Pharmaceuticals and Personal Care Products Detected in Streambed Sediments of the Lower Columbia River Basin

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Abstract

One byproduct of advances in modern chemistry is the accumulation of synthetic chemicals in the natural environment. These compounds include “pharmaceuticals and personal care products” (PPCPs) and “anthropogenic waste indicators” (AWIs), some of which are endocrine disrupting compounds (EDCs) that can have detrimental reproductive effects in wildlife and in humans. Methods have been developed to screen for large suites of PPCPs in aqueous media, but the role of sediments in exposure of aquatic organisms to these chemicals needs to be considered.

The first methods capable of analyzing these compounds in solid media were published in 2005 (Burkhardt et al., 2005, *Analytica Chemica Acta*, 534, 89-100), but have not previously been applied to the Columbia River. Here we present a small-scale reconnaissance of PPCPs in natural bed sediments of the lower Columbia River Basin. Surficial bed sediment samples were collected from the Columbia River, the Willamette River, the Tualatin River, and several small urban tributaries in Oregon.

Forty-nine pharmaceuticals and personal care products were detected at concentrations ranging from <1 to >1000 ng [g sediment]$^{-1}$ (<1 to >75 µg [g OC]$^{-1}$). Concentrations and frequency of detection were higher in tributaries and small urban creeks than in the Columbia River mainstem, suggesting that the highest risk of toxicity to juvenile salmonids and other aquatic life is present in lower order streams. Thirteen known or suspected EDCs were detected during the study. At least one EDC was detected at 22 of 23 sites sampled; several EDCs were relatively widespread among the sites. The samples were also analyzed for 54 current-use and legacy pesticide compounds. In contrast to the AWI compounds, only seven out of 54 pesticide compounds were detected at seven of the sites sampled.

This study is the first to document the occurrence of a large suite of PPCPs in the sediments of the lower Columbia River Basin. A better understanding of the fate and effects of these classes of emerging contaminants is needed, especially because their use and discharge into the environment is likely to increase in the future.

Origins and Fate of PPCPs in the Environment

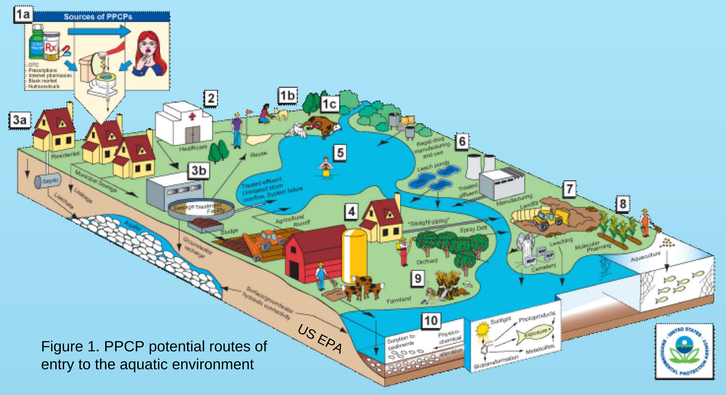


Figure 1. PPCP potential routes of entry to the aquatic environment

Site Map

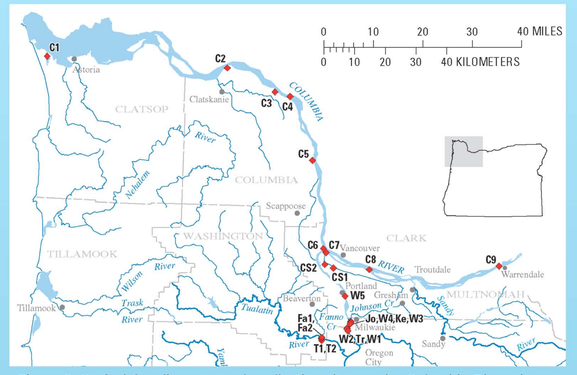
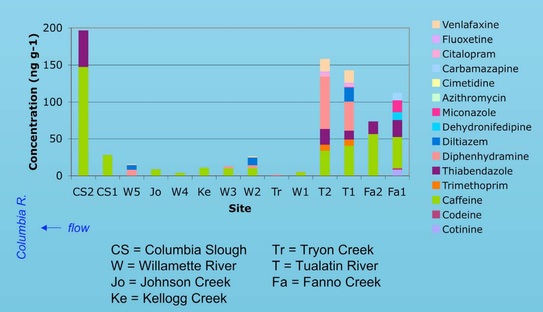


Figure 2. Surfacial sediment sample collection sites on the Columbia River, the Willamette River, the Tualatin River, and several small urban creeks.

Tributary Sites – Pharmaceuticals Detected in Sediments



CS = Columbia Slough
W = Willamette River
Jo = Johnson Creek
Ke = Kellogg Creek
Tr = Tryon Creek
T = Tualatin River
Fa = Fanno Creek

Figure 3. Pharmaceutical compounds detected at tributary sites.

Tributary Sites - Wastewater Indicator Compounds in Sediments

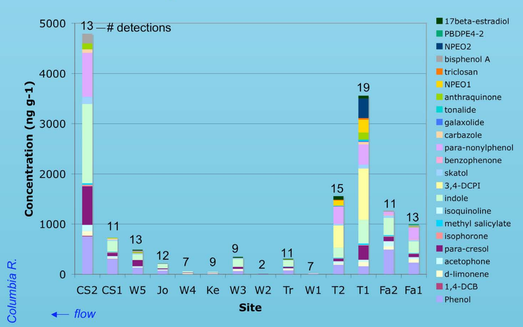


Figure 4. Anthropogenic waste indicator (AWI) compounds detected at tributary sites. Numbers above bars are detections at each site.

Columbia R. Sites - Pharmaceuticals Detected in Sediments

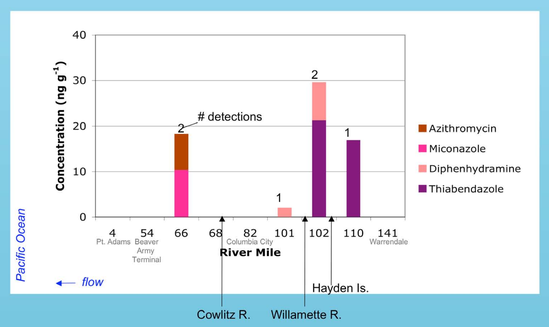


Figure 5. Pharmaceutical compounds detected at mainstem Columbia River sites. Arrows mark where tributaries or effluent enter Columbia River.

Columbia R. Sites - Wastewater Indicator Compounds in Sediments

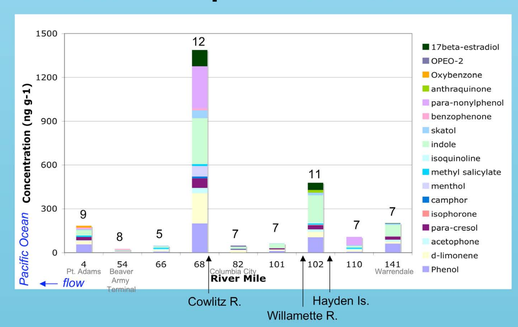


Figure 6. AWI compounds detected at mainstem Columbia River sites.

Endocrine Disrupting Compounds

- What they do: mimic or block hormones and disrupt normal function
- Examples of affected wildlife:
  - Fish and piscivorous birds in Great Lakes area
  - Declining alligator population in Lake Apopka, Florida
  - Feminization of males; collapse of lake population of fathead minnow in Ontario, Canada

Suspected and Known EDCs

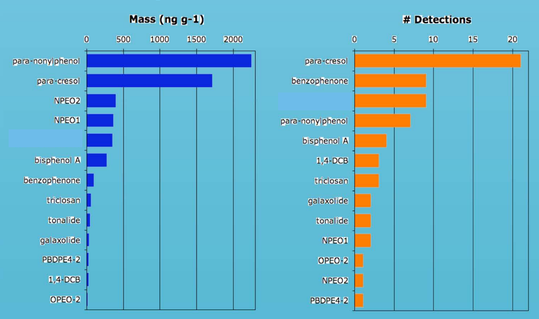


Figure 8. EDCs ranked by total mass of compound measured at all sites (left) and by frequency of detection at sites (right).

Tributary Sites - EDCs in Sediments

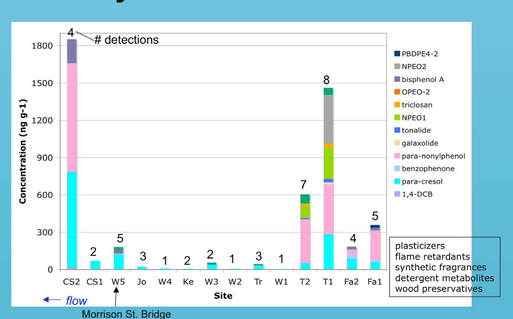


Figure 9. EDCs detected at the tributary sites. Compound uses are noted in the text box.

Columbia R. Sites - EDCs in Sediments

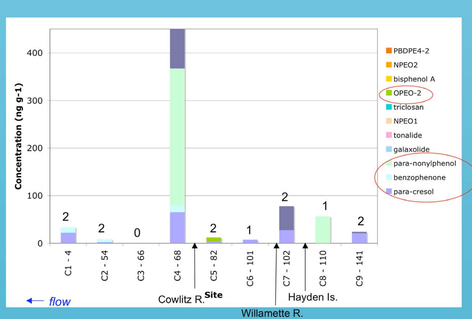


Figure 10. Compounds circled in red are EDCs detected at the Columbia River sites.

Summary and Future Work

This work is the first documented case of the positive occurrence of a large suite of PPCPs in the sediments of the Columbia River Basin. It is now known that these compounds are present in the system, and that they accumulate in the sediments. Several of the compounds detected are known to have detrimental impacts on aquatic life, although little is yet known about their sedimentary concentrations of concern. The effects of many compounds are not understood and require further study. Their presence in this ecosystem raises the possibility of biomagnification through the food web.

A monitoring strategy is needed for these classes of emerging contaminants in this and other ecosystems, especially because their use and subsequent discharge into the environment is likely to increase into the future. The results of this reconnaissance work suggest that it would be valuable to monitor the mouths of tributaries and sites downstream of WWTFs. Lower order streams appear to pose greater exposure risks to juvenile salmonids and other wildlife, although, even on the mainstem Columbia, most sites had at least one EDC present. Future work is needed to determine effects levels for these compounds and relate sedimentary concentrations to water column concentrations and/or loads.

Future efforts should also focus on understanding routes of exposure and bioaccumulation pathways. Management implications include increasing public awareness to reduce entry of these compounds into the wastewater stream, and the need to work toward removing more of these compounds during wastewater treatment processes, possibly by increasing solids retention times or implementing reverse osmosis (e.g., Christen, K., 2007. Removing nutrients and pharmaceuticals. *Environmental Science & Technology*, 41(3), 672-673).

Table 1. Current use and legacy pesticides detected in sediments at tributary and Columbia River sites. Seven compounds were detected out of fifty-four for which the pesticide analytical method[a] screens.

	Organophosphate pesticide	Organochlorine pesticide	Dinitroaniline herbicide	Pyrethroid insecticide	Legacy chlorinated hydrocarbon		Triazine herbicide
SITE	CHLORPYRIFOS	PENTACHLOROANISOLE	PENDIMETHALIN	PERMETHRIN	p p' DDE	p p' DDT	PROMETRYN
Columbia Sl at Smith & Bybee Park (CS2)	ND	6.29	4.79	ND	ND	ND	56.5
Johnson Cr at Willamette River (Jo)	ND	ND	ND	(0.836)	1.40	1.51	ND
Willamette d/s Tryon Cr (W2)	(0.743)[b]	ND	(0.868)	ND	37.7	ND	46.0
Willamette River d/s Kellogg Cr (W4)	ND	ND	ND	ND	ND	ND	21.4
Tualatin River at Fanno Cr (T1)	ND	ND	(0.912)	ND	ND	ND	ND
Tualatin River d/s Durham WWTF (T2)	ND	ND	(0.266)	ND	ND	ND	ND
CR at Cowlitz River (RM 68)	ND	ND	ND	1.51	ND	ND	ND

[a]Smalling, K.L., Orlando, J.L., and Kuivila, K.M., 2005, Analysis of Pesticides in Surface Water and Sediment from Yolo Bypass, California, 2004–2005: U.S. Geological Survey Scientific Investigations Report 2005-5220, 20 p.
[b]Concentrations in ng/g dry weight basis (ppb); values in parentheses are less than calculated method detection limits and are considered estimates
Sl = slough; Cr = creek; ND = not detected; d/s = downstream; WWTF = waste water treatment facility; RM = river mile

Acknowledgements

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