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Calculating Sediment Screening Levels for DDT

INTRODUCTION

To develop potential sediment screening levels for 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane (dichlorodiphenyltrichloroethane, DDT) and associated compounds 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene (DDE) and 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane (DDD), we looked at three approaches. For human health, acceptable fish tissue levels were calculated based on fish consumption. These levels were then used to calculate acceptable sediment levels. For ecological effects based on bioaccumulation, a similar approach was used, starting with acceptable fish tissue levels to fish-eating birds or mammals. For birds, an additional calculation was done to determine potential threats to bird eggs. DEQ is in the process of also developing levels protective of fish as the receptor of interest, but these values have not yet been calculated.

HUMAN HEALTH

Sediment bioaccumulation screening levels values for humans (SLV_H) were calculated by first calculating acceptable fish tissue levels for carcinogens ($ATLh_C$) and noncarcinogens ($ATLh_N$), and then using a relationship between fish concentrations and sediment to calculate acceptable sediment values.

Acceptable Tissue Levels for Humans

For human consumption, acceptable tissue levels for carcinogens ($ATLh_C$) and noncarcinogens ($ATLh_N$) are back-calculated from acceptable risk levels in accordance with federal guidance for establishing fish consumption limits and for conducting human health risk assessments (EPA 1989, 1997). Separate levels were not calculated for men and women, as differences in consumption rates relative to body weight are minor.

Acceptable fish tissue levels for humans are calculated using the following equations.

For carcinogens:

$$ATLh_C = \frac{ARL_C \cdot BW \cdot AT \cdot CF}{SF_O \cdot IR_P \cdot ED} \qquad [1]$$

and for noncarcinogens:

$$ATLh_N = \frac{RfD \cdot BW \cdot ARL_N \cdot CF}{IR_P} \quad [2]$$

where:

$ATLh_C$ = Acceptable carcinogen tissue level for human receptors (ug/kg);

$ATLh_N$ = Acceptable noncarcinogen tissue level for human receptors (ug/kg);

ARL_C = Acceptable risk level for carcinogens (unitless; 1×10^{-6});

ARL_N = Acceptable risk level for noncarcinogens (unitless; 1);

AT = Averaging time (years);

CF = Conversion factor (1000 ug/mg)

ED = Exposure duration (years);

SFo = Oral slope factor $(mg/kg \cdot d)^{-1}$;

RfD = Reference dose (mg/kg·d);

BW = Body weight (kg); and

IR_P = Fish and/or shellfish ingestion rate for the exposed population (mean daily rate over a year in kg/day).

Parameter values are shown in Table 1. Calculated ATLh values are shown in Table 2.

The ATLh values in Table 2 represent the maximum concentration of a given chemical in fish tissue that will NOT:

1. Generate a risk greater than the maximum acceptable risk level (ARL) used for carcinogens; or
2. Cause adverse noncarcinogenic health effects based on a lifetime of daily consumption at an exposure scenario-specific ingestion rate (IR, see Table 1).

Therefore, the ATLh values permit a specific population of humans to consume safely any combination of fish and/or shellfish for an extended period, provided that the combined daily consumption rate remains below the value of IR used to calculate ATLh.

Calculation of SLV_{BH}

ATLh values were then used to calculate chemical concentrations in sediment at and below which chemicals would not be expected to accumulate in tissues of fish above levels acceptable for human consumption. These values were calculated as follows:

$$SLV_{BH} = f_{oc} \cdot \left(\frac{ATLh}{BSAF \cdot f_L} \right) \quad [3]$$

$$SLV_{BH} = \frac{ATLh}{BAF} \quad [4]$$

where:

SLV_{BH} = Sediment bioaccumulation screening level value for human population (ug/kg)

BSAF = Biota-sediment accumulation factor for organic COIs (kg sediment organic carbon / kg organism lipid)

BAF = Bioaccumulation factor for organometallic COIs (L/kg)

ATLh = Acceptable tissue level for carcinogens or noncarcinogens, whichever is smaller (ug/kg);

f_{oc} = Fraction of total organic carbon in surface sediment (unitless); default = 0.01

f_L = Fraction of organism lipid content of fillet (unitless)

BSAF is the ratio between the concentration of a bioaccumulating nonpolar organic chemical in the total extractable lipids of an organism normalized on the lipid fraction, to the concentration in sediment normalized on the organic carbon content of sediment. When using BSAFs, the assumption is that the sediment is the only source of contamination in the habitat. BSAF values are provided in Table 1.

If total organic carbon (TOC) data are not available for the site, assume that f_{oc} is 1% (0.01). For fish lipid, the assumption is to assume that f_L is 3% (0.03) for general human health exposure based on consumption of fillets only, and 8.8% (0.088) for human health risk assessments based on consumption of whole fish (e.g., tribal consumption) and for all wildlife risk assessments. The value of 8.8% is the highest whole-body mean value reported by EPA (1997), and should be protective of most fish, with the exception of high-lipid content fish such as peamouth and carp.

SLVs for the DDT compounds are shown in Table 4.

SLVs for Populations Other Than the General Population

The human bioaccumulation SLVs shown in Table 4 are based on the lower of the carcinogen or non-carcinogen acceptable tissue levels, and BSAF values derived from the U.S. Army Corps of Engineers BSAF database (2006). SLVs are provided for a range of fish consumers considered in the Portland Harbor Superfund site investigation (general population to tribal). SLVs protective of the general population may not be protective for recreational, subsistence, Native American populations engaged in traditional fish consumption practices, or for populations consistently consuming whole fish, for example in soups, stews or bullion. At sites

where there is a current or reasonably likely future use by these other populations, SLVs based on acceptable tissue levels for these populations should be used.

WILDLIFE

Similar to the human health approach, sediment bioaccumulation SLVs for wildlife were calculated from acceptable tissue levels for fish.

Acceptable Tissue Levels for Wildlife

An acceptable tissue level for wildlife (ATLw) is the concentration of a contaminant that an animal could consume in its prey that would result in a dose equal to a given toxicity reference value (TRV). This assumes that the animal receives no additional exposure to that contaminant through other environmental media. Calculated ATLw values are provided in Table 3.

An ATLw can be calculated from a TRV for a chemical (either a no-observable-effect-level (NOAEL) for individuals or a lowest-observable-effect-level (LOAEL) for populations) by assuming a receptor's total diet contains that chemical concentration (Sample *et al.* 1996). When the chemical concentration in all food items is constant, the relationship between dose and the concentration in food items can be represented by the following equation:

$$ATLw = \frac{TRV_W \cdot CF}{(IR/BW)} \qquad [5]$$

where:

ATL_W = Acceptable tissue level for wildlife receptors (ug/kg, wet weight);

TRV_W = Toxicity reference value for wildlife (mg/kg·day, dry weight); NOAEL-based for individuals, LOAEL-based for populations;

CF = Conversion factor (1000 ug/mg)

BW = Body weight (kg); and

IR = Daily food ingestion rate (kg/day).

Mink and great blue heron were chosen as representative fish-eating receptors for mammals and birds, respectively. Their diet was assumed to consist entirely of fish. Toxicological information on bird and mammal responses to various chemicals was obtained primarily from Sample *et al.* (1996). TRVs for both individual animals and populations are shown in Table 1.

The default calculations of ATLw do not take into consideration (1) the entire feeding range of the mammal relative to the part of the range where fish can be found that have been contaminated from sediment at the site, or (2) the fraction of the total fish consumed by the

mammal that comes from the site. Both of these factors may be considered if a site-specific ATLw is calculated. The receptor classes could also be changed if the ones that were used to calculate the generic ATLw values are not appropriate for the site. If you are considering making changes, be sure to discuss them with the DEQ project manager and get approval prior to making them.

Consideration of Bird Eggs

For certain chemicals (*e.g.*, DDTs, PCBs, chlorinated dibenzo-*p*-dioxins, and chlorinated dibenzofurans), adverse impacts are greater on bird eggs than on adult birds, at least for osprey and eagles. In these cases, an SLV for osprey bird eggs was calculated.

$$ATL_W = \frac{ATL_{W-egg}}{BMF_{egg}} \qquad [6]$$

ATL_W = Acceptable tissue level for wildlife receptors (ug/kg, wet weight);

$ATL_{W\text{-}egg}$ = Acceptable egg level for bird receptors (ug/kg); NOAEL-based for individuals, LOAEL-based for populations;

BMF_{egg} = Biomagnification factor, fish tissue to bird eggs

Table 3 presents ATLw values for both protection of the adult bird and bird eggs.

Calculation of SLV_{BW}

Bioaccumulation SLVs represent COI concentrations in sediment which are not expected to result in tissue residue levels that could adversely affect the health of humans or wildlife that consume fish. The details of their derivation are discussed below.

$$SLV_{BW} = f_{oc} \cdot \left(\frac{ATLw}{BSAF \cdot f_L} \right) \qquad [7]$$

$$SLV_{BW} = \frac{ATLw}{BAF} \qquad [8]$$

where:

SLV_{BW} = Sediment bioaccumulation SLV for fish-eating wildlife receptors (ug/kg)

BSAF = Biota-sediment accumulation factor for organic COIs (kg sediment organic carbon / kg organism lipid)

BAF = Bioaccumulation factor for organometallic COIs (L/kg)

ATL_W = Acceptable tissue level for wildlife receptors (ug/kg); NOAEL-based for individuals, LOAEL-based for populations

f_{oc} = Fraction of total organic carbon in surface sediment (unitless); default = 0.01

f_L = Fraction of organism lipid content of fillet or whole-body dry weight (unitless); the default = 0.088

Concentrations greater than the table values indicate that bioaccumulation could be a threat to humans or wildlife that consume fish.

Values in the "Individual" columns of Table 4 for birds and mammals represent chemical concentrations in sediment at and below which chemicals would not be expected to accumulate in the tissues of prey items (*i.e.*, fish) above NOAEL-based acceptable levels. They are the lowest and most protective type of sediment bioaccumulation SLVs. These values should be used in circumstances where fish-eating threatened and endangered species are currently or reasonably likely to exist.

Values in the "Population" columns of Table 4 for birds and mammals represent chemical concentrations in sediment at and below which chemicals would not be expected to accumulate in the tissues of prey items (*i.e.*, fish) above LOAEL-based acceptable levels. These values imply the possibility of adverse effects in individuals within a local population but not to the local population as a whole. They are appropriate at sites where:

- No threatened and endangered or sensitive species reside or are likely to reside;
- Critical habitat values are not expected to be a concern;
- Protection is extended only at the population level per OAR 340-122-084(1)(h)(B)(ii); and
- The intent is consistency with the point before significant adverse impacts language of ORS 465.315(1)(b)(A).

"Individual" values should be used if there is doubt as to compliance with these criteria.

Critical Tissue Levels for Fish

Critical tissue levels (CTL) are concentrations in fish tissue above which adverse effects are expected *in the fish*, rather than in consumers eating the fish. There are two approaches being considered for their derivation: (1) on the basis of empirical-effects data and (2) application of a narcosis model. Additional work will be required to determine the best approach for calculating CTL values.

At present, CTL values are under development. Until DEQ has default CTL values to use, you will have to either use site-specific bioassays to determine the potential impact from bioaccumulation on the health of fish, or search for relevant CTLs in the literature.

REFERENCES

EPA (1989). *Risk Assessment Guidance for Superfund: Volume I – Human Health Evaluation Manual, Part A*. EPA/540/1-89/002. U. S. Environmental Protection Agency. December 1989.

EPA (1997). *Guidance for Assessing Chemical Contamination Data for Use in Fish Advisories, Volume 2, Risk Assessment and Fish Consumption Limits.* Second Edition. EPA 823-B-97-009. U. S. Environmental Protection Agency. July 1997.

Henny et al. (2003). *Biomagnification Factors (Fish to Osprey Eggs from Willamette River, Oregon, U.S.A.) for PCDDs, PCDFs, PCBs, and OC Pesticides*. Environmental Monitoring and Assessment. 84: 275-315.

Sample, B.E., Opresko, D.M., and Suter, G.W. (1996). *Toxicological Benchmarks for Wildlife*. ES/ER/TM-86/R3. Oak Ridge National Laboratory, Oak Ridge, TN.

USACE (2006). U.S. Army Corps of Engineers, BSAF Database. http://el.erde.usace.army.mil/bsaf/

USFWS (1998). *Environmental Contamination in Aquatic Resources from the Columbia River*. U. S. Fish and Wildlife Service, 21 May 2004.

WDOH (1995). *Tier I Report, Development of Sediment Quality Criteria for the Protection of Human Health*. Office of Toxic Substances, Washington State Department of Health. June 1995.

Wiemeyer S.N., Bunck C.M., and Stafford C.J. (1993). *Environmental Contaminants in Bald Eagle Eggs – 1980-84 – and Further Interpretations of Relationships to Productivity and Shell Thickness*. Arch. Environ. Contam. Toxicol. 25: 213-227.

Table 1
Parameters Used in Calculating Sediment Screening Levels

Parameter	Units	Description	Value
$ATLh_C$	ug/kg	Acceptable carcinogen tissue level	Calculated
$ATLh_N$	ug/kg	Acceptable noncarcinogen tissue level	Calculated
ARL_C	unitless	Acceptable risk level for carcinogens	1×10^{-6}
ARL_N	unitless	Acceptable risk level for non-carcinogens	1
AT	Years	Averaging time	70
ED	Years	Exposure duration	General = 30 Tribal = 70
SFo	$(mg/kg/day)^{-1}$	Slope factor – oral	DDD = 0.24 DDE = 0.34 DDT = 0.34
RfD	mg/kg/day	Reference dose	DDT = 0.0005
BW	Kg	Body weight – adult human	70
IR_P	Kg/day	Ingestion rate of fish by human	General = 0.0175 Tribal = 0.175
SLV_{BH}	ug/kg	Sediment bioaccumulation screening level for humans	Calculated
BSAF	Kg-oc/Kg-lipid	Biota-sediment accumulation factor for organics (USACE 2006)	DDD = 4.5 DDE = 32 DDT = 2.0
BAF	L/kg	Bioaccumulation factor for organometallics	Not applicable to DDT
f_{oc}	Unitless	Fraction of total organic carbon	0.01
f_L	Unitless	Fraction of lipid content	General humans = 0.03 Tribal or wildlife = 0.088
TRV_W	mg/kg/day	Toxicity reference value for wildlife (Sample 1996)	Heron = 0.009 ind Heron = 0.027 pop Mink = 0.8 ind Mink = 4 pop
IR_W	Kg/day	Ingestion rate by wildlife	Heron = 0.42 Mink = 0.137
BW_W	Kg	Body weight – wildlife	Heron = 2.39 Mink = 1
ATL_W	ug/kg	Acceptable tissue level for wildlife	Calculated
$ATL_{W\text{-}egg}$	ug/kg	Acceptable tissue level for bird eggs (Wiemeyer et al. 1993)	NOAEL = 720 LOAEL = 3,600
BMF_{egg}	Unitless	Biomagnification factor – fish tissue to bird eggs (Henny 2003)	Osprey/DDE = 87
SLV_{BW}	ug/kg	Sediment bioaccumulation SLV for fish-eating wildlife	Calculated

Table 2
Acceptable Tissue Levels (ATLs) for Chemicals in Fish Consumed by Humans

		$ATLh_c$ for Carcinogens (ug/kg)			$ATLh_n$ for Non-Carcinogens (ug/kg)		
CHEMICAL	**CASRN**	**General Population[a]**		**Tribal[b]**	**General Population[a]**		**Tribal[b]**
DDD	72-54-8	32		1.5	2,000		200
DDE	72-55-9	23		1.1	2,000		200
DDT	50-29-3	23		1.1	2,000		200

Notes

a) Based on IR = 0.0175 kg/day, ED = 30 yr

b) Based on IR = 0.175 kg/day, ED = 70 yr

Table 3

ATLs for Chemicals in Fish/Shellfish Consumed by Birds and Mammals

CHEMICAL	CASRN	BIRDS (ug/kg)		MAMMALS (ug/kg)	
		Individual	Population[c]	Individual	Population
		Adult Birds (Heron)			
DDD[a]	72-54-8	51	150	5,800	29,000
DDE[a]	72-55-9	51	150	5,800	29,000
DDT	50-29-3	51	150	5,800	29,000
		Bird Eggs (Osprey)			
DDD[b]	72-54-8	8.3	41		
DDE	72-55-9	8.3	41		
DDT[b]	50-29-3	8.3	41		

Notes

a) Values for DDD and DDE based on values for DDT.

b) Values for DDD and DDT based on values for DDE.

c) Population ATL = 5 x Individual ATL for bird eggs

Table 4
Sediment Bioaccumulation SLVs for Fish Consumption

CHEMICAL	CASRN	Sediment Bioaccumulation SLV[a] (ug/kg)						Detection Limit (ug/kg)
		Birds		Mammals		Humans		
		Individual	Population	Individual	Population	General	Tribal	
		Adult Birds (Heron)						
DDD	72-54-8	1.3	3.9	150	740	2.4	0.039	0.1
DDE	72-55-9	0.18	0.55	21	100	0.24	0.0038	0.1
DDT	50-29-3	2.9	8.7	330	1,700	3.8	0.062	0.1
		Bird Eggs (Osprey)						
DDD	72-54-8	0.039	0.20					
DDE	72-55-9	0.034	0.17					
DDT	50-29-3	0.039	0.20					

Notes

a) Calculated from SLV = f_{oc} x ATL / (BSAF x f_L)
ATL taken from Tables 2 and 3.
BSAF, f_{oc} and f_L taken from Table 1.