PBT Trend Monitoring: Measuring Lead in Suspended Particulate Matter, 2012 Results

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2012 Highlighted Findings

- Elevated Lead Levels in the Spokane River and Upper Columbia River
- High Lead Concentrations in Urban Streams, Compared to Other Streams and Rivers
- Increasing Lead Levels in the Middle Columbia River from 2008 to 2012

Why Lead?

Ecology monitors lead in Washington State rivers and streams because of concern over its toxic and persistent properties. While lead is a naturally occurring element, human activities have spread environmental contamination. Lead affects humans and wildlife by harming developing nervous systems, as well as other bodily systems. There are many sources of lead exposure from the indoor and outdoor environment, and even minor exposures may cause some harm.

Project Overview

The Washington State Departments of Ecology (Ecology) and Health developed a chemical action plan in 2009 to identify the toxic effects of lead, describe its occurrence in the environment, and recommend ways to reduce exposure to humans and wildlife (Ecology and WDOH, 2009).

Ecology began a long-term monitoring program in 2008 to assess temporal changes of lead levels in rivers and streams in Washington. The primary objectives of the program were to (1) establish baseline levels of lead in the freshwater environment, and (2) measure spatial and temporal trends in environmental lead levels as reduction strategies are implemented.

As part of the monitoring program, Ecology collects suspended particulate matter (SPM) samples from 15 monitoring sites throughout Washington for analysis of total lead. Samples are collected twice in the spring and twice in the fall at each site. Monitoring sites (shown in Figure 1) cover a range of watershed size, land use, and potential lead sources. Roberts et al. (2011) discuss the potential lead sources in Washington. This report summarizes results from the fifth year of sampling (2012).

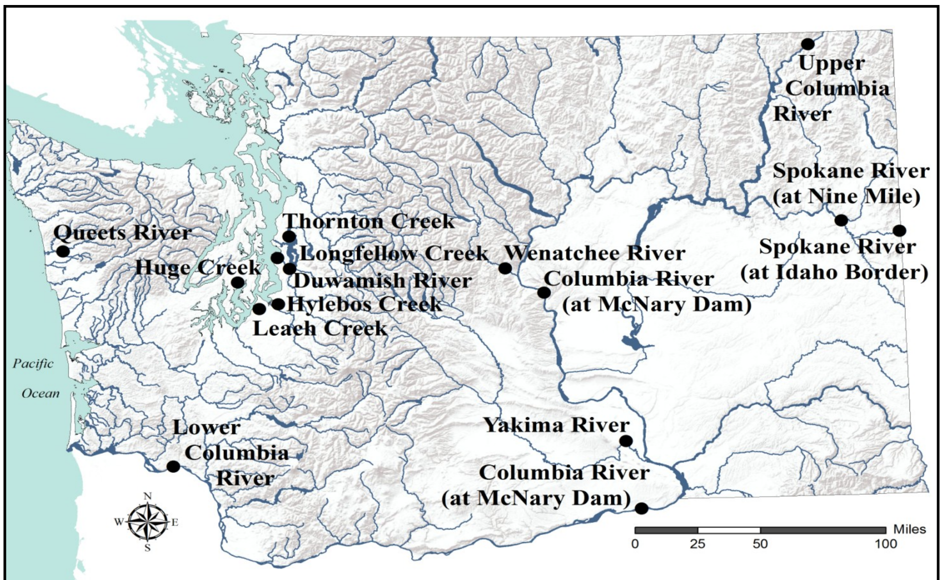

Figure 1. SPM Lead Monitoring Sites in Washington, 2012.

For More Information

PBT Monitoring Program website: www.ecy.wa.gov/programs/eap/toxics/pbt.html

Lead Chemical Action Plan website: www.ecy.wa.gov/programs/swfa/pbt/lead.html

Methods

Field Methods: SPM samples were collected following Ecology's standard operating procedure (SOP) for collection of suspended particulates using in-line filtration (Meredith, 2008). Ambient water temperature, pH, and conductivity were measured following Ecology's SOP for collection and analysis of pH (Ward, 2007).

Laboratory Methods: Ecology's Manchester Environmental Laboratory analyzed lead in the SPM samples following Environmental Protection Agency Method 200.8 (ICP-MS). Total suspended solids (TSS) were estimated as dried SPM weight on sample filters divided by filtrate volume. Standard TSS analyses are conducted using 1.5 µm pore-size filters. This study used 0.45 µm pore-size filters.

Data Quality: Laboratory and field quality control (QC) tests met measurement quality objectives (MQO) set for this project (Meredith and Furl, 2008). One field blank contained lead above the reporting limit (0.05 µg/filter). That field blank, performed at Huge Creek during the second spring sampling, contained 0.06 µg/filter of lead. The lead concentration of the corresponding Huge Creek field sample was below the reporting limit. Detailed quality assurance information is available on request.

Results

Sixty samples were analyzed for lead in 2012. Lead concentrations ranged from below detection limits to 2,652 mg/kg, with a median of 53 mg/kg. A statistical summary of the 2012 lead results is shown in Table 1. Complete 2012 SPM lead data are available for download at www.ecy.wa.gov/eim by searching User Study ID: PbTrends12.

Table 1. Statistical Summary of Lead in Suspended Particulate Matter, 2012 (mg/kg).

Season	n	Det. Freq	Min	Max	Median	Mean	SD
Spring	30	90%	ND	2652	51.1	302	613
Fall	30	90%	ND	659	66.9	128	158
2012	60	90%	ND	2652	53.4	215	452

n = number of samples, Det. Freq = detection frequency, ND = not detected above reporting limit of 0.5 ug/filter, SD = standard deviation

The Sediment Management Standard rule incorporating a freshwater Sediment Cleanup Objective (SCO) for lead will take effect September 1, 2013 (WAC 173-204). The criteria are for bottom sediment; no criteria or standards currently exist for SPM.

Seven of the 60 samples (11.7%) contained lead concentrations above Ecology's proposed freshwater SCO of 360 mg/kg (Figure 2). All samples collected from the Spokane River at the Idaho border, both spring samples from the Spokane River at Nine Mile, and one spring sample from the upper Columbia River were above the SCO for lead in freshwater sediment.

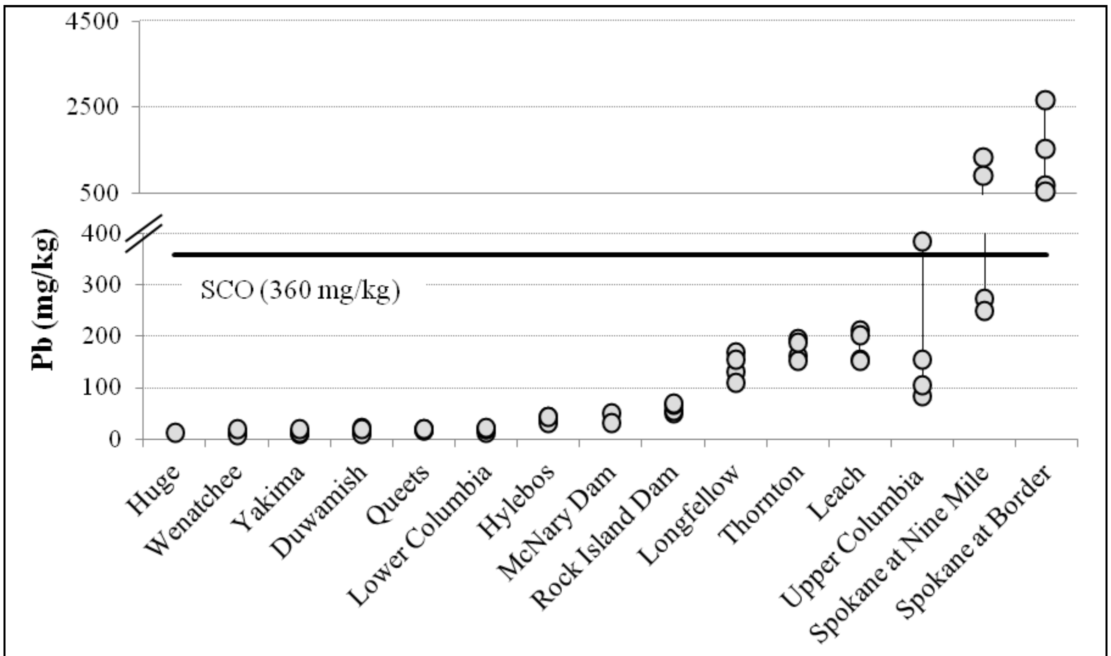

Figure 2. Monitoring Sites Ranked by Annual Average Lead Concentration, 2012 (mg/kg).
Note the broken y-axis. SCO = Sediment Cleanup Objective

Loading

Daily particulate lead loads were estimated for each sampling site, except Hylebos Creek, using daily mean flow (cfs) and lead concentrations per volume filtered (ug/L). Streamflow data were provided by the U.S. Geological Survey, U.S. Army Corps of Engineers, and the City of Seattle. Figures 3 and 4 display the mean lead loads for the river and small stream monitoring sites, respectively. The monitoring sites are arranged in order of increasing spring lead load.

Particulate lead loads were highest in the Columbia River at the Canadian border, ranging from 25 to 11,178 kg/day. The 11,178 kg/day lead load value corresponds to one spring sample that contained a slag particle, which may have elevated the lead concentration of the sample. The Spokane River had the next highest lead loads: 1.1 to 1,325 kg/day at Nine Mile and 1.9 to 1,018 kg/day at the Idaho Border.

The small steams had the lowest lead loads (0.0003 to 0.0097 kg/day), with the rural reference stream, Huge Creek, ranking lowest. These low lead loads correspond to lower flows in the small streams.

Spring lead loads were higher than fall loads at all sites, except Leach Creek. On average, the spring lead loads were 25, 47, and 369 times greater than the fall loads in the mid-sized, Columbia, and Spokane Rivers, respectively. Sampling events captured high-flow spring conditions and low-flow fall conditions at all river sites.

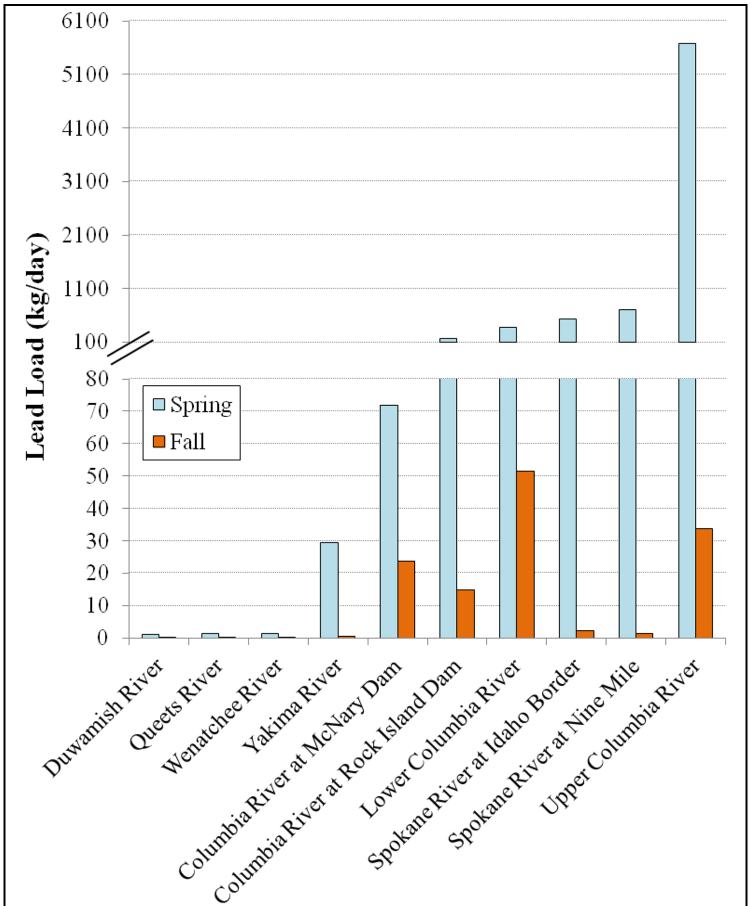

Figure 3. Estimated Mean Particle-Bound Lead Loading at River Monitoring Sites, Spring and Fall 2012 (kg/day). *Note the broken y-axis. Values show the average of two samples per season.*

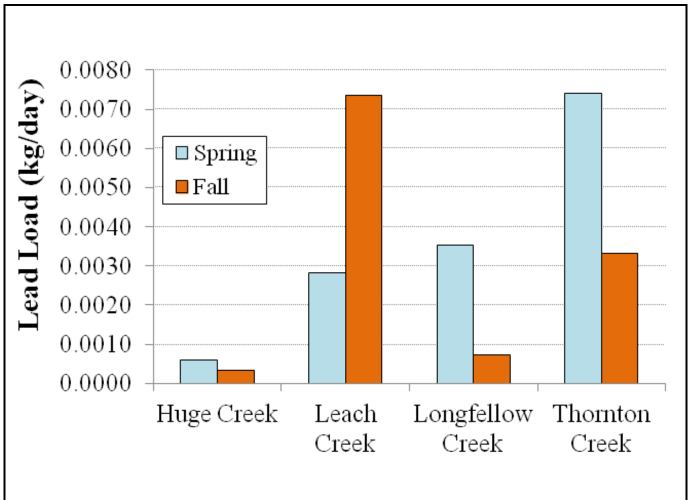

Figure 4. Estimated Mean Particle-Bound Lead Loading at Small Stream Monitoring Sites, Spring and Fall 2012 (kg/day).

High streamflows in the small streams are driven by rain events in fall and winter. In 2012, sampling at the small streams did not capture any storm events. The seasonal flow variability at the other sampling sites is controlled by snowmelt.

Temporal Trends

As of 2012, five years of SPM lead data have been collected at 11 of the monitoring sites. It may not be possible to draw conclusive statistical trends from only five years of data. However, some general patterns can be observed. The following sections describe patterns in lead levels observed at the monitoring sites between 2008 and 2012.

We used least squares linear regression and the Mann-Kendall test to evaluate the data for temporal trends. Linear regression is a parametric model. The better the model fit, the closer the resultant R^2 value is to 1. Mann-Kendall is a non-parametric rank test for identifying trends in time- series data. Mann-Kendall compares the relative magnitudes of sample data rather than the data values themselves. If the resultant tau value is 0, then no consistently increasing or decreasing pattern is evident. Negative tau values indicate a decreasing trend, and positive values indicate an increasing trend. Data below detection limits were excluded from the analyses.

Table 2. Temporal Trend Statistics for All SPM Lead Data, 2008 to 2012 (mg/kg).

Waterbody	n	Mann-Kendall		Linear Regression	
		tau	p-value	R^2	p-value
Spokane River	40	0.051	0.6496	0.0020	0.7860
Spokane River at Idaho Border	20	0.032	0.8711	0.0001	0.9637
Spokane River at Nine Mile	20	0.126	0.4555	0.0180	0.5701
Columbia River	71	0.120	0.1391	0.0050	0.5491
Columbia River, Upper	20	0.011	0.9741	0.0310	0.4574
Columbia River at Rock Island Dam	18	**0.451**	**0.0100**	**0.3241**	**0.0137**
Columbia River at McNary Dam	15	**0.486**	**0.0133**	**0.3194**	**0.0145**
Columbia River, Lower	18	0.020	0.9396	0.0196	0.5794
Mid-Sized Rivers	67	-0.019	0.8286	0.0136	0.3334
Duwamish River	19	-0.012	0.9721	0.0134	0.6376
Queets River	20	0.074	0.6732	0.0398	0.3993
Wenatchee River	12	0.091	0.7317	0.0018	0.8793
Yakima River	16	-0.133	0.4995	0.0567	0.3577
Small Streams					
Hylebos Creek	17	-0.132	0.4838	0.1484	0.1267

Bold, shaded values are significant at the 95% confidence level.
p-values < 0.05 indicate significance at 95% confidence.

Spokane River

Figure 5 shows lead concentrations and streamflow at the Spokane River sites from 2008 to 2012. Separate regression lines for spring and fall are provided. No consistently increasing or decreasing patterns emerged at either of the Spokane River sites. Maximum lead concentrations for both sites occurred in the spring of 2008 and 2012 during the highest flows. Fall concentrations remained fairly stable. Hallock (2010) found that metals, including lead, have decreased in the Spokane River since 1994.

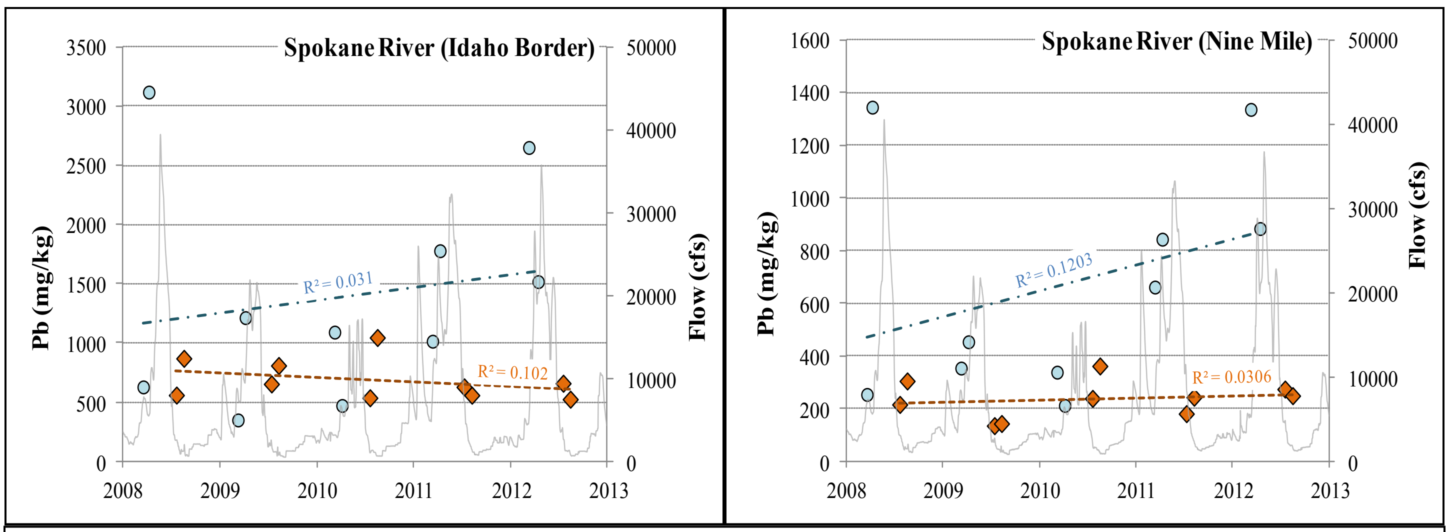

Figure 5. SPM-Associated Lead Concentration (mg/kg) at Spokane River Sites, 2008 to 2012.

Note the variable y-axis scale. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. The R^2 values are shown parallel to each trendline. Spokane River flow data are provided by the U.S. Geological Survey.

Columbia River

Figure 6 displays the Columbia River lead concentrations and streamflow from 2008 to 2012, with separate regression lines for spring and fall.

The Mann-Kendall test and linear regression both indicated increasing lead levels for the Columbia River at the Rock Island and McNary Dam sites from 2008 to 2012 (Table 2). Spring lead concentrations increased more than fall concentrations (Figure 6). The increasing lead trends are statistically significant for the spring data and all of the lead data combined. The fall data did not show significant patterns.

The upward trend in SPM lead at the middle Columbia River sites may be due to increased streamflow carrying more suspended sediment. Streamflow had a slight, yet statistically significant, increase at both of the middle Columbia River sites from 2008 to 2012. In addition, TSS values are positively correlated with flow at both the Rock Island and McNary Dam sites. The spring samples were collected during high flows and show the greatest increase in lead concentration. The above correlation and streamflow trend analysis results are available upon request.

No statistically significant trends were found for the upper or lower Columbia River sites from 2008 to 2012. The lower Columbia River lead levels remained fairly stable throughout the sampling period. The highest lead concentrations at the upper Columbia River site were measured in spring of 2008 and 2012, during rising spring flows when streambed and bank erosion increase the suspended sediment load of the river.

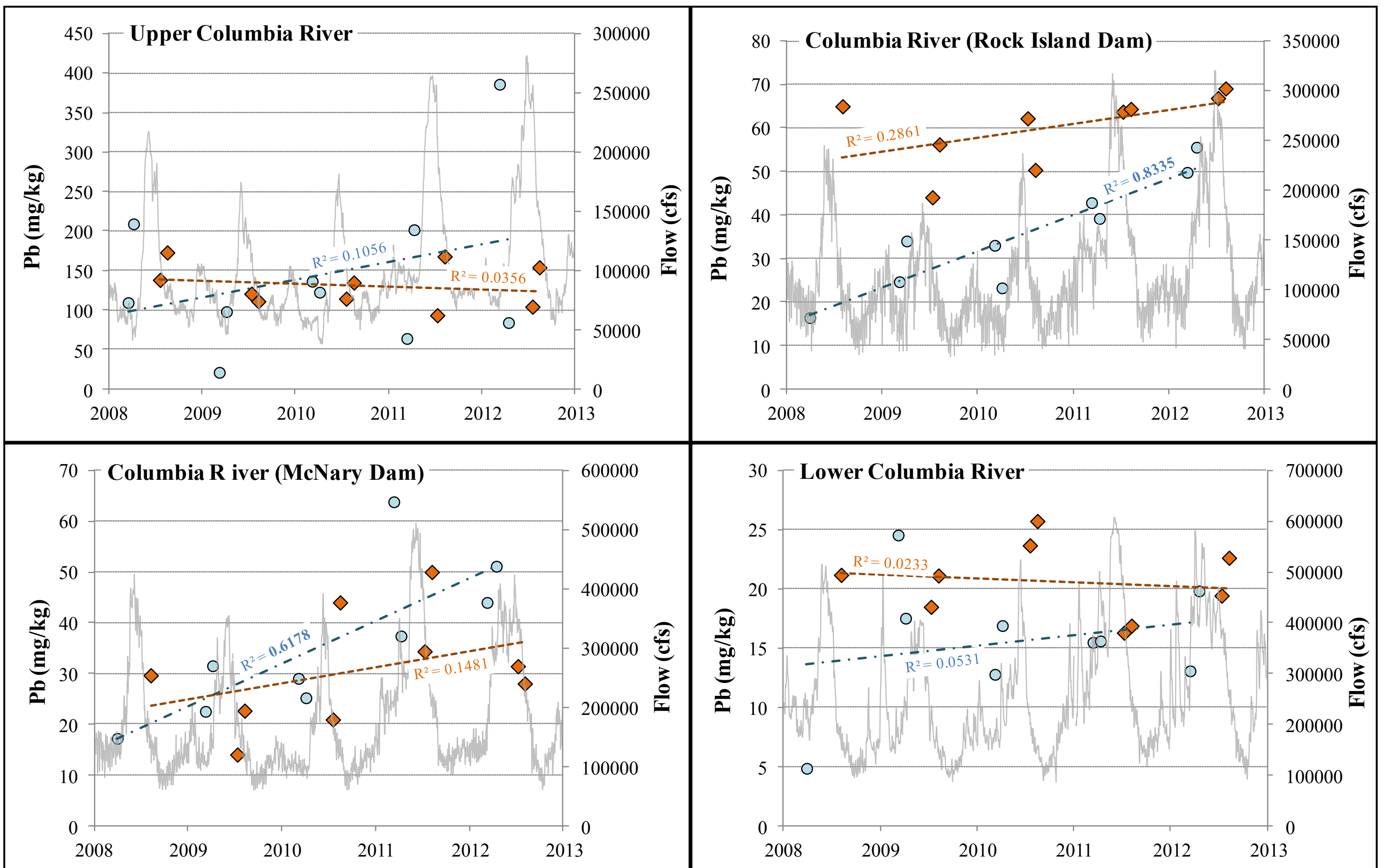

Figure 6. SPM-Associated Lead Concentrations (mg/kg) at Columbia River Sites, 2008 to 2012.

Note the variable y-axis scale. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. The R^2 values are shown parallel to each trendline. Bold R^2 values are significant at the 95% confidence interval. Columbia River flow data are provided by the U.S. Geological Survey and U.S. Army Corps of Engineers.

Mid-Sized Rivers

The mid-sized rivers sampled for this study include the Duwamish, Queets, Wenatchee, and Yakima. Figure 7 displays the SPM lead concentration and streamflow data for these rivers from 2008 to 2012. Separate regression lines for spring and fall are provided.

No consistently increasing or decreasing patterns emerged for the mid-sized rivers, except the Queets. Queets River lead concentrations significantly increased in the spring samples and generally decreased in the fall samples, although low levels were recorded in both seasons. No significant temporal change was found when all data were combined (Table 2). The Queets River site is included in this study as a reference stream, representing a mid-sized river with few roads and very little development.

Lead concentrations have generally been very low at all of the mid-size river sites, reflecting baseline levels. Spring lead levels show a very stable pattern at the Duwamish and Wenatchee River sites. Fall lead levels at those rivers were more erratic with no apparent pattern. The Yakima River lead levels show no apparent pattern in either spring or fall.

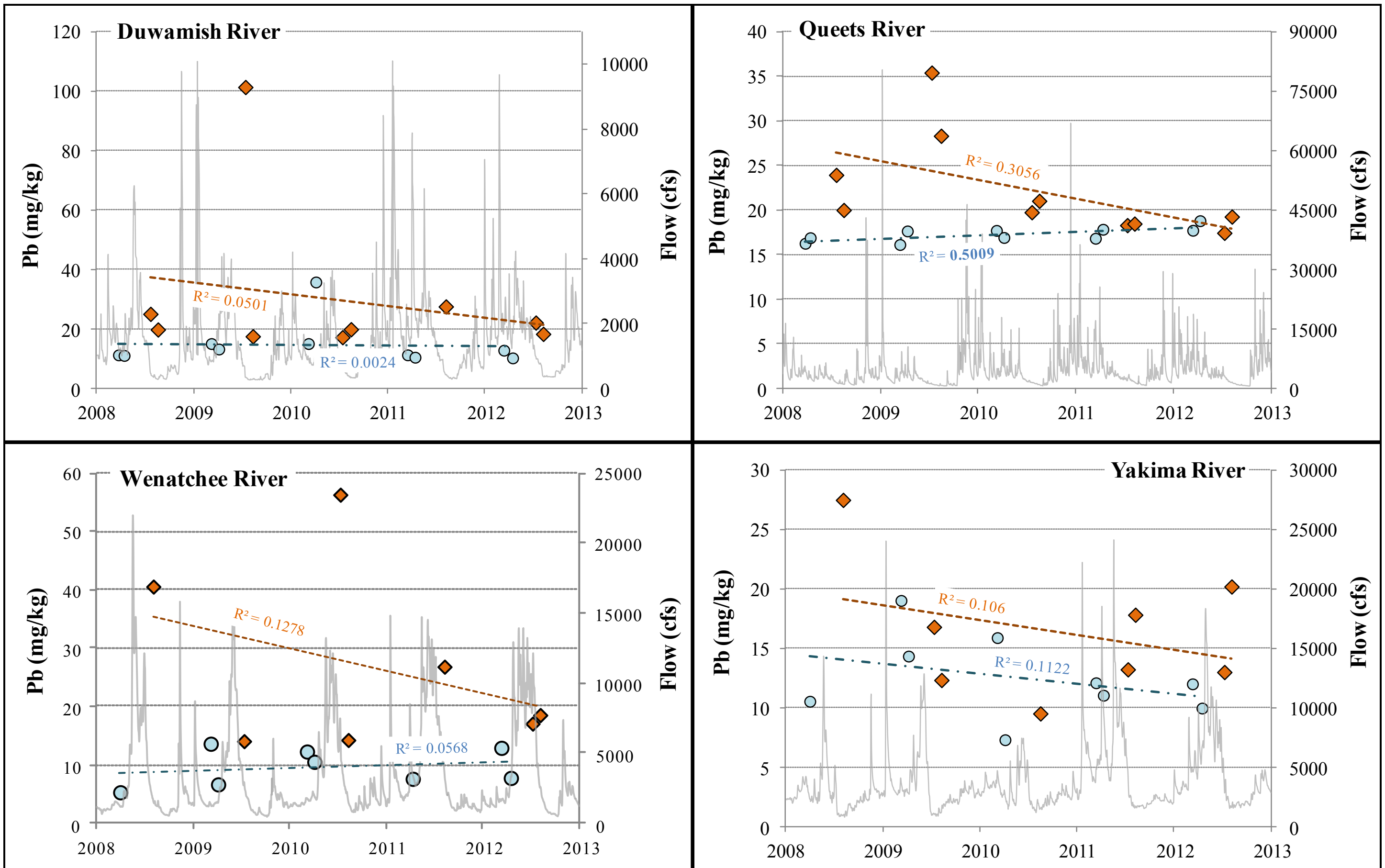

Figure 7. SPM-Associated Lead Concentration (mg/kg) at Mid-Sized River Sites, 2008 to 2012.

Note the variable y-axis scale. Blue Circles=Spring Samples, Orange Diamonds=Fall Samples, Gray Line=Streamflow, Blue Dot-Dash Line=Spring Trendline, Orange Dashed Line=Fall Trendline. The R^2 values are shown parallel to each trendline. Bold R^2 values are significant at the 95% confidence interval. Flow data for the mid-sized rivers provided by the U.S. Geological Survey.

Small Streams

Lead concentrations in Leach, Longfellow, and Thornton Creeks were consistently higher than levels at most other monitoring sites. The Spokane and upper Columbia River sites had lead levels similar to or greater than levels in the urban streams. Hylebos Creek lead concentrations were not as high as in Leach, Longfellow, and Thornton Creeks. The Huge Creek lead levels were less than 30% of the lead measured from all other sites sampled for this project.

Figure 8 provides a comparison of 2012 lead levels at the five small streams. Figure 9 shows how the small stream lead values compare to all of the SPM lead data collected from 2008 to 2012.

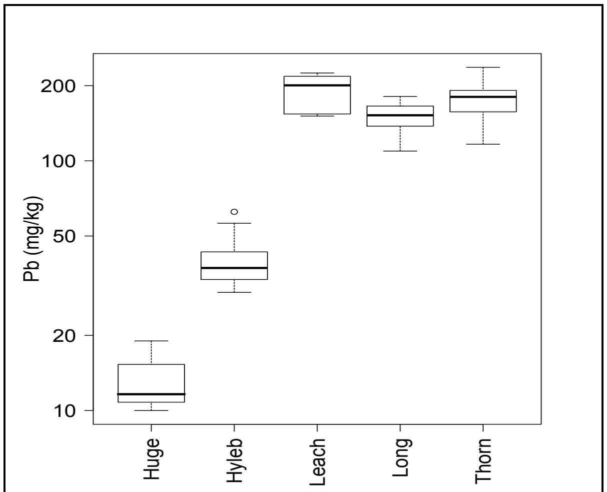

Figure 8. Boxplot of Small Stream Lead Data, 2012. *Huge = Huge Creek, Hyleb = Hylebos, Leach = Leach Creek, Long = Longfellow, Thorn = Thornton.*

Site Descriptions

All five small streams are located on the west side of the Cascade Mountain Range and are similar in drainage area (4-18 square miles), average elevation (250-350 feet), and streamflow (2-9 cfs). Streamflow data are not available for Hylebos Creek.

Leach, Longfellow, and Thornton Creeks were added to the project in 2011 to represent small, urban watersheds with high percentage of impervious surfaces and heavy traffic volumes. Huge Creek was also added in 2011 as a reference site due to its rural and relatively underdeveloped watershed (Mathieu and Friese, 2012). Hylebos Creek has a small, urban watershed and has been sampled for lead in SPM since 2008 (Meredith and Furl, 2009).

Results

Lead concentrations in Leach, Longfellow, and Thornton Creeks ranged from 109-237 mg/kg. Lead values at those urban sites were greater than 68% of all other lead data collected for this project from 2008 to 2012. In Hylebos Creek during that period, lead concentrations ranged from 30 to 63 mg/kg (45-65% of all lead data collected). The Huge Creek lead values varied from 11 to 19 mg/kg, less than 30% of all lead values in this dataset.

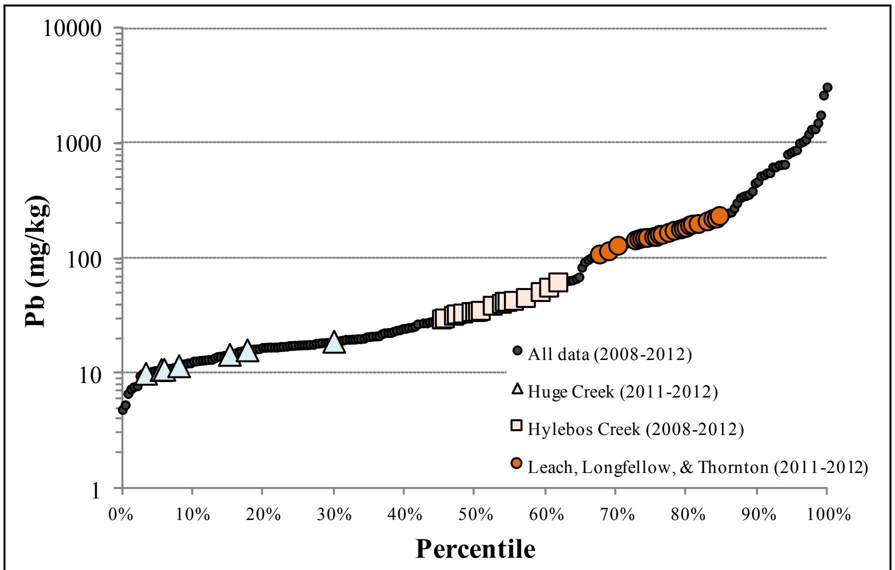

Figure 9. Frequency Distribution of All Lead Data Collected, 2008 to 2012. *The small stream data are grouped into Reference stream (triangles), Hylebos Creek (boxes), and Urban streams (circles).*

As seen in Figure 8, the three urban streams have similar lead levels which are higher than at Hylebos and Huge Creeks. A one-way ANOVA comparison test of the log-transformed lead concentration data confirms the following relationships.

- Huge ≠ Leach, Longfellow, Thornton
- Huge ≠ Hylebos
- Hylebos ≠ Leach, Longfellow, Thornton
- Leach = Longfellow = Thornton

The above relationships are statistically significant at a 95% confidence interval.

ANOVA is a parametric analysis of variance test. It compares the mean value of data groups.

Conclusions

This report summarizes results from the fifth year of a long-term study to evaluate the spatial and temporal trends in environmental levels of lead in Washington State waterbodies. A total of 60 suspended particulate matter (SPM) samples from 15 rivers and streams were analyzed for lead in 2012. Results of this study support the following conclusions:

- Samples from the Spokane River at the Idaho border contained the highest lead concentrations, followed by samples from the Spokane River at Nine Mile. Lead levels were also elevated at the three urban streams (Leach, Thornton, and Longfellow Creeks) and the upper Columbia River near the Canadian border.
- Seven out of 60 samples (11.7%) contained lead levels above Ecology's proposed freshwater Sediment Cleanup Objective (SCO) of 360 mg/kg. All samples collected from the Spokane River at the Idaho border, both the spring samples from the Spokane River at Nine Mile, and one spring sample from the upper Columbia River were above the SCO for lead. The 360 mg/kg SCO for lead is for freshwater sediment, not SPM.
- Temporal analysis for lead samples measured from 2008 to 2012 indicated few consistently increasing or decreasing trends in lead levels. The two mid-section Columbia River sites (Rock Island and McNary Dams) had statistically significant increases in lead concentrations. This increase may be due to a slight increase in streamflow over the same period.
- Particulate lead concentrations (mg/kg) measured at the urban streams were consistently higher than at other monitoring sites, with the exception of the Spokane and upper Columbia Rivers. Mean lead concentrations were significantly higher at the three urbanized streams than Huge Creek, the reference stream. Hylebos Creek, an urban stream where substantial wetland restoration efforts have been carried out, contained lead concentrations significantly greater than the reference stream, but less than the other urban streams.
- Particulate lead loading (kg/day) was greatest in the Columbia and Spokane Rivers. The Columbia River at the Canadian border had the highest lead load value. The lowest lead loads were found in the small streams.

Recommendations

Results from the 2012 study support the following recommendations:

1) Increase sampling frequency. Additional samples throughout the year may better highlight temporal patterns.
   - Collecting more samples throughout the year will provide the opportunity to sample a wider range of the flow regime. Spring lead levels have increased at some sites, whereas fall levels have not. Samples collected in summer and winter may indicate if lead levels are increasing during the rest of the year.
   - Studies with a longer record for the Spokane River have seen a decline in levels of toxic metals. Filling in seasonal gaps in our data record and increasing the number of data points may elucidate these or other trends in particulate lead levels.
   - The middle reaches of the Columbia River show increasing particulate lead concentrations. Additional samples throughout the year may help determine if spring samples are the primary driver of this trend.
2) Add more small streams to the monitoring site list. The lead levels in small, urban streams are likely to be the most dynamic as Chemical Action Plan reduction strategies are implemented.
3) Discontinue sampling from the mid-sized rivers, with the exception of the reference site, Queets River. Reallocate the freed-up resources for additional seasonal and small stream sampling. The mid-sized rivers did not reveal any trends after five years of data. Instead, the levels measured from these sites are reflective of baseline conditions. Trends are more likely to be seen in smaller streams or lead-impacted rivers.

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