# Control of Toxic Chemicals in Puget Sound

## Executive Summary
## Assessment of Selected Toxic Chemicals in the Puget Sound Basin, 2007-2011

DEPARTMENT OF ECOLOGY
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# Executive Summary

## Background and Approach

The Washington State Department of Ecology (Ecology) and other agencies initiated the Puget Sound Toxics Loading Analysis (PSTLA) in late 2006 to provide scientific information that could be used to guide decisions about how best to direct and prioritize resources and strategies for controlling toxic chemicals in the Puget Sound basin. The primary focus of PSTLA was to estimate toxic chemical loading to Puget Sound through major pathways such as surface water runoff, publicly-owned treatment works (POTWs), and direct air deposition.

PSTLA used a phased approach to develop technical information on toxics chemicals in the Puget Sound basin.

- Phases 1 and 2 relied on existing data to estimate chemical loadings and identify the most important delivery pathways.
- Phase 3 studies included collection of new monitoring data to fill data gaps identified during earlier phases.

Other important components of the project included:

- Assessing pharmaceuticals and personal care products in wastewater treatment plants.
- Assessing persistent organic pollutants in three guilds of marine species.
- Developing numerical models for polychlorinated biphenyls (PCBs) in Puget Sound.
- Developing a framework for a toxicant-based biological monitoring system.
- Preparing a report on the estimated release of chemicals from human-caused (anthropogenic) sources.

The present *Assessment Report* aims to synthesize information from all phases of the PSTLA, focusing primarily on the Phase 3 loading studies. Since information on loading and delivery pathways, primary chemical sources, and other PSTLA studies may not by itself be sufficient to meet the overall goal of PSTLA, a screening-level hazard evaluation of selected chemicals was conducted and included in this report. The hazard evaluation provides information about the relative risk of toxic effects posed by selected chemicals at observed concentrations in the Puget Sound basin. The information provides a scientific basis to develop a source control strategy for toxic chemicals in the Puget Sound Basin, and to prioritize actions.

The report is organized in a chemical-by-chemical fashion. For each of the selected chemicals addressed in the report, the major ongoing anthropogenic sources are discussed and release rates are estimated, an assessment of loading to Puget Sound and major pathways is presented, and the results of the hazard evaluation for the specific chemical are discussed. These elements are expressed by asking the following questions about toxic chemicals in the Puget Sound basin:

- Where do they come from?
- How much is being delivered?
- What delivery pathways contribute to the loading?
- What is the relative toxic hazard posed by these chemicals at observed concentrations?

In order to focus source control actions, a lines-of-evidence approach was developed to identify (1) chemicals with large ongoing anthropogenic releases from primary sources (does not include natural sources or legacy pollution, *and* (2) a relatively high potential to elicit effects based on the results of the hazard evaluation and regionally important biological-effects data. Combining information on chemical releases and loadings with the relative potential for effects provides for a more robust prioritization of possible future source control efforts. Recommendations for filling data gaps are also included.

The PSTLA focused on an abbreviated list of chemicals of concern (COCs). This list was developed during Phase 1 of the project based on observed harm or the threat of harm to the Puget Sound ecosystem. There is a wide range of chemicals in the Puget Sound basin for which we lack environmental information, and yet the chemicals may have the potential to cause biological or ecological harm. In addition, there is a large degree of uncertainty about the sources, pathways, and hazards for the chemicals that have been addressed. Therefore, this assessment should be viewed as the starting point for developing a larger toxic chemical control strategy in which a much broader spectrum of chemicals is considered.

## Summary of Major Findings

### Sources, Loads, and Pathways

COCs (listed in Table ES-1) were selected as the core group of chemicals analyzed in PSTLA studies (1) based on a documented history of their presence in Puget Sound and their capacity to harm or threaten the Puget Sound ecosystem and (2) to ensure that a broad variety of delivery pathways would be represented. While there is general consensus that a much larger number of potentially harmful chemicals are released to Puget Sound, the identification and evaluation of all of these chemicals were beyond the scope of the PSTLA projects.

To remain consistent with other PSTLA projects, the geographical scope of this *Assessment Report* includes Puget Sound, the U.S. portions of the Straits of Georgia and Juan de Fuca, and the entire U.S. watershed for Puget Sound and the Straits.

Chemical loads were calculated for most of the major pathways identified during the initial phase of the PSTLA effort. These include surface water runoff, POTWs, atmospheric deposition directly to marine waters, and direct groundwater discharge. Table ES-1 summarizes the estimated quantities of COCs released in the Puget Sound basin and the loads delivered to Puget Sound. Although these estimates are based on the best available information, releases and loads for some COCs remain incomplete or reflect high levels of uncertainty. In particular, air deposition and groundwater loading data are unavailable for many of the organic COCs.

In general, the load of metals to Puget Sound is approximately an order of magnitude lower than the total release from ongoing anthropogenic sources. Arsenic is an exception, apparently due to a high level of enrichment from natural sources.

For organic chemicals, loads are generally one to three orders of magnitude lower than releases from ongoing anthropogenic sources. The comparatively large differences between release and loading rates for organics may simply reflect the fewer number of pathways assessed for some

organics. Closer agreement between anthropogenic releases and loads for metals may also be due in part to natural enrichment which contributes to the loads. Historic releases may also be a factor in loading of both metals and organic compounds.

**Table ES-1. Toxic Chemical Releases and Loading in the Puget Sound Basin (metric tons/year).**

| COC | Total Release in the Puget Sound Basin[a] | Major Sources | Total Load to Puget Sound[b,c] | Major Pathway(s) |
|---|---|---|---|---|
| Arsenic | 0.8 | Industrial air emissions.<br>CCA-treated wood leaching.<br>Roofing material leaching. | 14 – 25 | Surface Runoff |
| Cadmium | 1.0 | Roofing material leaching. | 0.05 – 0.53 | Groundwater<br>Atm. Deposition |
| Copper | 180 - 250 | Pesticides use on urban lawns and gardens.[d]<br>Residential plumbing component leaching.<br>Brake pad abrasion.<br>Roofing material leaching.<br>Vessel anti-fouling paint leaching. | 33 – 80[e] | Surface Runoff |
| Lead | 520 | Ammunition and hunting shot use.<br>Loss of fishing sinkers and wheel weights.<br>Roofing material leaching.<br>Aviation fuel combustion. | 3.6 – 12 | Surface Runoff |
| Mercury | 0.5 | Consumer product improper disposal.<br>Crematoria and industrial air emissions. | 0.11 – 0.37 | Surface Runoff |
| Zinc | 1,500 | Roofing material leaching.<br>Vehicle tire abrasion. | 140 - 200 | Surface Runoff |
| Total PCBs | 2.2 | Electrical equipment spills and leakage.[d]<br>Residential trash burning.<br>Building sealant (caulk) volatilization and abrasion. | 0.003 – 0.02 | Surface Runoff |
| Total PBDEs | 0.7 | Furniture, computer monitors, and other components of residential and commercial indoor environments. | 0.028 – 0.054 | Atm. Deposition<br>POTWs |
| PCDD/Fs | 0.000009[f] | Backyard burn barrels. | NA | NA |
| Total DDT | NA | NA | 0.0025 – 0.032 | Surface Runoff |
| Total PAHs | 310 | Woodstoves and fireplace combustion emissions.<br>Vehicle combustion emissions.<br>Creosote-treated piling, railroad ties, and utility poles. | 0.19 – 1.0[e] | Groundwater<br>Surface Runoff |
| DEHP | 17 | Polymer (primarily PVC) off-gassing.<br>Industrial, commercial, and institutional air emissions.<br>Roofing material leaching. | 2.0 – 3.2 | Surface Runoff |
| Triclopyr | 150 | Herbicide use on crops and golf courses. | 0.64 – 0.69 | Surface Runoff |
| Nonylphenol[g] | 0.18 | Industrial, commercial, and institutional air emissions. | 0.023 – 0.024 | Surface Runoff |
| Petroleum | 9,300 | Motor oil drips and leaks.<br>Used oil improper disposal.<br>Gasoline spillage during fueling. | 330 – 500 | Surface Runoff |
| Oil & Grease[h] | NA | NA | 8,500 – 11,000 | Surface Runoff |

NA=Not analyzed

[a] Includes the Puget Sound, the U.S. portions of the Straits of Georgia and Juan de Fuca, and the entire U.S. watershed for Puget Sound and the Straits.

[b] Includes the Puget Sound and the U.S. portions of the Straits of Georgia and Juan de Fuca.

[c] Range of all pathways combined expressed as the sum of the 25th percentile values for each pathway – sum of the 75th percentile values for each pathway.

[d] Estimate is highly uncertain.

[e] Does not include estimated direct releases to marine waters (54 metric tons/yr for PAHs and 26 metric ton/yr for copper).

[f] Expressed as Toxic Equivalents (TEQs).

[g] Sources were not fully assessed.

[h] Category includes all hexane extractable material

The relationships between rates of initial release, rates of loading to Puget Sound, and the major delivery pathways are discussed for each COC. For most COCs, it is clear that a simple assessment of overall release from primary sources will not translate to levels measured in the environment. The type, mechanism, and setting of a chemical release are important factors governing their presence in environmental pathways. For instance, large quantities of polycyclic aromatic hydrocarbons (PAHs) are potentially released from creosote-treated railroad ties and utility poles throughout the basin, but the mechanisms and settings of release (volatilization and near-field leaching primarily to soil) do not translate to elevated concentrations of PAHs in surface runoff. In contrast, estimated zinc releases from major sources such as roof materials and vehicle tires occur in manners and settings (leaching from precipitation, abrasion to roadway surfaces) that result in substantial entrainment of zinc to surface waters.

For the majority of COCs, surface runoff contributed the largest loads to Puget Sound, typically accounting for more than one-half of the total loads from all pathways combined. Surface runoff from commercial/industrial land covers typically had the highest concentrations. However, agricultural areas produced the highest concentrations for several metals. Loading calculations were strongly influenced by the areas occupied by different land cover types. As a result, the largest loads were typically from forested areas (occupying 83% of all land cover), even though COC concentrations in forest areas were often the lowest among land covers or below reporting limits.

Loads delivered directly to the Puget Sound marine environment through groundwater were estimated using literature values for COC concentrations and discharge estimates. Groundwater loads were estimated to be an order of magnitude lower than surface runoff for most COCs. Exceptions were PAH loads, which were similar to surface water, as well as cadmium, gasoline, and diesel fuel, which had low to non-detectable surface water loads. Like surface runoff, load calculations for groundwater were strongly influenced by methods used to estimate concentrations from non-detected values.

Atmospheric deposition directly to marine waters was an important loading pathway for polybrominated diphenyl ethers (PBDEs) and high molecular weight PAHs. PBDEs was the only COC for which direct deposition from air appeared to be the largest delivery pathway to Puget Sound. COC flux from the atmosphere was comparatively high at a monitoring station located in a high-density urban area with nearby commercial, industrial, and major roadway contaminant sources.

POTWs generally accounted for less than one-tenth of the delivery to Puget Sound for each of the COCs assessed. Exceptions were diethylhexyl phthalate (DEHP, a.k.a. bis(2-ethylhexyl) phthalate) and PBDEs, the latter of which had POTW loads larger than those in surface runoff. POTW loads for other chemicals not specifically addressed in this report, such as pharmaceuticals, are expected to be much higher in POTWs than in other delivery pathways.

## Hazard Evaluation

To assess the relative hazards, observed environmental concentrations of COCs in various environmental media (surface water, sediment) were compared to available data on biological effects or to established criteria to protect aquatic life and consumers of aquatic organisms.

Evaluations were conducted for the following categories:

- Direct hazards to aquatic life through surface water exposure
- Direct hazards to benthic organisms through sediment exposure
- Direct hazards to aquatic life based on tissue residue levels
- Hazards to wildlife based on ingestion of prey, water, and sediment
- Hazards to human health through fish/seafood consumption

The results of these comparisons were grouped into three broad "level of concern" categories: Priority 1 level of concern, Priority 2 level of concern, or unknown (U) level of concern. Results were classified as Priority 1 when the upper end of a set of observed concentrations (e.g. $90^{th}$ percentile values) exceeded the lower end of a set of effects concentrations (e.g. $10^{th}$ percentile values), or exceeded selected threshold values such as water quality criteria. A Priority 2 level of concern was assigned in cases where the upper end of a set of observed concentrations was below the lower end of a set of effects concentrations or other threshold values. In cases where there were not sufficient data to make a meaningful comparison, results were assigned a U.

The hazard evaluation has several limitations that should be considered prior to acting on the results. In particular, the hazard evaluation is not a risk assessment but is instead designed to assess the *relative* level of concern of COCs *across the entire Puget Sound basin*. Although a COC may be assigned Priority 2 or U for a particular sub-category, this should not be interpreted to mean there are no hazards associated with that COC. All of the COCs evaluated pose some level of concern for Puget Sound. Locally, concentration hot spots may exist near major sources and may cause localized toxicity to aquatic organisms or lead to violations of standards that would not necessarily be emphasized in this broad regional assessment. To address this shortcoming in the hazard assessment, a limited review was conducted of regionally important biological effects information.

Results of the hazard evaluation showed that all of the COCs except lead are a Priority 1, where sufficient data were available for evaluation, for at least one of the categories evaluated. There were not sufficient data to conduct evaluations for PBDEs, triclopyr, nonylphenol, or petroleum. PCBs is the only COC assigned a Priority 1 for all five categories evaluated.

COC concentrations in surface waters and sediments – particularly freshwater – resulted in the most COCs assigned Priority 1. Tissue residue effects, wildlife, and human health evaluations generally resulted in fewer COCs receiving a Priority 1 assignment. However, only bioaccumulative chemicals were evaluated for these latter categories.

In addition to the hazard evaluation, reviews of regionally important biological-effects data showed that levels of the following chemicals found in the Puget Sound basin result in documented or potentially adverse effects to a variety of aquatic organisms:

- copper
- mercury
- PCBs
- PBDEs
- polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs)
- dichlorodiphenyltrichloroethane (DDT) and metabolites DDD and DDE
- PAHs

## Priorities for Source Control Actions

A lines-of-evidence approach was used to move further toward a goal of deciding how best to prioritize actions and resources for controlling toxic chemicals in the Puget Sound basin. This lines-of-evidence approach considers information on the four major components of the assessment (sources, loading, pathways, and the relative hazards), but the approach mostly relies on COC sources and the relative hazards posed by COCs as determined by the hazard evaluation and review of other regional studies.

This approach adopts the rationale that chemicals with the greatest potential to elicit toxic effects at existing concentrations should be an important factor in determining the priority for source control efforts. Priority was also given to COCs for which we have large opportunities for source control. This reflects the extent to which there are existing regulatory actions to control releases, such as bans, management of materials, or other permanent actions which reduce releases to the environment. Given the uncertainty associated with individual estimates of releases or loadings, this lines-of-evidence approach provides a supportable rationale for establishing relative priorities for control actions.

Opportunities for source control are considered large where the major sources of a COC have not been addressed by control actions; where some of the major sources have been addressed, opportunities may be considered medium. In cases where actions have been implemented to control and reduce all or most of the major sources and this appears to have resulted in low rates of loading to Puget Sound, the opportunities for controlling a COC are considered small. This assessment relies principally on the *Sources Report* (Ecology, 2011) with limited input by Ecology staff and management to gauge the opportunities for source control; the assessment was not intended to be a detailed review of management initiatives. Table ES-2 summarizes major sources for each COC and possible opportunities for reducing those sources.

Based on the lines-of-evidence approach, copper, PAHs, DEHP, and petroleum sources were rated as have the highest priority for early actions. The reasoning for this determination is as follows:

- A substantial portion of the fresh and marine water copper data observed basin-wide falls within concentrations where effects have been documented (including reduced olfactory function in salmonids). Copper is released in large quantities from a variety of sources which appear to translate to substantial loads to the Puget Sound ecosystem. The use of copper in pesticide applications and the release of copper from roofing materials are sources which warrant further investigation. In addition, the effectiveness of recent legislation to limit copper in brake pads and vessel anti-fouling paint should be evaluated.
- A number of individual PAHs surpass (do not meet) freshwater sediment guidelines and human health criteria. In addition, a variety of studies have demonstrated links between PAH exposure and adverse effects to regionally relevant aquatic species. There appear to be numerous opportunities for control actions, primarily for combustion sources and for creosote-treated wood.

- Observed DEHP concentrations in both freshwater and marine environments exceed (do not meet) criteria for protection of benthic species and human health. Substantial amounts of DEHP are released in the Puget Sound basin, much of which occurs initially through releases to air from off-gassing of plasticized polymers and point-source air emissions. Several non-polymer uses of DEHP may also provide opportunities for source reduction.
- The relative hazard posed by petroleum in the Puget Sound basin was not able to be evaluated due primarily to the lack of biological-effects data and the absence of criteria to protect aquatic organisms, wildlife, or human health. However, some of the COCs addressed in this assessment are components of petroleum and may be released in substantial quantities along with the release of petroleum. In particular, substantial releases of PAHs are estimated to be released from petroleum. The major sources of petroleum are diffuse, such as motor oil drips and leaks and minor gasoline spillage during vehicle fueling, and therefore offer ample opportunities for reduction efforts.

Several COCs were found to be a Priority 1 level of concern based on the hazard evaluation but were not determined to be among the highest priorities for reduction actions since the major sources have been addressed through regulatory programs or other efforts. For instance, mercury poses a relatively high hazard to freshwater and marine aquatic organisms and wildlife based on doses calculated from observed data. However, many of the historical regional sources of mercury to the Puget Sound basin have been eliminated or are being addressed by the Mercury Chemical Action Plan (Ecology and WDOH, 2003). Similarly, PCBs are a Priority 1 level of concern for all hazard evaluation categories, but PCBs have been banned for decades, the major sources (use in electrical equipment) are highly regulated, and current loads to Puget Sound appear to be small.

Although the systematic prioritization approach identified four COCs for early actions, other factors should be considered to determine the need and feasibility for developing control and reduction strategies for other COCs. For instance, PBDEs are ubiquitous environmental contaminants, and although voluntary actions and bans have removed major PBDE formulations from new consumer products, much of the PBDEs produced historically may remain in consumer products and commercial office products and these potentially represent substantial diffuse ongoing sources. The hazard evaluation was not able to adequately assess the relative hazards associated with PBDEs due to a lack of environmental standards, although there is evidence in the available literature to suggest this COC may pose a hazard at observed concentrations.

Additional research is needed to assess the relative hazards posed by PBDEs and other COCs for which there are only limited environmental data. By the same token, COCs with limited source information should be further evaluated to assess additional opportunities for source control. Of the COCs addressed in this report, PBDEs and nonylphenol were the COCs that should receive top attention for further research on potential hazard as well as possible opportunities for source control.

**Table ES-2. Summary of Possible Actions to Reduce COCs in the Environment.**

| COC | Opportunities for Source Control | Major Ongoing Anthropogenic Sources | Possible Actions for Reductions |
|---|---|---|---|
| Arsenic | Medium | Industrial air emissions | Maintain existing permit controls. |
| | | CCA-treated wood leaching | Continue ban for most non-structural uses. |
| | | Roofing material leaching | Possible opportunity for source control, but more data needed on extent of releases. |
| Cadmium | Medium | Roofing material leaching | Possible opportunity for source control, but more data needed on extent of releases. |
| **Copper** | Large | Pesticides use on urban lawns and gardens | More data needed on actual pesticide use. |
| | | Residential plumbing component leaching | Continue to implement Lead and Copper Rule. |
| | | Brake pad abrasion | Continue to implement legislation enacted to reduce source. |
| | | Roofing material leaching | Possible opportunity for source control, but more data needed on extent of releases. |
| | | Vessel anti-fouling paint leaching | Continue to implement legislation enacted to reduce source. |
| Lead | Small | Ammunition and hunting shot use | Implement CAP and enforce existing regulations. |
| | | Loss of fishing sinkers and wheel weights | Implement CAP and enforce existing regulations. |
| | | Roofing material leaching | Possible opportunity for source control, but more data needed on extent of releases. |
| | | Aviation fuel combustion | Implement CAP and enforce existing regulations. |
| Mercury | Medium | Consumer product improper disposal | Continue to implement CAP and enforce existing regulations. |
| | | Crematoria and industrial air emissions | Continue existing permit limits. |
| Zinc | Large | Roofing material leaching | Possible opportunity for source control, but more data needed on extent of releases. |
| | | Vehicle tire abrasion | Investigate source where it poses local concern. |
| Total PCBs | Small | Electrical equipment spills and leakage | Continue programs for management and disposal. |
| | | Residential trash burning | Continue enforcing existing ban. |
| | | Building sealant (caulk) volatilization and abrasion | Investigate source where it poses local concern. |
| Total PBDEs | Medium | Furniture, computer monitors, and other components of residential and commercial indoor environments | Enforce ban on new products but consider control actions to reduce the release from existing products. |
| PCDD/Fs | Small | Backyard burn barrels | Continue enforcing existing ban. |
| Total DDT | Small | None apparent | Investigate source where it poses local concern. |
| **Total PAHs** | Large | Woodstoves and fireplace combustion emissions | Continue change out programs, investigate catalysts/capture devices, promote alternatives to wood heat. |
| | | Vehicle combustion emissions | Anti-idling programs, continue/expand engine retrofits for private section engines, enforce existing vehicle controls. |
| | | Creosote-treated piling, railroad ties, and utility poles | Control actions needed, gather information to identify highest priority areas. |
| **DEHP** | Large | Polymer (primarily PVC) off-gassing | Gather additional information on extent of releases. |
| | | Industrial, commercial, and institutional air emissions | Maintain existing permit controls. |
| | | Roofing material leaching | Possible opportunity for source control, but more data needed on extent of releases. |
| Triclopyr | Medium | Herbicide use on crops and golf courses | More data needed on pesticide use. |
| Nonylphenol | Unknown | Industrial, commercial, and institutional air emissions | More information needed on emissions from these sources and unidentified releases. |
| **Petroleum** | Large | Motor oil drips and leaks<br>Used motor oil improper disposal | Expand existing education/workshop programs. |
| | | Gasoline spillage (minor) during fueling | Possible opportunity for source control, but more data needed on extent of releases. |

**Bold**=Recommended as priority for near-term actions based on lines-of-evidence approach.

## Recommendations

Broad recommendations are provided below. These are intended to guide development of a long-term strategy to reduce toxic threats to Puget Sound. The reader is directed to the main body of the report for more detailed results of this assessment that should provide further direction towards specific chemical control actions and further source/pathway investigations.

While this report identifies sources of toxic chemicals entering Puget Sound and recommends ways to reduce this contamination, these recommendations should be prioritized and balanced alongside current efforts and regulatory programs that already keep millions of pounds of business-generated COCs safely managed.

In 2010 the U.S. Environmental Protection Agency selected Ecology to lead the development and implementation of a long-term toxic chemical control strategy for Puget Sound. Results from the PSTLA will be a key piece of information to help design and implement actions to reduce threats from the most important sources of toxic chemicals to the Puget Sound ecosystem. Ecology will use funding from a National Estuary Program grant to implement priority actions under this long-term toxics control strategy.

Major recommendations from this assessment can be summarized as follows:

- A variety of diffuse (nonpoint) sources appear to account for the majority of contaminant releases in the Puget Sound basin. In addition, surface water runoff during storms was identified as the major delivery pathway for most contaminants. High priority should be given to (1) implementing control strategies to prevent the initial release of contaminants and (2) reducing or treating stormwater inputs.

- Vehicles and vehicle-related activities represent an important source of a number of contaminants. Examples include: copper and zinc from brake and tire wear, PAHs from fuel combustion, and petroleum from motor oil drips and leaks as well as refueling operations. Source control strategies should be developed around reducing contaminant inputs from vehicles.

- Runoff and leaching from roofing materials were estimated to be a major source of several metals, particularly cadmium, copper, and zinc. Roof runoff may also be a substantial source of DEHP. Field investigations should be conducted to gauge the accuracy of this information, and if warranted, alternative assessments should be considered for this source category.

- Developed lands (commercial/industrial, agricultural, and residential) had higher concentrations of COCs compared to undeveloped forest land. Source control strategies should focus on identifying and controlling contaminant releases from existing and new developments.

- This assessment focused on a short list of contaminants that were known to, or threaten to, harm the Puget Sound ecosystem. Data are needed on the spatial distribution and impacts

from a much wider range of potential contaminants (e.g. pharmaceuticals and personal care products, brominated flame retardants, nanomaterials) in the basin.

- Businesses in Washington that routinely handle large amounts of COCs should be inspected on a routine basis; once every three years appears to be a reasonable schedule.

Examples of other recommendations are provided below:

- One of the largest potential releases of copper is due to the urban lawn and garden use of products containing copper. Due to the lack of good pesticide-use information, there is a high degree of uncertainty surrounding this conclusion. Additional information is needed to determine release rates for this potentially important source of copper.

- Wood-burning stoves and fireplaces along with vehicle emissions were identified as some of the largest sources of PAHs in the Puget Sound watershed. Regional air programs should continue to pursue abatement programs to reduce wood smoke emissions and vehicle emissions.

- Creosote-treated wood represented approximately one-third of the PAHs released to the Puget Sound basin. In particular, direct release to Puget Sound occurs from treated pilings in marine (salt) water. Programs such as the Department of Natural Resources Marine Piling Removal program should be supported to reduce the release of PAHs from marine pilings and bulkheads.

- More information is needed to help distinguish natural and legacy sources of contaminants in environmental pathways such as surface water runoff. This will help gauge the feasibility and effectiveness of actions taken to reduce releases of chemicals from contemporary anthropogenic (human-caused) releases.

- Resources should be provided for local source control programs that identify and prevent the release of contaminants on a local scale.