ATTACHMENT U-3

SOIL GAS EVALUATION

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U.A3-1. Casmalia Soil Vapor Sample Locations.

1.0 INTRODUCTION

Ecological risks to burrowing receptors at the Former Casmalia Hazardous Waste Management Facility (the Site) in Casmalia, California were evaluated as part of the Site's overall remedial investigation (RI).

Soil gas data were collected at the Site and 40 volatile organic compounds (VOCs) were detected. Based on the process for selecting chemicals of potential ecological concern (CPECs) as described in Appendix U (Section 3.2), 3 of the VOCs (1,1,2–trichloroethane, 1,4-dioxane, and chloroethane) were detected in less than 5% of the samples (sitewide) and therefore, these VOCs were not included in this evaluation. Although isobutane was detected, it was not considered a CPEC as it was used as a tracer for the leak test (see Section 3.4 of the main RI) and therefore, not included in this evaluation. Burrowing mammals are the potential ecological receptors most susceptible to exposures from VOCs migrating into their burrows from soil and/or groundwater. According to Carlsen (1996), soil gas data can be conservatively assumed to represent burrow air concentrations.

Potential risks to burrowing receptors via the inhalation pathway was not evaluated as dose (see Section E4.4 of Appendix U), but as burrow air concentrations which were compared to burrow air inhalation toxicity reference values (TRVs).

Burrow air inhalation TRVs are defined as the chemical-specific concentration at which ecological relevant effects might occur. Burrow air inhalation TRVs were developed herein and compared to VOC concentrations in soil gas from the Site to evaluate whether VOCs are present at levels that may elicit adverse ecological effects to endemic ecological receptors and receptor classes. Species observed or likely to occur onsite that may be exposed to soil gas in burrows include the California ground squirrel, the striped skunk, the American badger, and the coyote. Burrowing owls were initially identified as potentially occurring on the Site; however, they were not observed onsite during any of the surveys (see Appendix P for details).

Burrow air inhalation TRVs were developed for all 37 soil gas CPECs using the following approach:

1) Identify mammalian toxicity studies examining adverse effects following inhalation exposure from the following sources:
   a) EPA's Integrated Risk Information System (IRIS; USEPA, 2007a);
   b) The Agency for Toxic Substances and Disease Registry's (ATSDR) Toxicological Profiles (ATSDR Toxicological);
   c) EPA's Provisional Peer Reviewed Toxicity Values (PPRTV; USEPA, 2007b);
   d) The National Institutes of Health's (NIH) Hazardous Substances Database (NIH HSDB) and;
   e) The mammalian inhalation TRVs developed for the Edwards Air Force Base were also reviewed, as requested by USEPA.
2) Document each study's test species, exposure duration, effect, and resultant effect dose or concentration (lowest observable adverse effect level [LOAEL] and/or no observable adverse effect level [NOAEL] where available).
3) Adjust each study's LOAEL/NOAEL (where available) to account for a worst-case exposure scenario (24-hour day, 7-day week).

4) Apply uncertainty factors to the adjusted LOAEL/NOAEL in cases where the study duration was insufficient or when a NOAEL could not be identified from the study.
5) Select the most appropriate inhalation TRV for each chemical.
6) Estimate risks based on NOAEL- and LOAEL-based TRVs. Exceedances of the NOAEL-based TRVs indicate a potential for risk. Exceedances of the LOAEL-based TRVs indicate potential significant risks to burrowing mammals via the inhalation of burrow air pathway.

Further details associated with the approach towards burrow air inhalation TRV development are provided below along with an evaluation of the Site soil gas concentrations.

2.0 METHODOLOGY

Soil gas data were collected from 40 locations from the Site and from 3 locations offsite as shown in Figure U.A3-1. Because the CSC expected the soil vapor concentrations to be greatest adjacent to the major site sources, the data collection program targeted collecting data as close to the source areas as practicable and focused on the landfill areas of the Site. The primary source areas included: the Terrestrial Capped Area, the PCB Landfill, the Liquids Treatment Area, around the margins of the Central Drainage Area, and the Burial Trench Area. Soil gas samples were not collected in the interior of the Central Drainage Area where the worst-case light non-aqueous phase liquid (LNAPL) and dense non-aqueous phase liquid (DNAPL) conditions occur because it is anticipated that this area will be capped and the potential exposure pathway will be eliminated. Uncertainties associated with this potential data gap are discussed in Section 4 below.

The CSC collected the soil vapor data at depths representing the 0- to 10-foot-depth interval as well as depths of 20 feet (during the Phase II soil vapor sampling). Soil gas samples were collected and analyzed as described in Section 3.4 of the main RI; sampling and results are discussed in Appendix C. The sections below describe the methods used to develop burrow air inhalation TRVs for the soil gas CPECs. The results of this effort are presented in Table U.A3-1.

2.1 Selection of Toxicity Studies

Peer-reviewed sources of toxicological and adverse health effect information were queried for toxicity data relating to effects on small mammals from VOC inhalation at various doses. These sources include the USEPA's IRIS, ATSDR's Toxicological Profiles, USEPA's PPRTVs, and NIH's HSDB.

Mammalian toxicity studies were selected from these sources since the receptor class/receptor of concern for potential VOC soil gas exposures at the Site is burrowing mammals. No specific receptor was identified for the quantitative evaluation of soil gas; instead, conservative risk-based concentrations were developed for mammals in general and screened against soil gas data. All mammals at the site were assumed to burrow and the American badger was selected as the representative deep burrower (greater than 6 feet below ground surface [bgs]). The California Department of Toxic Substance Control (DTSC) guidance states that in cases where data from the representative species are not available or of questionable quality, a wider range of taxa can be considered (CalEPA, 1996). Most of the species used in the toxicity studies are rats and mice which are sufficiently similar in taxa and body size to the ground squirrel for burrow air inhalation TRV development.

Toxicity studies examining effects via inhalation versus other exposure pathways were the focus of the evaluation since this is the pathway being evaluated herein (i.e., the use of inhalation-based TRVs is most relevant for comparison to the site-specific soil gas data). As discussed previously, soil gas data can be considered representative of air that burrowing mammals would likely be exposed containing VOCs that have migrated into confined spaces (i.e., burrows) at the Site. TRVs were developed as reference concentrations (RfCs) in units of milligrams per cubic meters (mg/m^3) to be comparable to the available soil gas data from the Site without

further assumptions or dose calculations. This approach has been used and approved by DTSC at Santa Susana Field Laboratory. Soil gas data were reported in parts per billion volume (ppbv) which were converted to mg/m^3 using the Ideal Gas Law equation:

$$mg/m3 = (ppbv/1000) *(molecular\ weight/24.45) \qquad \text{Equation 1}$$

2.2 Documentation of Toxicity Studies

The test species, test duration, test effect/endpoint, and resultant effect dose (NOAEL / LOAEL) were identified for each of the relevant mammalian inhalation studies. The individual studies were designated as acute, subchronic, or chronic studies based on the following criteria:

- Acute Test: exposure duration was less than one day;
- Subchronic Test: exposure duration was greater than a day but less than a lifetime; and
- Chronic Test: exposure duration was over approximately a lifetime or occurred during a critical period of time (e.g., reproductive or developmental bioassays were considered chronic studies when conducted during gestation).

Results from chronic studies were considered preferential to those from acute and subchronic tests because they span the most sensitive stage of the life cycle, when the organism would be at the greatest risk of effects. Uncertainty factors (UFs) were applied to results from studies with shorter exposure durations as described in Section 2.4.

2.3 Adjustment of Study Exposure Duration

The exposure duration for each study varied considerably, making it difficult to compare the resultant LOAEL/NOAELs. Each study, except those that derived an LC50 (lethal concentration corresponding to 50 percent mortality), was adjusted such that the exposure duration and resultant effect doses represented a 24 hours per day, 7 days per week (worst case) exposure duration.

2.4 Application of Uncertainty Factors

As mentioned above, NOAELs identified from chronic toxicity studies provide the most appropriate indicator of the dose or concentration at which no adverse effect is observed over a lifetime exposure. Studies in which both a NOAEL and a LOAEL were identified were preferred since unbounded NOAELs (i.e., where none of the doses tested in the study showed an effect, and thus, the threshold for the effect is unknown) are not very useful in determining a toxicity threshold compared to NOAELs that are bounded by LOAELs. Unbounded NOAELs are only reflective of the highest study dose tested, with no information about what dose would results in an effect. Studies reporting toxicity results from acute or subchronic toxicity tests, or studies with only LOAEL values can still be used according to DTSC guidance (CalEPA, 1996), but UFs are applied to compensate for the following:

- Study duration less than one full life-cycle of the surrogate organism when the most sensitive stages of the life cycle were not tested;

- Studies that do not address sensitive indicators of toxicity, such as reproduction, behavior, or pathology; and
- Study duration is insufficient to obtain maximum tissue concentration or toxic effect.

The use of UFs for human health risk assessment is well known. Comparable protocols for the use of UFs in ecological risk assessments (ERAs) have been recommended (Calabrese and Baldwin, 1993). After reviewing several literature sources (Dourson and Stara, 1983, as cited in Calabrese and Baldwin, 1993; Sloof et al., 1986; Sample et al, 1996; CalEPA, 1996; USEPA, 1997) including personal communication, M. Anderson of DTSC, a conservative set of UFs were selected to account for differences in study duration and endpoint. The objective of the extrapolations is to normalize the study doses to chronic NOAELs, although LOAELs may be preferable or useful for some ERAs. The following default UFs were applied in these situations:

- A UF of 100 was applied to adjust from acute exposures to a chronic NOAEL;
- A UF of 10 was applied to adjust from an acute LOAEL to a chronic LOAEL; A UF of 10 was applied to adjust from a chronic LOAEL to a chronic NOAEL; and
- A UF of 2 was applied to adjust from a subchronic to chronic exposure.

2.5 Calculation and Selection of TRVs

Study-specific TRVs were calculated based on the adjusted LOAEL/NOAELs divided by the relevant UFs, if any. For example, the TRV for a chronic toxicity study that identified a NOAEL is simply the adjusted NOAEL. The TRV for an acute toxicity study that identified a LOAEL is the LOAEL divided by the UF of 100. Mortality studies, which are generally acute, were adjusted by a factor of 100 except where the study was subchronic or chronic (i.e., mortality was measured incidentally in a longer term study generally designed to evaluate a more sensitive endpoint).

All of the study-specific TRVs developed for each chemical were then evaluated collectively to select the most representative value for predicting the air concentration at or below which ecological effects are unlikely to occur from mammalian inhalation exposure to VOCs. The following preferences were used to select the most representative and appropriate TRVs:

- Preference was given to toxicity data that allowed development of a TRV without the use of UFs (i.e. chronic studies reporting a bounded NOAEL). The selected TRV generally represents the highest bounded NOAEL from a valid study that still fell below the lowest LOAEL;
- LOAELs were preferentially used where bounded NOAELs were unavailable (as discussed above, an unbounded NOAEL does not provide information relevant to establishing a threshold for effects, but rather is solely defined by the study design; unbounded NOAELs are presented in Table U.A3-1);
- Reproductive endpoints were favored first, followed by developmental endpoints, with mortality being the least preferred The exception was where the adjusted study dose for a mortality study was lower than that from a more sensitive endpoint study; in this case, the mortality study TRV was selected instead (this was the case for a majority of the VOCs); for the mortality study TRVs, preference was given to studies reporting observed effects and in the order of chronic > subchronic > acute effects; and;

- Where multiple chronic studies measured a similar endpoint, the lowest TRV amongst the studies was conservatively elected (even if it was not the highest NOAEL).
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The NOAEL-based TRVs were developed based on the approach described above. LOAEL-based TRVs were also developed based on the selected study for the NOAEL-based TRV, adjusting the dose for LOAEL using appropriate UFs to result in chronic LOAEL-based TRVs. The bold values under the TRV columns in Table U.A3-1 identify the selected burrow air inhalation NOAEL and LOAEL-based TRVs.

2.6 Review of Mammalian Inhalation TRVs Prepared for Edwards Air Force Base

As requested by the agencies, the mammalian TRVs developed for the Edwards Air Force Base (by Tetra Tech in 2002) were reviewed for this ERA. A summary of the TRVs was provided by USEPA in July 2009 (the technical memorandum describing the actual derivation approach details could not be obtained).

The approach, methods, and secondary sources used to develop the mammalian TRVs for the Edwards Air Force Base appear to be similar those used to develop burrow air TRVs for this ERA. The NOAEL-based TRVs developed for the Edwards Air Force Base (non-body weight adjusted) were compared with the NOAEL-based TRVs developed by the CSC and appropriate TRVs were selected for the ERA. The following steps were taken to evaluate the two sets of TRVs and select the appropriate ones for the ERA:

- The TRVs developed by CSC and the TRVs developed for the Edwards Air Force Base were compared for all the 37 soil gas CPECs;
- If an Edwards Air Force Base TRV for a CPEC was not available, then the TRV developed by CSC was retained as the selected TRV for this ERA; these included TRVs for 10 of the CPECs (1,3-butadiene, 2-propanol, 4-ethyltoluene, 4-methyl-2-pentanone, bromomethane, cyclohexane, ethanol, heptane, hexane, and tetrahydrofuran);
- Of the remaining 27 CPECs, if the TRVs developed by CSC were similar or more conservative than the TRVs developed for the Edwards Air Force Base, then those TRVs were retained as the selected TRVs for this ERA. These included TRVs for 7 of the CPECs (1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,4-dichlorobenzene, acetone, chloroethane, methyl ethyl ketone, and tetrachloroethene);
- Of the 20 remaining CPECs, the endpoints used in the development of the TRVs were compared. Selection of TRVs for the ERA was based on the approach described above in Section 2.5; where sensitive endpoints related to population-level effects were preferentially selected.
    - A total of 16 TRVs developed for the Edwards Air Force Base were based on effects such as hepatic function, systemic function, neurological function, behavior, renal function, and respiratory function. For these CPECs (1,1,1-trichloroethane, 1,1-dichloroethane, 1,2-dichloropropane, 2-hexanone, benzene, carbon disulfide, chloroform, chloromethane. cis-1,2,-dichloroethene, ethylbenzene, m,p-xylene, methylene chloride, o-xylene, toluene, trichloroethene, and vinyl chloride) the TRVs developed by the CSC were considered more

appropriate as the endpoints were based on mortality, reproduction, and/or developmental effects.

- A total of 4 TRVs developed for the Edwards Air Force Base were based on sensitive endpoints related to population-level effects (1,1-dichloroethene, carbon tetrachloride, Freon 11, and Freon 113).
  - Although the study and endpoint used to develop the TRV for 1,1-dichloroethene is the same (Prendergast et al., 1967), the study dose reported for the Edwards Air Force Base (6 mg/m^3) assumed to be estimated from the study LOAEL dose of 15 parts per million (ppm) is an order of magnitude less than the dose reported by CSC (59.5 mg/m^3),[1] resulting in a TRV that is an order of magnitude lower (0.6 mg/m^3). As the calculations of the Edwards Air Force Base TRV for 1,1-dichloroethene cannot be verified (technical memorandum not available), the TRV developed by CSC is considered appropriate and was retained as the TRV for 1,1-dichloroethene for the ERA.
  - The endpoints selected for developing Edwards Air Force Base TRVs for carbon tetrachloride, Freon 11, and Freon 113 are considered appropriate and are more conservative than the ones developed by CSC for these CPECs. However as the development of the Edwards Air Force Base TRVs cannot be verified (technical memorandum not available), the TRVs developed by CSC will be retained for the ERA. However, the risks associated with use of Edwards Air Force Base TRVs are discussed below in the uncertainty analysis (Section 4).

To summarize, the TRVs developed by the CSC were considered more appropriate, based on selection of endpoints, for 34 of the 37 CPECs and these were selected as the TRVs for the ERA. The TRVs for the remaining 3 CPECs developed by CSC and for the Edwards Air Force Base were both considered appropriate; however, as the CSC TRVs are less conservative, the uncertainties associated with not selecting the Edwards Air Force Base TRVs for these 3 CPECs are discussed in Section 4.

[1] Converting 15 ppm to mg/m^3 using the Ideal Gas Law equation = (15 ppm*molecular weight of 1,1-dichloroethene)/24.45 = 59.5 mg/m^3.

3.0 RESULTS OF DATA EVALUATION

Soil gas concentrations were evaluated separately for onsite and offsite samples. For Site data, comparisons of the (1) maximum detected soil gas concentrations and (2) exposure point concentrations (EPCs) to the burrow air TRVs discussed above are presented in Table U.A3-2. Sitewide EPCs were lesser of the maximum detected concentration and 95 percent upper confidence level (95%UCL) on the mean soil gas concentration. The 95%UCLs were calculated using ProUCL V4.0 following the decision tree (see the main RI for details) for selecting the most appropriate value. For offsite data (Table U.A3-3), only the maximum detected concentrations were compared to the burrow air TRVs. Sufficient data were not available to calculate offsite EPCs. Hazard quotients (HQs), which are estimates of risk, were calculated as follows:

$$HQi = \frac{Ei}{TRVi} \qquad \text{Equation 2}$$

where:

HQi = Hazard quotient (unitless) for chemical i;
Ei = Exposure concentration for chemical i; and
TRVi = Toxicity reference value for chemical i.

Burrow air risks were estimated risks using NOAEL- and LOAEL-based TRVs. Exceedances of the NOAEL-based TRVs indicate the potential for risk. Exceedances of the LOAEL-based TRVs indicate potential significant risks to burrowing mammals via the inhalation of burrow air pathway.

Risk estimates for VOCs with HQs greater than 1 are shown in the table below. The results indicate the potential for unacceptable risk due to inhalation of burrow air from VOCs detected in soil gas.

Results of Onsite HQ Calculations:

Maximum Detected Concentrations and NOAEL-based TRVs	Maximum Detected Concentrations and LOAEL-based TRVs	EPCs and NOAEL-based TRVs	EPCs and LOAEL-based TRVs
1,1,1-trichloroethane (HQ = 4) 1,1-dichloroethene (HQ = 65) Carbon tetrachloride (HQ = 8) Chloroform (HQ = 13) Freon 113 (HQ = 4) Tetrachloroethene (HQ = 31) Trichloroethene (HQ = 3)	1,1-dichloroethene (HQ = 13) Carbon tetrachloride (HQ = 2) Freon 113 (HQ = 2) Tetrachloroethene (HQ = 3)	1,1-dichloroethene (HQ = 7) Tetrachloroethene (HQ = 9)	None

The offsite NOAEL TRV- and LOAEL TRV- based HQs for all VOCs are well below 1, indicating no likelihood for unacceptable risk due to inhalation of burrow air in offsite locations at concentrations posing unacceptable risks to offsite receptors.

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Although 1,1-dichloroethene and tetrachloroethene had NOAEL TRV-based HQs greater than 1, it should be noted that the burrow air TRVs developed are conservative and indicate only potential risk. LOAEL-based HQs for 1,1-dichloroethene and PCE are less than one. Based on this analysis, VOCs in burrow air are unlikely to pose an unacceptable risk to burrowing mammals.

4.0 UNCERTAINTY ANALYSIS

As discussed previously, a worst-case assumption that small mammals are exposed to burrow air 24 hours per day/7 days per week was used in this evaluation. This approach is overly conservative and likely overestimate risks to Species that hibernate may spend long periods of time consecutively in their burrows, although since metabolism is lowered during hibernation, exposure (i.e., inhalation rate) would be lower as well. For example, for some species breathing rates may drop to less than one breath per minute and some species may have prolonged periods of apnea (Milsom, 1991). Most burrowing species spend their time in their burrows sleeping (daytime for nocturnal animals and nighttime for diurnal animals). The rest of their time is generally spent foraging. The amount of time spent outside the burrow varies by species (www.enature.com/guides/select_Mammals.asp). In arid or hot areas, diurnal animals may spend more of the daytime in their burrows during the summer.

Evaluating potential risks from maximum detected concentrations is considered very conservative. Populations of receptors would be exposed over a larger area and even individual receptors would be unlikely to be exposed to the maximum concentration since most burrows extend several feet (up to 20 feet, for example, for ground squirrels; Zeiner et al., 1990). Also, some species move their burrow locations frequently (the American badger, for example, migrates constantly and may dig a new den each night; Zeiner et al., 1990; www.american-badgers.com).

Soil gas samples were not collected in the interior of the Central Drainage Area where the worst-case LNAPL and DNAPL conditions occur. There are uncertainties with the risks estimated herein based on this potential data gap. However, the maximum detected concentrations of VOCs collected from other areas would be in the range of the VOC concentrations within the Central Drainage Area; therefore, there may be potential unacceptable risks to burrowing receptors in this exposure area. Note that the CSC is contemplating extending the cap to encompass the Central Drainage Area and thereby, eliminating any potential exposure pathway.

The CSC TRVs used to estimate burrow air risks for 3 CPECs (carbon tetrachloride, Freon 11, and Freon 113) were not the most conservative TRVs, but were still retained as TRVs for the ERA as the TRVs developed for the Edwards Air Force Base could not be verified (technical memorandum not available). However, risks using the Edwards Air Force Base TRVs (estimated LOAEL-based TRVs) for these 3 CPECs indicate that carbon tetrachloride and Freon 113 could result in potentially unacceptable risks (HQs of 3 for both based on LOAEL-based TRVs and EPCs) but not Freon 11.

5.0 SUMMARY AND CONCLUSIONS

HQs calculated based on 95%UCL soil gas concentrations as EPCs were considered more appropriate than using maximum detected concentrations. NOAEL-TRV based HQs indicated that 1,1-dichloroethene and tetrachloroethene may cause potential risk to burrowing receptors. However, LOAEL-TRV based HQs were less than 1 for all the VOCs. Although, LOAEL-based TRVs are not protective of individual receptors, they are considered protective of populations. Additionally, the assumptions used in this assessment were conservative. Therefore, VOCs in burrow air are not considered to cause significant adverse effects on burrowing animals.

The risk estimates for offsite locations indicate no likelihood for unacceptable risk to burrowing wildlife due to inhalation of burrow air in offsite locations. This indicates minimum to no likelihood of migration of soil gas to offsite locations at concentrations posing unacceptable risks to offsite burrowing mammals.

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