Literature Review

REVIEW OF TISSUE RESIDUE EFFECTS DATA FOR TRIBUTYLTIN, MERCURY, AND POLYCHLORINATED BIPHENYLS

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For submittal to

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AOC	Administrative Order on Consent
CT	central tendency
LR50	lethal residue causing 50 percent mortality
PCB	polychlorinated biphenyl
RBSC	risk-based screening concentration
RME	reasonable maximum exposure
SOW	statement of work
TBT	tributyltin
TBTO	tributyltin oxide
USEPA	U.S. Environmental Protection Agency
WSOU	Waterway Sediment Operable Unit

1.0
INTRODUCTION

The Port of Seattle, Lockheed Martin Corporation, and Todd Shipyards Corporation voluntarily entered into an Administrative Order on Consent (AOC) with the U.S. Environmental Protection Agency (USEPA; May 14, 1998). The objective of the AOC and attached Statement of Work (SOW) is to address bioaccumulation risks to human health and the environment associated with tributyltin (TBT), mercury, and polychlorinated biphenyls (PCBs) at the Harbor Island Superfund Site, Waterway Sediment Operable Unit (WSOU). The SOW outlines specific tasks designed to address the significance of TBT, mercury, and PCB concentrations within the WSOU.

This report, *Review of Tissue Residue Effects Data for Tributyltin, Mercury, and PCBs*, fulfills Task 1 of the SOW. The objective of this scientific literature review was to compile, evaluate, and summarize tissue residue effects data for TBT, mercury, and PCBs in marine organisms. The TBT literature review results are used to develop a tissue residue effects "trigger" concentration by which site-specific bioaccumulation testing results (Task 3, Conduct Bioaccumulation Tissue Residue Testing for TBT) can be evaluated. Potential human health risks associated with TBT are also discussed (Appendix A, *Toxicological Review of Tributyltin*). The review of the mercury and PCB literature was conducted to determine whether tissue concentrations determined to be protective of human health from seafood consumption are also likely protective of aquatic receptors. The focus of this review was effects on aquatic organisms, specifically invertebrates and fish species. Human health risks will be assessed in Task 6 (Human Health Risk Assessment).

Data that directly relate adverse effects to tissue concentrations provide the basis of the critical body residue approach for evaluating the potential effects of contaminants. The critical body residue approach links the concentrations of a specific contaminant in an organism's tissues to toxicological effects in that organism. This approach has several advantages over more common approaches that relate concentrations in sediment or water to toxicological effects in organisms (McCarty and MacKay 1993). These advantages include:

- Bioavailability and exposure from all routes are integrated in the organism
- Assumptions regarding steady state, equilibrium, and uptake kinetics are not required
- Effects of metabolism are explicitly considered

However, there are limitations associated with using tissue residue effects concentrations to develop screening concentrations. For example, the tissue residue concentration may only constitute indirect evidence of effects, because it is the concentration of toxin at the site of toxic action that is relevant in determining a dose or screening concentration (Cardwell pers. comm. 1998). The use of a whole-body concentration assumes that the whole-body concentration is proportional to the concentration at the site of toxic action. Additionally, many contaminants are sequestered in the organism, e.g., metals are bound to metallothioneins. The sequestered compounds will contribute to the measured tissue residue concentration but may not result in toxic effects.

The contaminants addressed in this review are not known to target specific organs. In addition, TBT, mercury, and PCBs are not known to be sequestered by metallothioneins. Therefore, the tissue residue effects approach was considered appropriate for these compounds.

Literature was included in the review if it met the following criteria:

- Presents tissue residue data for aquatic organisms corresponding to the endpoints identified in the SOW
- Includes sufficient technical details and quality assurance to assess the reliability of the relationship between tissue residue data and effects

In studies where multiple tissue residue concentrations were reported for the same endpoint, the lowest residue concentration associated with each endpoint was reported for effects data, and the highest residue concentration associated with each endpoint was reported for no effects data. Other results were not included in the data summary.

In the following sections, the results of the literature survey for each contaminant are presented in terms of the range of tissue residue effects concentrations and no effects concentrations for invertebrates and fish. In addition, the tissue residue effects concentrations are compared to tissue concentrations determined to be protective of human health from seafood consumption in order to determine whether the human health-based concentrations are likely to be protective of aquatic organisms. The results for TBT are presented in Section 2.0. The results for mercury and PCBs are presented in Sections 3.0 and 4.0, respectively.

2.0
TRIBUTYLTIN

Tributyltin was identified as a contaminant of potential concern in the sediment of the WSOU of the Harbor Island Superfund site as part of the fund-lead remedial investigation (WESTON 1994). Currently, there are no federal or state sediment quality guidelines or standards for evaluating TBT concentrations in sediment. An interagency work group was formed to identify and evaluate various approaches to deriving a sediment effects-based cleanup concentration for use in Puget Sound (USEPA 1996). The work group evaluated available sediment and tissue data sets and concluded that bulk sediment concentrations are poor predictors of how much TBT is bioavailable (USEPA 1996). Few studies showed good correlations between laboratory bioassay or *in situ* benthic community responses and TBT concentrations in sediments. The group recommended that when TBT is a contaminant of concern in sediment, interstitial water concentrations should be measured and toxicity or bioaccumulation testing using sediments from the site should be conducted to confirm the ecological significance of measured interstitial water concentrations. The purpose of this literature review is to develop a tissue residue effects trigger concentration by which site-specific bioaccumulation testing results can be evaluated.

A total of 56 papers and reports were reviewed for TBT residue effects data. Effects considered relevant for the development of a site-specific trigger concentration included mortality, reduced growth, and reproductive impairment. These endpoints are consistent with USEPA guidelines for selecting endpoints in deriving water quality criteria (Stephan et al. 1985). Some of the commonly reported sublethal effects, such as bivalve shell thickening or induction of imposex or intersex in gastropods, were not included in the evaluation because these endpoints are not population level effects and because of the lack of suitable habitat at the site for the typically affected species—oysters and meso- and neogastropods. The WSOU is a deep (-30 to -60 ft mean lower low water), heavily industrialized waterway within the Duwamish River estuary. Very little intertidal habitat is available because of extensive channelization and dredging of the waterway and no commercial or recreational shellfish beds occur. In addition, gastropods are typically not a large component of the Duwamish River estuary benthic community and meso- and neogastropods make up only a small fraction of the total gastropod abundance. It should be noted that shell deformation and the induction of imposex may occur in some shellfish with TBT tissue residue concentrations below the concentrations associated with mortality, reduced growth, and impaired reproduction. Most of the papers that were reviewed and not included in the following discussion were rejected because of inappropriate endpoints for the purposes of this review. A compilation of all the literature reviewed, including explanations of why reports were rejected, is presented in Appendix B.

A variety of different conventions have been used in reporting TBT concentrations. The earliest measurements of TBT concentrations reported the concentration in terms of the measured tin concentration. TBT concentrations have also been reported as TBT chloride and tributyltin oxide (TBTO) concentrations. All TBT concentrations presented here are expressed in terms of TBT ion concentrations. All TBT concentrations that were not originally reported as TBT ion concentrations were converted to TBT ion concentrations by multiplying the original concentration by the appropriate conversion factor (Table 2-1).

Table 2-1. Conversion factors for tributyltin ion concentrations

ORIGINAL UNITS	CONVERSION FACTOR
Tributyltin chloride	0.89
Tributyltin oxide	0.49
Tin	2.44

In this section, invertebrate data is presented first, followed by fish data. These data are then compared to human health-based screening criteria developed in Appendix C. Finally, we propose an approach for deriving a tissue residue trigger concentration.

2.1 INVERTEBRATES

The tissue residue effects data collected from fourteen different studies representing thirteen species of invertebrates, including snails, bivalves, polychaetes, amphipods, and crabs are summarized in Figure 2-1 and Table 2-2. Only four major groups of invertebrate taxa are represented—Class Crustacea, Class Polychaeta, Class Bivalvia, and Class Gastropoda. Unrepresented taxa include Echinoderms and other types of Arthropods. Three studies were based on field-exposures of the organisms (Bryan et al. 1987; Davies et al. 1988; Bailey and Davies 1991; Oehlmann et al. 1996, 1998; Bauer et al. 1997; Salazar and Salazar 1998); the remaining studies involved laboratory exposures.

The data presented in Table 2-2 were selected based on the relevance of the ecological endpoint and the availability of a whole-body residue concentration associated with the endpoint. Studies in which only specific organ or tissue TBT concentrations were reported are presented in Appendix B, but are not presented in Table 2-2. Guolon and Yong (1995) reported reduced growth in two species of marine mussels associated with

Figure 2-1

Table 2-2

Table 2-2, page 2

Table 2-2, page 3

concentrations of 0.45–1.0 μg/g dry weight (0.1–0.2 μg/g wet weight) of tributyltin chloride in either the gill and viscera or the muscle and mantle tissues.

A study of the effects of TBT exposure on the growth of bivalve spat (Thain 1986) is presented in Appendix B, but was not included in Table 2-2. Thain (1986) reported reduced growth associated with tissue concentrations that ranged from 0.75 to 2.91 μg/g wet weight (3.75 to 14.6 μg/g dry weight). The study was rejected for two reasons. First, no true controls were included in the study; the cited controls contained substantial TBT concentrations. Second, the exposure concentrations ranged over several orders of magnitude; the wide range of concentrations does not support the derivation of threshold effects concentrations using this data.

Although the onset of imposex or intersex was not considered a relevant endpoint for the purposes of this review, sterilization due to imposex or intersex was included as a relevant endpoint. Imposex is defined as the development of male sexual characteristics in females. Bauer et al. (1993,1995) and Oehlmann et al. (1994) were the first to describe the intersex phenomenon in the periwinkle *Littorina littorea*. Females affected by intersex develop either male features on the female pallial organs, or female sex organs are supplanted by the corresponding male formations (Bauer et al. 1997).

Twenty-one tissue residue effects concentrations were reported. The highest effects concentrations were values reported by Meador (1997), Borgmann et al. (1996), and Langston and Burt (1991); these concentrations were associated with mortality for a polychaete, a clam, and four species of amphipods. The LR50 (lethal residue causing 50 percent mortality) values reported by Meador (1997) are different from, and not directly comparable to, the lowest effects concentrations reported for reduced growth, fecundity, and survival in the other studies. The lowest effects residue concentrations ranged from a maximum of 2.84 μg/g wet weight reported by Bryan et al. (1987) for an endpoint of sterility due to imposex in dogwhelk to a minimum of 0.14 μg/g wet weight reported by Oehlmann et al. (1998) for sterilization due to intersex in periwinkle.

The tissue residue TBT concentrations associated with no observed effects ranged from 0.06 to 0.8 μg/g wet weight. The maximum value of 0.8 μg/g wet weight was reported for reduced growth in field transplanted mussels (Salazar and Salazar 1998).

The range of reported endpoints included mortality, reduced growth, and sterilization. The highest effects concentrations were associated with mortality in amphipods, clams, and polychaetes (Langston and Burt 1991; Borgmann et al. 1996; Meador 1997) and the lowest effects concentrations were associated with sterilization (Gibbs et al. 1988; Oehlmann et al. 1996, 1998; Bauer et al. 1997).

2.2 FISH

Fourteen studies were reviewed for TBT tissue residue effects data for fish species. Two studies contained relevant data and endpoints for the purposes of this review, Shimizu and Kimura (1987) and Meador (1997). Shimizu and Kimura (1987) exposed a salt-water goby, *Chasmichthys dolichognathus* to TBTO and observed effects on gonadal development in the male fish as well as mortality in both male and female fish. A significant decrease in gonadal development was associated with a whole-body TBT concentration of 0.91 μg/g wet weight for male fish. In a 22-day laboratory exposure of starry flounder to TBT, Meador (1997) reported a whole-body TBT concentration of 8.3 μg/g wet weight associated with LR50-mortality.

Studies that were excluded reported either concentrations measured in specific tissues rather than whole body concentrations or concentrations associated with inappropriate endpoints. One study reported tissue concentrations associated with mortality for juvenile chinook salmon; the mean TBT concentrations reported were 7.44 μg/g wet weight in liver tissue, 3.46 μg/g wet weight in brain tissue, and 0.52 μg/g wet weight in muscle tissue (Short and Thrower 1987). Two studies reported chronic endpoints; Fent and Stegeman (1993) reported liver tissue concentrations associated with biochemical endpoints in the scup and Schwaiger et al. (1992) reported whole-body TBT concentrations associated with histopathological effects in rainbow trout.

2.3 COMPARISON TO HUMAN HEALTH RISK-BASED SCREENING CONCENTRATIONS

Risk-based screening concentrations (RBSCs) associated with potential human health effects from the consumption of seafood were calculated based on TBTO toxicity information, and national and regional seafood consumption data. For fish, the reasonable maximum exposure (RME) is based on a consumption rate of 105 g/day (Toy et al. 1996) and the central tendency (CT) exposure is based on a consumption rate of 31 g/day (Ecology 1999). For shellfish, the RME is based on a consumption rate of 61 g/day (Toy et al. 1996) and the CT exposure is based on a consumption rate of 5 g/day (derived from Toy et al. 1996). A detailed discussion of the derivation of the RBSCs is contained in Appendix C.

The RBSCs for TBT, calculated using USEPA's reference dose for TBTO (IRIS 1997) in fish, were 0.085 and 0.33 μg/g wet weight. For shellfish, the RBSCs for TBT were 0.17 and 2.1 μg/g wet weight. For both fish and shellfish, the lower concentration is an RME consumption rate that is based on subsistence fishing in Puget Sound (Toy et al.

1996). The higher concentration reflects a consumption rate based on a CT exposure or the median Puget Sound consumption rate for a recreational fisher.

The only residue effects concentration for fish was an LR50 value of 8.3 μg/g wet weight which is higher than the RBSCs calculated for fish ingestion.

The shellfish RBSCs for TBT were in the same range as the tissue residue effects concentrations. The RME-based RBSC was slightly lower than all of the tissue residue effects concentrations.

2.4 RECOMMENDED TRIGGER CONCENTRATIONS

The TBT tissue concentrations associated with ecological endpoints were used to derive a TBT trigger concentration. Two trigger concentrations were developed—the Respondents' (Port of Seattle, Lockheed Martin Corporation, and Todd Shipyards Corporation) site-specific trigger concentration, and the USEPA Superfund site-specific trigger concentration. A detailed discussion of the derivation of the Respondents' site-specific trigger concentration is presented in this section. The derivation of the USEPA Superfund site-specific trigger concentration is presented in Appendix D.

The trigger concentration will be used to:

- Evaluate TBT tissue data generated from laboratory bioaccumulation tests or field-collected bioaccumulation data

- Calculate a porewater or sediment TBT concentration that corresponds to tissue concentrations below the trigger concentration, assuming that a strong relationship is observed between tissue concentrations and either porewater or sediment TBT concentrations

2.4.1 Respondents' Site-Specific Trigger Concentration

The tissue concentrations associated with effects in marine invertebrates were reviewed for use in developing a trigger concentration. Studies for which mortality was the endpoint of concern (Langston and Burt 1991; Moore et al. 1991; Borgmann et al. 1996; Meador 1997) were not used. The highest effects concentration from Widdows and Page (1993) was also excluded because it was associated with lethal effects. In addition, effects concentrations that were estimated from non-linear regression relationships were not included in the data set (Bauer et al. 1997; Oehlmann et al. 1998). The final data set that was used to derive the Respondents' site-specific TBT tissue trigger concentration is presented in Table 2-3.

Table 2-3. Tributyltin data selected to derive Respondents' site-specific trigger concentration

Species[a]	Effects Concentration[b] (μg/g dry weight)	Effect Endpoint	Reference
Effects Observed			
Snail (*Ocinebrina aciculata*)	1.1	Sterilization due to imposex	Oehlmann et al. 1996
Dogwhelk (*Nucella lapillus*)	1.39	100% sterilization due to imposex	Gibbs et al. 1988
Dogwhelk (*Nucella lapillus*)	2.65[c]	Sterilization due to imposex	Bailey and Davies 1991
Pacific oysters (*Crassostrea gigas*)	3.75[c]	Reduced condition index relative to control stations (tissue weight as a percent of total weight)	Davies et al. 1988
Blue mussel (*Mytilus edulis*)	6.0	Growth rate inhibition	Salazar and Salazar 1998
Polychaete worm (*Neanthes arenaceodentata*)	6.27	Significant reductions in fecundity and emergent juvenile production	Moore et al. 1991
Blue mussel (*Mytilus edulis*)	5.44	Reduced growth rate	Widdows and Page 1993
Dogwhelk (*Nucella lapillus*)	3.39	Sterilization due to imposex	Bryan et al. 1987
Dogwhelk (*Nucella lapillus*)	8.52	Sterilization due to imposex	Bryan et al. 1987
No Effects Observed			
Dogwhelk (*Nucella lapillus*)	0.46	Imposex	Gibbs et al. 1988
Blue crab (*Callinectes sapidus*)	0.55[c]	Growth	Rice et al. 1989
Pacific oyster (*Crassostrea gigas*)	0.85[c]	Reduced condition index relative to control stations (tissue weight as a percent of total weight)	Davies et al. 1988
Polychaete worm (*Neanthes arenaceodentata*)	2.99	Growth, reproduction	Moore et al. 1991
Blue mussel (*Mytilus edulis*)	3.96	Reduced growth rate	Widdows and Page 1993
Blue mussel (*Mytilus edulis*)	4.0	Growth rate inhibition	Salazar and Salazar 1998

[a] All are marine species.
[b] TBT ion concentration; effects concentrations were converted as necessary; concentrations in units reported by author are presented in Appendix B.
[c] Concentration calculated assuming a moisture content of 80 percent, based on the average of moisture content reported for benthic infauna and fish species (Stephan et al. 1985).

Two approaches were used to estimate the trigger concentration from the selected data set. First, the geometric means of paired no effects and lowest observed effects concentrations were calculated to estimate the range of values within which the trigger concentration would likely occur. Second, the 20th percentile of the effects data was calculated using only effects data associated with endpoints relevant to organisms found within the WSOU site boundaries.

The geometric means of paired no effects and lowest observed effects concentrations were calculated for the five studies for which paired effects concentrations were available (Davies et al. 1988; Gibbs et al. 1988; Moore et al. 1991; Widdows and Page 1993; Salazar and Salazar 1998). The approach of using geometric means of paired no effects and lowest observed effects concentrations to estimate a chronic threshold value is based on Stephan et al. (1985). The calculated mean values ranged from 0.93 to 5.0 μg/g dry weight of TBT in tissue.

Percentiles were selected as another method for estimating the trigger concentration because using percentiles minimizes the influence of extreme data points. First, selected data (Table 2-3) were reviewed to determine if the effects endpoints reported are relevant to organisms found within the WSOU site boundaries. Four effects concentrations in the selected data set are associated with sterilization due to imposex in the dogwhelk, *Nucella lapillus*, and one effects concentration is associated with sterilization due to intersex in the snail, *Ocinebrina aciculata*. At this time, the only organisms that have been determined to be sensitive to imposex are meso- and neogastropod species such as the dogwhelk and the periwinkle. Gastropods are generally less abundant than polychaetes or crustaceans in the Elliott Bay benthic community and meso- and neogastropods make up only a small portion of the rare gastropod community. Therefore, the effects concentrations associated with sterilization due to imposex in gastropods (Bryan et al. 1987; Gibbs et al. 1988; Bailey and Davies 1991; Oehlmann et al. 1996) were excluded from the percentile calculation because of their lack of relevance to the site.

The 20th percentile of the remaining effects concentrations was calculated. The 20th percentile value was 4.8 μg/kg dry weight of TBT in tissue.

The Respondents propose a site-specific trigger concentration of 5 μg/g dry weight (1.0 μg/g wet weight, assuming a moisture content of 80 percent) of TBT in tissue based on examination of the paired no effects and effects concentrations and on the 20th percentile of the effects data associated with endpoints relevant to organisms found within the WSOU site boundaries.

2.4.2 USEPA Superfund Site-Specific Trigger Concentration

USEPA used a weight of evidence approach to develop a tissue trigger concentration to be protective of sublethal effects in marine invertebrates. Sublethal effects considered include sterilization due to imposex, reduced growth, and impaired reproduction. The weight of evidence approach was based on tissue residue effects data from the literature which was analyzed by:

- Identifying the highest no observed adverse effects level and the lowest observed adverse effects level reported for marine invertebrates (Table 2-2)

- Calculating selected percentiles for sublethal effects data for marine invertebrates

- Estimating the geometric means of paired no effects and effects tissue data

- Deriving critical body residues

- Calculating a sublethal effects threshold based on an acute to chronic ratio applied to tissue residue effects data for mortality

A detailed discussion of the derivation of the USEPA Superfund site-specific trigger concentration of 3 μg/g dry weight of TBT in tissue (0.6 μg/g wet weight of TBT in tissue) is provided in Appendix D.

3.0
MERCURY

In conducting the literature review for tissue residue effects for mercury, the following endpoints were specified in the SOW for consideration: mortality, growth, and reproductive effects in aquatic invertebrate and fish species. The purpose of this review was to determine whether tissue concentrations determined to be protective of human health from seafood consumption would also be likely to protect aquatic ecological receptors.

Almost all of the studies reviewed were laboratory studies that dosed with either methylmercury or mercuric chloride in food or water. Uptake of methylmercury by aquatic organisms is both more rapid and more extensive than uptake of inorganic mercury (e.g., Biesinger et al. 1982). Further, residues resulting from uptake of organic vs. inorganic mercury may be different from a toxicological perspective. Upon uptake, inorganic mercury can be converted by fish in the gut to methylmercury (Rudd et al. 1980), or detoxified by binding to metallothioneins (Roesijadi 1992). In nature, the fraction of total mercury that exists as methylmercury in organisms increases progressively from primary producers to fish (Hildebrand et al. 1980; May et al. 1987; Francesconi and Lenanton 1992; Watras and Bloom 1992); methylmercury is generally 95 to 99 percent of total mercury in adult freshwater fish (Huckabee et al. 1979; Grieb et al. 1990; Bloom 1992). However, in laboratory exposures to either inorganic mercury or methylmercury through dosing in water, residues can have different implications. For example, in Biesinger et al. (1982) *Daphnia magna* were exposed separately to waterborne concentrations of mercuric chloride and methylmercuric chloride. Adult survival was reduced at lower concentrations of methylmercury in water than mercuric chloride. However, high concentrations of total mercury in tissue were associated with fewer effects in methylmercury exposures than the mercuric chloride exposures. Thus, residue concentrations presented in this document need to be reviewed with these issues in mind, especially when used to evaluate concentrations of mercury measured in field-collected organisms that are exposed to both forms of mercury. Information regarding the species of mercury used in each study is presented in Tables 3-1 and 3-2.

Table 3-1

Table 3-2

Table 3-2
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3.1 INVERTEBRATES

Five studies were reviewed to identify a range of concentrations of mercury associated with adverse effects on survival, growth, and reproductive success in aquatic invertebrates (Figure 3-1 and Table 3-1). Effects concentrations ranged from 2.6 μg/g wet weight in daphnids associated with a significant decrease in the number of young (Biesinger et al. 1982) to 57.9 μg/g wet weight in polychaete worms associated with reduced growth rate (Kendall 1978). No effects concentrations ranged from 1.65 μg/g wet weight in grass shrimp associated with no effect on survival (Barthalmus 1977) to 15.5 μg/g wet weight in polychaete worms associated with no effect on growth (Kendall 1978).

Common endpoints assessed included growth, survival, number of young produced, and spat settlement. Endpoints associated with growth, number of young produced, and the settlement of spat appeared to be the most sensitive endpoints.

3.2 FISH

Eleven studies were reviewed to identify the range of mercury concentrations associated with adverse effects on survival, growth, and reproductive success in fish (Figure 3-2 and Table 3-2). One study was conducted with field-exposed fingerling rainbow trout (Matida et al. 1971) and the remaining studies involved laboratory exposures to either mercuric chloride or methylmercury.

Effects concentrations ranged from 0.1 μg/g wet weight measured in the gonads of rainbow trout associated with reduced larval survival (Birge et al. 1979) to 29 μg/g wet weight in Japanese medaka eggs associated with reduced hatching success (Heisinger and Green 1975). No effects concentrations ranged from 0.25 μg/g wet weight in juvenile walleye associated with no effect on growth (Friedman et al. 1996) to 16 μg/g wet weight in Japanese medaka eggs associated with no effect on hatching success (Heisinger and Green 1975).

The most common endpoints assessed were growth, survival, and hatching and spawning success. Larval growth and survival appeared to be the most sensitive endpoints.

Figure 3-1

Figure 3-2

3.3 COMPARISON TO HUMAN HEALTH RISK-BASED SCREENING CONCENTRATIONS

The tissue residue concentrations associated with ecological effects were compared to RBSCs, calculated using the same ingestion rates that were used to derive TBT RBSC values (Section 2.3). The details of the RBSC calculations are provided in Appendix C.

The RBSCs for methylmercury in fish are 0.058 μg/g wet weight for the RME scenario and 0.23 μg/g wet weight for the CT exposure scenarios. The RBSCs calculated for methylmercury in shellfish are 0.11 μg/g wet weight for the RME scenario and 1.4 μg/g wet weight for the CT exposure scenario. All of the invertebrate and fish tissue effects concentrations are higher than the corresponding invertebrate and fish RME-based RBSC values.

4.0
POLYCHLORINATED BIPHENYLS

In conducting the literature review for tissue residue effects for PCBs, the following endpoints were specified in the SOW (1998) for consideration: mortality, growth, and reproductive effects in aquatic invertebrate and fish species. The purpose of this review was to determine whether tissue concentrations determined to be protective of human health from seafood consumption would also be likely to protect aquatic ecological receptors.

PCBs were marketed in the United States as mixtures of congeners known as Aroclors. The earliest measurements of PCB concentrations were reported in terms of the concentrations of Aroclor mixtures measured in the sample. Modern analytical techniques have enabled the measurement of individual congener concentrations. Individual Aroclors contain different amounts of toxicologically important congeners. Therefore, it is important to know the identity of the individual Aroclors or congeners being summed to calculate a reported total PCB concentration. However, for the purposes of this review, total PCB concentrations are compared. The type of PCB detected in each study is presented in Tables 4-1, 4-2, and 4-3.

4.1 INVERTEBRATES

Six studies were reviewed to identify a range of total PCB concentrations associated with adverse effects on survival, growth, and reproductive success in aquatic invertebrates (Figure 4-1 and Table 4-1). Part of one study reported the effects associated with field exposure of grass shrimp (Nimmo et al. 1974). The remaining studies, and the other part of the Nimmo et al. (1974) study, involved laboratory exposures to a range of different Aroclors and congener mixtures. Some studies reported total PCB concentrations based on the sum of measured individual congener concentrations (e.g., Boese et al. 1995). These sums were only included if more than 10 congeners were measured.

Effects concentrations ranged from 1.1 μg/g wet weight measured in grass shrimp associated with reduced survival (Hansen et al. 1974) to 425 μg/g wet weight in young American oysters associated with reduced height and weight (Lowe et al. 1972). No effects concentrations ranged from 0.42 μg/g wet weight in grass shrimp associated with no effect on survival (Nimmo et al. 1974) to 101 μg/g wet weight in young American oysters associated with no effect on growth or survival (Lowe et al. 1972).

Figure 4-1

4.2 FISH

Twenty-eight different studies were reviewed to identify the range of total PCB concentrations associated with adverse effects on survival, growth, and reproductive success in fish. Eleven of these studies reported effects concentrations for either field-collected or field-exposed organisms. Five of these field studies (Hogan and Brauhn 1975; Westin et al. 1983; Spies et al. 1985; Black et al. 1988; Mac and Edsall 1991) were excluded from further consideration because of confounding factors associated with co-occurring contaminants or poor study design (Appendix E). The remaining six field studies are presented in Figure 4-2 and Table 4-2. Seventeen studies reported the results of laboratory exposures of organisms to a variety of Aroclors (Figure 4-3 and Table 4-3).

Effects concentrations measured in laboratory studies ranged from 0.5 μg/g wet weight measured in coho salmon liver associated with increased mortality (Folmar et al. 1982) to 645 μg/g wet weight in whole-body fingerling coho salmon associated with increased mortality (Mayer et al. 1977). No effects concentrations ranged from 8 μg/g wet weight in rainbow trout associated with no effect on growth or survival (Lieb et al. 1974) to 32 μg/g wet weight in whole-body fingerling channel catfish associated with no effect on growth or survival (Mayer et al. 1977).

Common endpoints assessed were reproductive measures such as egg hatchability and spawning success, growth endpoints involving length and weight measurements, and survival of fry, larvae, and fingerling fish. Reproductive endpoints were in general the most sensitive. Studies focusing on other endpoints, such as biochemical alterations, were not included in this compilation.

4.3 COMPARISON TO HUMAN HEALTH RISK-BASED SCREENING CONCENTRATIONS

The tissue residue concentrations associated with ecological effects were compared to RBSCs associated with potential human health effects. PCBs are classified as human carcinogens. RBSCs were calculated based on non-cancer endpoints and excess cancer risk (Appendix C). The lowest RBSCs were calculated for excess cancer risk. Therefore, excess cancer risk was selected as the endpoint for the human health evaluation.

The RBSCs for PCBs in fish are 0.0007 μg/g wet weight for the RME scenario and 0.0088 μg/g wet weight for the CT exposure scenario. Shellfish RBSCs are 0.0013 μg/g wet weight for the RME scenario and 0.054 μg/g wet weight for the CT exposure scenario. These screening criteria were developed based on exposure to the following Aroclor mixtures: Aroclor 1221, 1232, 1242, 1248, and 1254. A detailed discussion of

Figure 4-2
Page 1 of 1

the RBSC calculations is provided in Appendix C. Tissue residue concentrations that represent the sum of selected congeners may be lower than the concentration that would be reported on an Aroclor basis. Therefore, the use of Aroclor-based screening criteria represents a conservative estimate of human health risks. The lowest effects concentration reported for invertebrates of 1.1 μg/g wet weight (Hansen et al. 1974) was much higher than the shellfish RBSCs. None of the effects concentrations for fish were less than the fish RBSCs for the protection of human health.

5.0 CONCLUSIONS

The available data for TBT suggest that invertebrates, specifically bivalves, were more sensitive to the effects of TBT exposure than fish, though it should be noted that very limited data were available for tissue residue effects in fish. The comparison of measured TBT tissue residue effects concentrations with calculated RBSCs suggests that ecological effects are observed at concentrations in the same range as the calculated RBSCs. A subset of the ecological effects data was used to calculate a tissue concentration that can be used as a trigger concentration.

For mercury and PCBs, the reviews were conducted to determine whether tissue concentrations determined to be protective of human health from seafood consumption would also be protective of aquatic invertebrates and fish. The human health RBSCs were compared to measured tissue residue effects concentrations for mercury and PCBs and it was found that the RBSCs were lower than tissue concentrations associated with ecological endpoints.

6.0
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