Development of Human Health Water Quality Criteria for PCBs for the Delaware Estuary Using the 2000 U.S. EPA Methodology

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ABSTRACT

Identification of the governing water quality criteria is an essential step in the TMDL process. For the Delaware Estuary, available water quality criteria for PCBs include human health criteria for carcinogenic and systemic effects, wildlife criteria, and both freshwater and marine acute and chronic aquatic life criteria. Recent actions are causing regulatory agencies to update their current human health water quality criteria for PCBs. These actions include: 1) the change in the cancer potency factor for total PCBs reported in EPA's Integrated Risk Information System, and 2) the issuance of a revised methodology for deriving ambient water quality criteria for the protection of human health in the fall of 2000. The latter methodology also includes several new recommendations on the fish consumption rate to be used in criteria development, and the use of a bioaccumulation factor (BAF) rather than a bioconcentration factor (BCF).

A subcommittee of the Delaware River Basin Commission's Toxic Advisory Committee was tasked with developing revised human health criteria for four zones of the Delaware Estuary. Existing criteria for the estuary are 44.4 pg/l for Zones 2 and 3, 44.8 pg/l for Zones 4 and the upper portion of Zone 5, and 7.9 pg/l for the lower portion of Zone 5. The lower criterion in Zone 5 is due to a higher fish consumption rate being used while only Zones 2 and 3 are designated as a drinking water source. Values for five factors were needed to develop the revised criteria. Three of the factors used EPA-recommended default values. These three factors were 1) risk-specific dose (2.0 mg/kg-day at a risk level of 10^{-6}), 2) body weight (70 KG), and 3) drinking water intake (2 liters/day). Site-specific data was needed to develop appropriate values for the other two factors: fish consumption at each trophic level, and BAF at each trophic level. Site-specific data for fish consumption in Zone 5 and Delaware Bay indicated an average consumption rate for all species of 17.46 grams per day. This value is remarkably close to the national default value of 17.5 grams per day. Field studies were conducted to provide PCB

congener data on fish tissue concentrations of PCBs in species representative of trophic level 3 (channel catfish) and trophic level 4 (white perch). Ambient water concentrations of PCB congeners and organic carbon were also determined using low level sampling and analytical techniques for use in calculating the BAF in the new methodology. Data on the percent lipid of consumed fish were also determined from routine monitoring conducted by state agencies and the Commission since 1990. Data on the proportion of each trophic level consumed was assumed to be 50% based upon data from all zones that indicated roughly equal proportions for the two trophic levels.

Use of these data with the new EPA methodology results in a single criterion value of 16.0 pg/L. A probabilistic approach was also used to assess the impact of the uncertainty of the values used in the methodology. This analysis indicated that the median criterion value was close to that obtained using the deterministic approach, and that the interquartile range (25^{th} percentile to the 75^{th} percentile) fell between 6.2 pg/L to 49.7 pg/L. The final criterion selected will provide a uniform TMDL target throughout the estuary and eliminate the current sharp transition within the estuary.

KEYWORDS

Criteria, human health, TMDLs, PCBs, BAFs, Delaware River, probabilistic analyses

INTRODUCTION

Identification of the governing water quality criteria is an essential step in the TMDL process. For hydrophobic contaminants like polychlorinated biphenyls or PCBs, the ambient water quality criteria for the protection of human health is on the order of nanograms per liter to picograms per liter due to the high bioaccumulation of these compounds in fish tissue. As a consequence many water bodies are listed as impaired for PCBs including the Delaware River Estuary, resulting in the requirement to develop TMDLs for the water bodies.

As a consequence of the requirement of the 1986 amendments to the Clean Water Act many states were required to adopt water quality criteria for toxic pollutants including PCBs. Water quality criteria developed by EPA in the early 1980s were typically used to establish the states' water quality standards. These criteria were established using a methodology that addressed impacts to aquatic life, and both the carcinogenic and systemic effects of a chemical or, in the case of PCBs, a class of chemical compounds on human health for exposure through ingestion of water and fish (U.S. EPA, 1980b). This methodology included the consideration of six parameters: risk level, cancer potency factor, body weight, drinking water consumption, fish consumption, and the bioconcentration (BCF) of the chemical from water to fish tissue. The risk level is essentially a policy decision of the governmental agency adopting the criteria under their water quality standards regulations. Values for each of the remaining parameters were issued by the U.S. EPA for a group of chemicals referred to as the priority pollutants. While values for the cancer potency factor and BCF were chemical-specific, specified values for body weight, drinking water intake, and fish consumption were used in the methodology for all chemicals.

The specified values for these parameters were 70 kilograms, 2 liters per day, and 6.5 grams per day, respectively.

The human health criteria for protection from carcinogenic effects initially recommended by EPA was 79 picograms per liter. This value was derived using a cancer potency factor of 4.3396 (mg/KG)/day (U.S. EPA, 1980b). This factor was subsequently revised in January 1990 to 7.7 (mg/KG)/day. This revision resulted in a recommended criterion value of 44.4 picograms per liter. By the mid-1990's, human health criteria had been adopted for the Delaware River Estuary by Delaware, Pennsylvania, the Delaware River Basin Commission (DRBC) and the U.S. EPA. Criteria established by the DRBC varied between areas of the estuary due to changes in the designate use and the use of a different value for fish consumption in the lower portion of the estuary (DRBC, 1996). The criteria for the estuary are 44.4 pg/l for Zones 2 and 3, 44.8 pg/l for Zones 4 and the upper portion of Zone 5, and 7.9 pg/l for the lower portion of Zone 5. The lower criterion in Zone 5 is due to a higher fish consumption rate being used while only Zones 2 and 3 are designated as a drinking water source.

Several actions require the criteria originally adopted by the DRBC and most states to be revised. The first is the revision of the cancer slope factor from 7.7 (mg/KG)/day to a range of factors based upon the persistence of the chemical in the environment and the bioaccumulation potential (U.S. EPA, 1999). For hydrophobic chemicals with high bioaccumulation potential like PCBs, the upper bound of the slope factor was recommended by the U.S. EPA. For total PCBs, this slope factor was 2.0 (mg/KG)/day . In 2000, the U.S. Environmental Protection Agency issued revised guidance on developing human health criteria (U.S. EPA, 2000). Two significant changes recommended in this guidance were the recommendations to use site-specific values for fish consumption for the water body covered by the criteria, and to use a bioaccumulation factor or BAF rather than a BCF. In lieu of site-specific values on the consumption of fish by recreational fisherman, the guidance also recommended a default value of 17.5 grams per day. In February 2001, the Delaware River Basin Commission's Toxic Advisory Committee charged a subcommittee to develop revised human health criteria for the protection from carcinogenic effects for total PCBs for use in the TMDLs being developed by the Commission for the Delaware River Estuary.

METHODOLOGY

The subcommittee recommended that the revised criteria be developed using the October 2000 guidance issued by the U.S. EPA. The equation recommended in the guidance is:

$$AWQC = RSD\left[\frac{BW}{DI + \sum_{i=2}^{4}\left(FI_i \bullet BAF_i\right)}\right]$$

where:

AWQC =	Ambient Water Quality Criterion (mg/l)
RSD =	Risk-specific dose for carcinogens based on a linear low-dose extrapolation (mg/KG-day) such as 10^{-6}. Can also be expressed as Risk Level/Cancer Potency Factor.
BW =	Body weight (KG)
DI =	Drinking water intake per day (default = 2 Liters)
FI_i =	Fish intake at trophic level i (where i = 1, 2, 3, 4)
BAF_i =	Bioaccumulation Factor at trophic level i

Each of the parameters used in the revised criteria methodology was evaluated by a subcommittee of the Delaware River Basin Commission's Toxic Advisory Committee. The evaluation approach involved the review of the rationale provided in the EPA guidance document for establishing national values for each of the parameters, and the evaluation of site-specific data for each of the parameters. The site-specific data available for evaluation included data on the consumption of fish by recreational fisherman in the lower estuary, Zones 5 and 6 (DNREC, 1994), and in the more urban portions of the estuary, Zones 2 through 4 (Faulds et al, 2004). DRBC also funded two studies to provide data for use in establishing bioaccumulation factors for PCBs. The first study involved measuring the concentration of PCBs in sediments and various trophic levels of the food chain of selected sport species in the Delaware River Estuary (Ashely et al, 2004). This study examined PCB concentrations in invertebrates, small prey fish, channel catfish and white perch in the fall of 2001 and the spring of 2002 in four zones of the estuary (Zones 2 - 5) that were the focus of TMDL development. The second study involved the measurement of 124 PCB congeners in water samples collected at 15 locations in Zones 2 through 5 (DRBC, 2003). Data from fish tissue surveys conducted in the estuary were also examined to determine the percent lipid of the consumed portion of channel catfish and white perch caught in the estuary (Greene, 2002).

In order to assess the uncertainty in the parameters that are used in the criteria equation, a probabilistic analysis was conducted using @Risk software (Palisade Corporation, 2004). This analysis involves assigning distributions to selected equation parameters and some of their components. Data for the parameters that would be assigned distribution Table 1 indicates which of the parameters and their components were assigned a distribution or a fixed value. The distributions used for each parameter and component were determined from the source of the data or from statistical analysis of the data.

Table 1: Summary of Parameters and Data Used in Calculating Human Health Criteria for Carcinogens

Parameter	**Policy**	**Fixed Value**	**Distribution Used**
Risk Level of 10^{-6}	X		
Body weight - 70 kilograms		X	
Drinking water intake per day - 2 liters per day		X	
Cancer potency factor			Uniform
Fish intake at each trophic level			
Total consumption rate			Triangular
Proportion of each trophic level species		X	
Bioaccumulation factor at each trophic level (BAF_i)			
Octanol-water partition coefficient (K_{ow})			Discrete
Particulate organic carbon (POC)			Lognormal
Dissolved organic carbon (DOC)			Lognormal
% lipid of consumed portion			Lognormal
Intermediate Parameters			
Fraction of PCB freely-dissolved in water			Calculated
Baseline BAF for channel catfish			Gumbel
Baseline BAF for white perch			Gumbel
Trophic level BAF for channel catfish			Calculated
Trophic level BAF for white perch			Calculated

The distributions were then sampled 10,000 times using the Latin Hypercube procedure and summarized in frequency distributions.

RESULTS

The value(s) selected for each parameter in the revised criteria equation are discussed below:

Cancer potency factor

The value selected for use is the upper bound factor for total PCBs published in the U.S. EPA's Integrated Risk Information System (U.S. EPA, 2004). This factor was first published in 1997 along with central estimate and upper bound factors for high risk and persistence, low risk and persistence, and lowest risk and persistence. as a result of a reevaluation of the data on the carcinogenicity of PCB Aroclors. The upper bound slope factor is recommended for use where there is exposure through the food chain; dioxin-like, tumor-promoting, or persistent congeners are present; or early life exposure is expected. The subcommittee recommended the use of the upper bound estimate of 2.0 (mg/KG)/day.

Body weight

The value selected for use is the average weight of male and female adults of 70 kilograms. This value is recommended by the U.S. EPA for establishing ambient water quality criteria (U.S. EPA, 2000). Although is slightly lower than that reported in the latest National Health and Nutrition Examination Survey (NHANES III). The mean body weight of men and women ages 18 to 74 years observed in this survey was 75.6 kilograms. U.S. EPA recommends continued use of 70 kilograms for consistency since this value is used in the Integrated Risk Information System for deriving cancer slope factors and unit risks for drinking water.

Risk level

The risk level used in establishing ambient water quality criteria is a risk management policy decision. It is defined as the number of cases of disease such as cancer in a population exposed to a chemical or chemicals. While the U.S. EPA believes that a risk level of either 10^{-5} or 10^{-6} may be acceptable as a *de minimus* risk for the general population, it uses a level of 10^{-6} for criteria actions under Sections 304(a) and 303(c) of the Clean Water Act. The agency believes that this risk level reflects an appropriate risk for the general population, and is consistent with the policies and regulations of the agency as a whole (U.S. EPA, 2000). The recommendation of a range of risk levels does provide flexibility to government entities in establishing water quality standards.

A risk level of 1 additional cancer case in 1 million exposed individuals or 10^{-6} was selected for use in the equation. This risk level is used by the Commission, the states of Delaware and New Jersey, and the Commonwealth of Pennsylvania in establishing their water quality standards. In March 2003, the Commission adopted Resolution 2003-11 following discussion of the recommendations of the Commission’s Toxics Advisory Committee on revised human health criteria and wildlife criteria for total PCBs. This resolution directed the Commission staff to solicit comment on the revised human health criteria for PCBs including the appropriate cancer risk level.

Drinking water intake rate

A value of 2.0 liters/day was selected for this parameter. This value was used in the development of the 1980 national water quality criteria, and continues to be recommended by the U.S. EPA in the 2000 guidance (U.S. EPA, 2000). This recommendation was based upon a more recent survey of food intake by individuals conducted by the U.S. Department of Agriculture entitled “1994-96 Continuing Survey of Food Intake by Individuals” (U.S.D.A., 1998). This survey reported a mean and 90th percentile drinking water consumption for adults 20 years of age and older of 1.1 and 2.2 liters/day, respectively. The U.S. EPA believes that new studies continue to support the use of 2.0 liters/day as a reasonable and protective consumption rate for the general population (U.S. EPA, 2000).

Fish consumption rate

In the 2000 guidance, the U.S. EPA recommends that a hierarchy of preference be used in the selection of a fish consumption rate for used in the criteria equation (U.S. EPA, 2000). This hierarchy is: 1) the use of local data on fish consumption patterns, 2) use of data reflecting similar geography or population groups for the water body of concern, 3) use of data from national surveys, and 4) use of the U.S. EPA default consumption rates. The default rate recommended by the U.S. EPA for both recreational fisherman and the general population is 17.5 grams per day. Ths rate is based upon the 1994-96 Continuing Survey of Food Intake by Individuals (U.S.D.A., 1998)

Two sources of data were available on the fish consumption patterns of recreational fisherman in the Delaware River Estuary. A study commissioned by the State of Delaware examined catch and consumption patterns in Zones 5 and 6, the lower portion of the tidal Delaware River and Delaware Bay (KCA, 1994). The study involved dockside intercepts and follow-up phone interviews of over 800 participants. The northern part of Zone 5 adjoins the urban area of Wilmington, and the surrounding suburban area of New Castle County in Delaware. The second study by Faulds et al, 2004 examined catch and consumption patterns in Zones 2, 3 and 4 of the tidal Delaware River by intercepting and interviewing shore anglers at six sites in Pennsylvania. These zones include the urban areas in and around the City of Philadelphia.

The average consumption of all species in Zones 5 and 6 was 17.46 grams per day, and the maximum fish consumption by any particular demographic group was 53.9 grams per day (KCA, 1994). Channel catfish and white perch were consumed at approximately equal rates. Faulds et al (2004) reported that channel catfish, striped bass and white perch were the most frequently consumed species in Zones 2 through 4. Ethnic groups reporting the highest consumption were Cambodian, Vietnamese and Afro-American. Faulds et al (2004) reported the number of meals of the species consumed by shore anglers. This data was converted to grams per day, the unit used in the criteria equation, and resulted in consumption rates of 17.9 grams per day for channel catfish and 21.7 grams per day for white perch assuming a meal size of 8 ounces.

The consumption rate selected for use in the criteria equation was 17.5 grams per day. This value is consistent with the national default value and the site-specific data for Zones 2 through 6. The consumption data reported by Faulds et al (2004) on urban fisherman in Zones 2 - 4 was not substantially higher than the rate observed in the lower estuary, and did not support the use of a different consumption rate for zones in the Philadelphia area, especially in light of the management benefits associated with a consistent, estuary-wide criterion.

Bioaccumulation factor

Bioconcentration factors, or BCFs, represent the accumulation of chemical in an aquatic species due to uptake from the water only. In contrast, bioaccumulation factors, or BAFs, represent the accumulation due to all routes of exposure, including exposure through the water and through the consumption of contaminated prey and sediment. Use of a bioaccumulation factor rather than a bioconcentration factor was endorsed by the Commission's Toxics Advisory Committee at their meeting in February 2001 and directed by the Commission in Resolution 2000-13 in March 2003. The 2000 guidance calls for the use of a separate factor for each of the trophic levels represented in the species consumed in the water body for which the criteria will apply. In the case of the Delaware Estuary, two trophic levels were used. Trophic level 3 represents species whose diet consists of consumers of primary producers and detritus, principally invertebrates such as amphipods of the genus *Gammarus*. The species selected to represent this trophic level was the channel catfish. Trophic level 4 represents species whose diet includes more fish. The species selected to represent this trophic level was the white perch. The use of a single value for the BAF for these two trophic levels was unanimously endorsed by the Commission's Toxics Advisory Committee in February 2003.

The 2000 guidance recommends two possible procedures for deriving BAFs for nonionic organic chemicals (U.S. EPA, 2000). Procedure #1 is recommended for nonionic organic chemicals with log K_{ow} values equal to or greater than 4.0 where metabolism is expected to be sufficiently low. PCB homologs have log K_{ow} values that range from 4.69 for monochlorobiphenyls to 8.18 for decachlorobiphenyls. The guidance specifically mentions PCBs as a group of chemicals for which Procedure #1 is deemed appropriate. Procedure #1 contains four methods for calculating the BAFs. The first method uses field measurements to derive the BAFs. The 2000 guidance recommends this method over the other three methods which utilize predictive approaches for establishing BAFs (U.S. EPA, 2000).

The first step in using measured data to derive the BAFs is to calculate Baseline BAFs. Baseline BAFs are defined as a BAF in units of Liters/kilogram-lipid that is based upon the concentration of freely dissolved chemical in the ambient water and the lipid-normalized concentration in the fish tissue (U.S. EPA, 2000). Baseline BAFs are calculated using the formula:

$$Baseline\ BAF_{l}^{fd} = \left[\frac{Measured\ BAF_{T}^{t}}{f_{fd}} - 1\right]\left[\frac{1}{f_{l}}\right]$$

where:

Baseline BAF $^{fd}_{l}$ =	BAF based upon the total concentration of the chemical in tissue and ambient water
Measured BAF $^{t}_{T}$ =	BAF based upon the total concentration of the chemical in tissue and ambient water
f_l =	The fraction of tissue that is lipid
f_{fd} =	The fraction of the total chemical that is freely-dissolved in water

Zone-specific data on PCB concentrations in fish tissue and ambient water were obtained from two studies: a bioaccumulation study conducted by the University of Maryland and the Academy of Natural Sciences in the fall of 2001 and spring of 2002 (Ashley et al, 2004), and ambient water measurements of PCBs conducted by the Delaware River Basin Commission in late 2001 and early 2002 (DRBC, 2003). Each of these studies measured a common set of 124 congeners which were summed to derive total PCB concentrations. The fraction of the total chemical that is freely-dissolved in water is determined using the octanol water partition coefficient, and the concentration of particulate organic carbon and dissolved organic carbon in the ambient waters determined in surveys conducted by DRBC in the fall 2001 and spring 2002. The formula is:

$$f_{fd} = \frac{1}{\left[1 + \left(POC \bullet K_{ow}\right) + \left(DOC \bullet 0.08 \bullet K_{ow}\right)\right]}$$

where:

POC =	Particulate organic carbon concentration in ambient water in Kilograms/liter
K_{ow} =	octanol water partition coefficient for the chemical
DOC =	Dissolved organic carbon concentration in ambient water in Kilograms/liter
f_{fd} =	The fraction of the total chemical that is freely-dissolved in water

Table 2 contains the ambient water, tissue concentration, organic carbon concentrations and fraction lipid that were used in the derivation of the Baseline BAFs.

Table 2: Data used in the derivation of the Baseline BAFs.

Study Period	**Tissue Concentration (ng/g)**	**Ambient Water Concentration (pg/L)**	**POC (mg/L)**	**DOC (mg/L)**	**fraction lipid**
Fall 2001		3194.4	1.51	6.44	
Channel catfish	1230.4				0.0892
White perch	1013.4				0.0734
Spring 2002		4691.8	1.84	10.74	
Channel catfish	1621				0.0817
White perch	1127.6				0.0684

Baseline BAFs are then converted to trophic level BAFs using the following formula:

$$BAF_{(TL\,n)} = \left[Baseline\, BAF_{l}^{fd} \bullet (f_l)_{TL\,n} + 1 \right] \bullet (f_{fd})$$

where

$BAF_{(TL\ n)}$ =	Final trophic level baseline BAF expressed on a freely-dissolved and lipid-normalized basis for trophic level n
Baseline BAF $^{fd}_{l}$ =	BAF based upon the total concentration of the chemical in tissue and ambient water
f_l =	The fraction of tissue that is lipid for trophic level n
f_{fd} =	The fraction of the total chemical that is freely-dissolved in water

Table 3 lists the Baseline BAFs, fraction lipid of consumed tissue, fraction of chemical freely-dissolved and the final trophic level BAFs.

Table 3: Values used in the calculation of final trophic level baseline BAFs.

Trophic Level	**Baseline BAF (L/KG-lipid)**	**fraction lipid of consumed tissue**	**fraction freely-dissolved**	**Trophic Level BAF (L/KG-lipid)**
Level 3 - Channel catfish				
Fall 2001	35288611	0.0387	0.122	167200
Spring 2002	44088605	0.0387	0.095	162465
Level 4 - White perch				
Fall 2001	22458380	0.0248	0.122	68190
Spring 2002	35267280	0.0248	0.095	83281

Prior to calculating the water quality criterion, the proportion of fish intake from each trophic level must be determined. Faulds et al, 2004 reported that 42.6% of the fish consumed by shore anglers in Zones 2 through 4 were channel catfish while 42% of the fish consumed were white perch. Since these data indicated similar proportions for both trophic levels 3 and 4, equal proportions of each trophic level were assumed in calculating the revised ambient water quality criteria.

Criterion calculation

Values for each of the parameters in the criteria equation presented in the 2000 guidance and the resulting ambient water quality criterion for the protection of human health from the carcinogenic effects of PCBs for Zones 2 through 5 is presented in Table 4.

Table 4: Parameter values used in the equation for calculating the human health criterion for the protection from carcinogenic effects for PCBs.

Parameter	Value
Risk Level	38630
Cancer potency factor	2.0 (mg/KG)/day
Risk Specific Dose	5.0×10^{-7}
Body Weight	70 KG
Drinking Water Intake	2.0 liters/day
Fish Intake	17.5 grams per day
Proportion of fish intake at each trophic level	Trophic level 3 - 0.5 Trophic level 4 - 0.5
BAF at each trophic level	Trophic level 3 - 164,832 Trophic level 4 - 75,736
Ambient Water Quality Criterion	**15.9 picograms/liter**

This ambient water quality criterion applies where exposure is from drinking water and fish consumption or only from fish consumption.

Probabilistic analyses of parameters

POC, DOC, % lipid for channel catfish, and % lipid for white perch were each treated as lognormal distributions based upon the underlying data. The octanol water partition coefficient, which is used to calculate the fraction of freely dissolved chemical, was treated as a discrete distribution, with homolog-specific Kow values assigned to different frequencies based upon the possible number of PCB congeners at each homolog level. Fish consumption rate was considered as a triangular distribution with a minimum of zero, a most likely value of 17.46 grams per day, and a maximum value of 53.9 grams per day, based upon the KCA study (1994). The cancer potency slope was treated as a uniform distribution spanning a range from 1 to 2 (mg/KG-d)-1. Finally, baseline BAFs for channel catfish and white perch were specified as Gumbel distributions based upon best fits to the field data.

The distributions described above, in combination with the fixed values for risk level, body weight, and drinking water ingestion, were sampled 10,000 times using the Latin Hypercube procedure to produce a range of possible water quality criterion values for the protection of human health from carcinogenic effects, each with an associated frequency. The results of the probabilistic analysis from exposure through drinking water and fish consumption, and through fish consumption only are presented in Table 5 and Figure 1. The 50th percentile of the criterion was 16.4 pg/liter for both exposure scenarios.

Table 5: Results of probabilistic analysis using @Risk.

Percentile	Ambient Water Quality Criterion	
	Fish and Water Consumption	**Fish Consumption Only**
10%	3	3
25%	6.2	6.2
50%	**16.4**	**16.4**
75%	49.6	49.7
90%	144.5	145.4

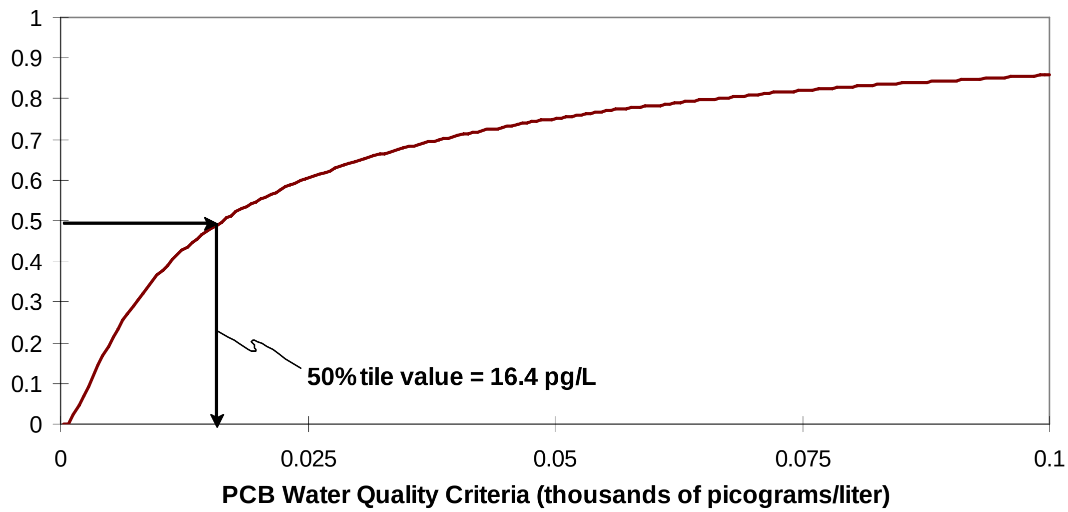

Figure 1: Distribution of ambient water quality criterion for PCBs

DISCUSSION

The keystone of any TMDL is the water quality criterion upon which it is based. In developing TMDLs for PCBs for the Delaware Estuary, several factors influence the selection of the governing criterion. These factors include: 1) a change in the cancer potency factor for total PCBs reported in EPA's Integrated Risk Information System, 2) the potential adoption of wildlife criteria for PCBs for one of the states bordering the estuary, and 3) the issuance of a revised methodology for deriving ambient water quality criteria for the protection of human health in the fall of 2000. The latter methodology also includes several new recommendations on the fish consumption rate to be used in criteria development, and the use of a bioaccumulation factor (BAF) rather than a bioconcentration factor (BCF).

Another confounding factor that influences the development of TMDLs for hydrophobic contaminants like PCBs in interstate waters is the existence of different human health criteria adopted by bordering states. Furthermore, the requirement under the Clean Water Act that states update their criteria every three years can result in changing criteria over time, thus making the basis of the TMDLs difficult to establish. An example of the impact of these factors is the human health criteria for Zones 2 through 5 of the Delaware Estuary. In 1996, the Delaware River Basin Commission, the states of Delaware and New Jersey, and the Commonwealth of Pennsylvania all had the same criteria for PCBs, 44.4 picograms/liter. With the issuance of a revised slope factor and revised methodology for deriving human health criteria by the U.S. EPA, the adoption of different criteria by each of the three states during their triennial review was possible depending on the extent to which the new data and methodology were implemented. In 2004, both Delaware and New Jersey proposed revised human health criteria for PCBs. Delaware developed their revised criterion using the new cancer slope factor and site-specific fish consumption data, and derived a value of 64 picograms per liter. New Jersey developed their revised criterion using only the new cancer slope factor, deriving a value of 170 picograms per liter. The Commission still retains the criterion value of 44.4 picograms per liter adopted in 1996.

Adoption of the revised human health criteria for carcinogenic effects for PCBs presented in this paper by the Commission will result in a uniform standard that fully implements the October 2000 guidance issued by the U.S. EPA. Even if the three states bordering the estuary have different criteria for PCBs depending on the extent to which they have implemented the new guidance, provisions in the standards of New Jersey and Delaware deferring to standards adopted by the Commission will make the revised criteria the governing criteria. Pennsylvania water quality standards do not have language deferring to the Commission's standard, but do have regulations stating that the more stringent of state, interstate or international criteria will apply in interstate or international bodies of water.

Wildlife criteria could be more stringent than human health criterion for carcinogenic effects. Factors affecting this determination include the numerical values of both the wildlife and human health criteria, and the exposure duration used in applying the criteria. The exposure duration for human health criteria for protection from carcinogenic effects is 70 years. The exposure duration for wildlife criteria is 90 days. Figure 2 compares the assimilative capacity (a close analog of a TMDL) of Zones 2 - 5 of the Delaware Estuary based upon existing human health criteria, proposed wildlife criteria, and revised human health criteria implementing one or more recommendations of the October 2000 guidance. This graph indicates that existing criteria are not the most controlling, and that only by fully implementing the recommendations of the October 2000 guidance with respect to the cancer slope factor, fish consumption rates and the use of BAFs will the revised human health criteria be controlling.

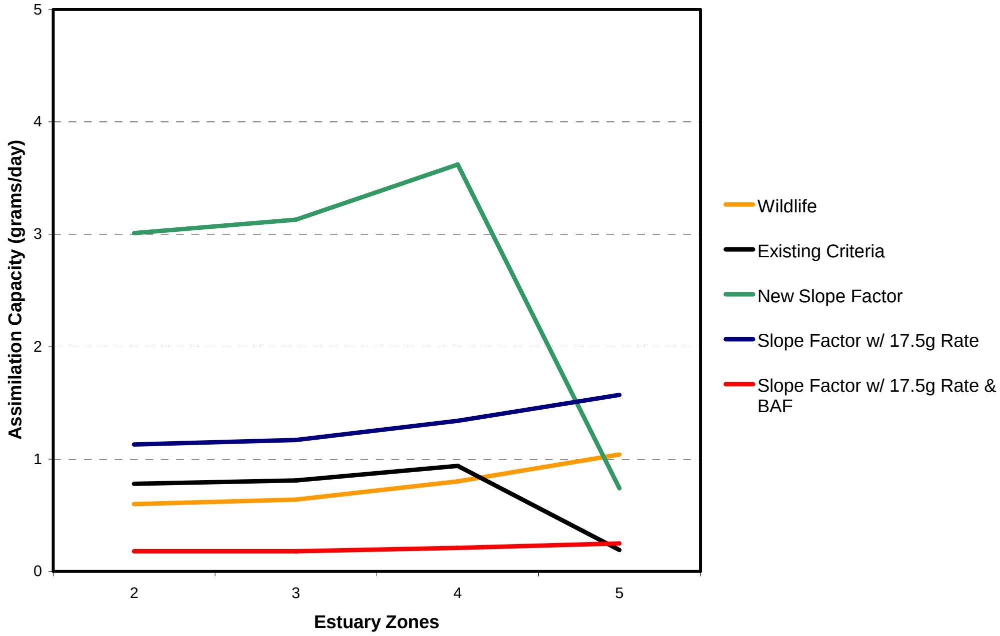

Figure 2: Comparison of assimilative capacity at different criteria values.

CONCLUSION

Revised human health criteria for the protection of human health from carcinogenic effects were developed using the updated cancer potency factor of 2.0 (mg/KG)/day and the October 2000 guidance issued by the U.S. EPA. Two significant changes recommended in this guidance were the recommendations to use site-specific values for fish consumption for the water body covered by the criteria, and to use a bioaccumulation factor or BAF rather than a BCF. A value of 17.5 grams/day was selected for use in the criteria formula. This value is similar to site-specific values of 17.5 and 19.8 grams per day observed in two studies conducted in the Delaware Estuary, and is also the recommended national default value. Site-specific BAFs were developed for two trophic levels in the estuary using fish tissue data collected during the fall 2001 and spring 2002, and data on concentrations of PCB congeners in water samples collected during the same time period. Trophic level BAFs of 164,832 L/KG-lipid for trophic level 3 and 75,736 L/KG-lipid for trophic level 4 were determined using these data.

Values for other parameters in the criteria equation were a risk level of 10^{-6}, body weight of 70 kilograms, drinking water intake of 2.0 liters/day. The revised ambient water quality criterion for the protection of human health from carcinogenic effects from exposure through drinking water and fish consumption using these parameter values is15.9 picograms/L.

The results of a probabilistic analysis of selected equation parameters and some of their components indicated a 50^{th} percentile value of 16.4 picograms/L for the revised water quality criterion. This value is close to that obtained with the deterministic approach.

The values obtained using the revised criteria equation are approximately 2.5 more stringent than the criteria in Zones 2 - 4 and in the upper portion of Zone 5, and 2.2 times less stringent than the current criterion in the lower portion of Zone 5. Criteria of this magnitude would be more stringent than the wildlife criterion proposed for the State of New Jersey. Use of revise water quality criterion for the development of TMDLs for PCBs in the Delaware Estuary will ensure consistency and stability in the value of the TMDLs.

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