ATTACHMENT U-1

BIOACCUMULATION FACTORS

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1.0 INTRODUCTION

This attachment describes the development of bioaccumulation or uptake factors for estimating exposures to ecological receptors at the former Casmalia Hazardous Waste Management Facility located in Casmalia, California (the Site).

Bioaccumulation in animal tissue or uptake in plants is the process where chemicals of potential ecological concern (CPECs) in the surrounding media are accumulated within the tissues of ecological receptors, especially to concentrations higher than in the surrounding media. Any CPEC that is excreted or metabolized at a slower rate than its uptake through absorption and ingestion will increase in tissues over time, resulting in bioaccumulation. Chemicals with high octanol-water partitioning coefficient (log K_{ow}) are more likely to bioaccumulate in tissues of prey (plants, invertebrates, and mammals) due to their lipophilic nature (USEPA, 2000). Additionally, some metals that are not readily excreted are also known to bioaccumulate (e.g., lead). CPECs that bioaccumulate have the potential to be passed up the food chain.

Bioaccumulation factors (BAFs) are multipliers that are used to estimate concentrations of chemicals that can accumulate in tissues through any route of exposure (USEPA, 2000). For plants, the BAF is sometimes referred to as a plant uptake factor (PUF). For aquatic invertebrates, the BAF is referred to as the bioconcentration factor (BCF). In this report, BAFs and BCFs were used to estimate concentrations of CPECs in biota and food item tissue (i.e., prey) from Site media. Chemicals with low octanol-water partitioning coefficient (log K_{ow}) values generally do no bioaccumulate (CalEPA, 1996, USEPA, 2000). Only CPECs with the potential to bioaccumulate were evaluated for the food ingestion pathway, namely some metals and organics with log K_{ow} values greater than 3.5 (USEPA, 2000). Volatile organic compounds (VOCs) and ionic compounds with high water solubility and low log K_{ow} were assumed to not bioaccumulate and therefore, BAFs were equal to zero for such compounds. All CPECs were evaluated for ingestion of soil, sediment, and surface water.

BAFs and BCFs for the Site Screening-Level and Tier 1 ecological risk assessment (ERA; presented as Appendix U) were primarily obtained from guidance documents or other commonly used sources as listed in order of preference in the following sections. The following media-to-biota BAFs/BCFs were developed for this Screening-Level and Tier 1 ERA:

- Soil-to-Plant;
- Soil-to-Soil Invertebrate;
- Soil-to-Mammal;
- Sediment-to- Aquatic Invertebrate; and
- Surface Water-to-Aquatic Invertebrate.

It was assumed that uptake into aquatic biota is primarily associated with sediment-to-biota uptake pathways. This is because most chemicals, and in particular organics, tend to partition from sediment-to-biota to a greater extent than from water-to-biota. However, as a conservative step, ingestion of food was accounted for in the surface water-to-biota pathway for aquatic invertivorous wildlife in the A-Series Pond exposure area. For the remaining ponds, the surface water-to-biota pathway was not considered significant for wildlife and therefore, only the sediment-to-biota pathway was evaluated. Note that assessing uptake from both surface water and sediment into prey items is uncertain because it requires an assumption about the amount of benthic and water column prey ingested.

All BAFs and BCFs selected or developed for the Screening-Level and Tier 1 ERA were on a dry-weight basis. If BAFs in literature were not available on a dry-weight basis, they were converted to dry weight using appropriate assumptions as described in the following sections. Dry-weight BAFs and BCFs were paired with food/prey item ingestion rates expressed on a dry weight basis in the exposure assessment of the Screening-Level and Tier 1 ERA.

2.0 BIOACCUMULATION FACTORS

The following describes the methods used to develop BAFs for soil-to-biota to evaluate Screening-Level and Tier 1 exposures to wildlife receptors at the Site.

2.1 Soil-to-Plant Bioaccumulation Factors

Soil-to-plant BAFs were selected from the following sources listed in order of preference:

- BAFs and uptake equations derived from regression analysis in U.S. Environmental Protection Agency's (USEPA's) updated Guidance for Developing Ecological Soil Screening Levels (EcoSSLs; USEPA 2007a) Attachment 4-1 (updated; USEPA, 2007);
- Oak Ridge National Laboratory (ORNL): plant BAFs reported by Bechtel-Jacobs (1998a);
- Baes, et al. (1984) uptake model for inorganic chemicals to plants. This source is also cited in some cases in the USEPA EcoSSLs guidance (USEPA, 2007a);
- BAFs in USEPA Region 6 Screening Level Ecological Risk Assessment Protocol, Appendix C (USEPA, 1999);
- BAFs based on empirical data from the US Army Center for Health Promotion and Preventive Medicine (USACHPPM, 2004);
- BAFs based on empirical data from peer-reviewed literature; and
- BAFs derived from surrogates.

The soil-to-plant BAFs used in the Screening-Level and Tier 1 ERA to estimate exposures to wildlife are presented in Table U.A1-1.

2.2 Soil-to-Invertebrate Bioaccumulation Factors

Soil-to-invertebrate BAFs were selected from the following sources listed in order of preference:

- Soil-to-earthworm BAFs from uptake equations derived from regression analysis in USEPA EcoSSLs guidance (USEPA, 2007a);
- ORNL: soil invertebrate BAFs reported by Sample et al. (1998a). These BAFs are also presented in the USEPA EcoSSLs guidance (USEPA, 2007a);
- Jager model (1998) for soil-to-earthworm uptake. This model is based on equilibrium partitioning (EqP) theory and is recommended by the USEPA EcoSSLs guidance (USEPA, 2007a). It should be noted that this model does not take into account potential elimination routes of the CPEC, such as metabolic breakdown or excretion. The Jager model (Jager, 1998) is described in detail in Section 2.5;
- BAFs based on empirical data from the US Army Center for Health Promotion and Preventive Medicine (USACHPPM, 2004);
- BAFs based on empirical data from peer-reviewed literature; and
- BAFs derived from surrogates.

The soil-to-invertebrate BAFs used in the Screening-Level and Tier 1 ERA to estimate exposures to wildlife are presented in Table U.A1-2.

2.3 Soil-to-Mammal Bioaccumulation Factors

Soil-to-mammal BAFs were selected from the following sources listed in order of preference:

- BAFs from uptake equations derived from regression analysis in USEPA EcoSSLs guidance (USEPA, 2007a). According to USEPA EcoSSLs guidance (USEPA, 2007a), semi-volatile organic compounds (SVOCs), including polycyclic aromatic hydrocarbons (PAHs) tend to metabolize rapidly in birds and mammals, and therefore, uptake of these CPECs from soil-to-mammal were assumed to be zero (USEPA, 2007a);
- ORNL: Mammal BAFs reported by Sample et al. (1998b). These BAFs are also presented in the USEPA EcoSSLs guidance (USEPA, 2007a);
- Baes, et al. (1984) uptake model for inorganic chemicals to beef cattle. This source is also cited in some cases in the USEPA EcoSSLs guidance (USEPA, 2007a);
- BAFs in USEPA Region 6 Screening Level Ecological Risk Assessment Protocol, Appendix D (USEPA, 1999); these values are modeled from log K_{ow} for organic chemicals (Travis and Arms, 1988). These values are not appropriate when evidence for metabolic degradation exists;
- BAFs based on empirical data from peer-reviewed literature; and
- BAFs derived from surrogates.

The soil-to-mammal BAFs used in the Screening-Level and Tier 1 ERA to estimate exposures to wildlife are presented in Table U.A1-3.

2.4 Sediment-to-Invertebrate Bioaccumulation Factors

Sediment-to-invertebrate BAFs were selected from the following sources listed in order of preference:

- Aquatic invertebrate BAFs estimated from biota-sediment accumulation factor (BSAFs) from the U.S. Army Corps of Engineers (USACE) BSAF database (USACE, 2007). BAFs were estimated from BSAFs as described below in Section 2.6;
- ORNL: BAFs and regression equations published in Bechtel-Jacobs (1998b);
- BAFs based on empirical data from peer-reviewed literature; and
- BAFs derived from surrogates.

The sediment-to-invertebrate BAFs that were based on wet weight were converted to dry weight assuming 79% moisture content for sediment invertebrates (USEPA, 1993). The sediment-to-invertebrate BAFs that were used in the Screening-Level and Tier 1 ERA to estimate exposures to wildlife are presented in Table U.A1-4.

2.5 Surface Water-to-Aquatic Invertebrate Bioconcentration Factors

Surface water-to-aquatic invertebrate BCFs were obtained from:

- USEPA Region 6 Screening Level Ecological Risk Assessment Protocol, Appendix C (USEPA, 1999); these values were based on experimental data for aquatic invertebrates including crustaceans, aquatic insects, bivalves, etc.).

For organic chemicals, field measured data were assumed to be total concentrations in water and were converted to dissolved concentrations (equation presented in guidance [USEPA, 1999] and laboratory measured data were assumed to be dissolved concentrations). For organic chemicals with no measured data, BCFs were based on surrogates or estimated using the model by Southworth et al. (1978):

$$\log\ BCF = (0.819 \times \log K_{ow}) - 1.146 \qquad \text{Equation 1}$$

For inorganic chemicals with no measured data, the BCF was estimated as the arithmetic average of the available BCF values for other inorganic values.

The surface water-to-aquatic invertebrate BCFs that were based on wet weight were converted to dry weight assuming 79% moisture content for sediment invertebrates (USEPA, 1993). The surface water-to-aquatic invertebrate BCFs that were used in the Screening-Level and Tier 1 ERA to estimate exposures to wildlife are presented in Table U.A1-5.

2.6 Bioaccumulation Factors Developed Based on the Jager Model

As described in the USEPA EcoSSLs guidance (USEPA, 2007a), the Jager model (Jager, 1998) can be used to estimate uptake of non-ionic organic chemicals in soil invertebrates when regression analysis and additional empirical data are not available. The Jager model provides a mechanistic approach to estimating bioaccumulation. Jager (1998) found the following relationship after comparing concentrations of organic contaminants in earthworms to the log K_{ow} of those contaminants:

$$\log K_{ww} = (0.87 \times \log K_{ow}) - 2 \qquad \text{Equation 2}$$

Where:

$\log K_{ww}$ = water-earthworm partitioning coefficient; the log K_{ww} was reported on a wet-weight basis, which was converted to a dry-weight basis assuming a 16% solids content for earthworm (Jager, 1998); and
$\log K_{ow}$ = octanol-water partitioning coefficient; from the National Library of Medicine Hazardous Substances Data Bank (HSDB, 2007) or the Syracuse Research Corporation (SRC) Chem Fate database (SRC, 2007).

The BAF is estimated by calculating the relative difference in partitioning of the chemical between the earthworm and the soil:

$$BAF = \frac{K_{ww}}{K_d}$$ Equation 3a

and $$K_d = foc \times K_{oc}$$ Equation 3b

Where:

BAF = bioaccumulation factor;
K_{ww} = water-earthworm partitioning coefficient in liters per kilogram earthworm (L/kg earthworm in dry weight);
K_d = Constant (L/kg soil in dry weight);
foc = fraction of organic carbon; and
K_{oc} = water-organic carbon partitioning coefficient.

Following the Work Plan (CSC, 2004), an organic carbon content of 1% was used which is considered typical (USEPA, 2007a). The water-organic carbon partitioning coefficient (K_{oc}) values were obtained from HSDB (2007) and the SRC (2007) databases, or the USEPA Soil Screening Guidance Technical Background document (USEPA, 1996). If no K_{oc}s were available, values were estimated based on class-specific models from Gerstl (1990).

For bis(2-ethylhexyl)phthalate (BEHP) and di-n-butyl phthalate (DBP), data on bioaccumulation in invertebrates are less conclusive based on a review for phthalate esters by Staples et al. (1997): Lokke (1988) report no accumulation of BEHP in woodlice or their offspring fed a diet of BEHP-containing oak leaves in a 6-month microcosm experiment. However, Albro et al. (1993) report very slow BEHP breakdown in earthworms. No known BEHP metabolites were found and hydrolysis was slow. The authors conclude that bioaccumulation is likely to occur in this species. However, due to a lack of empirical data, the Jager model was used to estimate invertebrate BAFs for BEHP and DBP (i.e., phthalates with log K_{ow}s greater than 3.5).

The Jager model (Jager, 1998) was also used to develop soil-to-invertebrate BAFs for most of the organochlorine pesticides (except 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT) and for all the PAHs.

2.7 Bioaccumulation Factors Developed from Travis and Arm Model

Soil-to-plant BAFs for PCBs were calculated based on the uptake regression from Travis and Arms (1988) for organic chemicals:

$$\log BAF = 1.588 - 0.573 \times \log Kow$$ Equation 4

Where:

log BAF = bioaccumulation factor in kilogram soil per kilogram plant tissue (*kg tiss/kg soil*); and
log Kow = octanol-water partitioning coefficient for Aroclor 1260.

Using Equation 4 above results in a BAF of 0.0045 for Aroclor 1260. This was used as a surrogate for total PCB soil-to-plant BAFs. Aroclor 1260 was considered to be an appropriate surrogate for total PCBs at this site because Aroclor 1260 was the most frequently detected Aroclor in soil.

Soil-to-mammal BAFs for PCBs were modeled based on prey uptake rather than soil uptake, similar to the method described by Baes et al. (1984) used in the EcoSSL guidance (USEPA, 2007). The following equation was used to calculate the prey-to-animal uptake as described in USEPA guidance (USEPA, 1999), for organic chemicals used for PCBs (based on Aroclor 1254):

$$BAF_{F-M} = Ba \times IR_F \qquad \text{Equation 5a}$$

Where:

BAF_{F-M} = bioaccumulation factor for food-to-mammal in kilogram food item tissue per kilogram mammal tissue (kg wet food tissue/kg wet mammal tissue);
Ba = chemical-specific biotransfer factor applicable for the mammal in day per kilogram (day/kg wet mammal tissue); and
IRF_F = ingestion rate of food item in kilograms per day (kg wet food/day).

The chemical specific biotransfer factor (Ba) was calculated using the uptake regression by Travis and Arms (1988):

$$\log Ba_M = -7.6 + \log Kow \qquad \text{Equation 5b}$$

Where:

$logBa_M$ = chemical-specific biotransfer factor applicable for the mammal in day per kilogram (day/kg wet mammal tissue); and
log Kow = octanol-water partitioning coefficient of the chemical.

Using Equations 5a and 5b, food-to-mammal BAFs were calculated for a variety of wildlife receptors by USEPA (1999). The most conservative PCB food-to-mammal BAF (0.03) was for the salt marsh harvest mouse, an herbivore (based on Aroclor 1254). This was selected for the soil-to-mammal BAF calculations. The food-to-mammal BAF (Equation 5a) was converted to a dry weight by assuming 77% moisture in plants and 68% moisture in mammals (USEPA, 1993).

$$BAF_{F-M}(dw) = 0.03 \times \frac{(1-0.77)}{(1-0.68)} = 0.025 \qquad \text{Equation 5c}$$

Where:

BAF_{F-M} *(dw)* = bioaccumulation factor for food-to-mammal in kilogram plant tissue per kilogram mammal tissue (kg dry plant tissue/kg dry mammal tissue);
0.03 = BAF_{F-M} wet weight; and
0.77 and 0.68 = moisture content in plants and mammals, respectively.

To calculate a soil-to-mammal BAF, the following equation was used (similar to Baes et al., 1984):

$$soil - to - mammal \ \ BAF = 0.025 \times Cd \qquad \text{Equation 5d}$$

Where:

soil-to-mammal BAF = bioaccumulation factor for soil-to-mammal in kilogram soil per kilogram tissue (kg dry soil/kg dry tissue);
BAF_{F-M} = bioaccumulation factor for food-to-mammal in kilogram food item tissue per kilogram mammal tissue (kg dry food tissue/kg dry mammal tissue); and
Cd = concentration in soil-to-diet in milligrams of chemical per kilogram tissue dry weight (mg/kg).

2.8 Bioaccumulation Factors Developed from USACE Database

A BAF is the ratio of a substance's concentration in tissue of an aquatic organism to its concentration in ambient media (in this case sediment) and is calculated as:

$$BAF\,(kg\,sed\,/\,kg\,tiss) = \frac{Ct\ (mg\,/\,kg\,tiss)}{Cs\ (mg\,/\,kg\,sed)} \qquad \text{Equation 6}$$

Where:

BAF = bioaccumulation factor in kilogram sediment per kilogram tissue (*kg tiss/kg sed*);
Ct = concentration of a chemical in milligrams per kilogram tissue (*mg/kg tiss*); and
Cs = concentration of a chemical in milligrams per kilogram sediment (*mg/kg sed*).

A BSAF is defined as "the ratio of a substance's lipid-normalized concentration in tissue of an aquatic organism to its organic carbon-normalized concentration in surface sediment" (USEPA 2000). Sediment-to-invertebrate BAFs were estimated from BSAFs using the following equation (USEPA, 2000 and USACE, 2007):

$$BSAF\,(g\,OC\,/\,g\,lipid) = \frac{\left(\frac{Ct}{fl}\right)}{\left(\frac{Cs}{foc}\right)} = \frac{Ct\,(mg\,/\,kg\,tiss)}{Cs\,(mg\,/\,kg\,sed)} \times \frac{foc\,(g\,OC)}{fl\,(g\,lipid)} = BAF \times \frac{foc}{fl} \qquad \text{Equation 7a}$$

Site-specific sediment total organic carbon (TOC) data ranges from 0.13% to 3.5%. For this Screening-Level and Tier 1 ERA, the site-specific TOC or fraction of organic carbon (foc) was conservatively assumed to be 1%, which is at the low end of the site-specific TOC range and would more likely overestimate rather than underestimate bioaccumulation. Additionally, 1% TOC is considered representative of the Site; 1% to 10% TOC represents the average range of TOC in sediment (USEPA, 1988). The fraction of lipid (fl) was assumed to be 2%. The median lipid content in freshwater invertebrates reported in the USACE BSAF database (USACE, 2007) is approximately 4%. Therefore, the 2% lipid assumptions is likely to overestimate rather than underestimate boaccummulation.

$$BAF(kg\,dry\,sed\,/\,kg\,wet\,tiss) = \frac{Ct}{Cs} = BSAF\,(g\,OC\,/\,g\,lipid) \times \left(\frac{0.02\,kg\,lipid\,/\,1kg\,wet\,tiss)}{0.01kg\,OC\,/\,1kg\,dry\,sed)} \right)$$

Equation 7b

As mentioned earlier, all BAFs were converted to dry weight based on 79% moisture content in sediment invertebrates (USEPA, 1993). Therefore, to convert the wet BAFs to dry BAFs, the following equation was used:

$$BAF\,(kg\,dry\,sed\,/\,kg\,dry\,tiss) = \frac{BAF\,(kg\,dry\,sed\,/\,kg\,wet\,\;tiss)}{(1-0.79)}$$

Equation 7c

To summarize the conversion of BSAFs to dry sediment-to-invertebrate BAFs (Equations 6a through 6c), the following equation was used:

$$BAF\,(kg\,dry\,sed\,/\,kg\,dry\,tiss) = \frac{BSAF \times 2}{0.21}$$

Equation 7d

For Equations 7a through 7d:

BAF = bioaccumulation factor in kilogram sediment per kilogram tissue (*kg sed/kg tis*s);
BSAF = biota-sediment-accumulation factor in gram organic carbon per gram lipid (*g OC/g lipid*);
fl = fraction of lipid in kilogram lipid per 100 kilogram wet tissue (*kg lipid/ 100 kg wet tiss*); and
foc = fraction of organic carbon in kilogram organic carbon per 100 kilogram dry sediment (*kg OC/ kg dry sed*).

In order to calculate BAFs, BSAF data for each CPEC were retrieved from the continuously updated USACE BSAF Database (USACE, 2007), which contains accumulation data for fish and invertebrate species. The dataset for each CPEC was evaluated based on a series of requirements appropriate for developing BAFs for this Screening-Level and Tier 1 ERA as follows:

1. Only invertebrate species were selected; no pooled organism data or fish BSAF data were included;
2. Only BSAFs from whole organisms were selected;
3. The USACE database contains BSAFs calculated from both wet tissue and dry tissue, and wet sediment and dry sediment. In some cases, this information was not reported in the database. The unknown values were omitted in the evaluation, as accurate calculation of the BSAF could not be verified;
4. Although freshwater species were preferred, data were extremely limited in many cases. In order to retain a sufficient number of values for the BAF calculation of a robust estimate of central tendency, it was necessary to use additional available BSAF data,

including estuarine/marine species. Species that were classified as strictly marine were excluded; and

5. A minimum of three BSAF values were required in order to estimate the median BSAF. When less than three values were available, appropriate surrogate compounds were used, as described below.

After compiling the subset of acceptable BSAF data, the median of the BSAFs was calculated for each CPEC available in the database, and this composite value was used to derive the BAF according to the equation shown above. The sediment BAFs were converted to a dry-tissue basis assuming 79% moisture content in sediment invertebrates (USEPA, 1993).

Sediment-to-invertebrate BAFs were derived from BSAFs from the USACE database (USACE, 2007) following the methods described above for most of the organochlorine pesticides, polychlorinated biphenyls (PCBs), total dioxin/furan toxicity equivalent (TEQ), and most of the PAHs.

For 2-methylnapthalene, fluorene, endrin, endosulfan, heptachlor, and kepone, data for individual CPECs were not available or the number of BSAFs was less than three. Data for similar compounds or composite values were used as surrogates in these cases. For example, the median total PAH BSAF was used to calculate a BAF for 2-methyl naphthalene and fluorene according to the methods described above. The median endosulfan sulfate BSAF was used to derive BAFs for endosulfan isomers. Similarly, total organochlorine pesticides (107 values) were used to estimate BAFs for endrin, heptachlor, and kepone.

BSAFs presented by Loonen et al. (1997) were also considered for the Screening-Level and Tier 1 ERA. In this study, oligochaetes were exposed to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and octa-chlorinated dibenzo-p-dioxin (OCDD) in sediment for 28 days. For TCDD, BSAFs of 1.6 and 0.99 were reported for sediment aged 3 weeks and 21 months, respectively. For OCDD, the BSAFs were approximately two orders of magnitude lower. Because sediment-dwelling invertebrates are exposed to a mixture of dioxin and furan congeners in environmental media, uptake factors developed from experiments with a single congener were not considered appropriate for the Screening-Level and Tier 1 ERA. The wide range in the magnitude of BSAFs presented by Loonen et al. (1997) also support the use of multiple congeners to model uptake of dioxins. Therefore, median BSAF value of 0.224 (USACE, 2007) for dioxin and furan congeners was used to derive a BAF of 2.8 for the Screening-Level and Tier 1 ERA using the methods described above.

2.9 Bioaccumulation Factors for Ionic Chemicals

For some ionic chemicals such as organophosphate pesticides/herbicides, published BAFs were not available from available guidance or commonly used sources listed above. A literature search was conducted in order to develop BAFs based on empirical data available in literature. Ionic chemicals that have low log K_{ow}s tend to be water soluble and such chemicals do not generally bioaccumulate (Rand, 1995). Based on literature sources, the following assumptions were made for organophosphate pesticides/herbicides.

For BEHP and DBP, numerous studies show limited potential for bioaccumulation in plants and wildlife. In a review of data for phthalate esters, Staples et al. (1997) indicates that, in general, BEHP was not found to accumulate in plants and some wildlife. DBP was detected in some plant studies and some studies reported accumulation of both phthalates in wildlife. BEHP and DBP can be extensively metabolized by higher trophic levels (birds and mammals) (Aranda et al.,1989; Schmitzer et al., 1988; Kato et al., 1981, Lokke and Bro-Ramussen, 1981; Lokke , 1988; Belise, 1975; O'Shea and Stafford, 1980; Ishuida et al. 1982 – all as cited in Staples et al., 1997). Due to limited accumulation data for plants and wildlife, the BAFs for BEHP and DBP were assumed to be zero. For invertebrates, the data was not so conclusive, and therefore, the Jager model (Jager, 1998) was used to develop BAFs for BEHP and DBP as explained above in Section 2.5.

For 4-(2,4-dichlorophenoxy)butyric acid (2,4-DB), USEPA states in the Reregistration Eligibility Decision, this compound is not likely to bioaccumulate due to its ionic nature (USEPA, 2005) and low log K_{ow}. Therefore, for this Screening-Level and Tier 1 ERA, plant, invertebrate, and mammal BAFs were assumed to be equal to zero for 2,4-DB. A similar assumption was made for 2-sec-butyl-4,6-dinitrophenol (dinoseb).

For 2,4,5-trichlorophenoxy propanoic acid (2,4,5-TP), USEPA states in the Technical Factsheet for 2,4,5-TP (USEPA, 2006), that this compound is unlikely to bioaccumulate to an appreciable extent. Bioconcentration from water will "not be significant", and the compound is reportedly very likely to essentially be completely adsorbed to soils. The average half-life for biodegradation of 2,4,5-TP in moist soils is 3 -12 days, indicating rapid dissipation from the environment. A BAF could not be estimated by the Jager method because the Jager model is appropriate for non-ionic contaminants only (Jager, 1998). No registration eligibility information for this compound is available because it has been banned for use in the United States since 1985. Additionally, this compound is ionic in nature with relatively low log K_{ow} and is not assumed to bioaccumulate in biota from soil. Therefore, based on information supplied by the USEPA (USEPA, 2005, 2006), for plants, invertebrates, and wildlife, a BAF equal to zero was assumed for the Screening-Level and Tier 1 ERA.

2.10 Bioaccumulation Factors Developed Based on Surrogates or Other Assumptions

BAFs were not available for the following CPECs from the sources listed above. Additionally, empirical data were not available to develop BAFs, and therefore, BAFs for chemicals with similar structure and toxicological effects were selected as surrogates as described below.

For soil invertebrates, soil-to-invertebrate BAFs were not available for molybdenum and tin. For these CPECs, the mean of the available metal BAF data was used as a surrogate. In the absence of available BAFs, it is common practice to use a default BAF of 1 or to derive a surrogate BAF from chemicals with similar chemical/physical properties (e.g., periodic table group). For metals, the USEPA (1999) used the mean of available metal BAF data as a surrogate for metals when there were no empirical data available. Following the approach used in USEPA (1999), the mean of the available metal BAF data for barium, beryllium, chromium, cobalt, copper, thallium, and vanadium (mean BAF = 0.168) was used as a surrogate for molybdenum and tin. Similarly, sediment-to-invertebrate BAFs were not available for barium, manganese, molybdenum, selenium, thallium, and tin. Therefore, the mean of the BAFs for cadmium, chromium, lead, and mercury (1.186) was used as a surrogate. Using this approach may have over- or under-estimated uptake to these wildlife food items and therefore, may over- or under-estimated exposure and risk to wildlife receptors.

For aquatic invertebrates, sediment-to invertebrate BAFs were not available for the following metals: barium, manganese, molybdenum, selenium, thallium, and tin. Using the USEPA method as described above (USEPA, 1999), the mean of the available metal BAF data was used as a surrogate for these CPECs. BAFs were available for cadmium, chromium, lead, and mercury (Table U.A1-2) and the mean BAF calculated was 1.186.

Sediment-to-invertebrates BAFs were not available for 2-methylnapthalene, endrin, heptachlor, and kepone. As explained above (Section 2.6), the BSAF data for naphthalene was used to develop a BAF that was used as a surrogate for 2-methylnapthalene. BSAF data for total organochlorine pesticides (107 values) were used to estimate BAFs for endrin, heptachlor, and kepone.

Soil-to-mammal BAFs were not available for the following organochlorine pesticides: aldrin, benzene hexachloride (BHC), chlordane, endosulfan, endosulfan sulfate, endrin heptachlor, heptachlor epoxide, hexachlorobenzene, kepone, methoxychlor, and mirex. For these CPECs, the BAF used to derive the EcoSSL for dieldrin (USEPA, 2007b) was used as a surrogate. Although soil-to-mammal BAF values for heptachlor and hexachlorobenzene were available from USEPA (1999), they are derived from regression models based on log K_{ow} (Travis and Arms, 1988) and intake assumptions for various mammalian receptors. The recommended BAFs for these two pesticides are 3 orders of magnitude less than the BAF used to derive the EcoSSL for dieldrin (USEPA, 2007b). Due to uncertainty introduced from inclusion of intake assumptions as well as the use of log K_{ow} models, the BAF used to derive the EcoSSL for dieldrin was conservatively used as a surrogate for all organochlorine pesticides lacking specific soil-to-mammal BAFs. USEPA published a soil-to-mammal BAF for DDT in 2007 (USEPA, 2007). The DDT BAF is 4.83, which is less that the dieldrin BAF used in this ERA (17.6)[1]. Although a more recent BAF is available for DDT, the dieldrin BAF is approximately four times higher that the DDT BAF and likely overestimates rather than underestimates exposure.

BAFs for cyanide are available but limited (e.g., Ebbs et al., 2003). Cyanide is highly reactive and readily metabolized in organisms demonstrating low bioaccumulation potential (Eisler, 1991). Eisler (1991) also reported that cyanide seldom remains biologically available in soils because it is either complexed by trace metals, metabolized by various microorganisms, or lost through volatilization. Also, wildlife can detoxify sublethal doses of cyanide and excrete it as thiocyanate in urine (Eisler, 1991). Although this mechanisms can be saturated such that toxicity can occur (e.g., cases of human consumption of plants with high content of cyanogenic glycosides), low concentrations of cyanide at the site coupled with rapid metabolism of cyanide by plants suggest that bioaccumulations to wildlife is not likely significant. Therefore, the media-to-biota BAF for cyanide was assumed to be zero for all prey/food items.

[1] The soil-to-mammal dieldrin BAF is based on the concentration is tissue relative to the concentration in diet rather than the concentration in soil, as is typically done for soil BAFs. Therefore, the soil-to-mammal BAF for dieldrin is equivalent to the product of the soil-to-worm BAF (14.7) and diet-to-mammal BAF (1.2) and is equal to 17.6.

3.0 REFERENCES

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