LEVELS OF POLYCHLORINATED DIBENZO-P-DIOXINS (PCDDS), DIBENZOFURANS (PCDFS), AND POLYCHLORINATED BIPHENYLS (PCBS) IN THE HACKENSACK RIVER AND NEWARK BAY, NEW JERSEY USA

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Introduction

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), and biphenyls (PCBs) are recognized as ubiquitous and persistent chemicals in sediments and biota in the Newark Bay, New Jersey USA estuary [1,2]. Newark Bay is an enclosed estuary located in the heavily urbanized and industrialized New York City NY / Newark NJ (NY/NJ) metropolitan area and formed by the confluence of the Passaic and Hackensack Rivers in the north and the Arthur Kill and Kill Van Kull Rivers in the south. Several on-going and historical sources of dioxin and PCB contamination have been identified [1,3,4]. Some researchers speculate that the levels of these contaminants are decreasing due to the success of efforts to limit inputs of pollutants in natural waterways through restrictions of certain compounds, control of point sources, municipal sewage treatment facility upgrades, and the remediation of Superfund sites [5]. In response to current conditions in the estuary, state and federal environmental agencies recently announced a plan to restore a 17-mile reach of the Passaic River and to undertake a multi-year program to evaluate environmental conditions throughout the estuary [6].

As part of an investigation of the levels and risks posed by the occurrence of chemicals in sediments in the lower Hackensack River, the concentrations of PCDD/Fs and PCBs were measured in surface and buried sediments. For comparative purposes, sediments were collected and tested for PCDDs, PCDFs, and PCBs at several locations elsewhere in Newark Bay and the results, in conjunction with historical data, used to evaluate the potential health and ecological risks posed by sediments in the Hackensack River.

Materials and Methods

A total of 32 sediment cores and 8 surface grab samples were collected at the confluence of the Hackensack River. Six additional surface grab samples were taken from three other locations; near

the Pulaski Skyway Bridge in the lower Hackensack River, at the confluence with the Passaic River, and in Newark Bay near the Port of NY/NJ the (Figure 1). A total of 64 samples were tested for PCDD/Fs and PCBs.

Sediment cores were collected using either a piston coring or vibracoring device and polybutyrate plastic liners with 2.25- or 3.5- inch outer diameter (OD) core barrel to nominal depths between 8 and 17 feet. At some locations, surface sediments were collected using a Van Veen grab sampler. All core collection and sample-handling equipment was pre-cleaned prior to each sampling event. In each sediment core, surface sediments (0-0.5 ft) and buried sediments at 1.5-2.0 ft and 3.5-4.0 ft depths were collected directly from the core barrel for chemical testing.

Sediment samples were analyzed by Vista Analytical Laboratory (El Dorado Hills, CA) for seventeen 2,3,7,8-substituted PCDD and PCDF congeners and total mono- through deca-chlorinated PCB congeners according to USEPA draft Methods 1614. The cleanup procedures included columns containing silica gel and activated carbon. The quantification of PCDDs, PCDFs, and PCBs was performed by selective ion recording using an AutoSpec Ultima high-resolution gas chromatograph/high resolution mass spectrometer (HRGC/HRMS). Laboratory method blanks, as well as precision and recovery samples, were included in the analytical protocol. The percent recoveries of internal standards were within the limits specified by the method. Method detection limits (MDLs) varied from 0.139 to 0.709 picograms per gram (pg/g; parts per trillion; ppt) dry weight (dw) for all PCDD and PCDF congeners. The reporting limit for PCB congeners was 50 ppt.

Total and mean concentrations were calculated assuming that congeners reported as below the sample specific detection limit were present in the sediment at one-half that detection limit. Dioxin TEQs incorporating the seventeen 2,3,7,8-substituted congeners and twelve coplanar PCBs are presented using World Health Organization toxicity equivalence factors [7].

Results and Discussion

Sediment Chemistry Results

The range and arithmetic mean concentrations of PCDDs and PCDFs detected in all sediment samples are summarized in Table 1. PCB results are presented in Table 2. In general, lower concentrations of PCDDs were found in sediments adjacent to the Pulaski Skyway Bridge site than in sediments from elsewhere in Newark Bay. However, the concentrations of PCDDs detected in these sediments were not significantly different from levels in sediments at the other sites ($p > 0.05$).

The concentrations of PCDFs in Newark Bay surficial sediments did not follow the same depositional patterns as PCDDs. While concentrations of PCDFs were not significantly different between the Newark Bay site, Passaic River site, and the Hackensack River confluence site ($p > 0.05$), sediments at the Newark Bay and Passaic River sites had significantly higher concentrations of PCDFs than those found at the Pulaski Skyway Bridge site ($p < 0.05$).

Dioxin TEQ concentrations in sediments at the Hackensack River confluence, ranged from approximately 6.0 to 1,500 pg/g dw in surface sediments (0 to 6 inches) and 2 to 3,000 pg/g dw in buried sediments (6 inches to 4 feet). Among the PCDDs, 2,3,7,8-TCDD, 1,2,3,4,6,7,8-HpCDD, and OCDD were the predominant congeners in sediments at all sampling locations. The concentrations of these congeners measured in sediments at the Hackensack River confluence site ranged from approximately 0.4 to 2,600 pg/g dw, 1 to 1,600 pg/g dw, and 2 to 14,400 pg/g dw, respectively. Similarly, 1,2,3,4,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, and OCDF were the predominant PCDF congeners in sediments at all sampling locations. Their concentrations ranged from approximately 0.3 to 2,200 pg/g dw, 0.4 to 8,000 pg/g dw, and 2 to 13,000 pg/g dw, respectively.

Analogous to PCDDs and PCDFs, the lowest concentrations of PCBs were found at the Pulaski Skyway Bridge site relative to the three other sampling locations in Newark Bay ($p < 0.05$). Coplanar PCB TEQs were found to range from 0.02 to 8 pg/g dw and 0.06 to 2.5 pg/g dw in surface sediments at the Hackensack confluence site and at all other locations, respectively. Furthermore, PCB-77, PCB-105, PCB-106/118, PCB-156, PCB-170, and PCB-180 were the predominant congeners in surface and buried sediments at all sampling locations. The mean concentrations of these congeners at the Hackensack confluence site ranged between 1,700 to 19,500 pg/g dw for surface sediments and 1,400 to 16,400 pg/g dw for buried sediments.

Overall, the sediments in Newark Bay and its two confluences to the north have higher concentrations of PCDDs, PCDFs and PCBs than sediments further upstream in the Hackensack River. Thus, if the source of contamination is from the Bay, it appears that the sediment load does not reach the Pulaski Skyway Bridge. In addition, these results are comparable to those reported in other studies. In sediments collected in close proximity to sampling locations in this study, Bopp et al. reported levels of 2,3,7,8-TCDD, OCDD, and PCBs at 310 pg/g, 3100 pg/g, and 980,000 pg/g in the Northern Newark Bay, 730 pg/g, 9400 pg/g, and 4,120,000 pg/g in the lower Passaic River, and 300 pg/g, 12,000 pg/g, and less than 2,000,000 pg/g in the lower Hackensack River, respectively [5].

Screening Ecological Risk Evaluation

Using the approach by Finley et al. to evaluate PCBs in sediment [8], mean total PCB concentrations in the current study are 550 micrograms per kilogram (µg/kg) dw and 540 µg/kg dw in surface sediments and buried sediments, respectively. Comparing these results to National Oceanic and Atmospheric Administration (NOAA) effect range-low (ER-L, 22.7 µg/kg) and effect range-median (ER-M, 180 µg/kg) screening sediment quality values to assess the potential toxicity to benthic organisms, the occurrence of PCBs in the lower Hackensack River sediments potentially pose a toxic threat to aquatic life.

While Sediment Quality Guidelines (SQGs) for dioxin have not been promulgated in the United States, the most often cited benchmark values for dioxins include the United States (U.S.) Army Corps of Engineers (1,000 pg/g) [9], the U.S. Environmental Protection Agency (EPA) Region 10 dredge spoils disposal guideline (4 pg/g) [10], U.S. EPA Fish and Wildlife (bird and mammal) guidelines developed specifically for Lake Ontario (2.5 – 210 pg/g) [11], and the dioxin benchmark proposed by the Science Advisory Board of the International Joint Commission for Great Lakes sediments (10 pg/g). PCDD concentrations in all of the surficial sediments investigated in this

study exceed these benchmark concentrations, suggesting that PCDDs and PCDFs in these sediments may pose a threat to aquatic biota.

The U.S. EPA established a Historic Area Remediation Site (HARS)-specific worm tissue PCB criterion of 113 parts per billion (ppb) for use in determining the suitability of proposed dredged material for use as remediation material [12]. While results of tissue analysis from bioaccumulation tests performed in the current study showed some elevated levels of PCBs, the concentrations in *neanthes* bioaccumulation tests were below the worm tissue PCB criterion. Even though PCBs exceeded the ER-M/L values, they were not considered a factor in the sediment toxicity tests.

While concentrations of PCDDs, PCDFs, and PCBs in river sediment should not be compared too closely from river to river due to variable sedimentation and hydrodynamic processes, comparisons to different river systems can be useful to evaluate the relative level of contamination [13]. The results of this study suggest that additional work is warranted to evaluate body burdens in fish and other aquatic organisms in the Hackensack River. The dioxin TEQ levels in the sediment limit options for both in-bay and upland disposal of dredged materials. Accepting screening sediment quality benchmark values and the results of sediment studies conducted elsewhere as reliable indicators of the potential for adverse effects, PCDDs, PCDFs, and PCBs in the estuary may occur in some aquatic biota at levels approaching those associated with potentially adverse effects, and any disturbance of the sediments that facilitate bioaccumulation should be avoided in the River and the Bay.

References

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Figure 1. Surface and buried sediment sampling locations in upper Newark Bay and the lower Hackensack River, New Jersey USA.

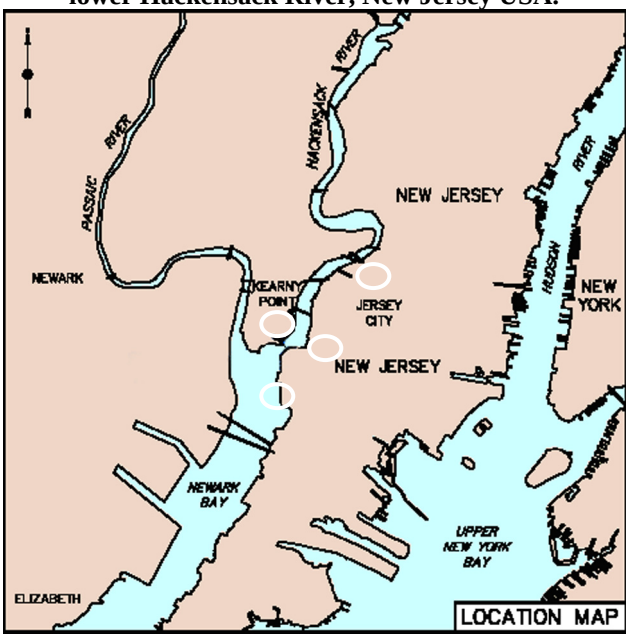

Table 1. The concentrations (pg/g dry weight) of PCDD/Fs in surface and buried sediments.

Chemical	Pulaski Skyway Bridge		Passaic River Confluence		Northern Newark Bay		Hackensack River Confluence			
	Surface n=2		Surface n=2		Surface n=2		Surface n=37		Buried n=27	
	Range[a, d]	Mean (0-0.5')	Range[a, d]	Mean (0-0.5')	Range[a, d]	Mean (0-0.5')	Range[a]	Mean (0-0.5')	Range[a]	Mean (0.5-4.0')
Dioxins and Furans TEQ[b]	5.2 , 14	9.7	182 , 231	207	102 , 302	202	6.0 - 1,498	167	2.1 - 2,830	171
Total PCDD/Fs[c]	--- - ---[d]	1,295	--- - ---[d]	7,313	--- - ---[d]	7,436	--- - ---	5,117	--- - ---	3,345
2,3,7,8-TCDD	1.3 , 2.5	1.9	130 , 179	155	59 , 207	133	0.91 - 1350	103	0.41 - 2,570	141
1,2,3,7,8-PeCDD	0.56 , 0.75	0.66	3.5 , 4.1	3.8	2.6 , 7.0	4.8	0.37 - 25	3.8	0.55 - 29	3.0
1,2,3,4,7,8-HxCDD	0.50 , 0.91	0.71	5.3 , 5.4	5.38	2.8 , 6.2	4.5	0.18 - 22	4.2	0.80 - 20	3.3
1,2,3,7,8,9-HxCDD	0.98 , 1.5	1.2	11 , 13	12	6.1 , 24	15	0.45 - 29	7.5	0.80 - 46	5.8
1,2,3,6,7,8-HxCDD	1.0 , 2.1	1.6	19 , 20	19	11 , 52	31	0.77 - 84	15	0.81 - 102	10
1,2,3,4,6,7,8-HpCDD	20 , 36	28	411 , 437	424	189 , 702	446	2.5 - 1080	252	1.0 - 1,560	156
OCDD	793 , 1,280	1,037	4,650 , 4,860	4,755	1,980 , 6,140	4,060	90 - 9,710	2,332	1.8 - 14,400	2,014
2,3,7,8-TCDF	3.2 , 8.0	5.6	14 , 17	16	13 , 29	21	0.90 - 54	15	0.41 - 112	12
1,2,3,7,8-PeCDF	2.5 , 5.1	3.8	11 , 15	13	10 , 23	17	0.99 - 152	21	0.65 - 71	11
2,3,4,7,8-PeCDF	2.4 , 6.2	4.3	24 , 25	25	20 , 48	34	1.1 - 243	32	0.64 - 155	18
1,2,3,4,7,8-HxCDF	5.4 , 28	16	105 , 117	111	115 , 219	167	2.7 - 2,210	221	0.32 - 720	78
1,2,3,7,8,9-HxCDF	0.75 , 1.5	1.1	4.8 , 5.2	5.0	4.1 , 11	7.64	0.31 - 50	6.5	0.52 - 29	3.1
1,2,3,6,7,8-HxCDF	3.4 , 17	10	86 , 87	87	72 , 146	109	0.93 - 401	64	0.32 - 129	25
2,3,4,6,7,8-HxCDF	1.6 , 3.2	2.4	16 , 17	17	11 , 25	18	0.70 - 135	19	0.36 - 97	11
1,2,3,4,6,7,8-HpCDF	29 , 161	95	822 , 892	857	724 , 1,570	1,147	13 - 7,820	907	0.44 - 3,090	302
1,2,3,4,7,8,9-HpCDF	1.1 , 3.4	2.2	13 , 15	14	11 , 25	18	0.72 - 165	20	0.56 - 83	9.8
OCDF	32 , 135	84	721 , 871	796	707 , 1,700	1,204	38 - 13,100	1,095	2.1 - 5,050	543

[a] Ranges include all values. Sediment samples reported as below the level of quantification were assumed to be preset at ½ the detection limit.
[b] Dioxin and Furan toxic equivalent quotients (TEQs) were calculated using WHO [7] fish toxic equivalency factors.
[c] Total PCDD/Fs only include the seventeen 2,3,7,8-substituted congeners.
[d] Because n=2, the concentrations reported in each sample are reported.

Table 2. The concentrations (pg/g dry weight) of total mono through deca chlorinated homologue and mono / ortho coplanar PCBS in surface and buried sediments.

Chemical[a]	Pulaski Skyway Bridge		Passaic River Confluence		Northern Newark Bay		Hackensack River Confluence			
	Surface n=2		Surface n=2		Surface n=2		Surface n=37		Buried n=27	
	Range	Mean (0-0.5')	Range	Mean (0-0.5')	Range	Mean (0-0.5')	Range	Mean (0-0.5')	Range	Mean (0.5-4.0')
Coplanar PCBs TEQ	0.06 - 0.07	0.06	1.2 - 1.3	1.2	0.97 - 2.5	1.7	0.02 - 8.0	1.2	0.01 - 14	1.1
Total PCBs	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	546,533	---[b]	537,654
PCB-77	78 , 178	128	3,450 , 3,530	3,490	3,680 , 6,410	5,045	24 - 28,700	2,844	2.5 - 43,200	2,493
PCB-105	134 , 368	251	7,680 , 8,420	8,050	5,240 , 20,300	12,770	24 - 52,800	6,851	2.5 - 114,000	6,146
PCB-106/118	398 , 1,130	764	19,900 , 22,600	21,250	13,500 , 51,500	32,500	63 - 133,000	19,464	2.5 - 295,000	16,436
PCB-114	9.7 , 27	18	476 , 530	503	309 , 1,330	820	6.7 - 8,090	627	2.5 - 7,570	417
PCB-123	9.7 , 29	19	229 , 422	326	153 , 792	473	7.3 - 3,150	358	2.5 - 5,640	340
PCB-156	38 , 116	77	2,350 , 2,400	2,375	1,340 , 6,550	3,945	24 - 9,510	1,689	2.5 - 23,700	1,401
PCB-157	11 , 23	17	523 , 530	527	305 , 1,080	693	9.2 - 2,060	393	2.5 - 5,190	336
PCB-167	17, 53	35	1,020 , 1,050	1,035	585 , 2,700	1,643	16 - 9,310	918	2.5 - 8,950	571
PCB-170	96 , 369	232	6,450 , 7,080	6,765	3,350 , 31,900	17,625	24 - 43,100	4,747	2.5 - 43,100	2,950
PCB-180	277 , 1,090	684	16,500 , 18,300	17,400	8,280 , 81,900	45,090	24 - 99,200	12,008	2.5 - 103,000	7,436
							Surface n=36[c]		Buried n=19[c]	
Total monoCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	32 - 9,400	1,550	1.3 - 11,500	956
Total diCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	174 - 187,000	19,086	2.5 - 208,000	13,527
Total triCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	272 - 1,160,000	102,940	1.3 - 1,970,000	99,465
Total tetraCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	760 - 2,030,000	193,044	2.5 - 4,010,000	195,302
Total pentaCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	321 - 387,000	84,031	2.5 - 2,320,000	121,741
Total hexaCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	126 - 412,000	71,608	2.5 - 1,010,000	59,139
Total heptaCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	24 - 381,000	46,689	2.5 - 389,000	25,976
Total octaCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	37 - 99,600	16,346	3.8 - 107,000	11,416
Total nonaCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	37 - 53,000	6,732	3.8 - 114,000	7,141
Total decaCB	---[b]	---[b]	---[b]	---[b]	---[b]	---[b]	37 - 42,000	4,508	3.8 - 38,800	2,990

[a] Results for PCB-81, PCB-126, PCB-169, and PCB-189 are not reported.
[b] Not measured.
[c] A different total number of sediment samples were analyzed for mono through deca chlorinated PCB homologue groups.