factor is not applied as is done when assessing carcinogenic risk. This approach is considered conservative because it combines the higher 6-year exposure for children with

chronic toxicity criteria. NDEQ has adopted this approach for calculating soil VCP RGs for noncarcinogenic health concerns.

7.2 SOILS - VAPOR AND PARTICULATE INHALATION

U.S. EPA toxicity criteria indicate that risk from exposure to some contaminants via inhalation far outweigh the risk via incidental ingestion; therefore, soil VCP RGs have been designed to address this pathway as well. The models used to calculate VCP RGs for inhalation of volatiles and particulates are updates of risk assessment methods presented in RAGS: Part B (U.S. EPA 1991a) and are identical to the *Soil Screening Guidance: Technical Background Document* and *User's Guide (*U.S. EPA 1996a, 1996b).

Note that the soil-to-air pathway evaluated in the VCP RG calculations is based on direct inhalation exposure that results from volatilization or particulate emissions of contaminants from soil to outdoor air. The soil VCP RG calculations currently do not evaluate the potential for volatile contaminants in soil to migrate indoors.

To address the soil-to-outdoor air pathways, the VCP RG calculations incorporate a volatilization factor for soil (VF_s) value for volatile contaminants and a particulate emission factor (PEF) for nonvolatile contaminants. These factors relate soil contaminant concentrations to air contaminant concentrations that may be inhaled on site. The VF_s and PEF equations can be divided into two separate models: an emission model to estimate emissions of the contaminant from the soil and a dispersion model to simulate the dispersion of the contaminant in the atmosphere.

The dispersion model for both volatiles and particulates is the AREA-ST, an updated version of the Office of Air Quality Planning and Standards, Industrial Source Complex Model, ISC2. For the VCP RGs, the air dispersion factor (Q/C) of 81.64 $g/m^{2-}sec/kg/m^3$ for Lincoln, Nebraska, was used for both the VF_s and PEF equations. A default source size of 0.5 acre was chosen for the VCP RG calculations. For unusual site conditions of an area source substantially larger than the default source area assumed here, an alternative Q/C can be applied (see U.S. EPA 1996a, 1996b).

<u>Volatilization Factor for Soils</u>

VOCs were screened for inhalation exposure using chemical-specific, calculated VF_s values. VF_s values are provided in Attachment B, Table B-1. The emission terms used in the VF_s calculations are chemical-specific and were calculated from physical/chemical information originally obtained from several sources.

The priority of these sources was as follows: Soil Screening Guidance (U.S. EPA 1996a, 1996b), "Superfund Chemical Data Matrix" (U.S. EPA 1996c), *Handbook of Environmental Fate and Exposure Data for Organic Chemicals* (Howard 1991), *Subsurface Contamination Reference Guide* (U.S. EPA 1990b), and *Superfund Exposure Assessment Manual (SEAM)* (U.S. EPA 1988). When there was a choice between a measured or a modeled value (e.g. K_{oc}), modeled values were used. In those cases where Diffusivity Coefficients (D_i) were not provided in existing literature, D_i values were calculated using Fuller's Method described in SEAM (U.S. EPA 1988). A surrogate term was required for some contaminants that lacked physical/chemical information. In these cases, a proxy contaminant of similar structure was used that may over- or under-estimate the VCP RG for soils. Note that physical/chemical information for VOCs was obtained directly from the U.S. EPA RSL tables (U.S. EPA 2010).

The VF_s equation described herein forms the basis for deriving generic soil VCP RGs for the inhalation pathway. The following parameters in the standardized equation can be replaced with site-specific data to develop a simple site-specific VCP RG:

- Source area
- Average soil moisture content
- Average fraction organic carbon content
- Dry soil bulk density.

The basic principle of the VF_s model (Henry's Law) is applicable only if the soil contaminant concentration is at or below soil saturation ("sat"). Above the soil saturation limit, the model cannot predict an accurate VF_s-based VCP RG. How these particular cases are handled depends on whether the contaminant is liquid or solid at ambient soil temperatures (see Section 7.5).

Note that soil inhalation VCP RGs are not calculated for inorganics, even if they fit the volatility cutoffs (H >1E-05 atm-m^3/mole; MW<200 g/mole). These volatile inorganic contaminants are flagged with "n/a" in the VOC column in Table A-1.

Particulate Emission Factor for Soils

Inhalation of contaminants adsorbed to respirable particles (PM_{10}) were assessed using a default PEF equal to 1.2E+9 m^3/kg that relates the contaminant concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from contaminated soils. The generic PEF was derived using default values listed in the PEF equation herein. The relationship is derived by Cowherd and others (1985) for a rapid assessment procedure applicable to a typical hazardous waste site where the surface contamination provides a relatively continuous and constant potential for emission over an extended period of time (e.g., years). This represents an annual average emission rate based on wind erosion that should be compared with chronic health criteria; it is not appropriate for evaluating the potential for more acute exposures. Note that the generic PEF evaluates windborne emissions and does not consider dust emissions from traffic or other forms of mechanical disturbance that could lead to greater emissions than assumed here.

The impact of the PEF on the resultant VCP RG concentration (that combines soil exposure pathways for incidental ingestion, dermal contact, and inhalation) can be assessed by viewing the pathway-specific soil concentrations available with the VCP RGs. The PEF equation detailed herein forms the basis for deriving a generic PEF for the inhalation pathway. For more details regarding specific parameters used in the PEF model, the reader is referred to *Soil Screening Guidance: Technical Background Document* (U.S. EPA 1996a).

7.3 SOILS - DERMAL EXPOSURE

Dermal Contact Assumptions

Exposure factors for dermal contact with soil are based on recommendations in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* ("Part E, Supplemental Guidance for Dermal Risk Assessment") (U.S. EPA 2004).

Dermal Absorption

Chemical-specific dermal absorption factors recommended by the Superfund Dermal Workgroup (U.S. EPA 2004) were applied when available. The dermal absorption factors (ABS_d) are used to to estimate the percentage of applied chemical that will absorbed across the skin barrier to calculate a dermal dose. Chemical-specific values are included for the following contaminants: arsenic, cadmium, chlordane,

2,4-D, DDT, lindane, TCDD, PAHs, PCBs, and pentachlorophenols. The *Risk Assessment Guidance for Dermal Risk Assessment* (U.S. EPA 2004) recommends a default dermal absorption factor for SVOCs of 10% as a screening method for the majority of SVOCs without dermal absorption factors. Default dermal absorption factors for other contaminants (VOCs and inorganics) are not recommended in this new guidance.

7.4 SOILS - MIGRATION TO GROUNDWATER

VCP RGs were developed for soil contaminants that have the potential to contaminate underlying groundwater. Migration of contaminants from soil to groundwater can be envisioned as a two-stage process: (1) release of contaminant in soil leachate and (2) transport of the contaminant through the underlying soil and aquifer to a receptor well. The soil-to-groundwater VCP RG methodology considers both of these fate and transport mechanisms.

Soil-to-groundwater VCP RGs are back-calculated from target groundwater concentrations (i.e., MCLs per Title 118, or risk-based VCP RGs for the remaining compounds). First, the target groundwater concentration is multiplied by a dilution factor to obtain a target leachate concentration. For example, if the dilution factor is 20 and the target groundwater concentration is 0.05 mg/L, the target soil leachate concentration would be 1.0 mg/L. The partition equation presented herein is then used to calculate the total soil concentration (i.e., VCP RG) corresponding to this soil leachate concentration.

The soil-to-groundwater VCP RG methodology was designed for use during the early stages of a site evaluation when information about subsurface conditions may be limited. Because of this constraint, the methodology is based on conservative, simplifying assumptions about the release and transport of contaminants in the subsurface. For further information, the reader is referred to the Soil Screening Guidance documents (U.S. EPA 1996a, 1996b, and 2002a).

7.5 SOIL SATURATION LIMIT

The soil saturation concentration (“sat”) corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the soil contaminant may be present in free phase, i.e., nonaqueous phase liquids (NAPLs), for contaminants that are liquid at ambient soil temperatures and pure solid phases for compounds that are solid at ambient soil temperatures. The “sat” equation included herein is used to calculate “sat” for each volatile contaminant. This equation takes into account the

amount of contaminant that is in the vapor phase in soil in addition to the amount dissolved in the soil's pore water and sorbed to soil particles.

Chemical-specific "sat" concentrations should be compared with each VF_s-based VCP RG because a basic principle of the VCP RG volatilization model is not applicable when free-phase contaminants are present. How these cases are handled depends on whether the contaminant is liquid or solid at ambient temperatures. Note that contaminants that are solids at ambient temperatures are indicated in the VCP RG lookup tables. Liquid contaminants with a VF_s-based VCP RG that exceeds the "sat" concentration are set equal to "sat," whereas for solids (e.g., PAHs), soil screening decisions are based on the appropriate VCP RGs for other pathways of concern at the site (e.g., incidental ingestion).

7.6 GROUNDWATER—INGESTION AND INHALATION

Calculation of VCP RGs for ingestion and inhalation of contaminants in domestic water is based on the methodology presented in RAGS Part B (U.S. EPA 1991a). Ingestion of drinking water is an appropriate pathway for all contaminants. For the purposes of this guidance, however, inhalation of volatile chemicals from water is considered routinely only for those contaminants defined as VOCs (see Section 5.5). For volatile contaminants, an upper-bound volatilization factor ($VF_w = 0.5$) is used that is based on all uses of household water (e.g., showering, laundering, and dish washing). Certain assumptions were made. For example, it is assumed that the volume of water used in a residence for a family of four is 720 L/day, the volume of the dwelling is 150,000 L, the dwelling occupies 900 square feet, and the air exchange rate is 0.25 air changes/hour (Andelman 1990 in RAGS Part B [U.S. EPA 1991a]). Furthermore, it is assumed that the average transfer efficiency weighted by water use is 50 percent (i.e., half of the concentration of each contaminant in water will be transferred into air by all water uses). Note: the range of transfer efficiencies extends from 30% for toilets to 90% for dishwashers.

7.7 DEFAULT EXPOSURE FACTORS

Default exposure factors were obtained primarily from RAGS "…Supplemental Guidance: Standard Default Exposure Factors" (U.S. EPA 1991b), and more recent information from U.S. EPA's Office of Solid Waste and Emergency Response (OSWER) and U.S. EPA's Office of Research and Development (ORD). Default values are identified in Attachment C, Table C-1. Because contact rates may differ for children and adults, carcinogenic risks during the first 30 years of life were calculated using age-adjusted factors ("adj"). Use of age-adjusted factors is especially important for soil ingestion exposures, which are higher during childhood and decrease with age. Age-adjusted factors are used for groundwater ingestion

(when a Title 118 MCL is not available) and dermal exposures. These factors approximate the integrated exposure from birth until age 30, combining contact rates, body weights, and exposure durations for two age groups—small children and adults. Age-adjusted factors were obtained from RAGS Part B (U.S. EPA 1991a) or developed by analogy (see derivations below).

Incidental Ingestion ([mg-yr]/[kg-day]):

$$IFS_{adj} = \frac{ED_c \; x \; IRS_c}{BW_c} + \frac{(ED_a - ED_c) \; x \; IRS_a}{BW_a}$$

Dermal contact ([mg-yr]/[kg-day]):

$$DCF_{adj} = \frac{ED_c \; x \; AF_c \; x \; SA_c}{BW_c} + \frac{(ED_a - ED_c) \; x \; AF_a \; x \; SA_a}{BW_a}$$

Noncarcinogenic effects are evaluated in children separately from adults. No age-adjustment factor is used in this case. The focus on children is considered protective because of the higher daily intake rates of soil and ground water by children and their lower body weights.

The standardized equations used to calculate the VCP RGs are described in detail in Attachment C.

8.0 SUMMARY

This document describes the protocol followed to develop VCP RGs. The protocol provides an adequate level of protection to residential, recreational, industrial, and construction worker populations. Where possible, the values are specific to Nebraska through the use of, for example, Title 118 for ground water values and Nebraska-specific PEFs. Overall, this approach protects human health and the environment, and allows maximum flexibility to VCP participants.

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