Quality of Bottom Material and Elutriates in the Lower Willamette River, Portland Harbor, Oregon

By Gregory J. Fuhrer

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 89-4005

Prepared in cooperation with the
U.S. ARMY CORPS OF ENGINEERS

Portland, Oregon
1989

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CONVERSION FACTORS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound units	By	To obtain metric units
	Length	
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Temperature	
degree Celsius (°C)	(9/5) °C + 32	degree Fahrenheit (°F)
	Specific Conductance	
microsiemens per centimeter at 25° Celsius ($\mu S/cm$ at 25° C)	1.000	micromhos per centimeter at 25° Celsius ($\mu mho/cm$ at 25° C)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

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QUALITY OF BOTTOM MATERIAL AND ELUTRIATES IN THE LOWER WILLAMETTE RIVER, PORTLAND HARBOR, OREGON

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By Gregory J. Fuhrer

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ABSTRACT

In October of 1983 the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, collected bottom-material and water samples from Portland Harbor to determine concentrations of trace metals and organic compounds in elutriate-test filtrate and bottom material. These data were combined with data from earlier harbor studies and were evaluated relative to chemical concentrations in local soils, spatial location within the harbor, and U.S. Environmental Protection Agency criteria for quality of water.

Of the trace metals examined in bottom material, concentrations of cadmium (less than 0.5 to 1.8 micrograms per gram) slightly exceed those of local soils, whereas lead (3 to 236 micrograms per gram) and zinc (20 to 779 micrograms per gram) exceedance is substantially larger. The largest concentrations of cadmium, lead, and zinc in bottom material occur in ship-docking areas outside of the main navigation channel. Of the organochlorine compounds examined in bottom material, chlordane, dichloro diphenyl dichloroethane (DDD), dichloro diphenyl dichloroethylene (DDE), dichloro diphenyl trichloroethane (DDT), dieldrin, and polychlorinated biphenyls (PCB) were detected and quantified in at least 30 percent of the samples tested. A large DDT concentration (2,700 micrograms per kilogram) near Doane Lake outlet is indicative of recent contamination, because it exceeds degradation-product maximums for DDE (100 micrograms per kilogram) and DDD (613 micrograms per kilogram). Polychlorinated biphenyls are ubiquitous in bottom sediments; median concentrations are 63 micrograms per kilogram, and maximum concentrations are 550 micrograms per kilogram. Particle size appears paramount in controlling PCB concentrations; particles finer than 62 micrometers in diameter are significantly correlated (ρ = 0.005) with PCB concentrations, as are percent silt (ρ = 0.01). The acid and base-neutral extractable di-N-butyl phthalate and bis(2-Ethylhexyl)phthalate occur in sediments of Portland Harbor Terminal No. 2 in concentrations as large as 1,965 and 2,200 micrograms per kilogram, respectively.

Of the trace metals examined in both standard and oxic elutriate-test filtrate, antimony, barium, beryllium, cadmium, iron, lead, manganese, mercury, nickel, selenium, thallium, and zinc do not exceed U.S. Environmental Protection Agency quality-of-water criteria. However, the copper concentration in an oxic elutriate-test filtrate (19 micrograms per liter) exceeded the quality-of-water criteria (5.7 micrograms per liter) and is substantially larger than the 3 micrograms per liter found in the corresponding standard elutriate-test filtrate.

The PCB suspended-sediment load of the Willamette River has been estimated to be 72 kilograms per year. This is nearly five times the PCB-dredge load of 15 kilograms per year. Loading computations assume that PCB concentration in suspended sediment equals the median-PCB concentration in Portland Harbor bottom material.

INTRODUCTION

Background

The U.S. Army Corps of Engineers (COE) maintains a 40-foot deep navigation channel in Portland Harbor, from the mouth of the Willamette River to river mile (RM) 12 (fig. 1). Sediment deposition in the channel occurs primarily from RM 3 to RM 10. This is due to channel morphology and tide-induced flow reversals. As a result of this deposition, the COE projects that over 400,000 cubic yards of bottom material will be dredged from the harbor each year (U.S. Army Corps of Engineers, 1979a, p. 3-4). This amount includes dredge spoils from the main channel and from berthing areas. Dredged material historically has been placed at nearby upland disposal sites; however, at present these sites are nearly full (U.S. Army Corps of Engineers, 1979A). As an alternative disposal plan, the COE is considering disposal of this material into the Columbia River (flow lane disposal) a short distance downstream from the mouth of the Willamette River. The dredged material, if free of contaminants, would be nutrient-rich in comparison to Columbia River bottom material and could enhance Columbia River biota downstream from the disposal site (George Snyder, National Marine Fisheries Service, oral commun., 1977). To study this alternative disposal plan, the U.S. Geological Survey in cooperation with the COE collected data at 10 sites in Portland Harbor in October 1983.

Purpose and Scope

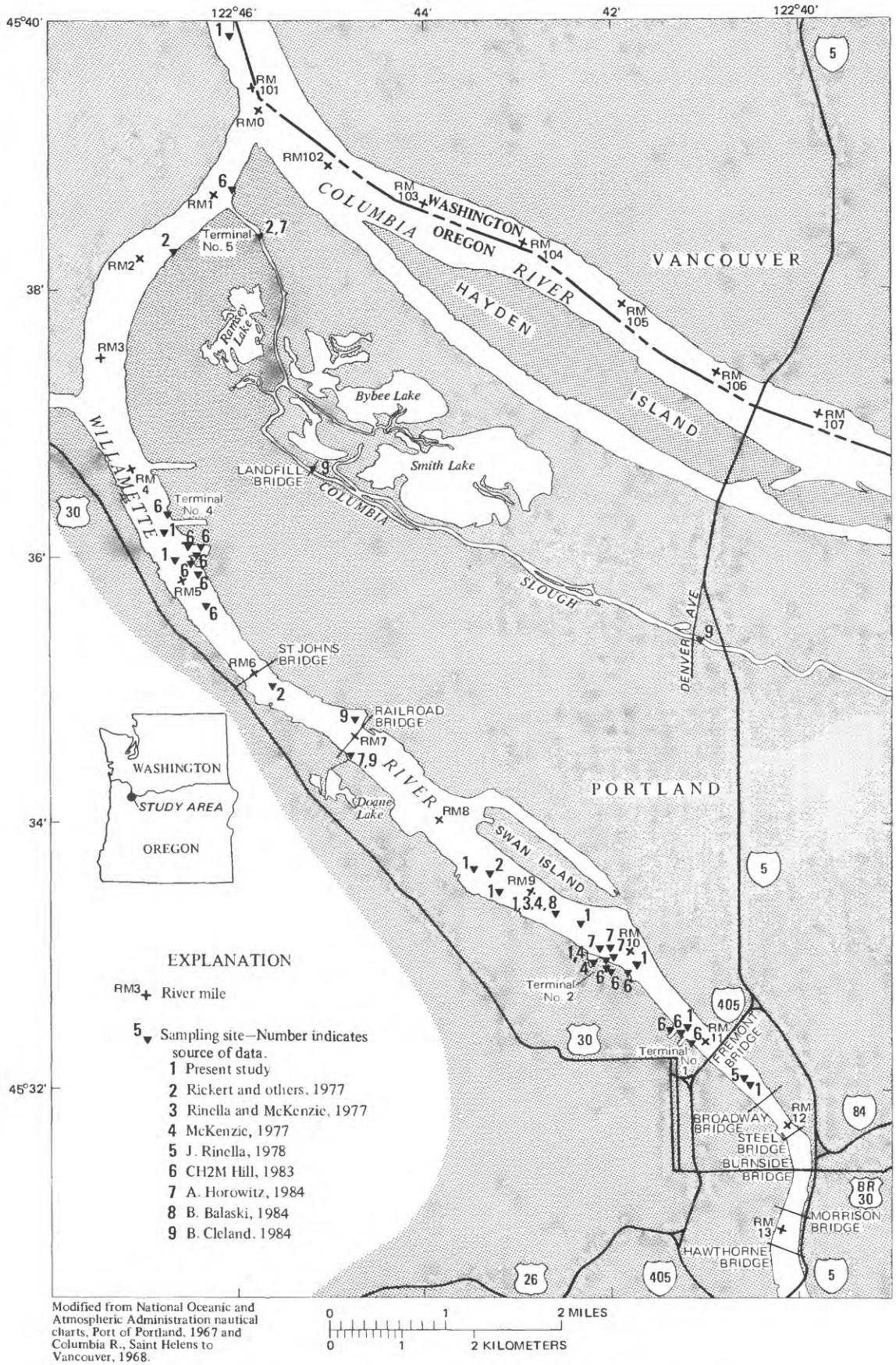
Aquatic organisms rely on a delicate balance of trace elements found in water and bottom material and may be affected if this balance is chemically degraded by contaminants associated with the disposal of dredge spoils. The purpose of this report is to describe chemical concentrations of Portland Harbor bottom material and elutriate-test filtrate (ETF) along with data from earlier studies (published and unpublished).

The objectives of this report are to:

1. Describe concentrations and spatial distribution of selected chemicals associated with Portland Harbor bottom material.

2. Compare estimated polychlorinated biphenyl (PCB) loading from suspended sediment in Portland Harbor to PCB loading from flow-lane disposal.

3. Describe the short-term release of chemicals that occurs when dredge-site bottom material from the Portland Harbor is mixed with disposal-site native water from the Columbia River (elutriation testing).



Modified from National Oceanic and Atmospheric Administration nautical charts, Port of Portland, 1967 and Columbia R., Saint Helens to Vancouver, 1968.

Figure 1.--Location of sampling sites, Portland Harbor, Oregon.

Previous Studies

Data from an earlier study of Portland Harbor (Rickert and others, 1977, p. 19) indicate that bottom material finer than 20 micrometers (μm) in diameter contains concentrations of chromium (Cr), copper (Cu), and mercury (Hg) that are small in comparison with those in local soils, claystones, and shales; however, less than 20-μm bottom-material concentrations of lead (Pb) and zinc (Zn) are relatively large in comparison with those in local soils, claystones, and shales. Trace-element determinations of local soils, claystones, and shales were made on size classes similar to less than 20-μm bottom material. More recent Pb and Zn determinations (1984) of harbor bottom material (A. Horowitz, U.S. Geological Survey, written commun., 1984) indicate that concentrations of these trace metals increase two- to three-fold as particle size decreases. For example, Pb concentrations in bulk sediment were 43 micrograms per gram (μg/g); Pb concentrations in sediment finer than 62 μm in diameter were 72 μg/g; and Pb concentrations in sediment finer than 2 μm were 143 μg/g. Concentrations of cadmium (Cd), Pb, and Zn in bottom-material samples from docking slips between RM 1 and 11 (CH2M Hill, 1983; B. Cleland, U.S. Environmental Protection Agency, written commun., 1984; and B. Balaski, Port of Portland, written commun., 1984) were found to exceed those of local soils, claystones, and shales (Boerngen and Shacklette, 1981; Rickert and others, 1977; Dave Dunnette, Oregon Department of Environmental Quality, oral commun., 1982).

First-generation organochlorine compounds were detected and quantified in harbor sediments at RM 9.2. (Quantified refers to a chemical concentration that is above the minimum reporting level for an analytical method; such a concentration would be reported as an absolute number.) The compounds detected and quantified include aldrin, chlordane, dichloro diphenyl dichloroethane (DDD), dichloro diphenyl dichloroethylene (DDE), dichloro diphenyl trichloroethane (DDT), diazinon, dieldrin, lindane, methyloxychlor, and PCB (McKenzie, 1977; Rinella and McKenzie, 1977). A more recent study (1982) made by the U.S. Environmental Protection Agency (EPA) confirms the occurrence of many of the above first-generation pesticides at RM 9.2 and identifies a possible point source near RM 7.1 (B. Cleland, U.S. Environmental Protection Agency, written commun., 1984). Concentrations of organochlorine compounds near RM 7.1 are significantly larger than those reported earlier at RM 9.2 (McKenzie, 1977; Rinella and McKenzie, 1977). Phenols, phthalate esters, and polycyclic aromatics also were detected in bottom material at RM 7.1. (B. Cleland, U.S. Environmental Protection Agency, written commun., 1984). Phenolic compounds were detected and quantified at concentrations as large as 2,100 μg/kg (micrograms per kilogram) for 2,4-dichlorophenol and 130 μg/kg for 2,4,6-trichlorophenol.

In a few studies (Rinella and McKenzie, 1977; B. Balaski, Port of Portland, written commun., 1984; U.S. Army Corps of Engineers, 1979B; and B. Cleland, U.S. Environmental Protection Agency, unpublished data, 1982) a limited number of chemical analyses were made on elutriate-test filtrate that results from mixing of Portland Harbor bottom material and Columbia River water. Of the trace metals and nutrients examined in these studies, the reported ETF concentrations of Cd, Cu, manganese (Mn), and Hg exceed EPA criteria (U.S. Environmental Protection Agency,

1986). Concentrations of Cd were as large as 158 micrograms per liter (μg/L) [U.S. Army Corps of Engineers, 1979B, p. 48], greatly exceeding the 1.4-μg/L 1-hour-average criteria (U.S. Environmental Protection Agency, 1986). Phthalate esters in these studies were found at concentrations exceeding the 3 μg/L criteria established for the protection of freshwater aquatic life (U.S. Environmental Protection Agency, 1986). Specifically, ETF concentrations of di-N-octyl phthalate at RM 9.7 range from 25 to 40 μg/L. This ETF concentration exceeds that of native harbor water (0.13 μg/L) by two orders of magnitude.

APPROACH AND METHODS

Available data and reports from previous harbor studies, as well as data collected during this investigation at 10 sites by the U.S. Geological Survey in October 1983, were used to describe the concentrations and spatial distribution of selected chemicals in Portland Harbor bottom material. Organic-compound determinations of bottom material were made at each of the 10 sites in the October 1983 sampling. Trace-element and nutrient determinations of bottom material and ETF were made on composite samples in the October sampling. Compositing samples from adjacent sites reduced the number of trace-element and nutrient determinations from ten to five. The river-mile location of composite samples, for graphic purposes, were represented as an average. For example, trace-element and nutrient determinations of bottom material and ETF were made by compositing bottom material collected from RM 11.3 and RM 10.7; an average of 11.0 would be used to represent the composite, when concentrations are plotted by river mile.

Data were compiled and examined using either a frequency-distribution plot, commonly referred to as a "box plot" (SAS, 1982), or a plot of chemical concentration compared to river miles (standard plot). For trace metals in bottom material, standard plots were used when metal concentrations exceeded average concentrations in local soils, claystones, and shales (as reported by Rickert and others, 1977, and by Boerngen and Shacklette, 1981). Box plots were used to describe the frequency distribution of organic-compound concentrations including quartiles and outlying values. Data values reported as less than method detection limits were assigned a value equal to one-half the detection limit. If the lower limit of detection for censored data (data with remarks) was more than an order of magnitude greater than the concentrations reported for uncensored data, censored data were excluded from the box plots.

Estimated PCB loading from the Portland Harbor was calculated using measured suspended-sediment concentrations, streamflow data, and estimated suspended-PCB concentrations. Streamflow and suspended-sediment data were collected at a U.S. Geological Survey National Stream Quality Accounting Network (NASQAN) station located on the Willamette River at RM 12.8. Additional streamflow and sediment-concentration data were obtained from an earlier pilot dredging study (Rinella and McKenzie, 1978). The bottom-material PCB data were obtained from numerous samplings in Portland Harbor.

Sampling-site Selection

Ten bottom-material sampling sites were located within the main navigation channel of Portland Harbor where bottom material was to be dredged (fig. 1 and table 1). Two sites are located near Port of Portland Terminal No. 4, four at mid-channel near Swan Island, two near Port of Portland Terminal No. 2 (one immediately adjacent to the terminal, the other near mid-channel), and another two are located near Terminal No. 1. Native-mixing water for elutriate tests was collected on the Oregon side of the Columbia River at RM 100.5, immediately downstream of the confluence of the Willamette and Columbia Rivers.

Sampling Procedures

The bottom-material samples were obtained at the ten sites by using either a gravity core sampler or ponar grab sampler (depending on sampling conditions). Sampler penetration ranged from 10 cm (centimeter) with the ponar sampler (used only at RM 11.3) to 1 meter with the gravity core sampler. Water samples were collected with a Van Dorn sampler at a depth of 1 meter below water surface. Bottom material, placed in butyrate acetate core liners, and water samples, placed in glass carboys, were chilled and stored at 4 °C. Sampling containers were cleaned with 7.5-percent hydrochloric acid (HCl) and rinsed several times with distilled deionized water before use.

Table 1.--Location of sample sites in Portland Harbor, Oregon, October 1983

Location (river mile)	Latitude	Longitude	Remarks
Willamette River:			
4.3	45°36'13"	122°46'41"	Near Terminal No. 4
4.5	45°36'05"	122°46'36"	Near Terminal No. 4
8.3	45°33'43"	122°43'29"	Mid-channel near Swan Island
8.7	45°33'36"	122°43'08"	Mid-channel near Swan Island
9.2	45°33'20"	122°42'38"	Mid-channel near Swan Island
9.6	45°33'12"	122°42'12"	Mid-channel near Swan Island
9.8	45°33'01"	122°41'58"	Left bank near Terminal No. 2
10.1	45°32'54"	122°41'40"	Mid-channel near Terminal No. 2
10.7	45°32'29"	122°41'19"	Near Terminal No. 1
11.3	45°32'08"	122°40'40"	Near Terminal No. 1
Columbia River:			
100.5	45°39'53"	122°46'04"	Water sample, left bank, downstream of confluence with Willamette River

At least two cores of bottom-material were collected at each site. One core was chilled immediately for future elutriate testing and bulk-sediment metals analyses. The other was extruded from the core liner, placed on acetone-rinsed aluminum foil, and longitudinally sectioned. The sectioned core contents then were longitudinally subsampled and the subsamples placed in specially treated glass containers for organic-compound determinations. Additional subsamples were prepared for particle-size, moisture-content, and total-volatile-solids determinations.

Analytical Methods

Determinations of selected trace metals and nutrients were made by the U.S. Geological Survey Central Laboratory in Arvada, Colorado, using methods described by Fishman and Friedman (1985). Specifically, metals in bottom material and water were first extracted with 0.3 molar HCL and then determined as follows: barium (Ba), beryllium (Be), iron (Fe), and Mn by atomic-adsorption spectrometry (AA); Cd, thallium (Tl), and Zn by AA with graphite furnace; arsenic (As) and selenium (Se) by AA with hydride generation; Cr, Cu, Pb, nickel (Ni), and silver (Ag) by AA with chelation extraction; and Hg by cold vapor AA. Determinations of organic compounds were also made at the Central Laboratory, using methods described by Wershaw and others (1983).

Particle-size analyses were made by the U.S. Geological Survey Oregon Office laboratory in Portland, Oregon. Representative bulk bottom-material subsamples for particle size were analyzed by (1) a visual-accumulation-tube method, for bottom materials between 53 and 2,000 μm in diameter, and (2) a pipet method for bottom materials less than 53 μm in diameter (Guy, 1969). Both methods determine particle size in terms of fall diameter in quiescent distilled water (Stokes law). Moisture content and total-volatile-solids determinations also were made by the Oregon Office laboratory, following methods described by Fishman and Friedman (1985).

To address the short-term release of chemicals into Columbia River disposal-site water in the October 1983 sampling, one part bottom material from the proposed harbor dredge site was mixed with four parts Columbia River disposal-site water (volume/volume for 30 minutes, followed by a 1-hour quiescent period and 0.45-μm filtration--the standard elutriate test as described by Plumb, 1981). A detailed explanation of processing elutriate samples is presented in Fuhrer (1984). The term "release" is used in this report to describe instances where ETF chemical concentrations exceed ambient chemical concentrations in native mixing water (the native water is Columbia River disposal-site water). The modifer "short term" denotes ETF chemical concentrations present at the end of the elutriation-test mixing and settling period (1.5 hours). The ETF and native-mixing water were analyzed for selected metals; bottom material was analyzed for a large number of the chemicals on the EPA priority pollutant list, excluding volatiles (Chapman and others, 1982).

The elutriate test simulates conditions that result in metal dissolution when bottom material is dredged, transported, and deposited at in-water disposal sites. The consumption of dissolved oxygen (DO) during the standard elutriate test may not reflect actual field conditions because DO is often depleted during the mixing portion of the elutriate test and because dredge spoils are often disposed of in well-oxygenated waters. To accurately represent the range of Columbia River disposal-site conditions, both standard and aerated (oxic) elutriate tests were made. Measurable DO was maintained throughout the oxic test by aeration. EPA criteria (U.S. Environmental Protection Agency, 1986) were used to evaluate the release of chemicals during elutriate testing.

QUALITY OF BOTTOM MATERIAL AND ELUTRIATES

Summary of Chemicals in Portland Harbor Bottom Material

Sediment-chemistry data from 1973 to 1984 (including the October 1983 sampling) are compiled in tables 2, 3, and 4. Data from the October 1983 sampling are presented separately, along with grain-size and total-volatile-solids data, in tables 5, 6, and 7. The compiled trace-metal data provide adequate definition of spatial variations; in comparison, organic-chemistry data--although available from 1977 to 1984--are limited in number and available in sufficient detail only for the past few years. Although analytical methods may vary among studies and among data at particular sites, intrasite-metal concentrations, with the exception of Cr, generally remain similar.

The harsh extraction (concentrated hydrofluoric, perchloric, and nitric acids) of Portland Harbor bottom material by Rickert (1977) and Horowitz (U.S. Geological Survey, written commun., 1984) generally results in larger Cr concentrations than does soft extraction (0.3 molar HCl) of Cr in the present study or soft extractions made by EPA (B. Cleland, U.S. Environmental Protection Agency, written commun., 1984 and CH2M Hill, 1983). Variations in Cr concentrations are probably a direct result of the extractants' ability to attack the mineral chromite (Horowitz, 1986). Variations in concentration appear to reflect spatial variability in chemical concentrations and not differences in analytical methods.

Trace Metals

Trace-metal enrichment of Portland Harbor bottom material is evaluated by comparing trace-element concentrations in local rocks, local soils, and worldwide averages of claystones and shales with median trace metal concentrations in Portland Harbor bottom material. Of the trace metals examined in Portland Harbor bottom material from 1973 to 1984 (table 2), median concentrations of Cd, Pb, and Zn exceeded concentrations in rocks, soils, and claystones and shales (table 8).

Grain size is one of the most important factors controlling sediment capacity for collecting and concentrating trace metals and possibly the most important factor causing spatial variability in sediment metal concentration (Forstner and Wittmann, 1979; Horowitz, 1984). In Portland Harbor bottom material, the relations between grain size, as measured by the percentage of bottom material finer than 62 μm, and sediment-metal concentrations of Cd, Pb, and Zn is poorly defined (fig. 2). The enrichment of Cd, Pb, and Zn may be more a function of local contamination sources (maintenance of ocean-going vessels, storm-drain runoff, etc.) than of particle size.

Cadmium enrichment in Portland Harbor bottom material varies with river-mile location (fig. 3). In the lower harbor (RM 0 to 7.1), concentrations range from less than 0.5 to 1.8 μg/g, whereas in the upper harbor (RM 8.3 to 11.3), concentrations range from less than 0.5 to 0.7 μg/g. The larger Cd concentrations in the lower harbor occur outside the main navigation channel, in areas like Columbia Slough (RM 1.2), in slips of Terminal No. 4 (RM 4.5), and adjacent to the outlet from Doane Lake (RM 7.1). Determinations of less than 2-mm bottom

Table 2.--Summary of trace-metal concentrations in Portland Harbor bottom material, 1973-84

[Concentrations reported in μg/g (micrograms per gram) except as noted, < = less than, pct = percent, mm = millimeter, μm = micrometer, "--" = analyses not made. Data Sources: 1 = Present study; 2 = Rickert and others, 1977; 3 = Rinella and McKenzie, 1977; 4 = McKenzie, 1977; 5 = J. Rinella, U.S. Geological Survey, written commun., 1978; 6 = CH2M Hill, 1983; 7 = A. Horowitz, U.S. Geological Survey, written commun., 1984; 8 = B. Balaski, Port of Portland, written commun., 1984; 9 = B. Cleland, U.S. Environmental Protection Agency, written commun., 1984]

Location (river mile)	Data source	Sample collection date	Bottom material size class	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Iron (pct)	Lead	Manganese (pct)	Nickel	Zinc	Mercury	Comments
1.0	6	07-83	<2mm	10.6	110	--	0.6	24	26	3.2	8	0.04	22	115	0.04	Near Terminal No. 5
--	7	07-84	<2mm	--	--	--	<.5	41	26	3.7	43	.06	26	146	--	Columbia Slough
--	2	09-73	<2mm	10	--	--	1	80	10	--	5	--	--	140	.17	Columbia Slough
--	9	08-84	<2mm	9.0	--	1.2	1.5	44	82	--	204	--	32	357	.12	Columbia Slough below Denver Avenue
--	9	08-84	<2mm	4.8	--	.7	1.5	16	28	--	6	--	15	148	.08	Columbia Slough below Landfill Bridge
1.5	2	09-73	<2mm	10	--	--	.5	85	10	--	20	--	--	195	.1	
1.5	2	09-73	<2mm	10	--	--	.5	100	15	--	10	--	--	215	.09	
1.5	2	09-73	<2mm	10	--	--	.5	90	10	--	20	--	--	210	.27	
1.5	2	09-73	<2mm	20	--	--	1	90	15	--	10	--	--	215	.08	
4.3+4.5	1	10-83	<2mm	5	110	--	<1	10	35	1.2	30	.05	30	120	.08	Composite, near Terminal No. 4
4.5	6	07-83	<2mm	12	--	--	1.8	26	52	5.2	236	.04	32	326	.04	Slip 412
4.5	6	07-83	<2mm	12	--	--	--	--	--	--	187	--	--	--	--	Slip 411
4.5	6	12-82	<2mm	9.7	--	--	1.7	15	52	2.2	172	.06	21	261	.05	Slip 410, 411
4.2+5.2	6	12-82	<2mm	7.6	--	--	.6	11	30	2.6	22	.06	17	103	.05	Berth 401, 414, 416 (composite)
6.0	2	09-73	<2mm	10	--	--	.5	55	5	--	10	--	--	145	.14	
6.8	9	08-84	<2mm	5.5	--	.9	.1	27	54	--	3	--	33	126	.07	East side of channel
7.1	9	08-84	<2mm	5.0	--	.7	<.1	19	26	--	3	--	22	147	.08	Near Doane Lake
7.1	7	07-84	<2mm	--	--	--	<.5	58	33	6.1	29	.08	34	127	--	Near Doane Lake
7.1	7	07-84	<63μm	--	--	--	<.5	79	48	6.2	32	.09	35	150	--	Near Doane Lake
7.1	7	07-84	<2μm	--	--	--	1.3	83	116	7.4	56	.11	60	192	--	Near Doane Lake
8.3+8.7	1	10-83	<2mm	5.0	120	--	<1	10	28	1.2	20	.05	30	85	.07	Composite
8.5	2	09-73	<2mm	10	--	--	.5	80	15	--	10	--	--	185	.11	
8.5	2	09-73	<2mm	10	--	--	.5	75	15	--	30	--	--	225	.08	
8.5	2	09-73	<2mm	10	--	--	.1	65	10	--	20	--	--	205	.13	
8.5	2	09-73	<2mm	10	--	--	.5	70	15	--	20	--	--	180	.20	
9.2+9.6	1	10-83	<2mm	4	110	--	<1	10	30	1.2	25	.05	30	110	.13	Composite
9.2	3	05-77	<2mm	3	--	--	--	18	35	2.3	20	.05	--	20	.01	
9.2	8	11-84	<2mm	5	--	--	<1	14	31	1.7	40	.05	15	87	.11	
9.2	8	11-84	<2mm	5	--	--	<1	14	31	1.6	35	.05	15	85	.11	
9.8+10.1	1	10-83	<2mm	5	--	--	<1	10	27	1.2	30	.05	40	90	.08	Composite
9.7	8	11-84	<2mm	2	--	--	.6	14	32	--	37	--	12	684	.10	Slip 201
9.7	8	11-84	<2mm	2	--	--	.7	13	30	--	35	--	13	779	.15	Slip 201
9.7	8	11-84	<2mm	1	--	--	.5	12	31	--	35	--	13	708	.12	Slip 201
9.7	8	11-84	<2mm	2	--	--	.3	12	29	--	25	--	14	436	.11	Slip 201
9.8	8	11-84	<2mm	1	--	--	.3	10	25	--	14	--	13	--	.13	Berth 202
9.8	8	11-84	<2mm	1	--	--	.3	11	27	--	27	--	13	--	.13	Berth 202
9.8	7	07-84	<2mm	--	--	--	<.5	55	34	4.8	11	.09	33	103	--	West side of channel
9.8	7	07-84	<63μm	--	--	--	<.5	87	55	5.4	19	.10	31	130	--	West side of channel
9.8	7	07-84	<2μm	--	--	--	<.5	87	79	6.0	19	.12	55	163	--	West side of channel
9.8+10.7	6	12-82	<2mm	11	--	--	.6	16	40	--	26	--	21	147	.05	Slip 103, 203, 204 (composite)
10+10.8	6	12-82	<2mm	9	--	--	.5	13	34	--	24	--	20	95	.05	Berth 104, 105, 205 (composite)
10.7+11.3	1	10-83	<2mm	3	100	--	<1	10	24	.9	30	.05	20	80	.08	Composite
11.2	5	06-78	<2mm	--	--	--	<1	--	30	--	60	.06	--	110	.10	

Table 3.--Summary of selected organochlorine concentrations and particle-size data for Portland Harbor bottom material, 1977-84

[Concentrations are reported in µg/kg (micrograms per kilogram) except as noted. DDD = dichloro diphenyl dichloroethane, DDE = dichloro diphenyl dichloroethylene, DDT = dichloro diphenyl trichloroethane, PCB = polychlorinated biphenyls, PCN = polychlorinated napthalenes, < = less than, "--" = analyses not made, TOC = Total organic carbon, µg/kg = micrograms per kilogram, pct = percent]

Data sources:
1 = Present study; 6 = CH2M Hill, 1983;
3 = Rinella and McKenzie, 1977; 8 = B. Balaski, Port of Portland, written commun., 1984;
4 = McKenzie, 1977; 9 = B. Cleland, U.S. Environmental Protection Agency, written commun., 1984.

Location (river mile)	Data source	Sample collection date	Aldrin	Chlordane	DDD	DDE	DDT	Dieldrin	Endosulfan	Endrin	Heptachlor	Lindane	Methoxychlor	Mirex	Perthane	Toxaphene	PCB	PCN	TOC (µg/kg)	Particle-size summary <62µm (pct)	Silt (pct)	Clay (pct)	Comments
1.0	6	07-83	<1	<11	<4	<3	<10	<2	<3	<4	<1	--	--	--	--	<108	<45	--	1.20	25	20.9	4.1	Near Terminal No. 5
1.2	9	08-82	<1	<1	20	17	<1	<1	<1	<1	<1	--	--	--	--	<50	115	--	--	--	--	--	Columbia Slough below Denver Avenue
1.2	9	08-82	<1	<1	7	6	--	<1	<1	<1	<1	--	--	--	--	<50	57	--	--	--	--	--	Columbia Slough below Landfill Bridge
4.3	1	10-83	<.1	6	14	3.9	1.3	.3	<.1	<.1	.4	<.1	<1	<.1	--	--	76	--	1.9	75	51	24	Near Terminal No. 4
4.5	1	10-83	<.1	5	8.8	2.9	.8	.2	<.1	<.1	.3	<.1	<.1	<1	--	--	58	--	1.9	65	51	14	Near Terminal No. 4
4.5	6	12-82	<1	<450	<99	<8	<159	<6	<2	<6	<1	--	--	--	--	<136	<45	--	2.57	67	56.9	10.1	Slip 410, 411 (composite)
4.5	6	07-83	<1	<14	<8	<4	<12	<3	<4	<4	<1	--	--	--	--	<23	55	--	1.90	30	23	7	Slip 412
4.2+5.2	6	12-82	<1	<39	<5	<4	<3	<3	<2	<3	<1	--	--	--	--	<47	63	--	1.17	78	59.3	18.7	Berth 401, 414, 416 (composite)
6.8	9	08-82	<1	<1	6	8	<1	<1	<1	<1	<1	--	--	--	--	<50	76	--	--	--	--	--	Near east bank
7.1	9	08-82	<1	<1	613	100	2,700	<1	<1	<1	<1	--	--	--	--	<50	314	--	--	--	--	--	Near Doane Lake
1/ 8.7	1	10-83	<.1	6	5.0	1.4	<.1	.2	<.1	<.1	.3	<.1	<1	<.1	--	--	75	--	1.7	70	53	18	
1/ 9.2	1	10-83	<.1	2	4.8	2.4	<.1	.1	<.1	<.1	.2	<.1	<1	<.1	--	--	40	--	2.3	54	38	16	
9.2	4	02-77	2	8	4.6	3.7	2.7	1	<.1	<.1	<.1	.8	6.1	--	--	--	51	<1	2.3	72	58	14	
9.2	4	02-77	7	10	6.7	7.5	1.4	2.1	<.1	<.1	<.1	<.1	9.0	--	--	--	57	<1	2.3	76	62	14	
9.2	3	05-77	<.1	15	16	9	1.1	5	<.1	<.1	<.1	<.1	<1	--	<.1	<.1	130	<1	--	--	60	12	
9.7	8	11-84	<1	<5	<1	<1	<5	<1	<5	<1	<1	--	--	--	--	<5	550	--	--	95	78	17	Slip 201
9.7	8	11-84	<1	<5	<1	<1	<5	<1	<5	<1	<1	--	--	--	--	<5	354	--	--	92.5	79	13.5	Slip 201
9.7	8	11-84	<1	<5	<1	<1	<5	<1	<5	<1	<1	--	--	--	--	<5	139	--	--	92.5	80	12.5	Slip 201
9.7	8	11-84	<1	<5	<1	<1	<5	<1	<5	<1	<1	--	--	--	--	<5	96	--	--	91	75.5	15.5	Slip 201
9.8	8	11-84	<1	<5	<1	<1	<5	<1	<5	<1	<1	--	--	--	--	<5	98	--	--	89.5	72	17.5	Berth 202
9.8	8	11-84	<1	<5	<1	<1	<5	<1	<5	<1	<1	--	--	--	--	<5	15	--	--	86.5	70	16.5	Berth 202
9.8	1	10-83	<.1	4	2.5	1.9	.7	.4	<.1	<.1	.2	<.1	<1	<.1	--	--	26	--	1.6	60	48	12	
9.8+10.7	6	12-82	<1	<36	<4	<5	<6	<6	<3	<6	<1	--	--	--	--	<90	41	--	1.95	87	70	17	Slip 103, 203, 204 (composite)
10+10.8	6	12-82	<1	<36	<4	<5	<7	<6	<3	<6	<1	--	--	--	--	<90	63	--	1.78	80	65.5	14.5	Berth 104, 105, 204 (composite)
10.1	1	10-83	<.1	10	6.2	<.1	<.1	.2	<.1	<.1	.4	<.1	<1	--	--	--	170	--	1.6	69	54	15	
10.7	1	10-83	<.1	7	4.5	4.8	.4	.2	<.1	<.1	.3	<.1	<1	--	--	--	53	--	1.7	66	52	14	
11.2	1	10-83	<.1	1	.7	.7	.2	.1	<.1	<.1	<.1	<.1	<1	--	--	--	14	--	1.7	13	9	4	

1/ Values represent concentration and particle-size averages from a longitudinally split core sample.

Table 4.--Summary of acid and base-neutral organic concentrations detected and quantified in Portland Harbor bottom material, 1982-84

[Concentrations reported µg/kg (micrograms per kilogram) except where otherwise noted, "--" = value less than detection limit. Data Sources referenced as follows: 1 = present study; 6 = CH2M Hill, 1983; 8 = B. Balaski, Port of Portland, written commun., 1984; 9 = B. Cleland, U.S. Environmental Protection Agency, written commun., 1984]

Location (river mile)	Data source	Sample collection date	Phthalate esters				Polycyclic aromatics								
			Butyl benzyl phthalate	Dimethyl phthalate	Di-N-butyl phthalate	bis(2-Ethylhyexyl phthalate	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(g,h,i)perylene	Benzo(a)pyrene	Chrysene
Columbia Slough	9	08-84	8	4	98	160	--	--	90	19	--	--	22	--	49
1.0	6	12-82	--	--	--	400	--	--	--	--	--	--	--	--	--
4.3	1	10-83	--	--	--	--	30	--	--	--	--	--	--	--	--
4.5	6	12-82	--	--	--	400	--	--	--	--	--	--	--	--	--
4.5	1	10-83	--	--	--	--	100	--	--	--	--	--	--	--	--
6.8	9	08-84	6	--	30	98	5	--	100	5	--	--	--	--	12
7.1	9	08-84	--	--	40	180	--	17	290	45	--	--	19	--	100
8.7	1	10-83	--	--	--	85	--	--	--	--	--	--	--	--	--
9.2	1	10-83	--	--	--	40	--	--	--	--	--	--	--	--	--
9.7	8	11-84	--	--	1,730	2,200	--	--	--	--	--	--	--	--	--
9.7	8	11-84	--	--	865	1,930	--	--	--	--	--	--	--	--	--
9.7	8	11-84	--	--	1,100	1,865	--	--	--	--	--	--	--	--	--
9.7	8	11-84	--	--	1,965	1,865	--	--	--	--	--	--	--	--	--
9.8	8	11-84	--	--	1,000	930	--	--	--	--	--	--	--	--	--
9.8	8	11-84	--	--	1,130	1,000	--	--	--	--	--	--	--	--	--
9.8	1	10-83	--	--	--	120	--	--	--	--	--	--	--	--	--
10.1	1	10-83	--	--	--	60	--	--	--	--	--	--	--	--	--
10.7	1	10-83	--	--	--	--	--	--	--	--	--	--	--	--	--
11.3	1	10-83	--	--	--	90	80	80	80	170	100	270	--	250	260

Location (river mile)	Data source	Sample collection date	Polycyclic aromatics					Monocyclic aromatic	Phenols			Comments
			Fluoranthene	Fluorene	Naphthalene	Phenanthrene	Pyrene	1,4-Dichlorobenzene	2,4-Dichlorophenol	Phenol	2,4,6-Trichlorophenol	
Columbia Slough	9	08-84	74	10	--	--	140	--	--	--	--	Below landfill bridge
1.0	6	12-82	--	--	--	--	--	--	--	--	--	Near Terminal No. 5
4.3	1	10-83	20	10	50	--	45	--	--	--	--	Near Terminal No. 4
4.5	6	12-82	--	--	50	--	--	--	--	--	--	Slip 412
4.5	1	10-83	--	50	--	80	--	--	--	--	--	Near Terminal No. 4
6.8	9	08-84	58	7	--	--	10	13	--	13	--	Near east bank
7.1	9	08-84	330	49	--	--	520	13	2,100	--	130	Near Doane Lake outlet
8.7	1	10-83	19	--	19	--	20	--	--	--	--	
9.2	1	10-83	9	--	35	--	26	--	--	--	--	
9.7	8	11-84	--	--	--	--	--	--	--	--	--	Slip 201
9.7	8	11-84	--	--	--	--	--	--	--	--	--	Slip 201
9.7	8	11-84	--	--	--	--	--	--	--	--	--	Slip 201
9.7	8	11-84	--	--	--	--	--	--	--	--	--	Slip 201
9.8	8	11-84	--	--	14	--	--	--	--	--	--	Slip 201
9.8	8	11-84	--	--	--	--	--	--	--	--	--	Berth 202
9.8	1	10-83	13	--	--	--	28	--	--	--	--	Berth 202
10.1	1	10-83	--	--	10	--	20	--	--	--	--	Near Terminal No. 2
10.7	1	10-83	--	--	20	--	--	--	--	--	--	
11.3	1	10-83	310	150	180	760	550	--	--	--	--	

Table 5.--Selected trace-metal, nutrient, and carbon analyses of Portland Harbor bottom-material composites, October 1983

[Concentrations are given in micrograms per gram (µg/g) except where otherwise indicated. Metals in bottom material are reported as "total recoverable" when less than 95 percent of the trace metals are solubilized; otherwise they are reported as "total." "--" indicates analyses not made, < = less than, P = phosporus, C = carbon, N = nitrogen, g/kg = gram per kilogram, mg/kg = milligram per kilogram]

Location of sample composites (river mile)	Antimony, total	Arsenic, total	Barium, total recoverable	Cadmium, total recoverable	Chromium, total recoverable	Copper, total recoverable	Cyanide, total	Iron, total recoverable, percent	Lead, total recoverable	Manganese, total recoverable, percent	Mercury, total recoverable
4.3 + 4.5	<1	5	110	<1	10	35	<1	1.2	30	0.05	0.08
8.3 + 8.7	<1	2	120	<1	10	28	<1	1.2	20	.05	.07
(9.2 + 9.6)A[1/]	<1	6	110	<1	10	30	<1	1.2	20	.05	.12
(9.2 + 9.6)B	<1	3	110	<1	10	30	<1	1.2	30	.05	.14
9.8 + 10.1	<1	5	110	<1	10	27	<1	1.2	30	.04	.08
10.7 + 11.3	<1	3	100	<1	10	24	<1	0.9	30	.04	.08

Location of sample composites (river mile)	Nickel, total recoverable	Selenium, total	Zinc, total recoverable	Ammonia, (mg/kg, as N)	Nitrogen, ammonia + organic, (mg/kg, as N)	Phosphorus, total, (mg/kg as P)	Carbon, inorganic, (g/kg, as C)	Carbon, inorganic + organic, total, (g/kg, as C)	Chemical oxygen demand, total, (mg/kg)	Oil and grease, (mg/kg)
4.3 + 4.5	30	<1	120	250	1,400	900	0.2	19	--	<1
8.3 + 8.7	30	<1	85	260	1,300	790	.2	17	55,000	<1
(9.2 + 9.6)A[1/]	30	<1	110	330	1,700	840	.4	23	69,000	1
(9.2 + 9.6)B	30	<1	110	290	1,700	890	.5	22	76,000	<1
9.8 + 10.1	40	<1	90	210	1,100	870	.2	16	69,000	<1
10.7 + 11.3	20	<1	80	220	1,300	880	.2	17	43,000	2

[1/] Samples A and B are replicate samples of composited bottom materials from river miles 9.2 and 9.6.

Table 6.--Concentrations of organic compounds in Portland Harbor bottom material, October 1983

[Concentrations given in micrograms per kilogram (μg/kg); "u" = unable to determine because of interference; "--" analyses not made, "<" = less than, DDD = dichloro diphenyl dichloroethane, DDE = dichloro diphenyl dichloroethylene, DDT = dichloro diphenyl trichloroethane, 2,4-D = 2,4-dichloro phenoxy acetic acid, 2,4-DP = 2,4-dichloro phenoxy propanoic acid, 2,4,5-T = 2,4,5-trichloro phenoxy acetic acid]

	Concentrations at indicated location (river mile)									
Compounds	11.3	10.7	10.1	9.8	[1]/ 9.2A	9.2B	[2]/ 8.7A	8.7B	4.5	4.3
Organochlorine compounds:										
Aldrin	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chlordane	1	7	10	4	2	3	5	7	5	6
DDD	.7	4.5	6.2	2.5	4.3	5.4	4.5	5.6	8.8	14
DDE	.7	4.8	<.1	1.9	2.4	2.4	2.7	<.1	2.9	3.9
DDT	.2	.4	<.1	.7	<.1	<.1	<.1	<.1	.8	1.3
Dieldrin	.1	.2	.2	.4	<.1	.1	.2	.1	.2	.3
Endosulfan	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Endrin	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Gross polychlorinated biphenyls (PCB)	14	53	170	26	39	41	67	83	58	76
Gross polychlorinated napthalenes (PCN)	u	u	u	u	u	u	u	u	u	u
Heptachlor	<.1	.3	.4	.2	.2	.2	.3	.3	.3	.4
Heptachlor epoxide	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Lindane	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Methoxychlor	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Mirex	--	<.1	--	<.1	<.1	--	<.1	--	--	<.1
Herbicide compounds:										
Silvex	--	<.1	--	<.1	<.1	--	<.1	--	--	<.1
2,4-D	--	<.1	--	<.1	<.1	--	<.1	--	--	<.1
2,4-DP	--	<.1	--	<.1	<.1	--	<.1	--	--	<.1
2,4,5-T	--	<.1	--	<.1	<.1	--	<.1	--	--	<.1
Halogenated aliphatics:										
bis(2-Chloroethoxy)methane	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Hexachlorobutadiene	<10	<20	<10	<15	<20	<30	<20	<30	<30	<20
Hexachlorocyclopentadiene	<10	<25	<10	<20	<30	<40	<20	<30	<40	<20
Hexachloroethane	<10	<30	<20	<25	<30	<40	<30	<40	<40	<30
Ethers:										
4-Bromophenyl phenyl ether	<10	<25	<10	<40	<25	<30	<20	<20	<60	<30
bis(2-Chloroethyl)ether	<10	<10	<10	<10	<10	<20	<10	<10	<20	<10
bis(2-Chloroisopropyl)ether	<10	<10	<20	<10	<10	<10	<10	<10	<10	<10
4-Chlorophenyl phenyl ether	<10	<20	<10	<30	<20	<20	<20	<20	<50	<25
Phthalate esters:										
Butyl benzyl phthalate	<10	<30	<10	<25	<30	<20	<10	<20	<50	<30
Diethyl phthalate	<30	<40	<20	<50	<40	<30	<50	<50	<40	<50
Dimethyl phthalate	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Di-N-butyl phthalate	<30	<20	<20	<20	<25	<20	<30	<30	<20	<15
Di-N-octylphthalate	<10	<20	<10	<20	<20	<10	<10	<10	<30	<20
bis(2-Ethylhexyl)phthalate	90	<20	60	120	40	40	110	60	<50	<20
Pesticides:										
Isophorone	<20	<30	<20	<30	<35	<50	<30	<40	<50	<30
2,3,7,8-Tetrachlorodibenzo-p-dioxin	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200

Table 6.--Concentrations of organic compounds in Portland Harbor bottom material, October 1983--Continued

Compounds	Concentrations at indicated location (river mile)									
	11.3	10.7	10.1	9.8	1/ 9.2A	9.2B	2/ 8.7A	8.7B	4.5	4.3
Polycyclic aromatics:										
Acenaphthene	80	<10	<10	<20	<10	<20	<10	<20	100	50
Acenaphthylene	30	<10	<10	<10	<10	<10	<10	<10	<10	<10
Anthracene	80	<10	<20	<20	<20	<30	<20	<30	<20	<50
Benzo(a)anthracene	170	<20	<10	<20	<20	<20	<10	<20	<40	<20
Benzo(b)fluoranthene	100	<35	<10	<30	<30	<30	<10	<20	<60	<35
Benzo(k)fluoranthene	270	<35	<10	<30	<30	<30	<10	<20	<60	<35
Benzo(g,h,i)perylene	<200	<390	<100	<350	<350	<260	<100	<210	<680	<360
Benzo(a)pyrene	250	<45	<20	<40	<40	<30	<10	<30	<80	<40
Chrysene	260	<20	<10	<20	<20	<20	<10	<20	<40	<20
Dibenzo(a,h)anthracene	<100	<150	<40	<140	<140	<100	<40	<80	<270	<140
Fluoranthene	310	<10	<10	13	9	<10	18	20	<40	20
Fluorene	150	<10	<10	<10	<10	<10	<10	<10	50	10
Indeno(1,2,3cd)pyrene	<100	<240	<60	<210	<220	<160	<70	<130	<420	<220
Naphthalene	180	20	10	14	30	40	18	20	50	50
Phenanthrene	760	<10	<20	<20	<20	<20	<20	<30	<80	<40
Pyrene	550	<20	20	28	22	30	11	30	70	45
Monocyclic aromatics:										
1,2-Dichlorobenzene	<10	<10	<10	<10	<10	<20	<10	<20	<20	<10
1,3-Dichlorobenzene	<10	<10	<10	<10	<10	<20	<10	<20	<20	<10
1,4-Dichlorobenzene	<10	<10	<10	<10	<10	<20	<10	<20	<20	<10
2,4-Dinitrotoluene	<10	<10	<10	<20	<10	<30	<10	<30	<60	<35
2,6-Dinitrotoluene	<20	<40	<20	<60	<40	<40	<30	<40	<100	<95
Hexachlorobenzene	<10	<20	<10	<25	<20	<20	<15	<20	<50	<20
Nitrobenzene	<10	<10	<10	<10	<10	<20	<10	<20	<20	<10
1,2,4-Trichlorobenzene	<10	<10	<10	<10	<10	<20	<10	<20	<20	<10
Compounds related to PCB:										
2-Chloronaphthalene	<10	<10	<10	<10	<10	<20	<10	<10	<10	<10
Nitrosamines and other:										
Benzidine	<10	<40	<10	<30	<40	<30	<10	<20	<70	<40
3,3-Dichlorobenzidine	<30	<85	<10	<75	<75	<60	<25	<50	<150	<80
N-Nitrosodiphenylamine	<10	<20	<10	<30	<20	<20	<20	<20	<40	<20
N-Nitrosodi-N-propylamine	<20	<30	<20	<30	<35	<50	<30	<40	<50	<30
Phenols and cresols:										
4-Chloro-3-methylphenol	<200	<10	<20	<10	<10	<40	<10	<20	<30	<10
2-Chlorophenol	<10	<40	<10	<10	<10	<20	<10	<20	<20	<10
2,4-Dichlorophenol	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
2,4-Dimethylphenol	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
4,6-Dinitro-2-methylphenol	<20	<40	<20	<60	<40	<50	<30	<40	<100	<50
2,4-Dinitrophenol	<30	<70	<20	<100	<70	<80	<60	<70	<170	<70
2-Nitrophenol	<10	<15	<10	<15	<15	<20	<15	<20	<20	<15
4-Nitrophenol	<300	<75	<20	<100	<70	<90	<60	<80	<100	<95
Pentachlorophenol	<30	<75	<20	<100	<70	<80	<60	<70	<180	<90
Phenol	<30	<50	<40	<30	<30	<40	<50	<40	<30	<30
2,4,6-Trichlorophenol	<10	<10	<10	<10	<10	<20	<10	<20	<20	<10

1/ Samples from RM 9.2A and 9.2B are longitudinal splits from the same core that was also split for particle-size analyses.

2/ Samples from RM 8.7A and 8.7B are longitudinal splits from the same core that was also split for particle size analyses.

Table 7.--Particle size, total-volatile solids, and moisture content of Portland Harbor bottom matarial, October 1983

["--" = analyses not made, pct = percent]

Sampling location (river mile)	Percent particle size finer than specified diameters (in micrometers)												Total volatile solids (pct)	Moisture (pct)
	Sands						Silts				Clays			
	700	500	350	175	125	88	62	31	16	8	4	2		
11.3	100	97	80	18	16	15	13	10	7	5	4	3	2.8	36
10.7	100	100	100	98	93	82	66	47	32	22	14	10	7.0	54
10.1	100	100	100	93	88	80	69	49	32	22	15	10	6.7	47
9.8	100	100	100	100	95	74	60	41	29	24	12	11	7.0	49
9.6	100	100	100	100	100	98	93	62	39	25	17	13	8.8	54
9.2A[1/]	100	99	94	68	63	61	59	52	36	23	18	11	6.0	50
9.2B	100	100	99	74	62	54	48	42	30	19	15	9	--	--
9.2C[2/]	100	100	98	79	70	64	57	47	30	21	14	9	--	--
8.7A[3/]	100	100	100	98	92	82	73	51	36	23	20	13	6.5	53
8.7B	100	100	100	99	91	79	68	46	30	21	14	11	--	--
8.3	100	100	100	99	97	89	77	42	32	17	10	5	8.1	50
4.5	100	99	94	79	77	72	65	50	34	22	14	11	6.4	51
4.3	100	100	97	88	86	82	75	60	42	28	24	14	7.4	49

1/ Samples from river miles 9.2A and 9.2B are longitudinal splits from the same core that was also split for organic analyses.

2/ Sample from river mile 9.2C is a subsample from the cores that were processed in the elutriate test (table 5).

3/ Samples from river miles 8.7A and 8.7B are longitudinal splits from the same core that was also split for organic analyses.

Table 8.--Comparison of trace element concentrations in Portland Harbor bottom material, 1973-84, with trace-metal concentrations found in rocks, soils, and claystones and shales

[Concentrations are reported in μg/g (micrograms per gram), "--" = analyses not made. Modes are shown in parenthesis. Data sources are shown in brackets as the following: [1] = Wedepohl and others, 1970a; [2] = Wedepohl and others, 1970b; [3] = Rickert and others, 1973; [4] = Dave Dunnette, Oregon Department of Environmental Quality, oral commun., 1982]

Trace metal	Portland Harbor bottom material[1/]				Trace-metal concentrations						
	Slough	Slips	Berths	Main Channel	Rocks [1]	Rocks [2]	Rocks[2/] [3]	Rocks[3/] [4]	Soils[4/] [4]	Soils[3/] [3]	Claystones[6/] and shales [3]
Cadmium	1.2	0.7	0.4	0.5	0.08-0.2	--	--	--	--	--	--
Lead	24	36	23	20	--	1.2-8.5	<10-15 (<10)	9-16	18	15	20
Zinc	147	436	99	127	--	119	<25-159 (<25)	53-70	51	68	88

1/ Median concentrations.

2/ Values represent concentration ranges and modes (parenthetical values) in 36 rock samples from throughout the Willamette River basin.

3/ Values represent concentration ranges from 80 stations throughout Oregon, 1979-81.

4/ Values represent average concentrations from 64 stations located in western Oregon, 1971-81.

5/ Lead values represent modal concentrations of 50 soils; zinc value represents average concentration of 3 soils.

6/ Values represent worldwide averages.

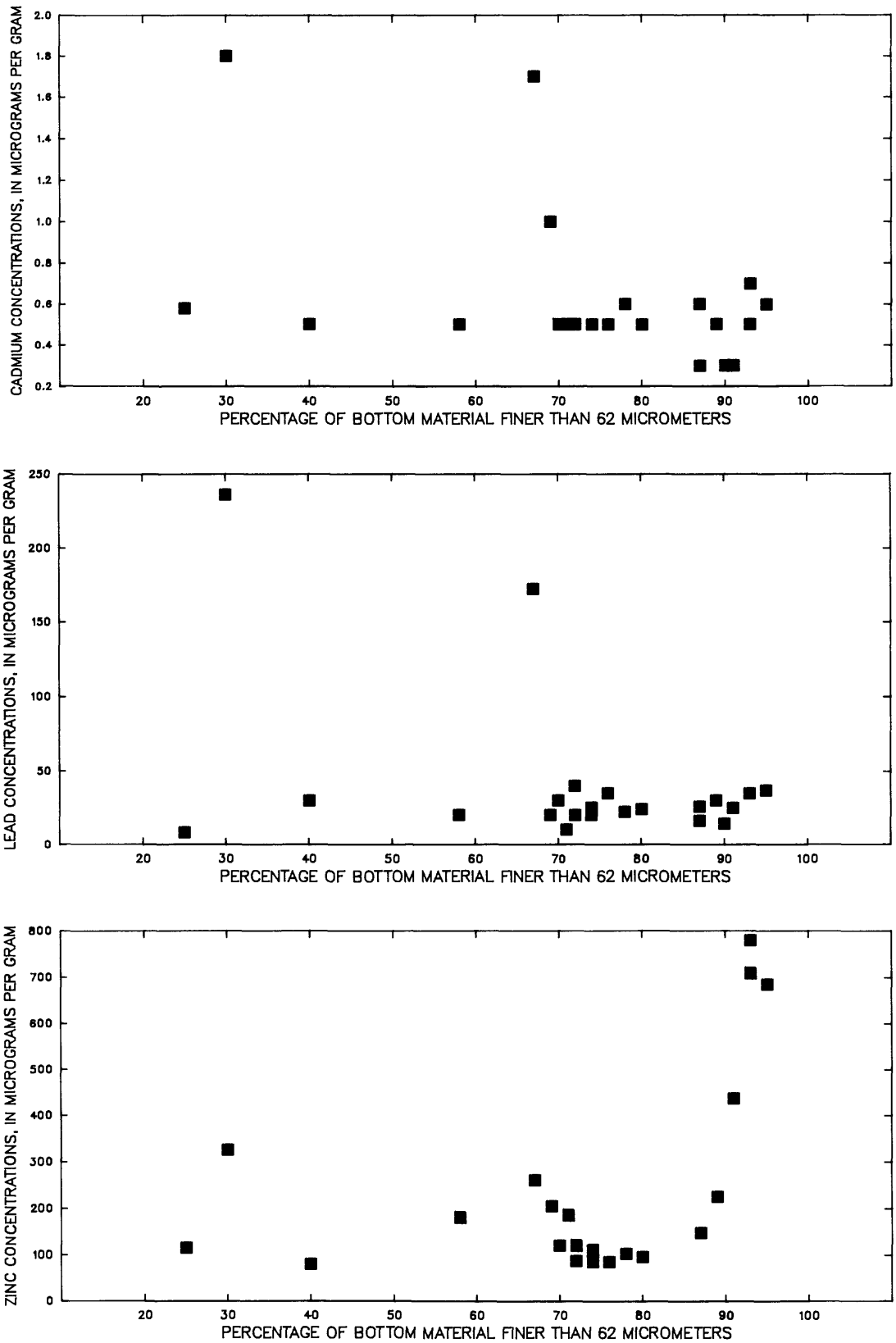


Figure 2.--Relation of cadmium, lead, and zinc in Portland bottom material to the percentage of bottom material finer than 62 micrometers in diameter. Data sources in addition to the October 1983 sampling are as follows: McKenzie (1977); CH2M Hill (1983); and B. Balaski, Port of Portland, written commun., 1984.

material from Columbia Slough, which flows adjacent to a solid-waste landfill and into Portland Harbor, show Cd concentrations as large as 1.5 μg/g (table 2). Investigations of Columbia Slough bottom material (A. Horowitz, U.S. Geological Survey, written commun., 1984) show even larger concentrations (3.1 μg/g) associated with clay-size particles (less than 4 μm).

As mentioned earlier, Pb and Zn are enriched in Portland Harbor sediments. The most notable Pb enrichment occurs in Columbia Slough below Denver Avenue and in slips of Terminal No. 4, where concentrations are as large as 236 μg/g (fig. 4). Large concentrations of Pb are associated with slips at Terminal No. 4 (RM 4.5). The small Pb concentration (30 μg/g) found within the navigation channel adjacent to terminal No. 4 (RM 4.3 + 4.5) indicates that Pb enrichment is localized to Terminal No. 4 (table 5).

Zn enrichment occurs at several locations in the harbor between RM 8 and RM 10, most notably at Terminal No. 2 (RM 9.7), where concentrations are as large as 779 μg/g. The largest concentrations of Zn are localized at slips. Concentrations in the navigation channel immediately adjacent to Terminal No. 2 are as small as 103 μg/g and suggest that Zn enrichment is localized to the slips at Terminal No. 2. In the October 1983 sampling, concentrations of Zn in the main channel (RM 9.8 + 10.1) adjacent to Terminal No. 2 were found to be as small as 90 μg/g (table 5). A similar situation exists at Terminal No. 4 (RM 4.5), except that Zn enrichment is not quite as pronounced as at Terminal 2 (fig. 5 and table 2).

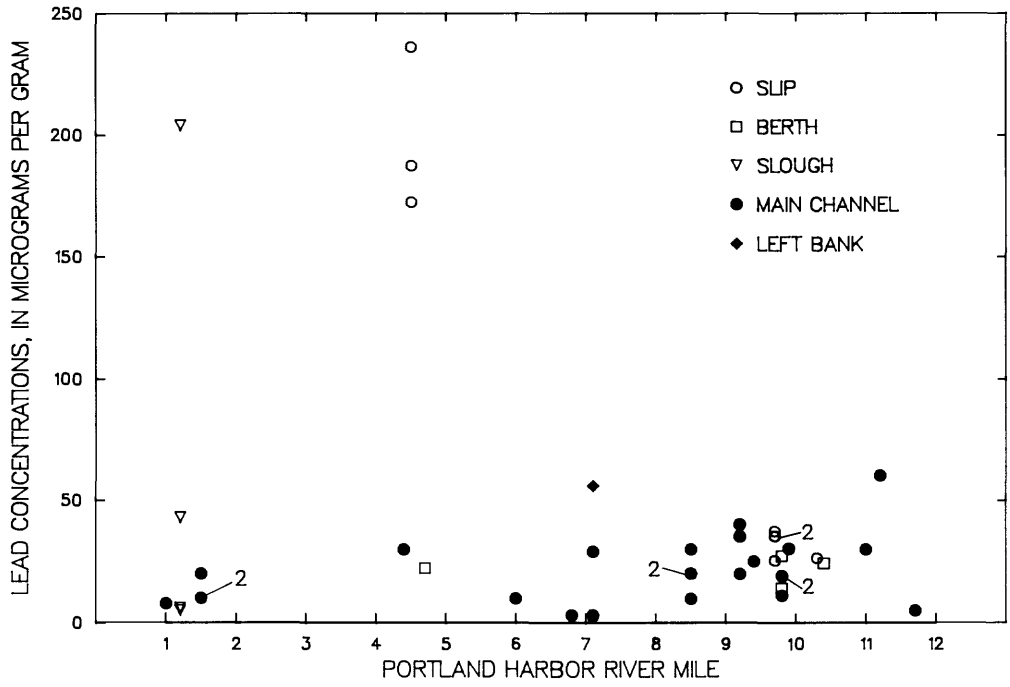


Figure 3.--River-mile variation of cadmium concentrations in Portland Harbor, 1973-84. Data sources in addition to the October 1983 sampling are as follows: Rickert and others (1977), J. Rinella, U.S. Geological Survey, written commun., 1978; CH2M Hill (1983); B. Cleland, U.S. Environmental Protection Agency, written commun., 1984; A. Horowitz, U.S. Geological Survey, written commun., 1984; and B. Balaski, Port of Portland, written commun., 1984. Numbers adjacent to symbols represent number of observations.

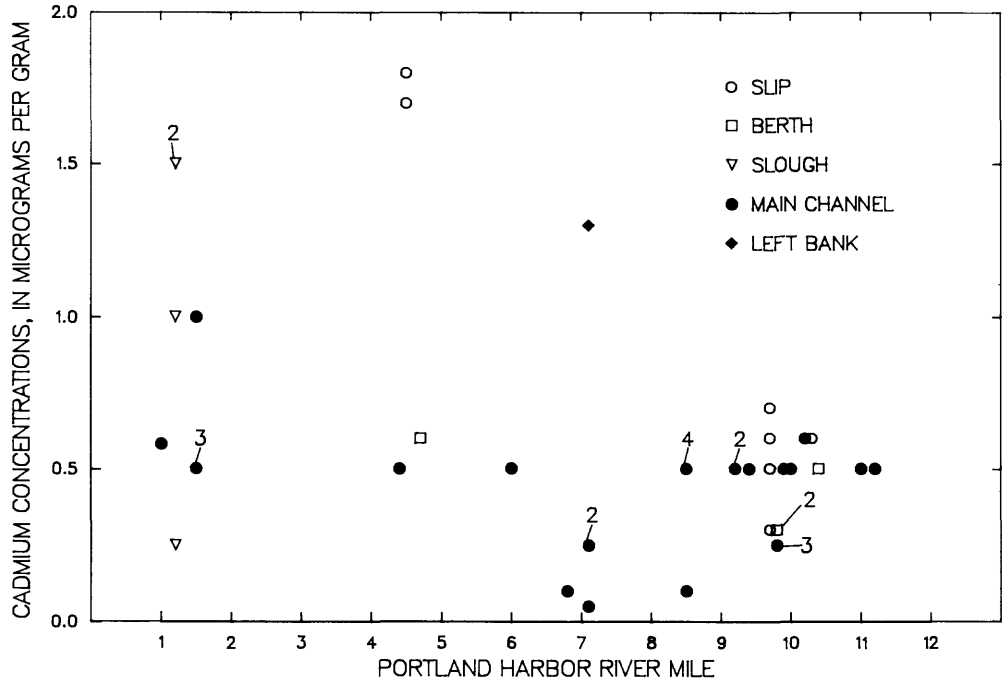


Figure 4.--River-mile variation of lead concentrations in Portland Harbor, 1973-84. Data sources in addition to the October 1983 sampling are as follows: Rickert and others (1977), J. Rinella, U.S. Geological Survey, written commun., 1978; CH2M Hill (1983); B. Cleland, U.S. Environmental Protection Agency, written commun., 1984; and B. Balaski, Port of Portland, written commun., 1984. Numbers adjacent to symbols represent number of observations.

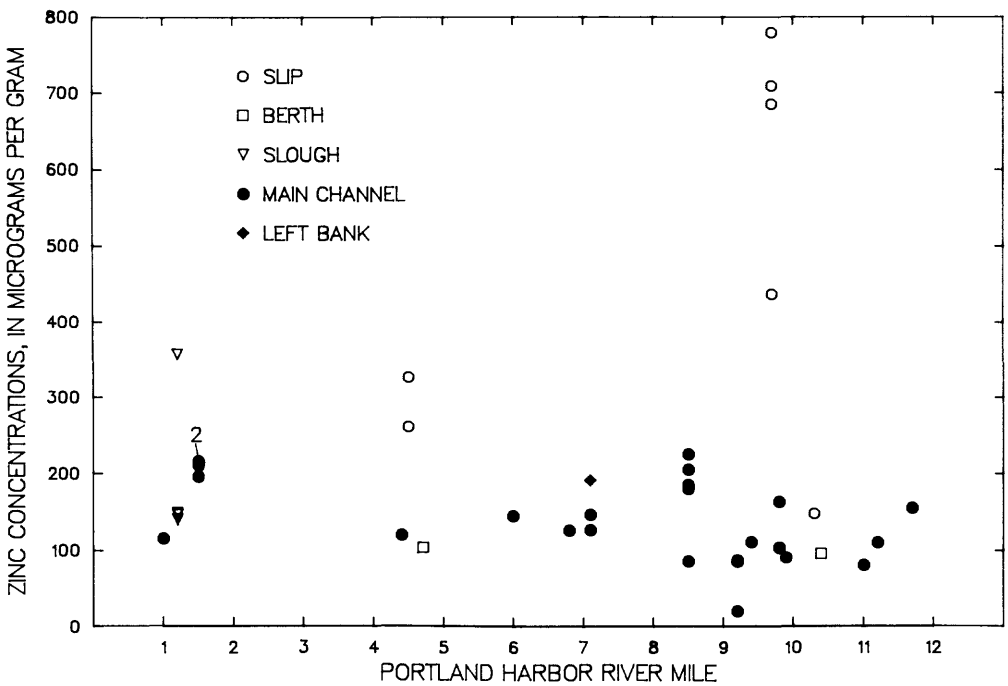


Figure 5.--River-mile variation of zinc concentrations in Portland Harbor, 1973-84. Data sources in addition to the October 1983 sampling are as follows: Rickert and others (1977); Rinella and McKenzie (1977); J. Rinella, U.S. Geological Survey, written commun., 1978; CH2M Hill (1983); B. Balaski, Port of Portland, written commun., 1984; B. Cleland, U.S. Environmental Protection Agency, written commun., 1984; and A. Horowitz, U.S. Geological Survey, written commun., 1984. Number adjacent to symbol represents number of observations.

Organic Compounds

Of the organochlorine compounds examined in Portland Harbor sediments between 1977 and 1984 (including those of the October 1983 study), chlordane, DDD, DDE, DDT, dieldrin, and PCB were detected and quantified in at least 30 percent of the samples tested (tables 3 and 6). Box plots have been used to show the distribution of organochlorine compounds in Portland Harbor (fig. 6). Numerous acid and base-neutral compounds, including phthalate esters, polycyclic aromatics, monocyclic aromatics, and phenols were detected (tables 4 and 6). However, organic extractions of bottom sediment are considered semi-quantitative because percent recoveries are unknown. A duplicate extraction of bottom material could yield concentrations which might vary an order of magnitude.

The median concentration of DDT (1.1 µg/kg) is slightly smaller than the DDE concentration (2.1 µg/kg) and smaller than the DDD concentration (4.6 mg/L) [fig. 6]. These results are to be expected, considering that the DDT slowly degrades to DDD and DDE. The degradation rate of DDT is dependent on several factors which include, but are not limited to, the amount of ultra-violet light, the concentration of iron and aluminum and the redox state of bottom sediment (Eisenreich and others, 1980; Hartley and Kidd, 1984). At RM 7.1, however, the concentration of DDT (2,700 µg/kg) is much larger than the concentrations of DDD and DDE (613 µg/kg and 100 µg/kg, respectively). The ratio of DDT to DDE or DDD is large and might

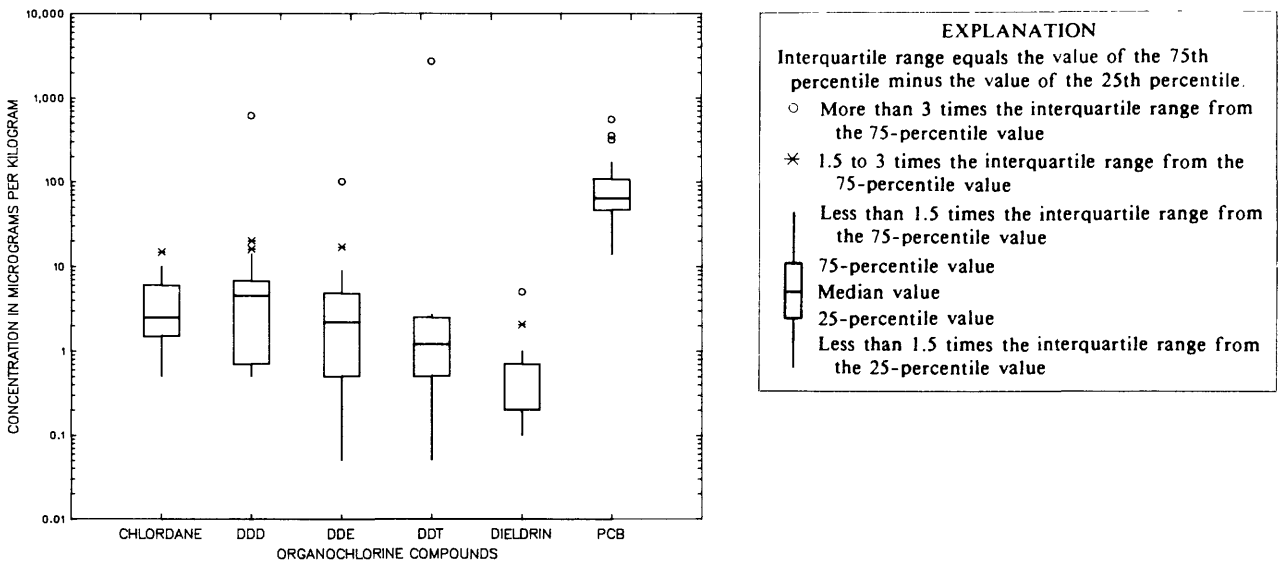


Figure 6.--Frequency distribution of organochlorine concentrations in Portland Harbor bottom material, 1977-84. Data sources in addition to the October 1983 sampling are as follows: McKenzie (1977); Rinella and McKenzie (1977); B. Cleland, U.S. Environmental Protection Agency, written commun., 1984; CH2M Hill (1983); and B. Balaski, Port of Portland, written commun., 1984. DDD = dichloro diphenyl dichloroethane, DDE = dichloro diphenyl dichloroethylene, DDT = dichloro diphenyl trichloroethane, and PCB = polychlorinated biphenyls.

suggest recent contamination near Doane Lake outlet at RM 7.1. Doane Lake outlet was not sampled in the October 1983 study because the zone was not to be dredged. In the October 1983 study, the largest concentrations of DDT and associated degradation products were located near Terminal No. 4 (RM 4.3 and 4.5). DDT concentrations at these two sites were as large as 1.3 and 0.8 μg/kg, and concentrations of degradation products like DDD were as large as 14 and 8.8 μg/kg, respectively, (table 6).

Results of the October 1983 sampling, along with those from earlier studies (McKenzie, 1977, and Rinella and McKenzie, 1977), indicate that PCB compounds are ubiquitous in Portland Harbor sediments. Median concentrations are nearly 65 μg/kg; however, the maximum concentration is significantly larger (550 μg/kg), extending well beyond the interquartile range (fig. 6). Concentrations that exceed three times the interquartile range occur near both Terminal No. 2 and Doane Lake outlet (fig. 6 and table 3). In the October 1983 study, PCB concentrations in the navigation channel, both upstream (RM 9.8) and downstream (RM 9.2) of Terminal No. 2, are 26 and 39 μg/kg, respectively. The smaller concentrations in the navigation channel indicate that PCB enrichment occurs in Terminal No. 2 slips and not in the navigation channel. However, this is not conclusive evidence that slips are the source, because particle-size data indicate that PCB enrichment is strongly governed by the settling of fine particles in the low-energy zones of the slips.

Little is known about the suspended-sediment transport of PCB compounds in Portland Harbor. Other river studies have shown that PCB concentrations in areas of deposition are controlled by the distribution of fine-grained material (Frink and others, 1982). Partly because of flow reversals in Portland Harbor, the reach from RM 3 to RM 10 is primarily depositional (Rickert and others, 1977). In this reach, particle size appears paramount in controlling PCB concentration in bottom material. On the basis of relations observed between PCB concentration and different particle-size groupings for data collected between 1977 and 1984 (table 3), the percentage of particles finer than 62 micrometers in diameter (<62 μm) is significantly correlated ($\rho \leq 0.005$) to PCB concentration (table 9). As would be expected given the relation between particle size and PCB concentration, bottom material with the largest PCB concentrations also contains the largest percentage of <62-μm particles (fig. 7). Conversely, bottom material with the smallest percentage of <62-μm particles contains the smallest PCB concentration. Thus larger PCB concentrations may be a consequence of the settling of finer sediments within the slips rather than of docking activities within the slips.

Of the acid and base-neutral organic compounds examined, di-N-butyl phthalate and bis(2-ethylhexyl) phthalate occur in concentrations as large as 1,965 and 2,200 μg/kg, respectively. These compounds are most concentrated at Terminal No. 2 (RM 9.7), particularly in slip 201 and berth 202 (table 4). Data from the October 1983 samplings show that concentrations of these chemicals within the main navigation channel (table 6) are at least an order of magnitude smaller than concentrations in slip 201 and berth 202 and suggest that, for the most part, phthalate enrichment is localized to Terminal No. 2.

Table 9.--Significance levels of Kendal Tau correlation coefficients for polychlorinated biphenyls and particle size in Portland Harbor bottom material, 1977-84

[μm = micrometers]

Particle size in percent finer than	Significance level
350 μm	0.71
125 μm	0.75
62 μm	0.005
4 μm	0.56

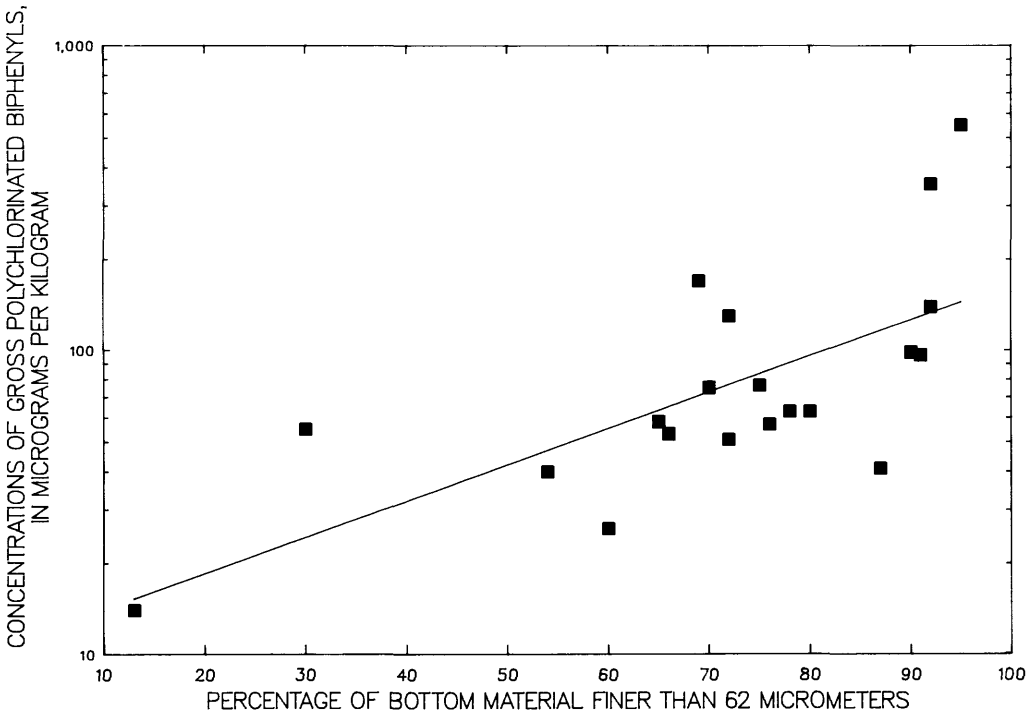


Figure 7.--Relation between percentage of bottom material finer than 62 micrometers in diameter and concentrations of gross polychlorinated biphenyls. The relation is described by the following equation: $Y = 10.8 \times e^{(0.027\ X)}$, where Y = polychlorinated biphenyl concentration in micrograms per kilogram and X = the percentage of bottom material finer than 62 micrometers. Data sources in addition to the October 1983 sampling are as follows: McKenzie, 1977; Rinella and McKenzie, 1978; B. Cleland, U.S. Environmental Protection Agency, written commun., 1984; CH2M Hill, 1983; and B. Balaski, Port of Portland, written commun., 1984.

Of the 16 polycyclic aromatics (PA) examined, 14 were detected and quantified in Portland Harbor bottom material (table 4). In the October 1983 sampling, PA compounds occur with greater frequency and at generally larger concentrations at RM 11.3 (table 6). Results of a second subsampling and organic extraction from the sample bottle, however, show all PA concentrations from RM 11.3 to be below analytical detection limits. The occurrence of a PA-enriched globule in the first subsampling (and not in the second) may explain this discrepancy.

The Doane Lake outlet to Portland Harbor appears to be the sole identifiable source of phenolic compounds; near the outlet, the concentrations of 2,4-dichlorophenol and 2,4,6,-trichlorophenol are 2,100 μg/kg and 130 μg/kg, respectively (table 4). The October 1983 sampling shows 2,4-dichlorophenol concentrations upstream and downstream of the Doane Lake outlet that are orders of magnitude smaller than those found at the outlet (table 6).

Estimated Polychlorinated Biphenyl Loading to the Columbia River from the Willamette River

Polychlorinated biphenyl loading to the Columbia River from the Willamette River suspended sediment was estimated and compared to the PCB load associated with the flow-lane disposal of Portland Harbor bottom material. This estimate required calculation of Willamette River suspended-sediment load along with the mass of bottom material dredged from Portland Harbor (dredge load). The dredge load, based on an annual 440,000 cubic-yard projection (U.S. Army Corps of Engineers, 1979b, p. 3-4) and 50 percent-moisture by volume (table 7) is 0.27×10^6 tons/year. The suspended-sediment load for the period of record (1973-1982) is 1.2×10^6 tons/year; thus the dredge load is nearly equal to one-quarter of the suspended load by weight.

The PCB load from dredging can be calculated directly, but the load attributed to suspended sediment must be estimated because the suspended-PCB concentration is unknown. The estimate of suspended PCB load is based on two assumptions: first, that suspended-PCB concentrations are equal to bottom-material concentrations, and second, that loss of PCB from bottom material, as dissolved, is insignificant. If the suspended-PCB concentration increases with the percentage of particles <62 μm, as does bottom-material PCB (fig. 7), the first assumption may underestimate the suspended-PCB concentration, because suspended sediments contain a larger percentage of fine particles. For example, the median percentage of particles <62 μm in Portland Harbor bottom material is 73.5 percent compared to 88 percent for suspended sediment. Therefore the median-PCB concentration in bottom material, 63 μg/kg, was used as a conservative estimate of suspended-PCB concentration and as a representative concentration for determining the dredge-PCB load. The use of the median percentage of particles <62 μm (88 percent) to estimate the suspended-sediment PCB concentrations, based on the relation between particle size and PCB concentration in bottom material (fig. 7), would have increased the estimated-PCB concentration to 116 μg/kg. The resulting suspended-PCB load, 72 kg/yr, is nearly five times the dredge-PCB load of 15 kg/yr (table 10). By using the 25th and 75th-percentile bottom-PCB concentrations--41 and 115 μg/kg respectively--as estimates of suspended-PCB concentration, the suspended load ranges from over three to nearly nine times the dredge

load (table 10). In addition, the 75th-percentile PCB load is nearly equal to the load derived using a value of 88 percent, the median percentage of suspended sediment <62 μm in diameter to estimate suspended-PCB concentration based on the relation in figure 7. In other words, if suspended-PCB concentrations are particle-size dependent, as is PCB concentration in bottom material, then the resultant suspended-PCB load would probably equal the 75th-percentile load of 132 μg/kg.

Table 10.--Estimated loads of Portland Harbor polychlorinated biphenyls (PCB) from dredging compared to suspended-sediment transport

[μg/kg = microgram per kilogram, kg/yr = kilogram per year]

PCB, in μg/kg		PCB load, in kg/yr		
Suspended sediment[1]	Bottom material[2]	Suspended sediment	Dredging	Ratio of suspended-sediment PCB load to dredge load
41	63	47	15	3.1
63	63	72	15	4.8
115	63	132	15	8.8

[1]Suspended-PCB concentrations are assumed equal to the 25, 50, and 75 percentile bottom-material PCB concentrations.
[2]Median-PCB concentration in bottom material.

Polychlorinated biphenyl loads, whether suspended or dredged or both, can bioaccumulate if they average ≤0.014 μg/L for a 24-hour interval (U.S. Environmental Protection Agency, 1986). The 0.014-μg/L criterion can be converted to a suspended-PCB concentration (critical PCB concentration) by multiplying it by a unit conversion factor (10^6) and then dividing the product by the suspended-sediment concentration (table 11). The suspended-sediment concentration corresponds to a flow which is equaled or exceeded a certain percentage of the time. As an example, the daily mean flow of 112,000 ft^3/s (cubic feet per second) is equaled or exceeded 5 percent of the time (fig. 8). On the basis of the sediment-transport curve, this flow corresponds to a suspended-sediment concentration of 70 mg/L (milligrams per liter) and a critical PCB concentration of 200 μg/kg (table 11). Thus, for 5 percent of the time, or 10 days in an average year, the flow is such that if suspended-PCB concentrations exceed 200 μg/kg for 24 hours or more, suspended-PCB concentrations violate the EPA standard of 0.014 μg/L.

At present there are few data that describe the fate of PCB compounds in the lower Columbia River estuary. In the few areas sampled between Columbia River miles 3 and 18, PCB bottom-material concentrations are one to two orders of magnitude smaller than concentrations in Portland Harbor (Fuhrer and Rinella, 1983; Fuhrer, 1984; and Fuhrer and Horowitz, 1988). Until studies addressing PCB transport and deposition are made, potential effects of flow-lane disposal on sediment quality in the lower Columbia River will remain unclear.

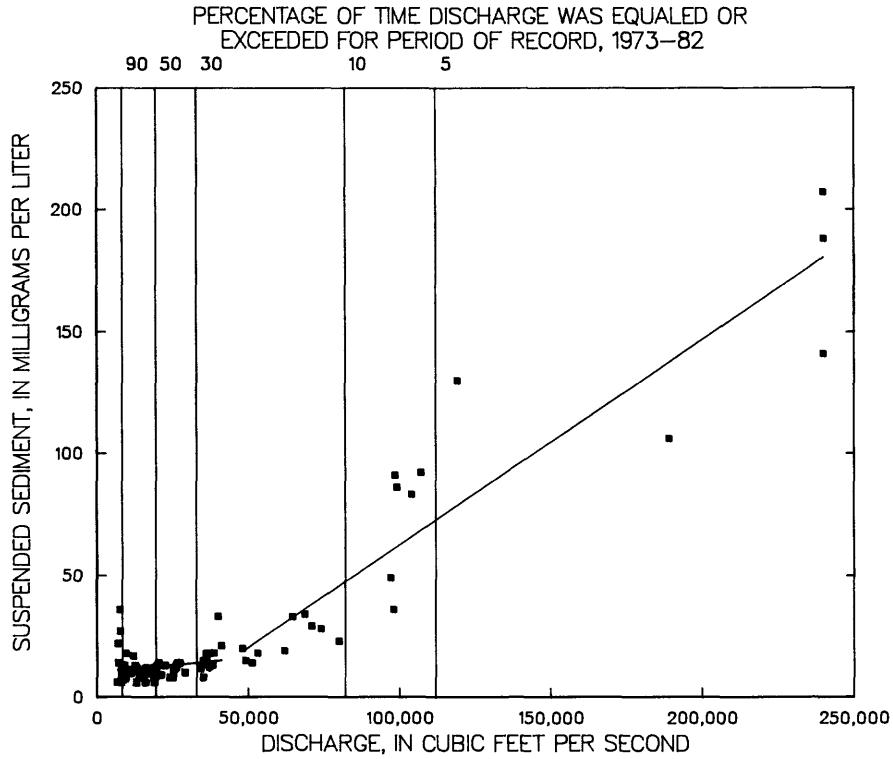


Figure 8.--Relation between stream discharge, flow duration, and suspended-sediment concentration in Portland Harbor, 1973-82. The equation for low flow is $Y = 1.0 \times 10^{-4} X + 10.4$, where Y = suspended-sediment concentration in milligrams per liter and X = discharge in cubic feet per second. The equation for high flow is $Y = 7.8 \times 10^{-4} X - 17.1$, where Y = suspended-sediment concentrations in milligrams per liter and X = discharge in cubic feet per second.

Table 11.--Critical polychlorinated biphenyl (PCB) concentration in suspended sediment

[ft^3/s = cubic feet per second, mg/L = milligrams per liter, $\mu g/kg$ = micrograms per kilogram]

Discharge exceeded[1], in percent	Discharge, in ft^3/s	Suspended sediment, in mg/L	Critical PCB[2], in $\mu g/kg$
5	112,000	70	200
10	81,900	47	300
15	32,700	30	470
50	19,300	12	1,160
90	8,270	11	1,270

[1]Percent of time that daily mean discharge, in ft^3/s, or suspended-sediment concentration, in mg/L, was equaled or exceeded, for the period of record, 1973-1982 (Friday and Miller, 1984).

[2]The 24-hour average suspended-PCB concentration that, if equaled or exceeded, violates the EPA 24-hour-average freshwater chronic criteria of 0.014 $\mu g/L$ PCB (U.S. Environmental Protection Agency, 1986).

Chemical Analyses of Elutriate Tests

Of the metals examined in the October 1983 sampling, Sb (antimony), Ba, Be, Cd, Fe, Pb, Mn, Hg, Ni, Se, Tl, and Zn show no substantial concentrations in standard and oxic ETF (table 12); nor do they exceed EPA criteria (U.S. Environmental Protection Agency, 1986). The disposal of dredged materials would not appear to affect the local concentrations of these metals. ETF ammonia concentrations (table 12) also fall below the 1-hour-average criteria (U.S. Environmental Protection Agency, 1986).

Conversely, copper did display significant concentrations in oxic ETF. Copper releases were as large as 19 μg/L (RM 11.3 + 10.7), compared to 3 μg/L in the corresponding standard ETF. Furthermore, for corresponding samples, Cu releases in oxic ETF consistently exceeded those in standard ETF. The difference between oxic and standard-test Cu release could result from the oxidation of both Cu organic acid complexes and Fe sulfides, or it could be an artifact of the method used to aerate the oxic test. Under reducing conditions, organic material--present in sediment and interstitial water--forms Cu organic acid complexes (chelates), which either directly precipitate or adsorb on bottom material (Forstner and Wittmann, 1979, p. 224). These chelates effectively immobilize the Cu ion and upon oxidation they may release the Cu back into solution (Burton and Liss, 1976, p. 48; Forstner and Wittmann, 1979, p. 219), causing the larger ETF Cu concentration in the oxic test. Also, under reducing conditions, Fe is likely to be in the form of sulfides and the observed differences in test concentrations may be explained on the basis of Fe sulfide dissolution. The Fe sulfides likely coprecipitate with Cu in the reduced interstitial water of bottom material (Forstner and Wittmann, 1979, p. 219). During the oxic test the continuous supply of oxygen served to release more and more Fe and Cu, hence larger Fe and Cu concentrations in the oxic ETF (table 12). The similar ratio of Fe to Cu in standard and oxic ETF, 7.3 and 7.9 respectively, is consistent with this theory of coprecipitation.

As mentioned earlier, the larger oxic-ETF Cu release may be an artifact of the method used to aerate the oxic test. Because the aeration step involved the bubbling of air into the elutriate-test mixture during the 1-hour settling period, more fine particles remained suspended at the time of filtration than during the standard test. Because the presence of suspended-particulate material quickly clogged the 0.45-μm filter, numerous filter changes and higher pressures were used during the oxic-test filtration step. The sample for filtration was withdrawn from the upper 2 to 3 cm of the elutriate-test mixture. Suspended particulates less than 0.45 μm in diameter in this interval can be largely colloidal Fe and incorrectly reported as dissolved Fe (Forstner and Wittmann, 1979, p. 82). The passage of these colloids along with sorbed Cu through the filter could account for the larger ETF Fe and Cu concentrations from the oxic test as well as the smaller ETF Fe and Cu in the standard test.

EPA criterion for the protection of freshwater aquatic life (U.S. Environmental Protection Agency, 1986) limits Cu concentrations to 5.7 μg/L (1-hour average, assuming a hardness of 30 mg/L as calcium carbonate). Oxic-ETF Cu concentrations in the upper harbor (RM 8.3 to 11.3) exceed EPA criterion and range in concentration from 7 to 19 μg/L. One-hour average Cu concentrations associated with the flow-lane disposal of Portland Harbor dredged material would probably be smaller than 5.7 μg/L, because ETF Cu concentrations reflect only dilution occurring in the hopper dredge. Much larger dilution could occur during flow-lane disposal.

Table 12.--Chemical analyses of filtrate from native mixing water and elutriate tests for Portland Harbor, October 1983

[Concentrations reported in µg/L (micrograms per liter) except as noted. NA = not applicable, "--" = analyses not made, µS/cm = microsiemens per centimeter at 25° Celsius, N = nitrogen, P = phosphorus, mg/L = milligrams per liter, ETF = elutriate test filtrate]

Sampling location (river mile)	Type of sample	Dissolved oxygen[1/] Upper layer (mg/L)	Dissolved oxygen[1/] Lower layer (mg/L)	Lab pH (units)	Specific conductance (uS/cm	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Copper	Iron	Lead
Columbia														
101	Native water	NA	NA	NA	166	<1	1	20	<0.5	0.03	<1	1	19	1
Willamette														
4.5+ 4.3	Standard ETF	0.1	0.0	6.8	145	<1	3	17	<.5	.60	<1	2	140	1
8.7+ 8.3	Standard ETF	1.2	.2	6.9	131	<1	2	16	<.5	<.01	<1	3	150	1
9.6+ 9.2	Standard ETF	.2	.0	6.6	204	<1	3	20	<.5	.12	<1	7	180	<1
10.1+ 9.8	Standard ETF	3.0	.3	6.9	134	<1	2	14	<.5	.09	<1	2	43	<1
11.3+10.7	Standard ETF	3.0	0.2	7.0	128	<1	2	14	<.5	<.01	<1	3	22	1
Willamette														
4.5+ 4.3	Oxic ETF	5.2	5.0	6.9	102	<1	2	9	<.5	.01	<1	3	230	1
8.7+ 8.3	Oxic ETF	5.4	5.3	6.9	116	<1	2	9	<.5	.15	<1	10	140	1
9.6+ 9.2	Oxic ETF	6.0	5.6	6.8	104	<1	3	16	<.5	.09	<1	13	310	<1
10.1+ 9.8	Oxic ETF	6.6	6.6	6.9	107	<1	1	9	<.5	.08	<1	7	210	1
11.3+10.7	Oxic ETF	6.5	6.6	6.9	94	<1	2	10	<.5	.16	<1	19	150	2

Sampling location (river mile)	Type of sample	Manganese	Mercury	Nickel	Selenium	Silver	Thallium	Zinc	Ammonia as N (mg/L)	Organic carbon Dissolved[2/] (mg/L)	Organic carbon Total[3/] (mg/L)	Ammonia, nitrogen + organic as N (mg/L)	Phosphorus as P (mg/L)	Total phenols (mg/L)
Columbia														
101	Native water	4	<0.1	1	<1	<1	<1	1.6	0.062	2.0	5.6	0.60	0.055	<1
Willamette														
4.5+ 4.3	Standard ETF	290	<.1	4	<1	<1	<1	--	7.9	8.3	--	7.8	.008	--
8.7+ 8.3	Standard ETF	240	<.1	8	<1	<1	<1	2.6	6.5	7.8	20	8.2	.005	56
9.6+ 9.2	Standard ETF	270	<.1	3	<1	<1	<1	.9	8.6	7.3	48	9.9	.009	56
10.1+ 9.8	Standard ETF	310	<.1	2	<1	<1	<1	2.9	5.4	7.2	17	3.7	.013	75
11.3+10.7	Standard ETF	300	<.1	2	<1	<1	<1	.5	4.4	6.3	--	5.1	.009	--
Willamette														
4.5+ 4.3	Oxic ETF	110	<.1	5	<1	<1	<1	1.6	5.3	12	--	7.5	.017	--
8.7+ 8.3	Oxic ETF	120	<.1	3	<1	<1	<1	4.4	5.2	12	--	8.3	.013	--
9.6+ 9.2	Oxic ETF	130	<.1	10	<1	<1	<1	2.5	5.6	10	--	5.0	.018	--
10.1+ 9.8	Oxic ETF	150	<.1	6	<1	<1	<1	4.0	4.8	6.4	--	4.7	.013	--
11.3+10.7	Oxic ETF	130	<.1	5	<1	<1	<1	5.1	3.5	6.2	--	4.4	.016	--

1/ Measured in the upper and lower layer of the elutriate-test mixture prior to filtration.

2/ Analysis of filtrate that passed through a 0.45-micrometer (pore-size) membrane silver filter.

3/ Analysis of whole-water sample.

SUMMARY

Upland disposal sites for dredge spoils from Portland Harbor are nearly full. Flow-lane disposal of these spoils to the nearby Columbia River may be an alternative. In October of 1983 the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, collected bottom-material and water samples from Portland Harbor to determine concentrations of trace metals and organic compounds in elutriate-test filtrate and bottom material. These data were combined with data from earlier harbor studies and evaluated with respect to chemical concentrations in local soils, spatial location within the harbor, and U.S. Environmental Protection Agency criteria for quality of water.

Of the trace metals examined in bottom materials from the Portland Harbor, concentrations of Cd, Pb, and Zn are enriched in selected areas as compared with average concentrations in local rocks and soils. Cadmium enrichment, considered as slight, occurs in Columbia Slough and in slips in the lower harbor (RM 0 to 7), where concentrations range from less than 0.5 to 1.8 μg/g. The largest concentrations of Pb and Zn (236 and 779 μg/g, respectively) occur at Port of Portland Terminals 4 and 2, respectively. Concentrations of these metals in the adjacent navigation channel are relatively small, suggesting that the maximum enrichment is localized around the terminals.

Of the organochlorine compounds examined in bottom material, chlordane, DDD, DDE, DDT, dieldrin, and PCB compounds were detected and quantified at least 30 percent of the time. The Doane Lake outlet to Portland Harbor (RM 7.1) appears to be an area of large DDT concentrations (2,700 μg/kg). This DDT concentration exceeds the corresponding degradation product concentrations for DDD and DDE, suggesting recent movement of DDT into Portland Harbor. PCB compounds appear to be ubiquitous in harbor bottom material; concentrations as large as 550 μg/kg occur in Port of Portland Terminal No. 2. Concentrations occurring in terminal berths and slips are generally larger than those found in the harbor navigation channel and are believed to be a consequence of fine particles settling in the low-energy zones of the slips.

On an annual basis, it is estimated that the Willamette River contributes nearly five times (72 kg/yr) the suspended-PCB load to the Columbia River than would flow-lane disposal. It should be noted, however, that the suspended PCB-load calculation assumes that suspended-PCB concentrations of the Willamette River are equal to the median PCB concentrations in Portland Harbor bottom material.

Of the trace metals examined in oxic elutriate-test filtrate, concentrations of Cu in the upper harbor (RM 8.3 to 11.3) were found to exceed U.S. Environmental Protection Agency criteria for the protection of aquatic life. ETF Cu concentrations exceeding these criteria (5.7 μg/L) range from 7 to 19 μg/L. The release of Cu occurred during oxic elutriation and is probably an accurate estimate of the effect of flow-lane disposal into well oxygenated water of the Columbia River, although dilution is not taken into consideration.

SELECTED REFERENCES

Boerngen, J.G., and Shacklette, H.T., 1981, Chemical analyses of soils and other surficial materials of the conterminous United States: U.S. Geological Survey Open-File Report 81-0197, 145 p.

Burton, J.D., and Liss, P.S., 1976, Estuarine chemistry: Great Britain, Academic Press, 229 p.

Chapman, P.M., Romber, G.P., and Vigers, G.A., 1982, Design of monitoring studies for priority pollutants: Water Pollution Control Federation, v. 54, no. 3, p. 292-297.

CH2M Hill, 1983, River bottom sampling and analysis report: CH2M Hill, prepared for Port of Portland, PD497.050.1, 40 p.

Eisenreich, S.J., Johnson, T.C., and Evans, J., 1980, Polychlorinated biphenyl and other microcontaminants--sediment interactions in Lake Superior, Chap. 4 in Baker, R.A., ed., Contaminants and sediments volume 1, Fate and transport, case studies, modeling, toxicity: Ann Arbor Michigan, Ann Arbor Science, p. 67-94.

Fishman, M.J., and Friedman, L.C., 1985, Methods for the determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 5, Chapter A1, 709 p.

Forstner, U., and Wittmann, G.T.W., 1979, Metal pollution in the aquifer environment: New York, Springer-Verlag, 486 p.

Friday, J., and Miller, S.J., 1984, Statistical summaries of streamflow data in Oregon - volume 2. Western Oregon: U.S. Geological Survey Open-File Report 84-454, 249 p.

Frink, C.R., Sawhney, B.L., Kulp, K.P., and Fredette, C.G., 1982, Polychlorinated biphenyls in Housatonic River sediments in Massachusetts and Connecticut: Determination, distribution, and transport: U.S. Geological Survey Bulletin no. 800, 23 p.

Fuhrer, G.J., 1984, Chemical analyses of elutriates, native water, and bottom material from Chetco, Rogue, and Columbia Rivers in western Oregon: U.S. Geological Survey Open-File Report 84-0133, 80 p.

Fuhrer, G.J., and Horowitz, A.J., 1989, The vertical distribution of chemicals in sediments of the proposed Columbia River deep-draft navigation channel, Oregon: U.S. Geological Survey Water-Resources Investigations Report 88-4099, 45 p.

Fuhrer, G.J. and Rinella, F.A., 1983, Analyses of elutriates, native water and bottom material in selected rivers and estuaries in western Oregon and Washington: U.S. Geological Survey Open-File Report 82-922, 147 p.

Guy, H.P., 1969, Laboratory theory and methods for sediment analyses: U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 5, Chapter C1, 58 p.

Hartley, D., and Kidd, H., eds., 1984, The agrochemicals handbook: Royal Society of Chemistry, Unwin Brother Limited, p. A118.

Horowitz, A.J., 1984, A primer on trace-metal sediment chemistry: U.S. Geological Survey Open-File Report 84-709, 118 p.

_____ 1986, Comparison of methods for the concentration of suspended sediment in river water for subsequent chemical analysis: Environmental Science and Technology, v. 20, no. 2, p. 155-160.

McConnell, R.J., Blahm, T.H., and Laird, M.C., 1979, Portland Harbor pilot dredging study and sediment bioassay tests: National Marine Fisheries Services, Seattle, Washington 41 p.

McKenzie, S.W., 1977, Analyses of bottom material from the Willamette River, Portland harbor, Oregon: U.S. Geological Survey Open-File Report 77-740, 8 p.

Plumb, R.H., Jr., 1981, Procedure for handling and chemical analysis of sediment and water samples: Technical Report EPA/CE-91-1, Prepared by Great Lakes Laboratory, State University College at Buffalo, N.Y., for the U.S. Environmental Protection Agency/Corps of Engineers Technical Committee on Criteria for Dredged and Fill Material: U.S. Army Engineers Waterways Experimental Station, Corps of Engineers, Vicksburg, Mississippi, p. 2-28.

Rickert, D. A., Kennedy, V. C., McKenzie, S. W., and Hines, W. G., 1977, A synoptic survey of trace metals in bottom sediments of the Willamette River, Oregon: U.S. Geological Survey Circular 715-F, 27 p.

Rinella, J.F., and McKenzie, S.W., 1977, Elutriation study of Willamette River bottom material and Willamette-Columbia River water: U.S. Geological Survey Open-File Report 78-28, 8 p.

_____, 1978, Monitoring water quality during pilot dredging in the Willamette and Columbia Rivers, Oregon: U.S. Geological Survey Open-File Report 78-554, 16 p.

Sainsbury. J.P., 1970, Willamette River bottom deposit and suspended solids studies 1968, 1969, and 1970: Oregon Department of Environmental Quality, 45. p.

SAS Institute, 1982, SAS user's guide: Statistics: SAS Institute, Curray, North Carolina, 584 p.

Schmitt, C.J., Ribick, M.A., Ludke, J.L., and May, T.W., 1983, National pesticide monitoring program: Organochlorine residues in freshwater fish, 1976-79: U.S. Fish and Wildlife Service Resource Publication 152, 62 p.

Thomas, N.A., 1970, Sediment oxygen demand investigations of the Willamette River, Portland, Oregon: Federal Water Pollution Control Administration Report, National Field Investigations Center, 22 p.

U.S. Army Corps of Engineers, 1979a, Dredging in Portland Harbor: U.S. Army Engineer District, Portland Corps of Engineers, p. 10-G.

_____ 1979b, Portland Harbor dredging and Columbia River in-water disposal water-quality investigations: U.S. Army Engineer District, Portland Corps of Engineers, Navigation Division Research and Evaluation Report No. 1-79, 61 p.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: Washington, D.C., EPA-440/9-76-023, 501 p.

_____ 1986, Quality criteria for water: Washington, D. C., EPA-440/5-86-001.

Walsh, D. F., Berger, B. L., and Bean, J. R., 1977, Residues in fish, wildlife, and estuaries: Pesticides Monitoring Journal, v. 11, no. 1, June 1977, p. 5-33.

Wedepohl, K. H., ed., 1970a, Cadmium abundance in rock-forming minerals, Chapter 48-D, in Handbook of geochemistry: Springer-Verlag, New York, p. 30-E-2.

_____ 1970b, Zinc abundance in common igneous rock types; crustal abundance, Chapter 30-E, in Handbook of geochemistry: New York, Springer-Verlag, p. 30-E-2.

Wershaw, R. L., Fishman, M. J., Grabbe, R. R., and Lowe, L. E., 1983, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 5, Chapter A3, 173 p.