Prioritized Chesapeake Bay Organic Toxics of Concern Method and Assessment

Toxics Subcommittee of the Chesapeake Bay Program

Chesapeake Bay Program

A Watershed Partnership

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Table of Contents

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List of Tables

List of Figures

List of Equations

List of Appendices

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Executive Summary

In order to focus the Chesapeake Bay Program Toxics Subcommittee's (TSC) efforts on toxic organics in the Chesapeake Bay with the most harmful potential, TSC developed an updated method for prioritizing these chemicals. Criteria for ranking were carefully selected to include considerations of each toxic substance's presence and effects within the Bay. To do so, this list prioritizes organic chemicals based on estimates of loads to the Bay, presence in the Bay, eco-toxicological properties, and any impacts that these chemicals are predicted to have in the Bay and its tidal rivers characterized by fish advisories or Clean Water Act 303(d) impairment designations.

Appropriate uses of this ranking were developed based on the data available and methods used. Once developed, the prioritization was peer reviewed and deemed acceptable for these identified uses.

The prioritization resulted in two lists, a ranking by chemical class and an individual ranking. Both lists indicate which substances, of those included in the ranking, are likely to be relatively most problematic within the Chesapeake Bay. By class PCBs were implicated as the most problematic, followed by PAHs and organochlorine pesticides. TSC will use these rankings to guide decision making and direct implementation efforts toward those chemicals of greatest concern.

Intended Uses

Because of the nature of the data and methods used, this list must only be considered a relative ranking between chemicals that had data present in both the 1999 Toxics Release and Loading Inventory, and the 1999 Characterization Report Data Files. *This prioritized list does not represent a risk assessment of chemicals in the Chesapeake Bay or its tributaries.*

The updated Toxics of Concern list is intended for:

- Internal use by the Chesapeake Bay Program Toxics Subcommittee as a general guide for directing and prioritizing efforts and activities that focus on specific chemicals or groups of chemicals, regarding both point source and non-point source loadings
- For use in targeting and prioritizing pollutants for reduction in Chesapeake Bay-focused voluntary pollution prevention activities that are encouraged by TSC and its workgroups

The updated Toxics of Concern list is **NOT** intended for:

- Use as a risk assessment of chemical contaminants in the Chesapeake Bay or its tributaries

- Use as a definitive list of all chemicals that may impact the Chesapeake Bay or its watershed
- Use as a prioritization of chemicals for any type of regulatory consideration

Toxics of Concern: Background

The Toxics of Concern (TOC) list, also sometimes referred to as the Chemicals of Concern list, has had several reincarnations in the Chesapeake Bay Program. It has been renamed with "Toxics" in place of "Chemicals" because the list focuses on chemicals with toxic properties (i.e. pesticides, PCBs) as it is utilized by TSC. Other chemicals such as nutrients are not included in the prioritization. The first list was born out of a commitment in the 1989 *Chesapeake Bay Basinwide Toxics Reduction Strategy* and was completed in 1991[1]. The list was intended to identify and document chemicals that adversely impacted or had the potential to impact the Bay[2]. Although the list was intended to be updated every two years, it was not updated, due to lack of data, until 1996 when the list was refreshed due to a commitment in the updated 1994 *Chesapeake Bay Basinwide Toxics Reduction and Prevention Strategy*[2]. This effort used a risk-based chemical ranking system[2]. The list was to be re-evaluated every three years using the chemical ranking system, updated with current science where appropriate[2].

The 2006 TOC prioritization is based on the same concepts of the chemical ranking system used in the 1996 re-evaluation. The TOC list was refreshed in 2000, but was not based on a chemical ranking system, and simply listed chemical contaminants identified in the 1999 *Toxics Characterization Report*[3] that were identified at levels that may cause toxic impacts to living resources, chemical contaminants responsible for listing water bodies as impaired or threatened on the jurisdictions 303(d) lists, and chemical contaminants responsible for finfish and shellfish consumption advisories[4]. Like the 1996 chemical ranking system, criteria for the 2006 revision incorporate source, fate, exposure/effect, and like the 2000 TOC list, fish consumption advisories and 303(d) impairments are also considered.

Improvements in the 2006 chemical ranking system include persistence, bioaccumulation, and toxicity (PBT) adjusted loadings estimates, frequency of detection of chemical contaminants in multiple media in the tidal rivers of the Bay, and the incorporation of state management outcomes including fish advisories and 303(d) impairments. Cumulative loading estimates derived from the 1999 Toxics Loading and Release Inventory for this list are improved over loadings estimates used in 1996. Furthermore, the loadings estimates are risk adjusted for bioaccumulation (BAF/BCF), persistence (sediment half-life), and aquatic life ecological toxicity. *Persistence, and bioaccumulation in current science have been shown to be inappropriate eco-toxicological assessment measures for metals and, therefore, only organics will be ranked using this system. Metals will be listed and ranked separately in a companion document when comparable guidelines for assessing metals become available.*

1996 Chemical Ranking System	2006 Chemical Ranking System for Organic Chemicals
<u>Source</u> • Loadings <u>Fate</u> • Bioconcentration • Persistence <u>*Exposure/Effects*</u> • Water column threshold • Sediment threshold • Fish Tissue threshold	<u>*Source adjusted by fate and effect:*</u> • Persistence, bioaccumulation, and toxicity adjusted loadings <u>*Environmental Presence:*</u> • Frequency of detection in sediment, water column, and fish tissue (from 1999 Characterization Data Files) <u>*Exposure/Effects*</u> • Sediment threshold • Water Column threshold • Fish Tissue Threshold • Fish Advisory • 303(d) Impairment

The TOC list has been a historically valuable strategic tool in guiding the activities and resources of TSC. As there is a universe of toxic chemicals that have been released into the environment, it is important that the TSC focus on those that have the largest potential to adversely effect the Bay's living resources, according to the available data. This will allow the subcommittee to be more effective in targeting pollution prevention and restoration activities.

Identifying Chemical Contaminants in the Bay for Prioritization

Over 1,000 chemicals were identified and listed in the 1992 "Chesapeake Bay Basin Comprehensive List of Toxic Substances" as contaminants that either reached the Bay or its tidal rivers or had been emitted to the watershed with potential to reach the Bay. Of these 1,000+ chemicals, 130 organic toxics have been detected either in sediment, water column, or fish tissue in the tidal Chesapeake Bay according to data used in the 1999 *Toxics Characterization Report*[3]. Appendix A (Table A-2) lists all 130 chemicals and in what media they were detected.

Detection of chemicals may be biased towards chemicals with lower detection limits. This data does not include chemicals that may be found in only the air, soil, and/or groundwater, and does not necessarily represent a comprehensive list of all toxic chemicals present in the tidal regions of the Chesapeake Bay.
Chemicals pooled for prioritization were chosen because they met three criteria:

1. The chemical appeared on lists of priority chemicals submitted by the Chesapeake Bay Program Toxics Subcommittee
2. The chemical had loadings estimates available in the 1999 Chesapeake Bay Basin Toxics Loading and Release Inventory (TLRI)[5]
3. The chemical had reported detections in the 1999 *Toxics Characterization Report*[3].

These criteria reduced the list of all chemicals found in the Bay to focus on 35 organic chemicals representing organochlorine pesticides, organophosphate pesticides, PCBs, PAHs, and other priority toxics (Table 1).

This list does not include emerging pollutants such as pharmaceuticals, personal care products, and flame-retardants. Emerging pollutants are chemicals which have not been commonly monitored in the environment but have the potential to enter the environment and cause known or suspected adverse ecological and/or human health effects. In some cases, release of emerging chemicals to the environment has likely occurred for a long time, but may not have been recognized until new detection methods were developed. For such cases, their presence in the environment is not necessarily new but they have historically received little attention. In other cases, the synthesis of new chemicals or changes in use and disposal of existing chemicals can create new sources of emerging pollutants.[8] Some specific examples of emerging pollutants are N-N-diethyltoluamide (insect repellent), caffeine (stimulant), triclosan (antimicrobial disinfectant, used in personal care products), Polybrominated diphenyl ethers ("PBDEs," flame retardants) and 4-nonylphenol (nonionic detergent metabolite).

Emerging contaminants are not included in this prioritization due to a lack of data currently available. They do not fulfill the prioritization criteria. This may be due to lack of loading estimates or of knowledge regarding the chemical's persistence, bioaccumulation, and/or toxicity in the environment. However, realized as potentially harmful, emerging contaminants are receiving increased attention. As necessary data becomes available for a given chemical TSC will review the chemical's potential harm within the Bay system.

Estimating Cumulative Loads of Organic Chemicals to the Bay

The TLRI[5] contains loadings estimates to the Bay from multiple source categories including: point source, urban storm water run-off, atmospheric deposition below the fall line, and above fall line (non-tidal) loadings (Figure 1). In order to estimate a cumulative load for a chemical, all loadings present in the TLRI for the specific chemical were summed (Appendix B, Table B-2). All chemicals have a detection limit for given means of testing (a concentration below which they cannot be detected by testing method used). When chemicals are below detection limits there is uncertainty as to the concentration of that chemical. It may be present at any concentration between zero (low estimate) and the value of the detection limit concentration (high estimate). Often the mean value between zero and the detection limit is used as an estimate. Where there was a high and low estimated load for a particular non-point source category, the mean was used. In the case of point source loadings only the low load estimate was used (non-detect values in the point source database used to calculate annual point source loads were assumed to be zero). This was done because most PAHs, PCBs, and pesticides were never detected in the point source database used to calculate annual point source loads, and estimated loads using the mean estimate for PAHs, PCBs, and pesticides resulted in unrealistically high load estimates.

Adjusting Organic Chemical Loads for Persistence, Bioaccumulation, and Toxicity

The EPA has established that persistence, bioaccumulation, and toxicity (PBT) criteria are not appropriate for assessing metals due to the physical and biochemical properties of metals, and is in the process of developing a metals assessment framework. For this reason metals were not prioritized with organic chemicals.

The estimated load of a chemical into an ecosystem such as the Chesapeake Bay, will not alone predict the degree of the effect it may have on the aquatic life of the system. For example, a large load of one chemical to the environment may have a lesser effect on aquatic life than a much lesser load of another more toxic, persistent, or bioaccumulative chemical. These three factors help predict a chemical's effects on organisms in a system. Chemical contaminants vary in how long they take to degrade in the environment (persistence). Chemicals with greater persistence result in prolonged exposure. Contaminants vary in how they concentrate in organisms in a food chain (bioaccumulation). Contaminants vary in how the chemical will affect the health of an organism at a given concentration (toxicity). Therefore, in order to make loads of different chemicals comparable for this prioritization effort, cumulative loadings estimates to the Chesapeake Bay were adjusted by a Persistence, Bioaccumulation, and Toxicity (PBT) factor (Equation 1, Appendix D) specific to each chemical, or chemical group where individual values for chemical within a group were absent. PBT values were obtained from EPA's Waste Minimization Prioritization Tool (WMPT)[6]. EPA created WMPT to develop the Resource Conservation and Recovery Act (RCRA) PBT chemical ranking. PBT values from WMPT, used in this prioritization have been reviewed and modified since launching of the first version of WMPT in 1998.

Environmental Presence of Toxic Contaminants in the Bay

In order to further examine the extent of chemical contamination in the Chesapeake Bay beyond loadings estimates, the presence of contaminants in sediment, water, and fish tissue was determined. The frequency of detection of contaminants in sediment, water column, and fish tissue was calculated using data compiled for the 1999 *Toxics Characterization Report*[3] because the data was previously thoroughly reviewed in order to conduct the characterization. The characterization data includes the results of 53 monitoring studies, comprising 124,087 observations, at 1062 stations, in 36 tidal river segments of the Bay (Appendix A, Table A-1). A majority of the data is sediment data (53%), followed by water column data (43%), and then fish tissue data (4%). Although fish tissue data comprised only a small percentage of the overall data it still consisted of 4,378 observations at 46 sampling stations. Equation 3 shows how environmental presence criteria was scored.

Effects Criteria: Sediment, Water Column, and Fish Tissue Thresholds

The extent of potential for adverse effects on aquatic organisms by contaminants present in the Bay was measured using the frequency that a contaminant exceeded a sediment, water column, or fish tissue threshold for aquatic life (Appendix C). Thresholds used were those determined by either EPA, FDA, or NOAA. The frequency that a contaminant exceeded either a sediment, water column, fish tissue threshold was determined by using the number of observations that a contaminant exceeded a threshold divided by the total number of observations, in the same way the environmental presence frequency was calculated (Equation 4.) This adds double weight to observations that exceeded a threshold, because they are also counted as above detection limit observations for the environmental presence criteria. However, the meaning is different, where as frequency of detection indicates environmental presence only, the frequency of exceeding a threshold indicates that the chemical occurs at a concentration that implies potential adverse effects for aquatic life. Not all observations that were above detection limit were also above a threshold.

Programmatic Concerns: Fish Consumption Advisories and 303(d) Impairments

Fish consumption advisories

Advisories developed by EPA or states identify fish that are not safe for human consumption due to toxic chemicals found in the tissue. In this assessment, 5 points are given for a toxin that is the risk driver of fish advisory. 2.5 points are assigned to a chemical that is a secondary contaminant of an advisory. Advisories with secondary risk drivers occur when another chemical is the primary cause for a fish advisory but the secondary chemical is also found in fish tissue at concentrations that indicate a risk if consumed by humans.

Maryland and Virginia use fish tissue information to develop risk assessments and fish consumption advisories to protect the health of recreational fishermen and their families. Concentration levels for impairment thresholds and fish advisories come from the U.S. EPA, Maryland Department of the Environment, Virginia Department of Environmental Quality, and Virginia Department of Health guidelines.

303(d) Impairment

Where states have designated waters within the Bay watershed as impaired under a Clean Water Act 303(d) listing, the chemical responsible for the listing is given a score of 5 points within this category. Chemicals causing no impairments under 303(d) listings within the watershed are given a score of 0.

Final Scoring

Subcriteria scores are summed with subcriteria weighting equal within each criteria category. Criteria scores (the sum of these subcriteria scores) are then adjusted for equal weighting and summed to yield the final score. Table 2 shows how weighting for subcriteria and criteria were kept equal. Figure 2 gives a visual representation of how final scores were calculated. Figure 3 shows how each criteria score contributed to finals scores for prioritized chemicals. Figure 4 gives further breakdown showing relative contributions of subcriteria. The outcome is a list of chemical classes ranked by mean score calculated using individual scores for each chemical across the class and an overall relative ranking of each individual chemical.

Discussion

An updated prioritized list of toxics within the Chesapeake Bay is needed to help guide planning and implementation by TSC. This list was created using available loadings data, PBT values that indicate the behavior of a chemical contaminant in the environment, monitoring data showing general presence as well as presence above thresholds indicating risk to aquatic life or humans, and programmatic concerns for each chemical considered.
The list that resulted from this assessment, providing a numerical ranking for chemical classes and individual chemicals meeting criteria for ranking, can be utilized by the TSC for guidance in implementation. Since toxics is very broad category capturing Bay pollutants other than nutrients and sediment, this list provides a necessary guideline to suggest which of these many pollutants are currently the most problematic.

Conclusion

This list is a successful ranking for chemicals considered as it provides ranking by class and by individual chemical and will be a source of information available for use by environmental managers to prioritize efforts within the Chesapeake Bay watershed. By class, PCBs rank as the most problematic chemicals, followed by PAHs and then organophosphates. The marginal difference in mean scores for PAHs (40.229) and organophosphates (40.139) indicate that both pollutant categories should be considered significant. PCBs (1), Benzo(a)pyrene, Chlorpyrifos, PCBs (2), and DDT rank as the top five individual toxics of concern. This list indicates that TSC's time will be best spent focusing on chemicals or chemical classes that rank highest in this assessment as high scores indicates they are the most problematic. Figure 4 represents graphically the relative significance of criteria in reaching a final score for each chemical.

Uncertainty/Data Gaps

Where TLRI loads were uncertain, low load estimates were used. This conservative approach should prevent a chemical's relative significance from being overestimated, however this does present a large degree of uncertainty in load estimates. Lack of TLRI loadings estimates for many chemicals that were detected within the Bay presents a data gap. (Appendix A, Table A-6) To use this prioritization scheme loadings estimates were needed, in the future when more information regarding loadings for detected chemicals becomes available these chemicals will be considered in new prioritizations. For those chemicals detected but not prioritized the ranking by class provides a general indication of how problematic each class of pollutants is within the Bay.

Using frequency of detection to indicate presence presents a potential bias toward those chemicals with lower detection limits. Those with lower limits may be detected at a given concentration while another chemical present at the same concentration may not be detected if that concentration is below its detection limit, thus the chemical with the lower limit is observed with greater frequency.

In the future, it will be a priority of TSC to fill gaps in the current data pool. The prioritization will be repeated in the future to ensure that the subcommittee continues to focus on those chemicals that pose the greatest threat the Chesapeake Bay ecosystem.

Metals could not be prioritized using this method. When a method becomes available, a companion document will be produced to prioritize toxic metals within the Bay. If data becomes available for emerging pollutants and indicates that they may be problematic in the Bay system, these will be considered in subsequent prioritizations.

References

1. *Chesapeake Bay Toxics of Concern List: Basinwide Toxics Reduction Strategy Commitment Report*, Chesapeake Bay Program Toxics Subcommittee, 1991.

2. *Chesapeake Bay Toxics of Concern List: Basinwide Toxics Reduction and Prevention Strategy Commitment Report*, Joint Toxics of Concern Workgroup of the Chesapeake Bay Program Toxics Subcommittee and Living Resources Subcommittee, 1996.

3. *Toxics Characterization Report*, Chesapeake Bay Program Regional Focus Workgroup, 1999. Available online: http://www.chesapeakebay.net/info/toxdata.html (from "Targeting Toxics"[7])

4. *Toxics 2000 Strategy*, Appendix A: "Chesapeake Bay Watershed Chemicals of Concern List," Chesapeake Bay Program Chesapeake Executive Council, 2000. Available online: http://www.chesapeakebay.net/pubs/subcommittee/tsc/toxics/pdf%20finals/toxics_2000_appendix_a.PDF

5. *The Chesapeake Bay Basin Toxics Loading and Release Inventory (TLRI)*, Directed Toxics Assessment Workgroup of the Chesapeake Bay Program Toxics Subcommittee, 1999. Available online: http://www.chesapeakebay.net/pubs/17.pdf

6. *Waste Minimization Prioritization Tool Background Document for the Tier III PBT Chemical List* (Draft), EPA Office of Solid Waste (OSW) and EPA Office of Pollution Prevention and Toxics (OPPT), July 2000

7. *Targeting Toxics: A Characterization Report A tool for Directing Management and Monitoring Actions in the Chesapeake Bay's Tidal Rivers: A Technical Work plan,* pages 28-30, Chesapeake Bay Program Regional Focus Workgroup, 1999. Available online: http://www.chesapeakebay.net/pubs/793.pdf

8. *Emerging Contaminants in the Environment*, USGS, 2006. Available online: http://toxics.usgs.gov/regional/emc/index.html

Table 1. Chemicals Pooled for Prioritization

PAHs	**PCBs**
Anthracene	PCBs(1) – All PCB congeners other than those listed below for PCBs(2)
Acenaphthene	PCBs(2) - Aroclors 1221, 1232, 1242, 1254, 1016, 1248, and 1260
Acenaphthylene	
Benzo(a)anthracene	
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(g,h,i)perylene	
Benzo(k)fluoranthene	
Chrysene	
Dibenzo(a,h)anthracene	
Fluoranthene	
Fluorene	
Indeno[1,2,3-cd]pyrene	
2-Methylnaphthalene	
Naphthalene	
Phenanthrene	
Pyrene	
Organochlorine Pesticides	**Organophosphate Pesticides**
Aldrin	Chlorpyrifos
Chlordane	Malathion
DDE	
DDT	
Dieldrin	
Endrin aldehyde	
Endosulfan, alpha & beta	
Methoxychlor	
Toxaphene	
Other Priority Pollutants	
1,4-Dichlorobenzene	
2,4-Dimethylphenol	
Dioxins/Furans	
Hexachlorobenzene	
Phenol	

Table 2. Weighting Design and Maximum Possible Final Scores

Criterion/Subcriterion	Maximum possible un-adjusted subcriteria score	Multiplication factor to adjust subcriteria for equal weighting	Maximum Possible Adjusted Subcriteria Points	Maximum Possible Criteria Points (sum of adjusted subcriteria points)
PBT Adjusted Load	5	5	25	**25**
Environmental Presence				**25**
Sediment	3	2.777	8.33	
Water Column	3	2.777	8.33	
Fish Tissue	3	2.777	8.33	
Sediment Criteria				**25**
Sediment thresholds	3	2.777	8.33	
Water Column thresholds	3	2.777	8.33	
Fish Tissue thresholds	3	2.777	8.33	
Programmatic Concerns				**25**
Fish Consumption Advisory	5	2.5	12.50	
303(d) Listing	5	2.5	12.50	
Total (maximum final score)				**100**

-All subcriteria within a given criteria category could receive the same maximum score to ensure equal weighting of subcriteria.
-All criteria were equally weighted so that each of the four criteria categories receives a maximum of 25 points.
-The multiplication factors given were used to adjust subcriteria and criteria scores to give equal weighting to each.
-For any given chemical the highest possible final score is 100.
-Higher scores indicate that a chemical is of greater concern.

Table 4. Final Scores for Chemical Contaminants

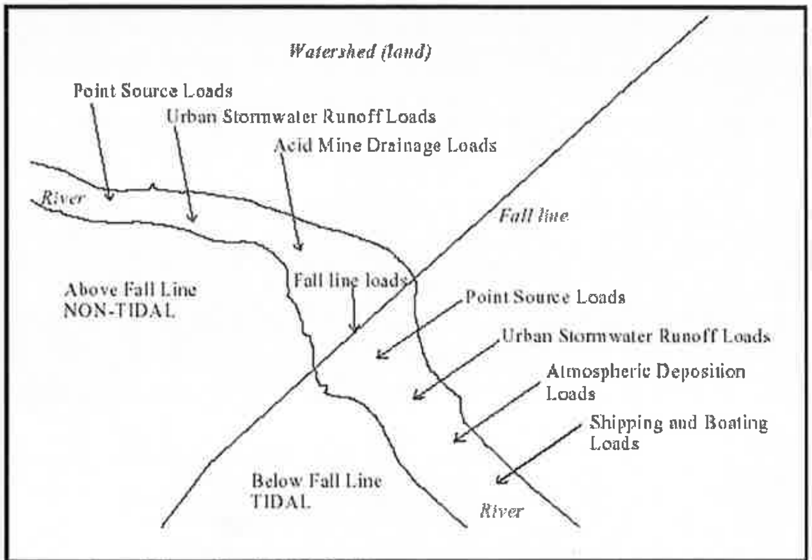
Criteria		PBT Load		Environmental Presence				Threshold Exceedence				Programatic Concerns			
Chemical	Class	PBT Load Bin (PLB)	PBT L (PL) PLB*5	Sed (S)	Water Col (W)	Fish Tiss (F)	Env Pres (EP) S*8.33+ W*8.33+ F*8.33	Sed (ST)	Water (WT)	Fish (FT)	Thresh (TE) ST*8.33+ WT*8.33+ FT*8.33	Fish Advis (FA)	303(d) (Td)	Prog (PC) FA*12.5+ Td*12.5	**Final PL+EP+ TE+PC**
PCBs (1)	PCB	4	20	3	0	2	13.889	1	0	0	2.778	5.0	5	25.00	**61.667**
Benzo(a)pyrene	PAH	5	25	3	0	3	16.667	2	0	0	5.556	0.0	5	12.50	**59.722**
Chlorpyrifos	OP	5	25	0	3	3	16.667	0	2	0	5.556	0.0	5	12.50	**59.722**
DDT	OC	5	25	2	1	1	11.111	1	0	0	2.778	2.5	5	18.75	**57.639**
PCBs (2)	PCB	4	20	2	0	1	8.333	0	0	0	0.000	5.0	5	25.00	**53.333**
Chlordane	OC	1	5	3	1	3	19.444	1	1	0	5.556	2.5	5	18.75	**48.750**
Dieldrin	OC	5	25	2	1	1	11.111	1	0	1	5.556	2.5	0	6.25	**47.917**
Fluoranthene	PAH	4	20	3	1	3	19.444	2	1	0	8.333	0.0	0	0.00	**47.778**
Benzo(k)fluoranthene	PAH	4	20	3	0	2	13.889	0	0	0	0.000	0.0	5	12.50	**46.389**
Aldrin	OC	5	25	2	0	1	8.333	0	0	0	0.000	0.0	5	12.50	**45.833**
Naphthalene	PAH	3	15	3	3	3	25.000	2	0	0	5.556	0.0	0	0.00	**45.556**
Benzo(a)anthracene	PAH	4	20	3	1	3	19.444	2	0	0	5.556	0.0	0	0.00	**45.000**
Chrysene	PAH	4	20	3	1	3	19.444	2	0	0	5.556	0.0	0	0.00	**45.000**
Fluorene	PAH	4	20	3	1	3	19.444	2	0	0	5.556	0.0	0	0.00	**45.000**
Phenanthrene	PAH	4	20	3	0	3	16.667	2	0	0	5.556	0.0	0	0.00	**42.222**
Pyrene	PAH	4	20	3	0	3	16.667	2	0	0	5.556	0.0	0	0.00	**42.222**
Anthracene	PAH	3	15	3	1	3	19.444	2	0	0	5.556	0.0	0	0.00	**40.000**
Acenaphthylene	PAH	3	15	2	0	3	13.889	2	0	0	5.556	0.0	0	0.00	**34.444**
2-Methylnaphthalene	PAH	2	10	3	0	3	16.667	2	0	0	5.556	0.0	0	0.00	**32.222**
Acenaphthene	PAH	2	10	3	0	3	16.667	2	0	0	5.556	0.0	0	0.00	**32.222**
DDE	OC	3	15	3	1	1	13.889	1	0	0	2.778	0.0	0	0.00	**31.667**
Benzo(b)fluoranthene	PAH	3	15	3	0	3	16.667	0	0	0	0.000	0.0	0	0.00	**31.667**
Dibenzo(a,h)anthracene	PAH	3	15	3	0	1	11.111	2	0	0	5.556	0.0	0	0.00	**31.667**
Benzo(g,h,i)perylene	PAH	3	15	3	0	2	13.889	0	0	0	0.000	0.0	0	0.00	**28.889**
Indeno[1,2,3,-cd]pyrene	PAH	3	15	3	0	2	13.889	0	0	0	0.000	0.0	0	0.00	**28.889**

1,4-Dichlorobenzene	PP	4	20	2	0	0	5.556	0	0	0	0.000	0.0	0	0.00	**25.556**
Endosulfan, alpha & Endosulfan, beta	OC	1	5	2	2	1	13.889	0	1	0	2.778	0.0	0	0.00	**21.667**
Malathion	OP	3	15	0	1	0	2.778	0	1	0	2.778	0.0	0	0.00	**20.556**
Methoxychlor	OC	3	15	2	0	0	5.556	0	0	0	0.000	0.0	0	0.00	**20.556**
Dioxins/Furans	PP	1	5	3	0	2	13.889	0	0	0	0.000	0.0	0	0.00	**18.889**
Hexachlorobenzene	PP	2	10	2	0	1	8.333	0	0	0	0.000	0.0	0	0.00	**18.333**
Phenol	PP	2	10	2	0	0	5.556	0	0	0	0.000	0.0	0	0.00	**15.556**
Toxaphene	OC	1	5	3	0	0	8.333	0	0	0	0.000	0.0	0	0.00	**13.333**
Endrin aldehyde	OC	1	5	1	0	1	5.556	0	0	0	0.000	0.0	0	0.00	**10.556**
2,4-Dimethylphenol	PP	2	10	0	0	0	0.000	0	0	0	0.000	0.0	0	0.00	**10.000**

Table 5. Final Scores by Chemical Class Mean Score

Class	Class Mean	Chemical	Individual Final Score
PCB	**57.500**	PCBs (1)	61.667
		PCBs (2)	53.333
PAH	**40.229**	Benzo(a)pyrene	59.722
		Fluoranthene	47.778
		Benzo(k)fluoranthene	46.389
		Naphthalene	45.556
		Fluorene	45.000
		Chrysene	45.000
		Benzo(a)anthracene	45.000
		Pyrene	42.222
		Phenanthrene	42.222
		Anthracene	40.000
		Acenaphthylene	34.444
		Dibenzo(a,h)anthracene	31.667
		Acenaphthene	32.222
		2-Methylnaphthalene	32.222
		Benzo(b)fluoranthene	36.667
		Indeno[1,2,3,-cd]pyrene	28.889
		Benzo(g,h,i)perylene	28.889
OP	**40.139**	Chlorpyrifos	59.722
		Malathion	20.556
OC	**33.102**	DDT	57.639
		Chlordane	48.750
		Dieldrin	47.917
		Aldrin	45.833
		DDE	31.667
		Endosulfan, alpha & Endosulfan, beta	21.667
		Methoxychlor	20.556
		Toxaphene	13.333
		Endrin aldehyde	10.556
PP	**17.667**	1,4-Dichlorobenzene	25.556
		Dioxins/Furans	18.889
		Hexachlorobenzene	18.333
		Phenol	15.556
		2,4-Dimethylphenol	10.000

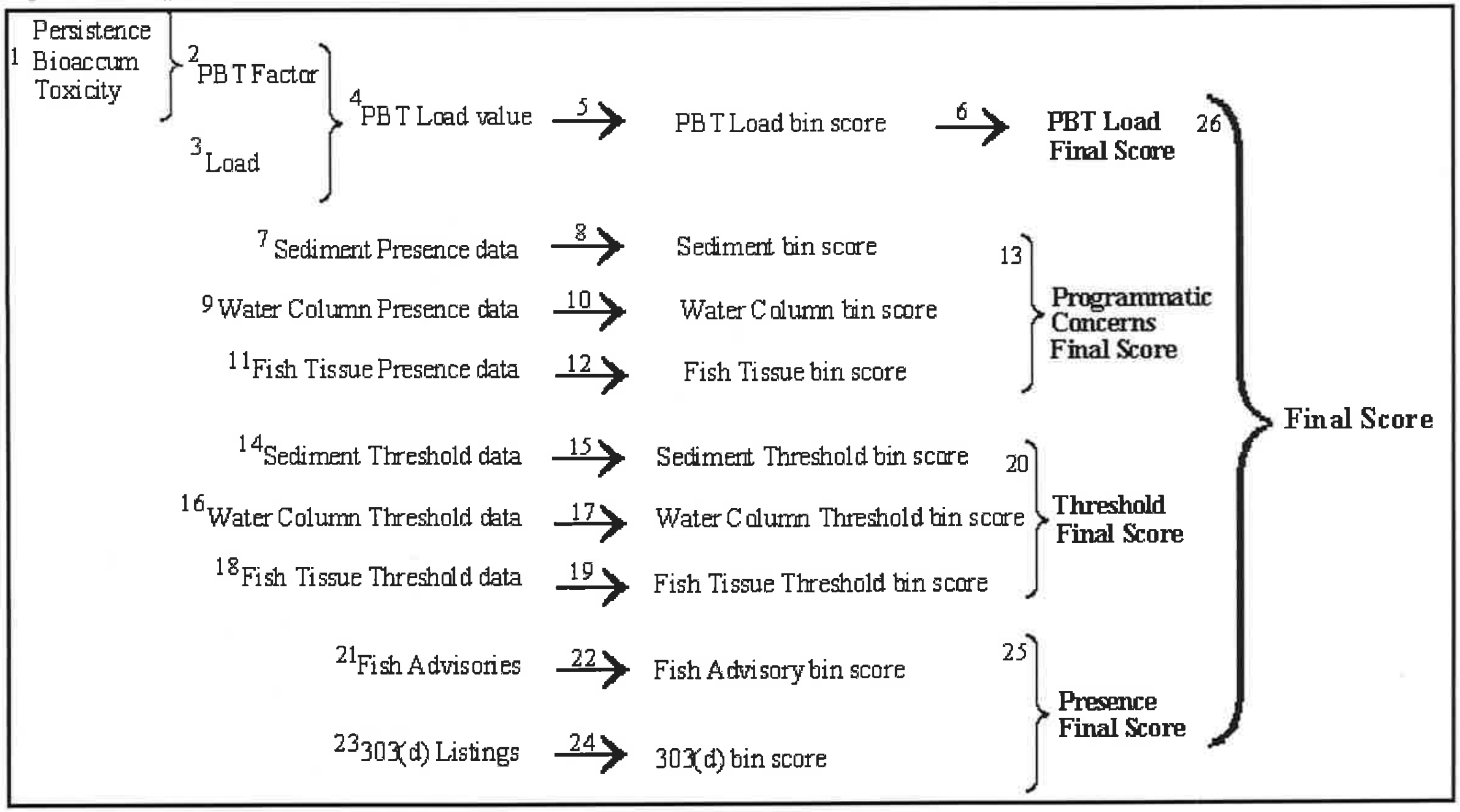
Figure 1. Sources Included in the TLRI



Reproduced from the 1999 TLRI

To find cumulative load this prioritization summed point source loads(PS), urban stormwater loads(USW), atmospheric deposition loads(ATM), and fall line loads(AFL).

Figure 2. Steps Taken to Arrive at Final Score



1. Persistence, Bioaccumulation, and Toxicity values obtained from WMPT. Persistence determined from Sediment Half-life (Appendix D), Bioaccumulation evaluated using BAF/BCF values (Appendix D), Toxicity (Appendix D).
2. Ecological Chronic Toxicity Values were adjusted to an Ecological Toxicity Multiplication Factor (Appendix D) and the PBT Factor was calculated using Equation 1.
3. Load was calculated from TLRI data, contaminant sources (Figure 1) were summed to determine a cumulative load to the Bay (Appendix B).
4. PBT Load value was calculated using PBT Factor and Load (Equation 2)
5. PBT Load bin score assessed placing PBT Load values in five bins (Equation 2).

6. PBT Load Final Score adjusted the bin score by multiplying it by 5 to ensure equal weighting across all criterion (Table 2).
7. Sediment Presence data (Appendix A)
8. Sediment Presence bin score (Appendix A, Equation 3).
9. Water Column Presence data (Appendix A)
10. Water Column Presence bin score (Appendix A, Equation 3).
11. Fish Tissue Presence data (Appendix A)
12. Fish Tissue Presence bin score (Appendix A, Equation 3).
13. Bin scores multiplied by 2.777 and summed to ensure equal weighting across criteria (Table 2).
14. Sediment Threshold data (Appendix C).
15. Sediment Threshold bin score (Appendix C, Equation 4).
16. Water Column Threshold data (Appendix C).
17. Water Column Threshold bin score (Appendix C, Equation 4).
18. Fish Tissue Threshold data (Appendix C).
19. Fish Tissue Threshold bin score (Appendix C, Equation 4).
20. Bin scores are multiplied by 2.777 and summed to ensure equal weighting across criteria (Table 2).
21. Fish Advisories provided by Maryland and Virginia
22. Fish Advisory bin score (Fish consumption advisories, page 5)
23. 303(d) Listings provided by Maryland, Virginia, and EPA
24. 303(d) bin score (303(d) Impairment, page 6)
25. Bin scores for Fish Advisories and 303(d) listings are multiplied by 5 and summed (Table 2)
26. Final Score equals the sum of all criterion final scores.

Figure 3. Chesapeake Bay Organic Toxics of Concern Graphical Representation of Final Scores by Criteria

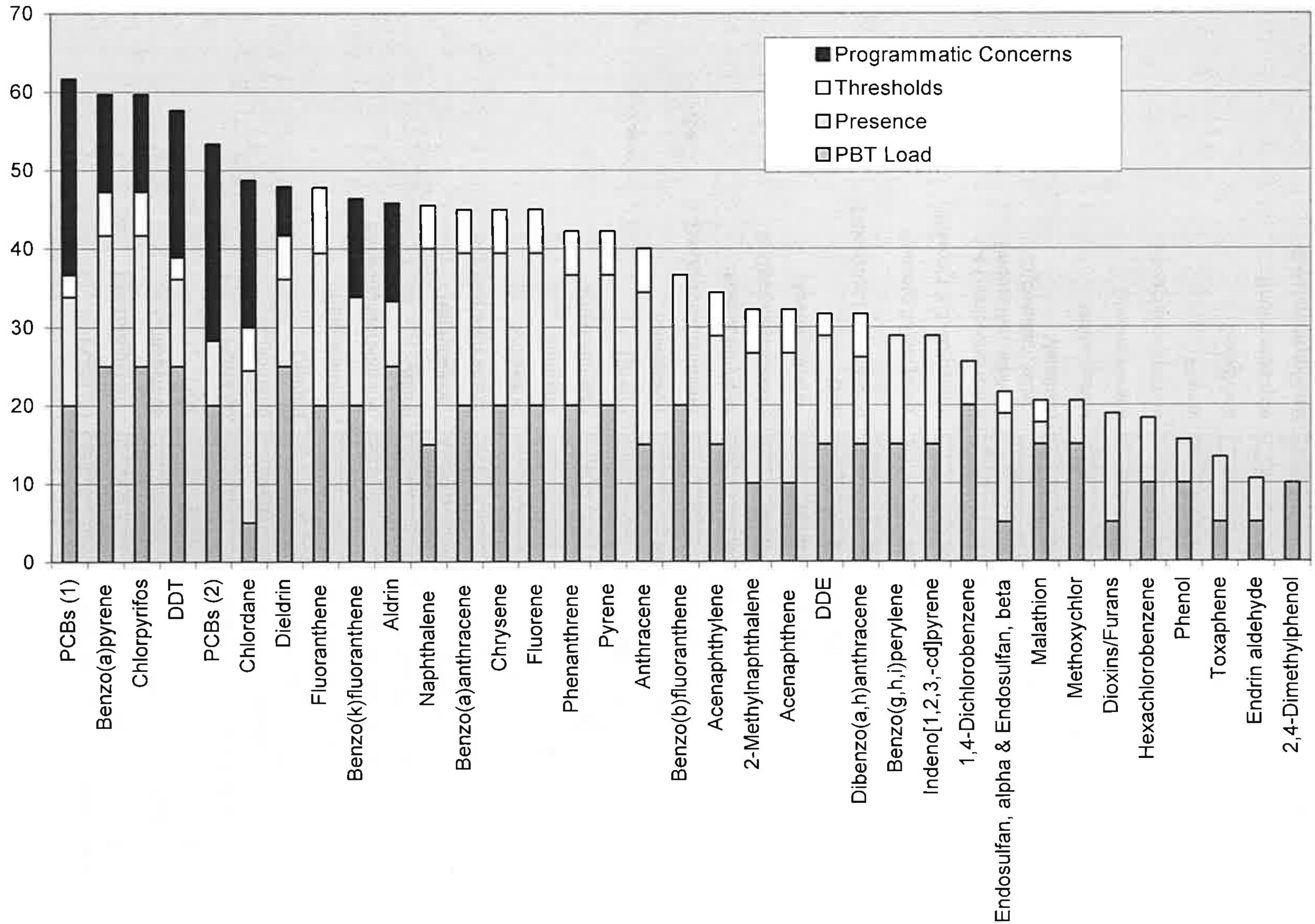
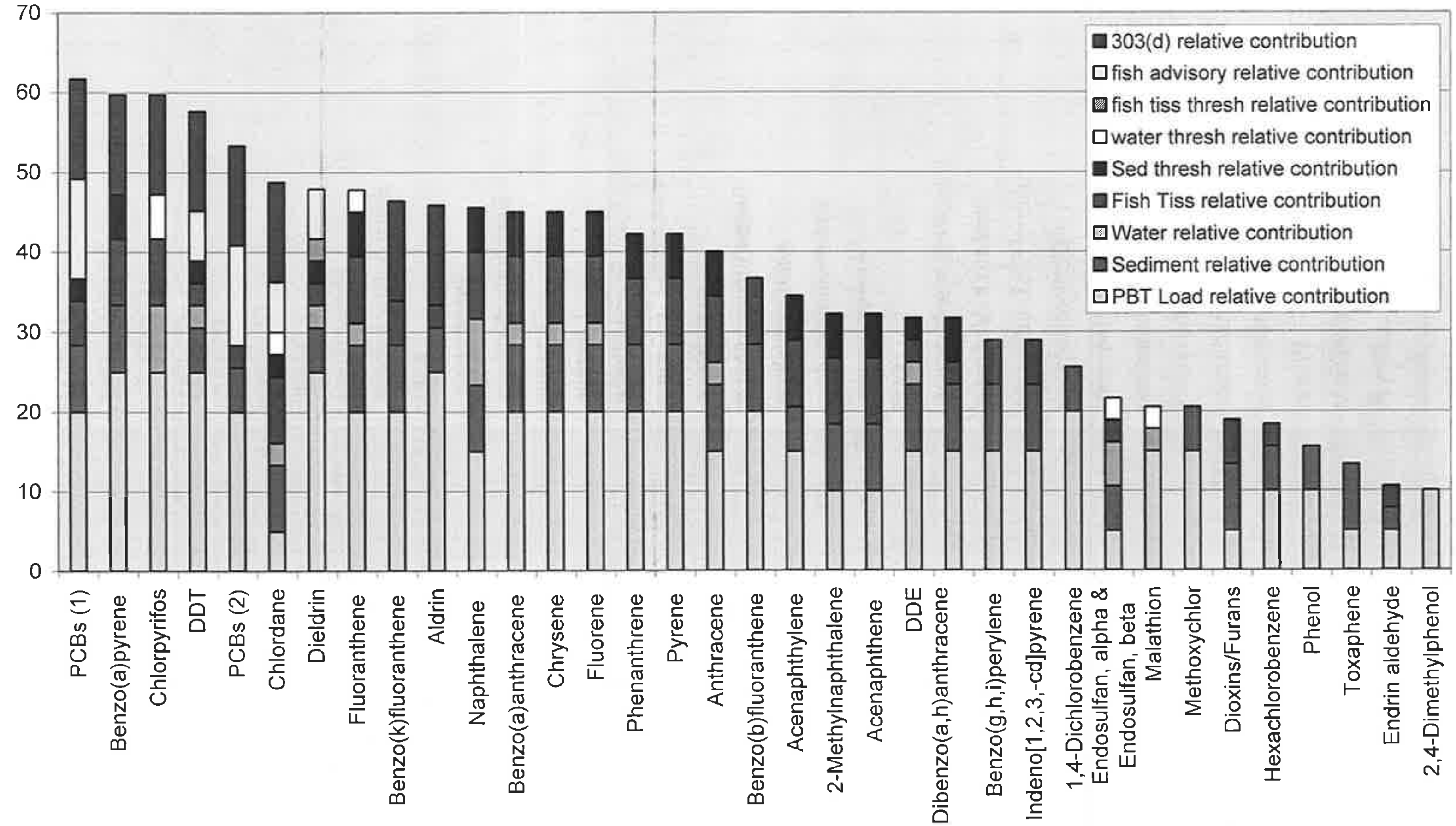


Figure 4. Chesapeake Bay Organic Toxics of Concern Graphical Representation of Final Scores by Subcriteria



Equation 1. PBT Factor

$$(P+B)(T) = \text{PBT Factor}$$

P = sediment half-life (hours)
B = BAF/BCF
T = Eco. Chronic Toxicity Multiplication Factor

Persistence, bioaccumulation, and toxicity values were taken from the EPA's Draft Waste Minimization and Prioritization Tool (WMPT)[6] that were selected using a peer reviewed preference hierarchy of published sediment half-life, BAF/BCF, and aquatic toxicity values. These values are listed in Appendix D.

Equation 2. PBT Adjusted Load for Organic Chemicals

The cumulative load of a chemical to the Bay was adjusted by the PBT factor for aquatic life as a measure of a chemical's potential to cause an impact to the aquatic life of the Bay. By doing so the loads of many different chemicals were made comparable for prioritization. Using the following equation, PBT values were used to adjust cumulative load estimates:

$$\ln[(\text{PBT Factor})(L)] = \text{PBT Load Value}$$

The natural log of the value was used, as the distribution of values was close to lognormal. K-means cluster analysis was applied to the data for the creation of 5 clusters, resulting in a possible score of 1 - 5.

Scoring bins created using k-means cluster analysis*
Bin values were assigned as follows:
Less than 13 lbs/yr = 1
13, <19 lbs/yr = 2
19, <24 lbs/yr = 3
24, <28 lbs/yr = 4
Equal to or greater than 28 lbs/yr = 5

*Using k-means cluster analysis, the data set is broken into k number of clusters (in this case 5). Centroids for each cluster are determined. Once centroids are identified, distance from the centroid to each data point is measured and data points are placed in the group containing the centroid which is closest. During this process data points may switch groups and as a result centroids will change. The process is repeated until no data points change groups.

Equation 3. Calculating Environmental Presence

To calculate the frequency of detection of a contaminant in sediment, water column, and fish tissue in the tidal Chesapeake Bay, all observations of a contaminant in the Toxics Characterization Data Files were summed. Then, the total number of Above Detection Limit (ADL) observations was divided by the total number of observations (See Appendix A). This provided a percentage-based value.

$$\text{Frequency of Detection} = (\text{ADL Observations} / \text{Total Observations}) * 100$$

To score the frequency of detection values, four scoring bins were created:
0% or No Data= 0
>0%, <33.3% = 1
33.3, <66.6% = 2
66.6% - 100% = 3

Note: Because detection limits vary among chemicals, scoring using frequency of detection creates potential bias towards contaminants with lower detection limits.

Equation 4. Calculating Threshold Exceedences

To calculate the frequency of threshold exceedences for a contaminant, all observations of a contaminant in the Toxics Characterization Data Files were summed. Then, the total number of observations where any of the EPA, NOAA, or FDA thresholds were exceeded was divided by the total number of observations (See Appendix C). This provided a percentage-based value.

$$\text{Frequency of Threshold Exceedences} = (\text{Observations above threshold(s)} / \text{Total Observations}) * 100$$

To score the frequency of detection values, four scoring bins were created:
0% or No Data= 0
>0%, <33.3% = 1
33.3, <66.6% = 2
66.6% - 100% = 3

Appendix A
Frequency of Detection

Table A-1. Reproduction of Table found in *Targeting Toxics: A Characterization Report*[7]

Medium	# Studies	# Observations (% total obs.)	# Monitoring segments	Date range	# (%) of sampling stations
Sediment	27	66,423 (53)	36	1984-1998*	644 (61)
Fish Tissue	7	4,378 (4)	13	1990-1997*	46 (4)
Water Column	19	53,286 (43)	29	1994-1998*	372 (35)

* Note: date ranges for data used in the *Characterization Report* were specific to each segment characterized. These ranges represent the earliest and latest dates of data used in any of the 36 segments.

Table A-2. All Chemicals Detected in the Chesapeake Bay's Tidal River Monitoring Segments (1999 Characterization Data)

Chemical	Sediment	Water Column	Fish Tissue
1,2,4-Trichlorobenzene	X		
1,2,7-Trimethylnaphthalene	X		
1,2-Dichlorobenzene	X		
1,3- Dichlorobenzene	X		
1,4- Dichlorobenzene	X		
1,6,7- Trimethylnaphthalene	X		X
1-Methylnaphthalene	X		X
1-Methylphenanthrene	X		X
2,3,5- Trimethylnaphthalene	X		
2,3-Benzofluorene	X		X
2,3-Benzothiophene	X		
2,4,5-TP – Penoxy Acid		X	
2,4-Dimethylphenol	X		
2,6-Dimethylnaphthalene	X		X
2-Methylnaphthalene	X		X
2-Methylphenanthrene	X		
2-Phenylnaphthalene	X		
3-Methylphenanthrene			X
4H-Cyclopenta[def]-Phenanthrene	X		X
4-Methyl Phenol	X		
Acenaphthene	X		X
Acenaphthylene	X		X
Acetochlor		X	
Alachlor	X	X	
Aldrin	X	X	X
Ametryn		X	
Aniline	X		
Anthracene	X	X	X
Anthraquinone	X		X

Chemical	Sediment	Water Column	Fish Tissue
Atrazine		X	
Benzo(a)anthracene	X	X	X
Benzo(a)pyrene	X		X
Benzo(b)fluoranthene	X		X
Benzo(g,h,I)perylene	X		X
Benzo(k)fluoranthene	X		X
Benzo[a]fluoranthene			X
Benzo[a]fluorene	X		
Benzo[c]phenanthrene	X		
Benzo[e]pyrene	X		X
Benzo[ghi]fluoranthene	X		X
Benzocarbazoles	X		
Benzoic Acid	X		
Benzonaphthothiophene	X		
BHC – alpha/beta/delta/gamma	X	X	X
Biphenyl	X		X
Bis(tri-n-butyltin)oxide	X		
Bromkal,pentabromo-			X
Butyl benzyl phthalate	X		
Carbazole	X		
Chlordane	X	X	X
Chloroform	X	X	X
Chlorothalonil		X	
Chlorpyrifos	X	X	
Chrysene	X	X	X
CIAT		X	
Cyanazine		X	
DCPA			X
DDE	X	X	X
DDT	X	X	X
De isopropylatrazine		X	
Desethyl Atrazine		X	
Di(2-ethylhexyl)phthalate	X	X	
Diazinon		X	
Dibenzo(a,h)anthracene	X		X
Dibenzothiphene	X		
Dibutyltin Dichloride	X		X
Dicofol	X		
Dieldrin	X	X	X
Diethyl Phthalate	X		
Dimethyl Phthalate	X		
Di-n-butyl Phthalate	X		
Dioxins/Furans	X		X
Endosulfan (alpha and beta)	X	X	X

Chemical	Sediment	Water Column	Fish Tissue
Endrin aldehyde	X	X	X
Ethylnaphthalene	X		X
Fluoranthene	X	X	X
Fluorene	X	X	X
Heptachlor	X		X
Heptachlor Epoxide	X		X
Hexachlorobenzene	X		X
Indeno[1,2,3-cd]pyrene	X		X
Malathion	X	X	
Me-dibenzothiophene	X		
Methoxychlor	X		X
Methyl Chrysene	X		
Methyl Dibenzothiophene	X		
Methyl Fluorene	X		X
Methyl Parathion		X	
METHYL Phenanthrenes	X		X
Methyl Phenylnaphthalene	X		
Methyl -202	X		
Methyl -228	X		
Methyl -252	X		
Metolachlor		X	
Metribuzin		X	
Mirex	X		X
Naphthalene	X	X	X
Oxychlordane	X		
PCBs (1)	X		X
PCBs (2)	X	X	X
Pentachloroanisole			X
Pentachlorophenol	X		
Permethrin	X		X
Perylene	X		X
Phenanthrene	X	X	X
Phenol	X		
Pyrene	X	X	X
Retene	X		X
Tetramethyloctahydrochrysene	X		
Toxaphene	X	X	X
Trifluralin			X
Trimethyltetra-hydrochrysene	X		

Table A-3. Environmental Presence Data for Chemicals Prioritized: Sediment

CHEMIAL	TOTSegments	TOTStations	ADLSegments	ADLStations	ADL/TOT OBS	%(ADL/TOT OBS)	Sediment Presence Bin Score
1,4-Dichlorobenzene	23	53	1	21	29/80	36.3	2
2,4-Dimethylphenol	23	32	0	0	0/42	0.0	0
2-Methylnaphthalene	35	341	34	292	308/365	84.4	3
Acenaphthene	35	434	32	334	395/515	76.7	3
Acenaphthylene	35	359	32	245	256/391	65.5	2
Aldrin	35	418	21	175	261/519	50.3	2
Anthracene	35	461	33	389	463/549	84.3	3
Benzo(a)anthracene	35	474	34	435	519/575	90.3	3
Benzo(a)pyrene	35	478	35	422	511/582	87.8	3
Benzo(b)fluoranthene	31	190	30	172	185/211	87.7	3
Benzo(g,h,i)perylene	35	392	35	335	353/425	83.1	3
Benzo(k)fluoranthene	26	171	26	155	164/185	88.6	3
Chlordane	35	423	30	272	444/612	72.5	3
Chlorpyrifos	4	12	0	0	0/12	0.0	0
Chrysene	35	483	35	431	514/579	88.8	3
DDE	35	462	35	370	603/865	69.7	3
DDT	35	445	31	282	712/1130	63.0	2
Dibenzo(a,h)anthracene	35	405	34	300	349/471	74.1	3
Dieldrin	35	431	30	239	335/540	62.0	2
Dioxins/Furans	29	70	21	50	110/143	76.9	3

Endosulfan, alpha & Endosulfan, beta	29	191	20	85	115/303	38.0	2
Endrin aldehyde	361	290	26	182	3/31	9.7	1
Fluoranthene	35	493	35	446	543/601	90.3	3
Fluorene	35	456	34	375	457/558	81.9	3
Hexachlorobenzene	35	338	26	161	131/364	36.0	2
Indeno[1,2,3,-cd]pyrene	35	469	35	412	493/567	86.9	3
Malathion	-	-	-	-	-	-	0
Methoxychlor	8	31	3	15	22/40	55.0	2
Naphthalene	35	398	35	351	370/437	84.7	3
PCBs (1)	35	410	35	377	5265/7669	68.7	3
PCBs (2)	5	29	1	24	47/108	43.5	2
Phenanthrene	35	410	35	375	400/448	89.3	3
Phenol	23	32	17	20	26/42	61.9	2
Pyrene	35	487	35	452	543/591	91.9	3
Toxaphene	16	102	15	97	171/178	96.1	3

TOTSegments = number of tidal river segments analyzed, TOTStations = number of stations analyzed, ADLSegments = number of segments where above detection limit observation were made, ADLStations = number of station where above detection limit observations were made, ADL/TOT OBS = number of above detection limit observations over the number of total observations made

Table A-4. Environmental Presence Data for Chemicals Prioritized: Water Column

CHEMICAL	TOT SEGMENT	TOT STATIONS	ADL SEGMENT	ADL STATIONS	ADL/TOT OBS	%ADL	Water Col. Presence Bin Score
1,4-Dichlorobenzene	1	1	0	0	0/1	0.0	0
2,4-Dimethylphenol	1	1	0	0	0/1	0.0	0
2-Methylnaphthalene	-	-	-	-	-	-	0
Acenaphthene	2	2	1	1	1/2	0.5	0*
Acenaphthylene	1	1	0	0	0/1	0.0	0
Aldrin	4	12	0	0	0/14	0.0	0
Anthracene	8	14	1	1	1/57	1.8	1
Benzo(a)anthracene	8	14	1	1	1/57	1.8	1
Benzo(a)pyrene	1	1	1	1	1/1	100.0	0*
Benzo(b)fluoranthene	-	-	-	-	-	-	0
Benzo(g,h,i)perylene	-	-	-	-	-	-	0
Benzo(k)fluoranthene	1	1	1	1	1/1	100.0	0*
Chlordane	11	29	5	8	43/202	21.3	1
Chlorpyrifos	5	14	5	14	73/80	91.3	3
Chrysene	8	14	1	1	1/56	1.8	1
DDE	10	27	3	3	10/92	10.9	1
DDT	8	16	2	2	2/20	10.0	1
Dibenzo(a,h)anthracene	-	-	-	-	-	-	0
Dieldrin	8	18	3	4	4/21	19.0	1
Dioxins/Furans	-	-	-	-	-	-	0
Endosulfan, alpha & Endosulfan, beta	6	13	1	1	57/104	54.8	2
Endrin aldehyde	5	12	0	0	0/14	0.0	0
Fluoranthene	9	15	2	2	2/58	3.4	1
Fluorene	8	14	1	1	1/57	1.8	1
Hexachlorobenzene	1	1	0	0	0/1	0.0	0*
Indeno[1,2,3-cd]pyrene	-	-	-	-	-	-	0
Malathion	7	16	5	5	5/96	5.2	1
Methoxychlor	2	2	0	0	0/3	0.0	0
Naphthalene	2	7	1	6	7/8	87.5	3

PCBs (1)	-	-	-	-	-	-	0
PCBs (2)	9	24	0	0	0/219	0.0	0
Phenanthrene	7	13	0	0	0/56	0.0	0
Phenol	2	2	1	1	1/2	50.0	0*
Pyrene	9	17	2	4	0/60	0.0	0
Toxaphene	9	24	0	0	0/69	0.0	0

TOTSegments = number of tidal river segments analyzed, TOTStations = number of stations analyzed, ADLSegments = number of segments where above detection limit observation were made, ADLStations = number of station where above detection limit observations were made, ADL/TOT OBS = number of above detection limit observations over the number of total observations made
* Where there were fewer than 3 total observations made, a score of 0 was automatically assigned.
Dashes indicate that no observations were made. For those chemicals with zero total observations in the water column a score of 0 is assigned. These chemicals are generally hydrophobic and therefore are not expected to be detected in the water column.

TABLE A-5. Environmental Presence Data for Chemicals Prioritized: Fish Tissue

CHEMICAL	TOTSegments	TOTStations	ADLSegments	ADL Stations	ADL/TOT OBS	%(ADL/TOT OBS)	Fish Tissue Presence Bin Score
1,4-Dichlorobenzene	-	-	-	-	-	-	0
2,4-Dimethylphenol	-	-	-	-	-	-	0
2-Methylnaphthalene	4	7	4	7	21/21	100.0%	3
Acenaphthene	4	17	4	16	36/42	85.7%	3
Acenaphthylene	4	7	4	7	18/20	90.0%	3
Aldrin	20	77	4	4	5/167	3.0%	1
Anthracene	4	17	4	17	32/36	88.9%	3
Benzo(a)anthracene	4	15	4	15	29/34	85.3%	3
Benzo(a)pyrene	4	16	4	13	24/35	68.6%	3
Benzo(b)fluoranthene	4	10	4	10	21/26	80.8%	3
Benzo(g,h,i)perylene	4	10	4	8	12/24	50.0%	2
Benzo(k)fluoranthene	4	6	4	5	13/20	65.0%	2

Chlordane	24	96	24	84	234/318	73.6%	3
Chlorpyrifos	1	1	1	1	20/20	100.0%	3
Chrysene	4	17	4	17	43/43	100.0%	3
DDE	19	96	12	31	73/308	23.7%	1
DDT	24	96	14	20	58/297	19.5%	1
Dibenzo(a,h)anthracene	4	8	3	4	7/21	33.3%	1
Dieldrin	19	84	6	9	21/256	8.2%	1
Dioxins/Furans	4	9	1	5	7/18	38.9%	2
Endosulfan, alpha & Endosulfan, beta	18	77	1	1	60/335	17.9%	1
Endrin aldehyde	21	80	2	2	4/240	1.7%	1
Fluoranthene	4	25	4	25	51/53	96.2%	3
Fluorene	4	18	4	18	49/53	92.5%	3
Hexachlorobenzene	21	74	5	6	12/159	7.5%	1
Indeno[1,2,3,-cd]pyrene	4	13	2	3	20/33	60.6%	2
Malathion	-	-	-	-	-	-	0
Methoxychlor	18	76	0	0	0/232	0.0%	0
Naphthalene	4	13	4	13	29/29	100.0%	3
PCBs (1)	6	8	6	8	252/383	65.8%	2
PCBs (2)	5	19	2	9	38/382	9.9%	1
Phenanthrene	4	13	4	13	34/34	100.0%	3
Phenol	-	-	-	-	-	-	0
Pyrene	4	25	4	25	59/61	96.7%	3
Toxaphene	18	76	18	76	0/232	0.0%	0

TOTSegments = number of tidal river segments analyzed, TOTStations = number of stations analyzed, ADLSegments = number of segments where above detection limit observation were made, ADLStations = number of station where above detection limit observations were made, ADL/TOT OBS = number of above detection limit observations over the number of total observations made.

Table A-6. Chemicals Detected[7] but Not Prioritized Due to Lack of Loadings Data

Detected Chemicals Not Included in Prioritization
1,2,4-Trichlorobenzene
1,2,7-Trimethylnaphthalene
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,6,7-Trimethylnaphthalene
1,6,7-Trimethylnaphthalene
1-Methylnaphthalene
1-Methylphenanthrene
2,2,4,4-Tetrachlorobiphenyl
2,3,5-Trimethylnaphthalene
2,3'5- Trichlorobiphenyl
2,3-Benzofluorene
2,3-Benzothiophene
2,4,5-Tp – Phenoxy acid
2,4,5-Trichlorobiphenyl
2,6-Dimethylnaphthalene
2-Methylphenanthrene
2-Phenylnaphthalene
3-Methylphenanthrene
4h-Cyclopenta[def]-phenanthrene
4-Methyl Phenol
Acetochlor
Alachlor
Alachlor
Ametryn
Aniline
Anthraquinone
Atrazine
Benzo[a]fluoranthene
Benzo[a]fluorene
Benzo[c]phenanthrene
Benzo[e]pyrene
Benzo[ghi]fluoranthene
Benzocarbazoles
Benzoic acid
Benzonaphthothiophene
BHC – Alpha/Beta/Delta/Gamma
Biphenyl
Bis(tri-N-butyltin)oxide
Bromkal,pentabromo-
Butyl benzyl phthalate
Carbazole
Chlorobiphenyl, Poly-
Chlorothalonil

Ciat
Cis-permethrin
Cyanazine
DCPA
DDD
De_Isopropylatrazine
Decachlorobiphenyl
Desethyl atrazine
Di(2-ethylhexyl)phthalate
Diazinon
Dibenzothiophene
Dibutyltin dichloride
Dicofol
Diethyl phthalate
Dimethyl phthalate
Di-N-butyl phthalate
Ethylnaphthalene
Heptachlor
Heptachlor epoxide
Heptachlorobiphenyls
Hexachlorobiphenyls
Me-dibenzothiophene
Methyl chrysene
Methyl dibenzothiophene
Methyl fluorene
Methyl parathion
Methyl phenanthrenes
Methyl phenylnaphthalene
Methyl-202
Methyl-228
Methyl-252
Metolachlor
Metribuzin
Mirex
Monobutyltin
Nonachlor
Nonachlor-cis
Nonachlorobiphenyls
Nonachlor-trans
Octachlorobiphenyls
Oxychlordane
Pentachloroanisole
Pentachlorophenol
Perylene
Perylene
Retene
Tetrachlorobiphenyls

Tetramethyloctahydrochrysene
Trans-nonachlor
Trans-permethrin
Tributyltin chloride
Trichlorobiphenyls
Trifluralin
Trimethyltetra-hydrochrysene

Appendix B
Loadings Categories and Values from the *Chesapeake Bay Basin Toxics Loading and Release Inventory (TLRI)*[5]

Table B-1. Chemical Load Estimates Reported in the TLRI for Organics

PS = Point Source, USW = Urban Storm Water, ATM = Atmospheric Deposition, SPIL = shipping and boating spills, AFL = Above Fall Line loadings of either: the Susquehanna, and/or James, and/or Potomac River.

Chemical	PS	USW	ATM	AFL
1,4-Dichlorobenzene		X		
2,4-Dimethylphenol	X			
2-Methylnaphthalene	X			X
Acenaphthene	X			X
Acenaphthylene				X
Aldrin	X			
Anthracene			X	
Benzo(a)anthracene	X	X	X	X
Benzo(a)pyrene	X	X	X	X
Benzo(b)fluoranthene		X	X	
Benzo(g,h,i)perylene	X		X	
Benzo(k)fluoranthene		X	X	
Chlordane	X			
Chloroform		X		
Chlorpyrifos	X		X	
Chrysene	X	X	X	X
DDE				X
DDT				X
Dibenzo(a,h)anthracene	X		X	
Dieldrin	X			X
Dioxins/Furans	X			
Endosulfan (aplha and beta)	X			
Endrin aldehyde	X			
Fluoranthene	X	X	X	X
Fluorene	X	X	X	X
Hexachlorobenzene				X
Indeno[1,2,3-cd]pyrene	X		X	
Malathion				X
Methoxychlor				X
Naphthalene	X			X
PCBs (2)	X		X	X
PCBs (1)	X		X	X
Phenanthrene	X	X	X	X
Phenol		X		
Pyrene	X	X	X	X
Toxaphene	X			

PS = Point Source, USW = Urban Storm Water, ATM = Atmospheric Deposition, SPIL = shipping and boating spills, AFL = Above Fall Line loadings of either: the Susquehanna, and/or James, and/or Potomac River.

Table B-2. Calculation of Cumulative Loads (lbs/year)

Chemical	PS	USW	ATM	AFL	Cumulative Load
1,4-Dichlorobenzene		27763.16	0	0	27763.16
2,4-Dimethylphenol	221.71	0	0	0	221.71
2-Methylnaphthalene		0	0	485.1	485.1
Acenaphthene	1.92	0	0	125.685	127.605
Acenaphthylene		0	0	110.25	110.25
Aldrin	540.41	0	0	0	540.41
Anthracene		0	183	0	183.015
Benzo(a)anthracene	54.92	21948.57	52.92	1182.983	23239.39
Benzo(a)pyrene	54.73	19212.17	74.97	1341.743	20683.61
Benzo(b)fluoranthene		22219.79	174.2	0	22393.98
Benzo(g,h,i)perylene	3.84	0	94.82	0	98.655
Benzo(k)fluoranthene		20076.53	112.5	0	20188.98
Chlordane		0	0	0	0
Chlorpyrifos	2878.05	0	61.74	0	2939.79
Chrysene	185.62	19174.68	202.9	727.65	20290.81
DDE		0	0	35.28	35.28
DDT		0	0	59.64525	59.64525
Dibenzo(a,h)anthracene	3.84	0	30.87	0	34.71
Dieldrin	0.1	0	0	88.2	88.3
Dioxins/Furans	0.07	0	0	0	0.07
Endosulfan, alpha & Endosulfan, beta		0	0	0	0
Endrin aldehyde		0	0	0	0
Fluoranthene	55.88	25650.77	1312	2491.65	29510.27
Fluorene	42.86	18632.25	297.7	264.6	19237.39
Hexachlorobenzene		0	0	8.82	8.82
Indeno[1,2,3-cd]pyrene	3.84	0	114.7	0	118.5
Malathion		0	0	378.1575	378.1575
Methoxychlor		0	0	9.9225	9.9225
Naphthalene	8543.91	0	0	931.6125	9475.523
PCBs (2)		0	-809	923.895	114.66
PCBs (1)		0	-809	923.895	114.66
Phenanthrene	76.94	35293.23	6505	1587.6	36957.77
Phenol		19911.15	0	0	19911.15
Pyrene	84.51	18272.84	637.2	2271.15	21265.74
Toxaphene		0		0	0

PS = Point Source, USW = Urban Storm Water, ATM = Atmospheric Deposition, SPIL = shipping and boating spills, AFL = Above Fall Line loadings of either: the Susquehanna, and/or James, and/or Potomac River.

Chemical loads for specific categories were provided by TLRI[4]. Cumulative load was calculated by summing those load categories considered for this prioritization.

Appendix C
Effects Thresholds and Data

Table C-1. Sediment, Water Column, and Fish Tissue Thresholds Used in the 1999 Toxics Characterization[3]

Media Type	Abbreviation	Threshold	Reference Number
Sediment	SQC	EPA Equilibrium Partitioning-based Sediment Quality Criteria (1993)	21
Sediment	SQAL	EPA Equilibrium Partitioning-based Sediment Quality Advisory Level (1996)	22
Sediment	EP	Lowest of the NOAA Effects Range-Median, Environment Canada Probable Effects Level, and Macdonald Probable Effects Level	23, 24, 25
Sediment	ET	Lowest of the NOAA Effects Range-Low, Environment Canada Threshold Effects Level, and the MacDonalds Threshold Effects Level	23, 24, 25
Water Column	CHRON	EPA/State Chronic Water Quality Criteria	
Water Column	ACUTE	EPA/State Acute Water Quality Criteria	
Fish Tissue	FAL	FDA Action Level	13
Fish Tissue	FLOC	FDA levels of concern	13
Fish Tissue	EPASL	EPA Screening levels	2

Reference numbers refer to references made on pages 28-30 in *Targeting Toxics: A Characterization Report*[7].

Table C-2. Observations that Exceeded Sediment Thresholds

CHEMICAL	ADL/TOT OBS	SQCTOT	SQALTOT	EPTOT	ETTOT	% above threshold (threshold exceedences/TOT OBS)	Sediment Threshold Bin score
1,4-Dichlorobenzene	29/80	X	0	X	X	0.0	0
2,4-Dimethylphenol	0/42	X	X	X	X	X	0
2-Methylnaphthalene	308/365	X	X	22	145	45.8	2
Acenaphthene	395/515	0	X	70	201	52.6	2
Acenaphthylene	256/391	X	X	5	137	36.3	2
Aldrin	261/519	X	X	X	X	X	0
Anthracene	463/549	X	X	68	150	39.7	2
Benzo(a)anthracene	519/575	X	X	76	219	51.3	2
Benzo(a)pyrene	511/582	X	X	72	195	45.9	2
Benzo(b)fluoranthene	185/211	X	X	X	X	X	0
Benzo(g,h,i)perylene	353/425	X	X	X	X	X	0
Benzo(k)fluoranthene	164/185	X	X	X	X	X	0
Chlordane	444/612	X	X	6	13	3.1	1
Chlorpyrifos	0/12	X	X	X	X	X	0
Chrysene	514/579	X	X	70	194	45.6	2
DDE	603/865	X	X	5	73	9.0	1
DDT	712/1130	X	X	10	43	4.7	1
Dibenzo(a,h)anthracene	349/471	X	X	62	231	62.2	2
Dieldrin	335/540	0	X	11	48	10.9	1
Dioxins/Furans	110/143	X	X	0	X	0.0	0
Endosulfan, alpha & Endosulfan, beta	115/303	X	0	X	X	0.0	0
Endrin aldehyde	3/31	0	X	0	0	0.0	0
Fluoranthene	543/601	0	X	72	258	54.9	2

CHEMICAL	ADL/TOT OBS	SQCTOT	SQALTOT	EPTOT	ETTOT	% above threshold (threshold exceedences/TOT OBS)	Sediment Threshold Bin score
Fluorene	457/558	X	0	66	206	48.7	2
Hexachlorobenzene	131/364	X	X	X	X	X	0
Indeno[1,2,3,-cd]pyrene	493/567	X	X	X	X	X	0
Malathion	X	X	X	X	X	X	0
Methoxychlor	22/40	X	0	X	X	0.0	0
Naphthalene	370/437	X	0	19	155	39.8	2
PCBs (1)	5265/7669	X	X	3	5	0.1	1
PCBs (2)	47/108	X	X	X	X	X	0
Phenanthrene	400/448	0	X	36	149	41.3	2
Phenol	26/42	X	X	X	X	X	0
Pyrene	543/591	X	X	74	220	49.7	2
Toxaphene	171/178	X	X	0	X	0.0	0
BHC-GAMMA (LINDANE)	**87/342**	**X**	**0**	**12**	**39**		

X = No threshold available, Bold = **Chemical not included in ranking but exceeded a threshold, ADL/TOT OBS = Observations above the detection limit over total observations.**

Table C-3. Observations Exceeding Water Column Thresholds

CHEMICAL	ADL/TOT OBS	Water Column Score	CHRONTOT	ACUTETOT
1,4-Dichlorobenzene	0/1	0	X	X
2,4-Dimethylphenol	0/1	0	X	0
2-Methylnaphthalene	-	0	-	-
Acenaphthene	1/2	0	0	0
Acenaphthylene	0/1	0	X	X
Aldrin	0/14	0	X	0
Anthracene	1/57	0	X	X
Benzo(a)anthracene	1/57	0	X	X
Benzo(a)pyrene	1/1	0	X	X
Benzo(b)fluoranthene	-	0	-	-
Benzo(g,h,i)perylene	-	0	-	-
Benzo(k)fluoranthene	1/1	0	X	X
Chlordane	43/202	1	1	1
Chlorpyrifos	73/80	2	17	12
Chrysene	1/56	0	X	X
DDE	10/92	0	X	0
DDT	2/20	0	0	0
Dibenzo(a,h)anthracene	-	0	-	-
Dieldrin	4/21	0	0	0
Dioxins/Furans	-	0	-	-
Endosulfan, alpha & Endosulfan, beta	57/104	1	1	1
Endrin aldehyde	0/14	0	X	X
Fluoranthene	2/58	1	1	1
Fluorene	1/57	0	X	X
Hexachlorobenzene	0/1	0	X	X
Indeno[1,2,3-cd]pyrene	-	0	-	-
Malathion	5/96	1	1	X
Methoxychlor	0/3	0	0	X
Naphthalene	7/8	0	0	0
PCBs (1)	-	0	-	-
PCBs (2)	0/219	0	X	0
Phenanthrene	0/56	0	0	0
Phenol	1/2	0	0	0
Pyrene	0/60	0	X	X
Toxaphene	0/69	0	0	0

X = No threshold available, - = No data available for chemical, ADL/TOT OBS = Observations above the detection limit over total observations.

Table C-4. Observations Exceeding Fish Tissue Thresholds

CHEMICAL	ADL/TOT OBS	Fish Tissue Score	FALTOT	FLOCTOT	EPASLTOT
1,4-Dichlorobenzene	-	0	-	-	-
2,4-Dimethylphenol	-	0	-	-	-
2-Methylnaphthalene	21/21	0	X	X	X
Acenaphthene	36/42	0	X	X	X
Acenaphthylene	18/20	0	X	X	X
Aldrin	5/167	0	0	X	X
Anthracene	32/36	0	X	X	X
Benzo(a)anthracene	29/34	0	X	X	X
Benzo(a)pyrene	24/35	0	X	X	X
Benzo(b)fluoranthene	21/26	0	X	X	X
Benzo(g,h,i)perylene	12/24	0	X	X	X
Benzo(k)fluoranthene	13/20	0	X	X	X
Chlordane	234/318	0	0	X	0
Chlorpyrifos	20/20	0	X	X	0
Chrysene	43/43	0	X	X	X
DDE	73/308	0	0	X	X
DDT	58/297	0	0	X	0
Dibenzo(a,h)anthracene	7/21	0	X	X	X
Dieldrin	21/256	1	0	X	7
Dioxins/Furans	7/18	0	X	X	X
Endosulfan, alpha & Endosulfan, beta	60/335	0	X	X	0
Endrin aldehyde	4/240	0	X	X	0
Fluoranthene	51/53	0	X	X	X
Fluorene	49/53	0	X	X	X
Hexachlorobenzene	12/159	0	X	X	0
Indeno[1,2,3,-cd]pyrene	20/33	0	X	X	X
Malathion	-	0	-	-	-
Methoxychlor	0/232	0	X	X	X
Naphthalene	29/29	0	X	X	X
PCBs (1)	252/383	0	X	X	X
PCBs (2)	38/382	0	X	X	X
Phenanthrene	34/34	0	X	X	X
Phenol	-	0	-	-	-
Pyrene	59/61	0	X	X	X
Toxaphene	0/232	0	X	X	0

X = No threshold available, - = No data available for chemical, ADL/TOT OBS = Observations above detection limit over total observations.

Appendix D
PBT Factors

Table D-1. Persistence, Bioaccumulation, and Toxicity Values and Calculated PBT Factor

Group[A]	Chemical	Sediment Half life value (hours)[B]	BAF/BCF value[B]	Eco. Chronic Toxicity Value[B]	Eco. Chronic Tox. Multiplication factor[C]	PBT Factor[D]
pp	1,4-Dichlorobenzene	17000.000	112.2018454	0.0151100	66.18	1,132,508.39
pp	2,4-Dimethylphenol	550.000	151.3561248	0.0627033	15.95	11,185.31
pah	2-Methylnaphthalene	832.000	190.5460718	0.0076313	131.04	133,993.69
pah	Acenaphthene	3399.200	389.0451450	0.0230000	43.48	164,706.31
pah	Acenaphthylene	17000.000	354.8133892	0.0076313	131.04	2,274,162.12
oc	Aldrin	55000.000	3715.3522910	0.0000180	55,555.56	3,261,964,016.17
pah	Anthracene	17000.000	602.5595861	0.0076313	131.04	2,306,626.60
pah	Benzo(a)anthracene	55000.000	81.0000000	0.0076313	131.04	7,217,774.17
pah	Benzo(a)pyrene	55000.000	912.0108394	0.0000130	76,923.08	4,300,923,910.72
pah	Benzo(b)fluoranthene	44987.038	5623.4132520	0.0060000	166.67	8,435,075.23
pah	Benzo(g,h,i)perylene	59450.282	25703.9578300	0.0020000	500.00	42,577,119.79
pah	Benzo(k)fluoranthene	133967.303	10000.0000000	0.0060000	166.67	23,994,550.58
oc	Chlordane	5760.000	15.8489319	0.0000040	250,000.00	1,443,962,232.98
op	Chlorpyrifos	1700.000	1698.2436520	0.0000056	178,571.43	606,829,223.57
pah	Chrysene	58473.379	81.0000000	0.0190000	52.63	3,081,809.40
oc	DDE	55000.000	51286.1384000	0.0003000	3,333.33	354,287,128.00
oc	DDT	55000.000	29512.0922700	0.0000010	1,000,000.00	84,512,092,270.00
pah	Dibenzo(a,h)anthracene	55922.781	45708.819	0.008	131.04	13,317,730.92
oc	Dieldrin	55000.000	4466.836	0.000	526,315.79	31,298,334,695.79
pp	Dioxins/Furans	55000.000	5754.399	0.063	15.95	968,918.18
oc	Endosulfan, alpha & Endosulfan, beta	507.984	1995.262	0.000	114,942.53	287,729,490.43
oc	Endrin aldehyde	5760.000	1000.000	0.032	31.25	211,250.00
pah	Fluoranthene	55000.000	506.000	0.008	123.46	6,852,592.59
pah	Fluorene	17000.000	1288.250	0.004	256.41	4,689,294.76
pp	Hexachlorobenzene	136584.791	18620.871	0.016	62.50	9,700,353.88
pah	Indeno[1,2,3-cd]pyrene	63534.306	28840.315	0.002	500.00	46,187,310.36
op	Malathion	1406.272	3.467	0.000	10,00 0.00	14,097,390.35
oc	Methoxychlor	5500.000	8128.305	0.000	33,33 3.33	454,276,838.73
pah	Naphthalene	832.000	457.088	0.008	131.04	168,921.18
pcb	PCBs (1)	3600.000	49168.000	0.000	71,42 8.57	3,769,142,857.14
pcb	PCBs (2)	3600.000	49168.000	0.000	71,42 8.57	3,769,142,857.14
pah	Phenanthrene	17000.000	3981.072	0.006	158.73	3,330,328.84
pp	Phenol	550.000	19.953	0.157	6.37	3,630.27
pah	Pyrene	60639.789	776.247	0.008	131.04	8,047,912.68
oc	Toxaphene	55000.000	49420.000	0.000	5,000,000.00	522,100,000,000.00

All values were taken from the EPA's *Waste Minimization Prioritization Tool Background Document for the Tier III PBT Chemical List (WMPT)*[6], selected using a peer reviewed preference hierarchy of published sediment half-life, BAF/BCF, and aquatic toxicity values.

A. Group classifications are abbreviated as follows:
oc=Organochlorine Pesticide
op=Organophosphate Pesticide
pah=Polyaromatic Hydrocarbon
pp=Priority Pollutant
pcb=Polychlorinated Biphenyls

B. Values for Sediment Half-life, Bioaccumulation Factors (BAF)/Bioconcentration Factors (BCF), and Ecological Chronic Toxicity were obtained from WMPT.

For Ecological Chronic Toxicity where values were not available, each chemical was classified by the groups identified and an average of the ecological chronic toxicity was computed based on the values that were available for each of the chemicals in that group*.

C. The Ecological Chronic Toxicity multiplication factor was computed as follows:
1/(ecological chronic toxicity value).
This step was taken due to the inverse relationship that exists between the ecological chronic toxicity value and the degree of toxicity (a smaller value corresponds to a more toxic chemical). This computation results in a direct relationship between the ecological chronic toxicity multiplication factor and the degree of toxicity and therefore can be used in comparisons in conjunction with the sediment half-life value and BAF/BCF value.

D. PBT Factor was computed as follows:
(sediment half-life + BAF/BCF)x(Eco. Tox. Multiplication Factor). – PBT Factor.
The sum of the sediment half-life value and the BAF/BCF value multiplied by the ecological chronic toxicity multiplication factor.