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Leah J. Smith
District and Business Support Program
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Florida Department of Environmental Protection
2600 Blair Stone Road
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Re: Derivation of acute soil and groundwater cleanup target levels for vinyl chloride

Dear Ms. Smith:

At your request, we have developed acute soil and groundwater cleanup target levels for vinyl chloride under a utility worker scenario. A default utility worker scenario is not currently available from the Florida Department of Environmental Protection (FDEP) or the United States Environmental Protection Agency (USEPA). Therefore, we developed equations and exposure assumptions for the calculation of utility worker cleanup target levels based on acute exposure to soil and groundwater. The methodology for the derivation of utility worker cleanup target levels is explained in detail below.

Under the utility worker scenario, it is typically assumed that a worker visits the site to repair utilities in a utility trench and has exposure to both soil and groundwater while working. The upper-end exposure frequency utilized by the USEPA and the FDEP at other sites for the utility worker is 20 d/y. However, it is unlikely that the utility worker would spend 20 consecutive days at the site. Instead, it is more probable that the utility worker would spend one to two days at a site a few times per year. In between these visits, there would be no exposure. Therefore, the exposure period of concern more closely resembles a series of intermittent acute exposures rather than a chronic or subchronic exposure period. An acute exposure scenario is defined as a short-term exposure usually lasting 24 hours or less, and acute exposure limits are often much higher than chronic exposure limits. For the purposes of this assessment, we have defined acute exposure to soil and groundwater as a one-day (24-hour) exposure.

Although vinyl chloride is classified by the USEPA as a known human carcinogen, oral and inhalation cancer potency values available for this and other chemicals are based upon lifetime exposure. When exposures are less than lifetime, cancer risk estimates are adjusted with the assumption that cancer risk is cumulative with exposure and proportional to the fraction of lifetime exposed. There is experimental evidence that this assumption may not be valid for many carcinogens (e.g., Halmes et al., 2000) and for very short exposures we consider cancer estimates derived using this assumption to be unsupported and unreliable. No alternative, generally accepted method for estimating cancer risk for acute exposures exists. For the purpose

of developing acute exposure limits for vinyl chloride, some cancer risk exists but is likely to be small, and the effort to derive numerical exposure limits is consequently focused on prevention of non-cancer health effects.

The Agency for Toxic Substances and Disease Registry (ATSDR) has developed an acute inhalation minimal risk level (MRL) of 0.5 ppm (1,278 $\mu g/m^3$). This is based on studies by John et al. (1977, 1981). Briefly, CF-1 mice were exposed to vinyl chloride for 7 h/d on gestational days 6-15 at concentrations of 0, 50, or 500 ppm. At 500 ppm, death was noted in 17% of the mothers. For mice that survived and gave birth, a significant increase in delayed ossification was observed in the pups. Therefore, 50 ppm was chosen as the no observed adverse effect level (NOAEL) and 500 ppm was chosen as the lowest observed adverse effect level (LOAEL) for acute inhalation exposures. An uncertainty factor of 300 was used, including 3 for dosimetric extrapolation from mice to humans and 10 for sensitive subpopulations/life stages. This results in an acute reference concentration (RfC) of 1,278 $\mu g/m^3$. An acute exposure guideline level (AEGL) is also available for vinyl chloride. The USEPA has developed an eight-hour AEGL Level 1 value of 70 ppm (1.8E+05 $\mu g/m^3$). The AEGL Level 1 values represent notable discomfort, irritation, and other non-sensory effects that are not disabling, are transient, and are reversible upon cessation of exposure (NAS, 2001). The vinyl chloride AEGL Level 1 was based on a study of 4-7 volunteers where two individuals developed a headache after 3.5 hours of exposure to 491 ppm vinyl chloride (NAS, 2012). This study identified frank effects and did not take into account systematic effects that may not be immediately apparent to the worker. Although the AEGL is based on human volunteers, the developmental effects seen in the mice pups represent an adverse effect on the fetus and warrant consideration as there is nothing to preclude a utility worker from being a woman of reproductive age. Therefore, the ATSDR MRL of 1,278 $\mu g/m^3$ was chosen for the development of acute soil and groundwater screening levels.

We could not locate an acute oral dose for vinyl chloride in the literature with the exception of lethal dose concentrations in animals. Because the acute RfC is based on developmental effects in the fetus, we utilized route-to-route extrapolation from the acute inhalation MRL rather than extrapolation from lethal oral concentrations. Vinyl chloride is rapidly and completely absorbed from the gastrointestinal (GI) tract in rats after oral administration (ATSDR, 2006). Therefore, we used a GI absorption of 1, a body weight of 80 kg, and a breathing rate of 20 m^3/d to derive an acute oral reference dose (RfD) of 0.32 mg/kg-d from the RfC of 1,278 $\mu g/m^3$ [(1.278 mg/m^3 x 20 m^3/d)/(80 kg x 1)].

The vinyl chloride acute soil cleanup target level (SCTL) for utility workers was calculated using a modified version of the equation used for calculating acute toxicity SCTLs in Chapter 62-777, F.A.C. (CEHT, 2005). The equation is provided in Figure 1 and the exposure parameters are listed in Table 1. For the development of a utility worker-specific acute SCTL, it was assumed that utility work is similar to construction work in that it involves soil intensive activities and may include exposure to subsurface soil and groundwater. Therefore, body weight (BW), the volatilization factor (VF), and the incidental soil ingestion rate (IR) were taken from the USEPA's Regional Screening Level (RSL) Calculator for construction workers (Table 1). The USEPA and ATSDR consider dermal absorption of vinyl chloride to be negligible and the USEPA does not calculate a dermal screening level for this chemical (ATSDR, 2006). Therefore, we removed the dermal component from the equation. This is equivalent to setting the dermal absorption to zero. Using the equation in Figure 1 and the exposure parameters listed in Table 1, we calculated a **utility worker acute SCTL of 1,200 mg/kg vinyl chloride** (rounded to two significant figures).

The acute groundwater cleanup target level (GCTL) for utility workers was calculated using a modified version of the VDEQ model for exposure to groundwater contaminants in a construction/utility trench. The equation is provided in Figure 2 and the exposure parameters are listed in Table 1. Based on the negligible dermal absorption of vinyl chloride, the dermal component of the equation was also removed for the derivation of an acute GCTL. The exposure parameters used in the calculation of the acute GCTL were obtained from the VDEQ model. Two separate volatilization factors exist for this model. The first assumes that groundwater is less than or equal to 15 feet deep and the worker has direct exposure to groundwater. Based on the shallow groundwater table located throughout most of Florida, this is the scenario used in the development of utility worker acute GCTLs. In this scenario, the trench is conservatively assumed to be 3 feet wide, 8 feet long, and 8 feet deep. If the trench at a site is expected to differ significantly from the area and volume proposed, a site-specific value should be calculated. The fraction of the trench floor through which the groundwater can enter is assumed to be 1. The air changes in the trench are assumed to be 2 per hour based on measured ventilation rates in buildings (VDEQ, 2020). Body weight and surface area were updated to reflect current USEPA exposure assumptions (OSWER Directive 9200.1-120). Using the equation in Figure 2 and the exposure parameters in Table 1, we calculated a **utility worker acute GCTL of 120 μg/L** (rounded to two significant figures).

Please let us know if you have any questions regarding the derivation of these values.

Sincerely,

Leah D. Stuchal, Ph.D.

Stephen M. Roberts, Ph.D.

References:

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Figure 1 – Acute soil cleanup target level equations for the utility worker scenario:

$$Acute\ SCTL_{ingestion} = \frac{BW}{\frac{1}{RfD_{acute}} \times IR \times 10^{-6}(kg/mg)}$$

$$Acute\ SCTL_{inhalation} = \frac{1}{\frac{1}{RfC_{acute}} \times \left(\frac{1}{VF} + \frac{1}{PEF}\right) \times 1000(\mu g/mg)}$$

$$Acute\ SCTL\ (mg/kg) = \frac{1}{\frac{1}{Acute\ SCTL_{ingestion}} + \frac{1}{Acute\ SCTL_{inhalation}}}$$

Figure 2 – Acute groundwater cleanup target level equations for the utility worker scenario:

$$Acute\ GCTL_{ingestion} = \frac{BW}{\frac{1}{RfD_{acute}} \times IR_w \times 0.001\left(\frac{mg}{\mu g}\right)}$$

$$Acute\ GCTL_{inhalation} = \frac{1}{\frac{1}{RfC_{acute}} \times VF_{lt}}$$

$$VF_{lt} = \frac{K_i \times A \times F \times 10^{-3}(L/cm^3) \times 10^4(cm^2/m^2) \times 3600(s/hr)}{ACH \times V}$$

$$K_i = \frac{1}{\frac{1}{k_{iL}} + \frac{R \times T}{H_i \times k_{iG}}}$$

$$k_{iL} = \left(\frac{MW_{O2}}{MW_i}\right)^{0.5} \times \frac{T}{298} \times k_{L,O2}$$

$$k_{iG} = \left(\frac{MW_{H2O}}{MW_i}\right)^{0.335} \times \left(\frac{T}{298}\right)^{1.005} \times k_{G,H2O}$$

$$Acute\ GCTL(\mu g/L) = \frac{1}{\frac{1}{Acute\ GCTL_{ingestion}} + \frac{1}{Acute\ GCTL_{inhalation}}}$$

Table 1 – Exposure parameters for the utility worker acute cleanup target levels for vinyl chloride

Abbreviation	Definition	Value
A	Area of the Trench	2.22 m^2
ACH	Air Changes per Hour	2 h^{-1}
BW	Body Weight	80 kg
F	Fraction of Floor through which Contaminant Enters	1
GCTL	Groundwater Cleanup Target Level	Calculated (μg/L)
H_i	Henry's Law Constant of i	2.8E-02 (atm-m^3/mol-K)
IR	Soil Incidental Ingestion Rate	330 mg/d
IR_w	Water Incidental Ingestion Rate	0.02 L/d
$k_{G,H2O}$	Gas Phase Mass Transfer Coefficient of Water at 25° C	0.833 cm/s
K_i	Mass Transfer Coefficient	Calculated (cm/s)
k_{iG}	Gas Phase Mass Transfer Coefficient of i	Calculated (cm/s)
k_{iL}	Liquid Phase Mass Transfer Coefficient of i	Calculated (cm/s)
$k_{L,O2}$	Liquid Phase Mass Transfer Coefficient of Oxygen at 25° C	0.002 cm/s
MW_{H2O}	Molecular Weight of Water	18 g/mol
MW_i	Molecular Weight of i	62.5 g/mol
MW_{O2}	Molecular Weight of Oxygen	32 g/mol
PEF	Particulate Emission Factor	1.24E+09 m^3/kg
R	Ideal Gas Constant	8.2E-05 atm-m^3/mol-K
RfC_{acute}	Acute Inhalation Reference Concentration	1,278 μg/m^3
RfD_{acute}	Acute Oral Reference Dose	0.32 mg/kg-d
SCTL	Soil Cleanup Target Level	Calculated (mg/kg)
T	Average System Absolute Temperature	298 K
V	Volume of the Trench	5.44 m^3
VF	Volatilization Factor	9.56E+02 (m^3/kg)
VF_{lt}	Volatilization Factor for Groundwater Less than or Equal to 15 Feet Deep	Calculated (L/m^3)