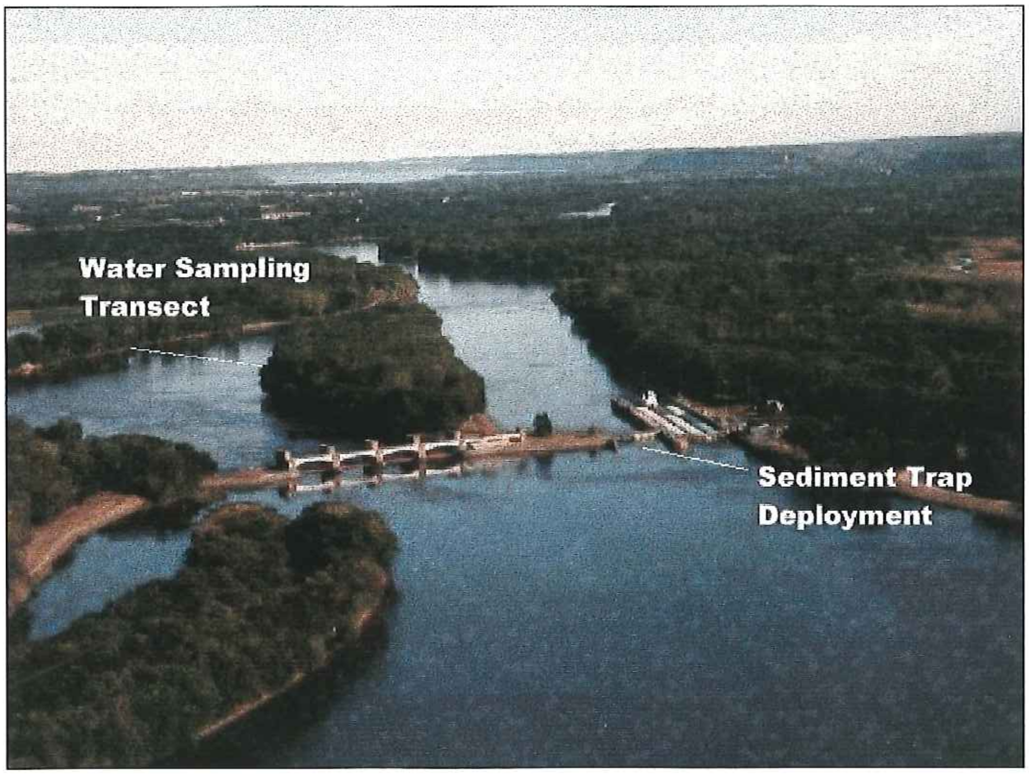
Polychlorinated Biphenyl Concentrations in the Mississippi River near Red Wing, Minnesota in the Spring of 1996



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Introduction

Polychlorinated biphenyl (PCB) contamination in the Upper Mississippi River has been a long term problem since first discovered in riverine fish about 25 years ago (Degurse and Ruhland 1972). Fortunately, State and Federal regulations controlling PCB use and production in the 1970s and 1980s have resulted in reduced discharges of these compounds to surface water. These actions resulted in substantial decreases in PCB burdens in Mississippi River fish and invertebrates (Sullivan 1988). However, PCB contamination of fish, especially in the Pool 2 to 4 river reach, is still a problem and results in consumption warnings to sport anglers (Wisconsin Division of Health and Wisconsin Department of Natural Resources 1998 and Minnesota Department of Health 1998).

In aquatic environments, PCBs have a strong affinity to adsorb to fine-grained sediment particles, especially sediments with high organic carbon content (Karickhoff et al. 1979). As a result, fine-grained bed sediments typically reflect a major source of anthropogenic PCB inputs, especially in impoundments below large urban and industrial areas where PCB use and releases were high.

Efforts to determine water column PCB concentrations in the Upper Mississippi River have been attempted in the past, but were often unsuccessful due to high detection levels (400 ng/L) or provided questionable results (extremely high values exceeding 2,500 ng/L), (Sullivan 1988). A possible problem with past water column sampling efforts may have been the inability to collect sufficient mass of suspended particulate matter for PCB analysis, since PCBs are primarily associated with the particulate phase in turbid river systems.

In 1987, the Wisconsin Department of Natural Resources (WDNR) began using cylindrical sediment traps in the Mississippi River as a means to collect time-integrated suspended sediment for contaminant analyses (Sullivan 1995), to investigate PCB source inputs (Sullivan and Steingraeber 1995) and for general limnological studies. Sediment traps provide an efficient and inexpensive method for collecting suspended particulate material (primarily sand, silt and clay) and can be used to estimate particulate-phase contaminant concentrations in water. However, sediment traps provide no information on contaminant concentrations associated with the dissolved or colloidal fraction.

In the spring of 1996, WDNR and the U.S. Geological Survey (USGS) collected water samples to determine particulate- and dissolved-phase PCB concentrations using low-level techniques. This sampling effort was conducted upstream from Red Wing, Minnesota near Lock and Dam 3 where sediment trap samples have been historically deployed (Cover photo and Photo 1). The primary purposes of this study were to determine PCB concentrations in water using low-level methods and to assess the ability of sediment traps to yield reasonable particulate-phase PCB concentration estimates for the water column.

Methods

Particulate and Dissolved PCBs

Composite samples for particulate- and dissolved-phase PCB analysis were collected from the Mississippi River about 0.5 miles below Lock and Dam 3 on three days from April to June, 1996. Field sampling followed similar procedures used on Wisconsin tributaries to Lake Michigan (House et al. 1993 and Steuer et al. 1995). A brief summary is provided here.

River samples were normally collected at approximately 25, 50 and 75 percent of the channel width and at the 0.6 depth. An exception was April 17 when surficial water was sampled due to high current velocity.

Approximately 80-L composite water samples were collected with a submersible pump and teflon tubing and passed through a stainless steel multiplate filter holder mounted in a USGS survey boat. The particulate phase was collected on three to five 293 mm diameter, 0.7 μm pore size, glass-fiber filters. More filters were necessary during periods of low suspended particulate matter concentrations. The filtrate, operationally defined as the dissolved phase or dissolved fraction, was then placed into four, 20-L glass carboys for shoreside extraction of dissolved PCBs within 3 hours of collection. Filtrate samples from the carboys were passed through an Amberlite XAD-2 resin column at a rate not exceeding 1-L per minute.

The filters and XAD-2 resins were analyzed for PCB congeners at the Wisconsin State Laboratory of Hygiene (WSLH) using capillary column (60m DB5, 0.2 mm diameter) gas chromatography (GC) and electron capture detection (HP 5890-II) following methods described by Fitzgerald and Steuer (1997). A congener standard provided by Michael Mullin, U.S. Environmental Protection Agency in 1994 (Degenhardt 1997) allowed for the determination of 101 (24 co-eluting) congeners. An equipment blank for both dissolved- and particulate-PCB phases was collected in March 1996. The dissolved blank detected eight PCB congeners (congener sum = 0.24 ng/L) while no congeners were detected in the particulate fraction. No blank or spike recovery corrections were applied to the congener results. Total PCB concentrations were derived by summing the congener results for a particular sample. Congener results reported less than the detection limit were assumed to be zero.

Composite water samples were also collected for particulate organic carbon (POC), dissolved organic carbon (DOC), chlorophyll-*a*, and total suspended solids (TSS) during PCB sampling. Particulate and dissolved organic carbon were separated using a stainless steel Gelman filtration apparatus containing a 0.45 μm filter and were analyzed by the U.S. Geological Survey National Water Quality Laboratory as described by Fitzgerald and Steuer 1997. Chlorophyll-a (uncorrected for pheophytin) and TSS analysis were determined by the WSLH following U.S. EPA approved methods (WSLH 1992). Additional measurements of chlorophyll-a and TSS at Lock and Dam 3 were available from the WDNR and Metropolitan Council Environmental Services ambient monitoring programs (Sullivan 1989 and Schellhaass 1996).

Sediment Traps

Cylindrical, glass sediment traps (ICHEM 500 ml certified-clean jars) were used to collect suspended particulate material in the auxiliary lock chambers at Lock and Dams 3 (Photo 1) following previous established procedures (Sullivan, 1995). Briefly, four sediment traps were attached to a 2 cm diameter, 3 m long metal conduit at approximately 0.5 m intervals. The traps were then suspended vertically in the water column about 1 to 3 m below the surface immediately above the auxiliary lock gate on April 1, 1996. Sediment traps were retrieved on June 6 and combined in the laboratory the next day to form a vertically-composited, time-integrated sample.

Polychlorinated biphenyl congeners were determined at the WSLH using capillary column (60m DB5, 0.25 mm diameter) gas chromatography and electron capture detection (HP 5880) following similar procedures used on bed sediments (WSLH 1993). Samples were quantified using two different congener standards and instruments to be consistent with long-term sediment trap data collected at this site and the analysis of particulate-phase water samples described previously. The first method quantified PCBs using a congener standard provided by Mullin (1985) and the older GC (HP 5880) and larger diameter capillary column, the method historically used on sediment trap samples for this site. This allowed the determination of 85 (22 co-eluting) congeners. A summary of this method has been described by Sullivan and Lodge (1997). The second quantification method followed similar procedures used for particulate-phase water samples as described above and are based on a congener standard received from Mullin in 1994 and the newer GC (HP 5890-II) and smaller diameter capillary column. This second quantification was delayed one year while the sediment trap extract was stored frozen. A re-analysis of a sediment trap sample using both Mullin 1985 and 1994 PCB standards was conducted on a sample collected at Lock and Dam 3 in the fall of 1998 to further evaluate quantification differences with these standards and instruments. Both Mullin PCB standards utilized the congener identification described by Ballschmiter and Zell (1980).

RESULTS and DISCUSSION

Eighty-Liter Water Samples

Particulate- and dissolved-phase PCB concentrations were collected on April 17, May 29 and June 20, 1998 during a typical spring high flow period (Figure 1A). The first sample was collected during the initial period of spring runoff when water temperature and total suspended solids concentrations were relatively low (Table 1 and Figure 1B). These conditions may have reflected a greater influence of snowmelt runoff in this sample. The second and third samples were collected at lower flows in late spring and early summer when rainfall runoff and erosional processes would have likely contributed to greater TSS concentrations.

Total PCB concentrations (congener sum) increased from 1.9 ng/L on April 17 to 4.8 ng/L on June 20 (Figure 1D). The percentage of total PCBs in the dissolved phase decreased from 62% to 20% during this period (Table 1). This may have reflected the increase in suspended particulate matter (TSS, Figure 1B) which provided increased adsorption sites on slit and clay-sized particles, an influx of PCB contaminated soil, or resuspension of sediments contaminated with PCBs. Uptake of PCBs by algae did not appear to be a major factor influencing partitioning between dissolved and particulate phases since chlorophyll-*a* measurements, a surrogate for algae biomass, did not follow the same trend as particulate-phase PCBs (Figure 1B and 1C). Further, algae likely represented a small proportion of suspended particulate material in the river during the collection period.

Dissolved- and particulate-phase PCB concentrations in the Mississippi River were generally comparable to similar data from some Wisconsin tributaries draining to Lake Michigan (Table 2). Exceptions were the Fox, Manitowoc and Milwaukee Rivers that have bed sediments with substantially greater PCB contamination producing an ongoing source of contamination in these rivers (House 1995, Steuer et al. 1995 and Fitzgerald and Steuer 1997). Average total PCB concentrations in all rivers summarized in Table 2 exceeded Wisconsin's human cancer criteria (0.01 ng/L) for warm water sport fish communities by a factor of 300 to 11,000 (Wisconsin Administrative Code NR 105.09).

PCB Congeners in Water Samples

A summary of congener results for the dissolved- and particulate-phase samples are provided in Table 3 and are illustrated graphically in Figures 2 and 3. Polychlorinated biphenyl congener composition in the dissolved and particulate fraction were distinctly different from each other in all three samples collected from the Mississippi

River (Figure 2). Dissolved-phase congeners were dominated by lower chlorinated PCBs consisting of the di-, tri-, and tetrachlorinated biphenyls. In contrast, particulate-phase PCBs where more heavily chlorinated with penta-, hexa-, hepta-, and octachlorinated biphenyls. These compositional differences are consistent with PCB partitioning theory which predict greater adsorption of the more hydrophobic (higher chlorinated) PCBs onto particulate organic matter (Karickhoff et al. 1979). The congener composition between sampling dates for both the dissolved and particulate phase was similar suggesting a similar source input.

Congener concentrations in the particulate fraction increased substantially between April and June (Figure 3). This response reflects the increase in TSS concentrations observed during this period (Figure 1B) and possibly an increased input of particulate-bound PCBs during the monitoring period from unidentified sources.

Sediment Traps versus Particulate-Phase Water Sample

Polychlorinated biphenyl concentrations of composite suspended material collected with sediment traps above Lock and Dam 3 during the spring of 1996 were compared to the average particulate-phase water samples collected just downstream from the dam during a similar period. The total PCB concentration of the sediment trap sample was 54.7 ng/g (Table 3) and was very similar to the average PCB concentration of the particulate-phase water sample (47.1 ng/g, Table 1) based on the Mullin 1994 PCB standard. Sediment trap samples quantified with the Mullin 1985 standard yielded an essentially identical total PCB concentration (44.5 ng/g, Table 4) than that reported for the particulate-phase water sample.

The total organic carbon content of the sediment trap sample was noticeably lower than the average particulate-phase water sample (2.9 versus 4.1 %, respectively) and suggests a difference in the type of particulate matter collected between the two methods. It was not possible to establish if the differences in PCB concentration or TOC content in traps versus filtered suspended material were statistically significant, since no replicate measurements were made with the sediment traps. Previous comparisons of suspended matter collected from river water versus sediment trap samples indicated significant differences in organic matter (volatile solids) content (Bartsch 1996). This difference could result from an under-collecting low density particulate matter in the sediment traps (algae, bacteria or colloidal matter), over-collecting silt- or sand-sized material with the sediment traps, or under-collecting high density solids in the filtered water samples. Additional factors could include site or collection period (time-composited versus grab) differences.

A comparison of the PCB congener composition of the average particulate-phase water sample versus the sediment trap sample indicated noticeable differences even when both matrices were quantified using the Mullin 1994 PCB standard (Figure 4). Part of this difference can be explained due to detection level differences between the two types of sample. Detection levels have not been established for sediment trap samples quantified with the Mullin 1994 standard. This resulted in more congeners being "reported" for the sediment trap samples, but they were present at very low concentrations. However, even when considering the dominant congeners (>0.05 ng/L) there were obvious differences between the two matrices. For example, the co-eluting di-chlorinated biphenyls 8/5 and the hexachlorinated biphenyl 136 were present in moderate amounts (0.08 ng/L) in the sediment trap material based on particulate-phase estimates (Figure 4C) but were not detected or were reported at low concentrations in the particulate-phase water sample (Figure 4A). In contrast, major tetra- to hexachlorinated biphenyls (77/110 and 163/138) were detected at noticeably greater concentrations in particulate-phase water samples than those reported for the sediment traps. These differences in congener concentration results between the two matrices were also apparent when presented on a solid basis (ng/g) as illustrated in a regression plot (Figure 5A).

The reason for the differences in dominant congener composition between filtered or sediment trap solids has not been identified. It may have been associated with a delay (about 1 year) in the analysis of the sediment trap extract using the Mullin 1994 PCB standard. A much closer agreement in major congener concentrations between matrices was apparent when comparing particulate-phase congeners quantified with the Mullin 1994 standard to sediment trap results determined with the Mullin 1985 standard (Figure 5B). Both of these analyses were performed at about the same time.

Fall sediment trap samples collected in November 1998 were analyzed with both the Mullin 1985 and 1994 standards as a further evaluation of standard and method differences (Figure 6A and B). Congeners 8/5 were present at low concentrations and congener 136 was not detected when quantified using the Mullin 1994 standard. This is the opposite response from what was observed in the spring sediment trap samples collected in 1996 (Figure 6C and D). There was no delay in the analysis of the fall 1998 sediment traps and this may support the belief that prolonged extract holding time influenced the congener concentrations found in the spring 1996 sediment trap samples that were quantified using the Mullin 1994 standard.

In general, the dominant congener concentrations in the Fall 1998 sediment trap sample exhibited a better correlation between the two Mullin standards as compared to the Spring 1996 samples (Figure 7A and B). However, the dominant co-eluting congeners 77/110 were still reported at noticeably lower concentrations when quantified using the Mullin 1994 standard. The WSLH evaluated relative response factor differences between the Mullin PCB standards in October 1994 using the same GC and capillary column (Tortorelli, 1998). These results indicated the co-eluting congeners 77/110 provided a lower response with the Mullin 1994 standard as compared to the Mullin 1985 standard. The results described here for suspended sediment collected from the Mississippi River are consistent with these findings.

Summary and Conclusions

Total PCB concentrations in the Mississippi River near Lock and Dam 3 ranged from 1.9 to 4.8 ng/L based on 3 samples collected during April to June of 1996. These concentrations exceeded Wisconsin's water quality criteria for the river by more than 300 times. In comparison, PCB contaminated rivers in eastern Wisconsin have revealed considerably higher concentrations (30 to 110 ng/L).

The concentration of PCBs in the operationally-defined dissolved phase was relatively uniform and ranged from 1 to 1.6 ng/L during the sampling period. However, the percentage of total PCBs in the dissolved phase decreased from 62 to 20% during the collection period. This response was likely influenced by increased partitioning to the particulate phase as a result of increased suspended particulate matter (total suspended solids), increased inputs of particulate-phase PCBs associated with runoff of contaminated soils or the resuspension of contaminated sediments during the sampling period.

Dissolved-phase PCB congeners were dominated by lower chlorinated biphenyls and particulate-phase congeners were comprised primarily by higher chlorinated biphenyls. These results are consistent with partitioning theory which predicts greater partitioning of the more hydrophobic chlorinated hydrocarbons (higher chlorinated PCBs) to particulate organic matter.

Total PCB concentration in suspended matter collected by sediment traps was similar to average (n=3) particulate-phase concentration measurements determined from filtered river water, 55 versus 47 ng/g respectively, when quantified using the same PCB standard. However, there appeared to be a noticeable difference in the congener composition between these two matrices. Part of this problem may have been due to a delay in the analysis of the sediment trap extract which was held frozen in storage for about 1 year prior to being quantified with the Mullin 1994 PCB standard. A much better agreement between matrices was noted when particulate-phase water samples, quantified with the Mullin 1994 standard, were compared with sediment trap results that were quantified with the Mullin 1985 standard at about the same time.

Additional evaluations of quantification differences of dominant congeners (> 1 ng/g) with the Mullin 1985 and 1994 PCB standards were made on sediment trap samples collected in the spring of 1996 and 1998. The congener concentrations determined with the two standards exhibited a closer agreement on the 1998 samples. It is suspected that prolonged extract holding time influenced the congener composition in the 1996 sediment trap sample that was quantified using the Mullin 1994 standard. However, both sediment trap samples indicated the major co-eluting congeners 77/110 were quantified at noticeable lower concentrations when quantified using the Mullin 1994 standard. The reason for this observation may be related to differences in the response factor between the two standards.

Further assessments of quantification differences between the 1985 versus 1994 PCB congener standards are recommended, especially if plans are made to switch to the more recent standard. This will be useful to more accurately account for laboratory method changes when evaluating PCB congener results on environmental samples.

These results lend support to the continued use of sediment traps as an efficient and simple method for collecting particulate-bound organic contaminants. A combination of suspended particulate matter concentration measurements during trap deployment and contaminant analysis of trapped sediment, can yield reasonable estimates of particulate-phase concentrations in water at relatively low levels.

Acknowledgements

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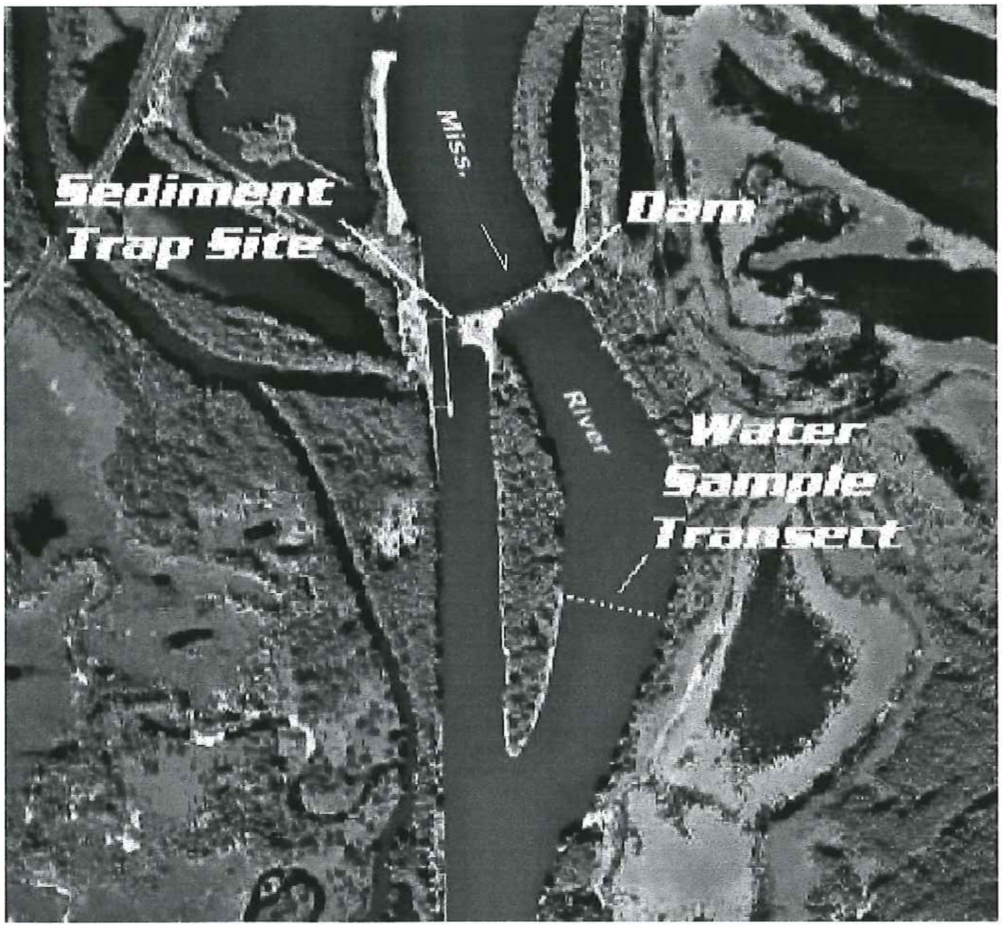

Photo 1. Mississippi River at Lock and Dam 3 near Red Wing, Minnesota showing sediment trap deployment site and water sampling transect. Aerial photograph (1994) obtained from the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, Onalaska, Wisconsin.

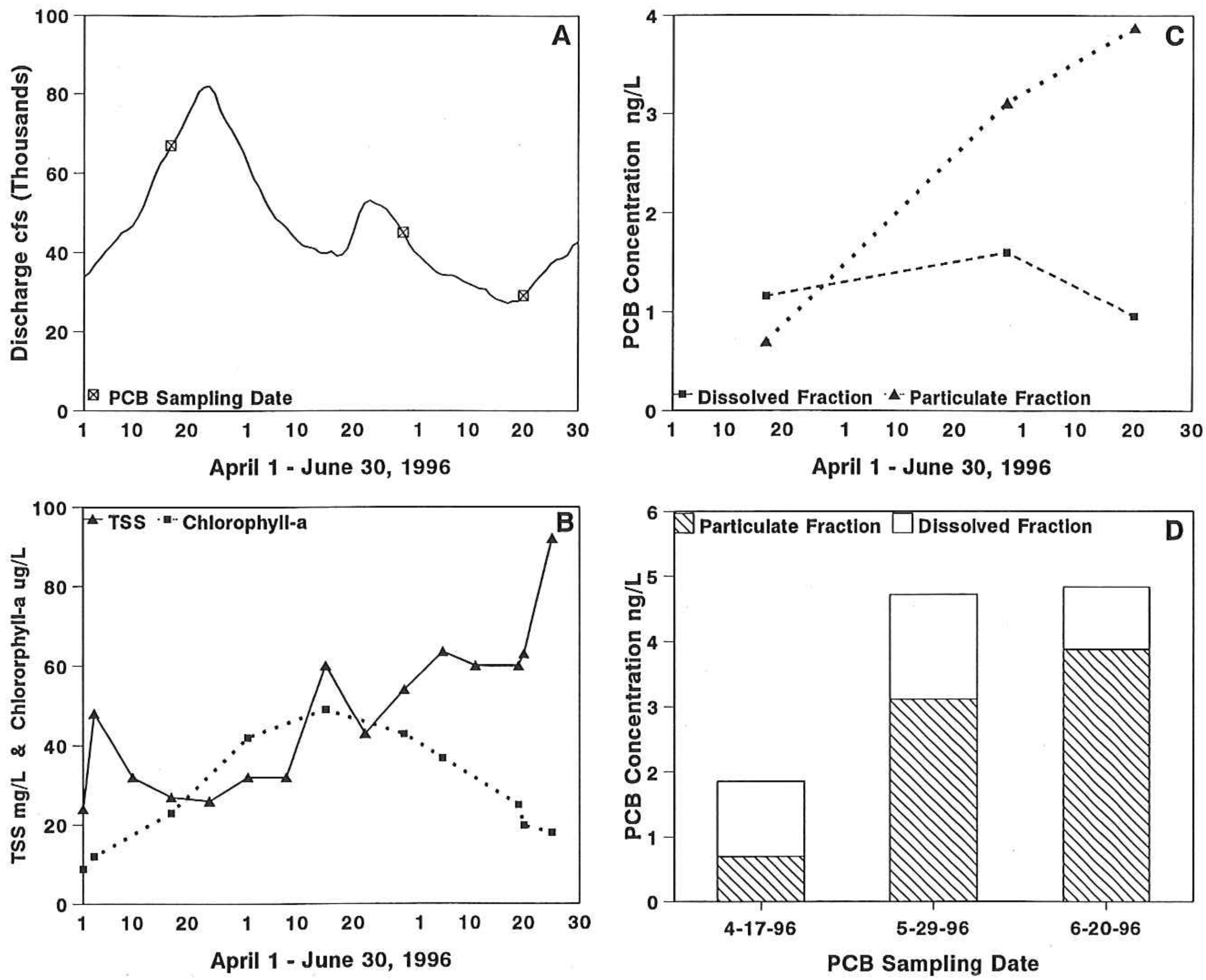

Figure 1. **A**. River flow in the Mississippi River at Lock and Dam 3 and dates of PCB sampling during the spring sampling period of 1996. **B**. Total suspended solids (TSS) and chlorophyll-a concentrations near Lock and Dam 3. **C & D**. Polychlorinated biphenyl (PCB) concentrations in dissolved and particulate fractions from 80-liter pump samples collected below Lock and Dam 3.

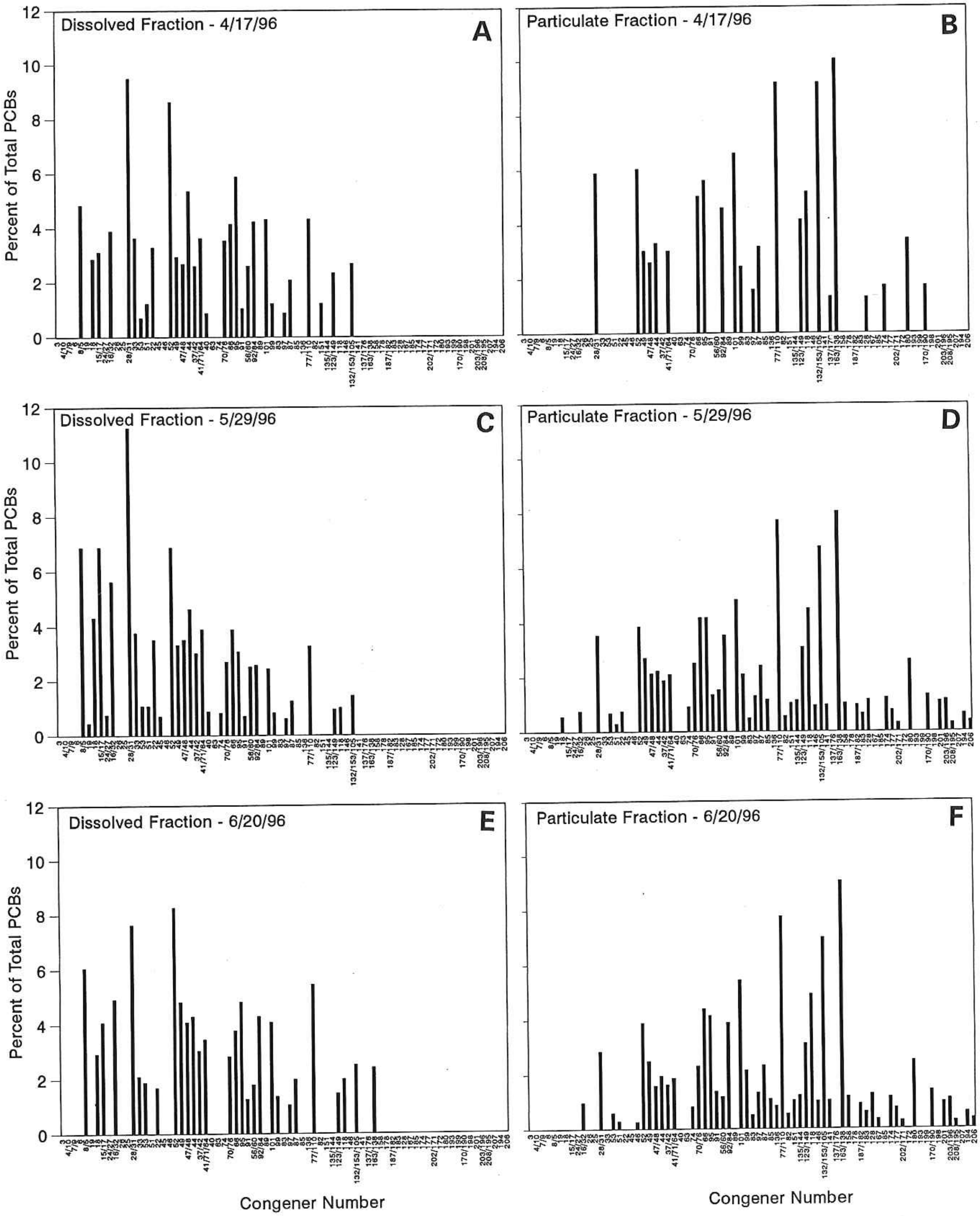

Figure 2. Polychlorinated biphenyl (PCB) congener composition in the dissolved (**A**, **C** and **E**) and particulate fractions (**B**, **D** and **F**) from samples collected in the Mississippi River below Lock and Dam 3 during the spring of 1996.

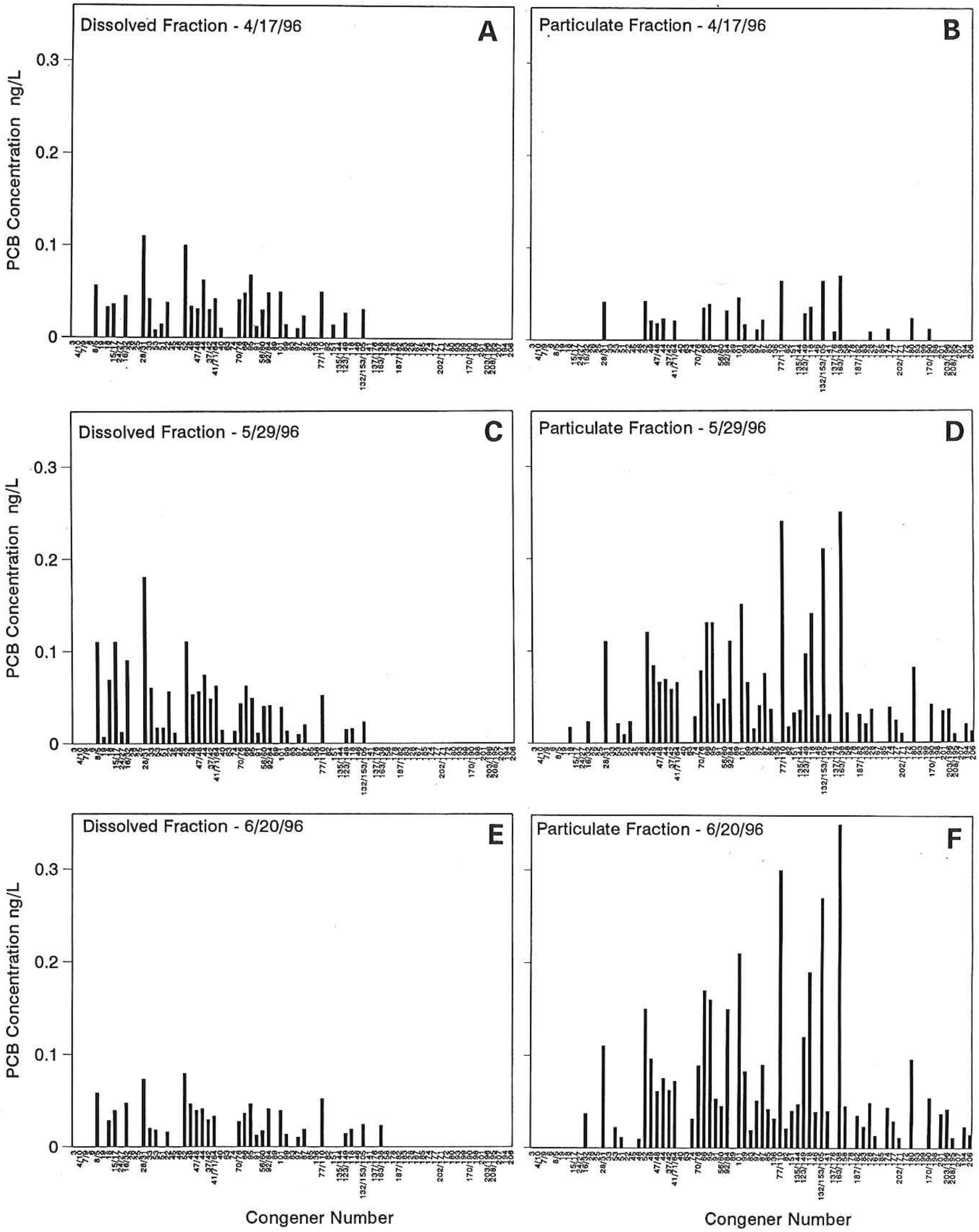

Figure 3. Polychlorinated biphenyl (PCB) congener concentrations in the dissolved (**A**, **C** and **E**) and particulate fractions (**B**, **D** and **F**) from samples collected in the Mississippi River below Lock and Dam 3 during the spring of 1996.

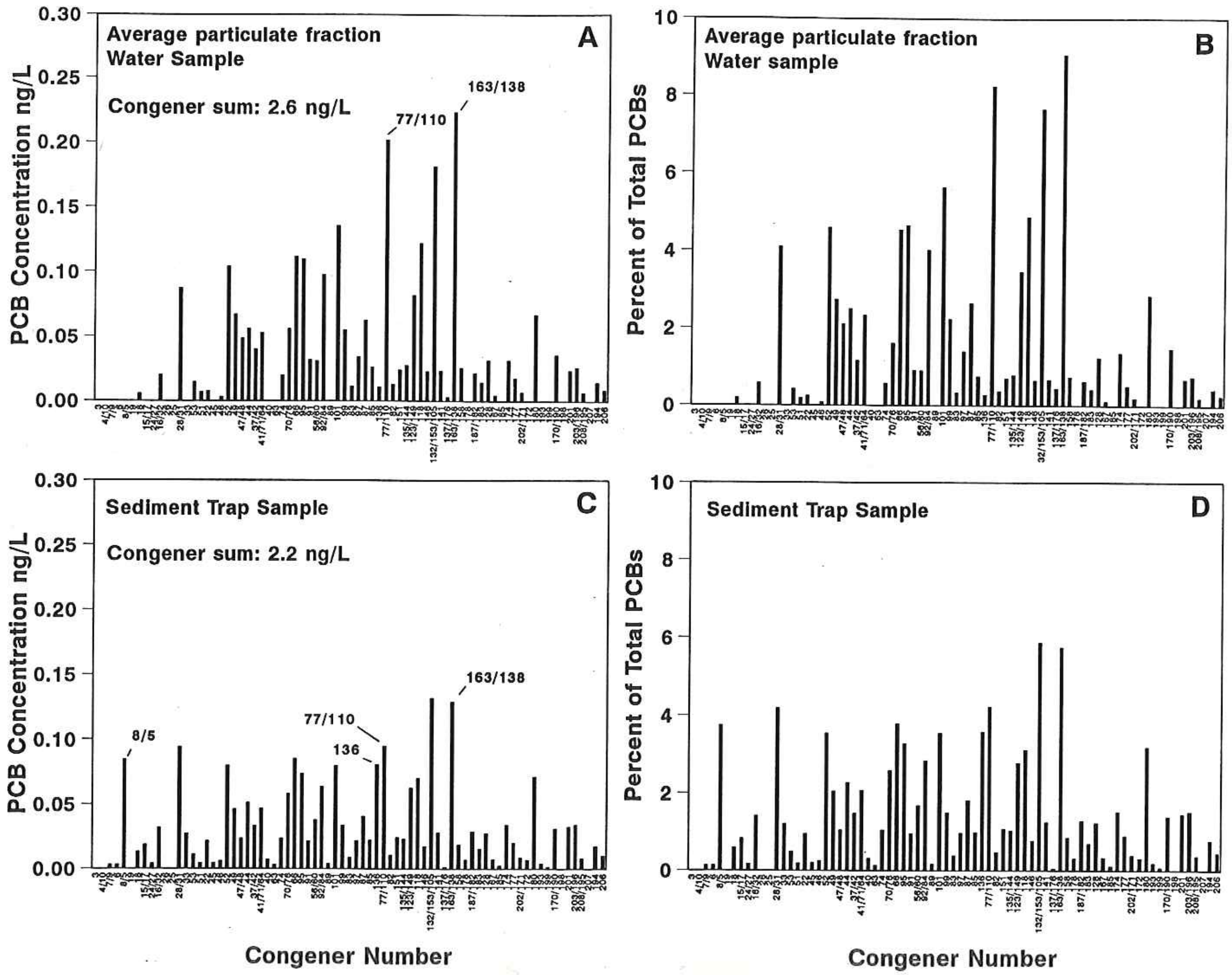

Figure 4. **A.** Average water column polychlorinated biphenyl (PCB) congener concentrations and their percent composition (**B**) in the particulate fraction of three water samples collected from the Mississippi River below Lock and Dam 3 during the spring of 1996. **C.** Estimated particulate-phase water column PCB congener concentrations and their percent composition (**D**) derived from sediment trap composite samples and ambient total suspended solids concentrations collected from the Mississippi River above Lock and Dam 3 during the spring of 1996. Both matrices were quantified using the Mullin 1994 PCB standard.

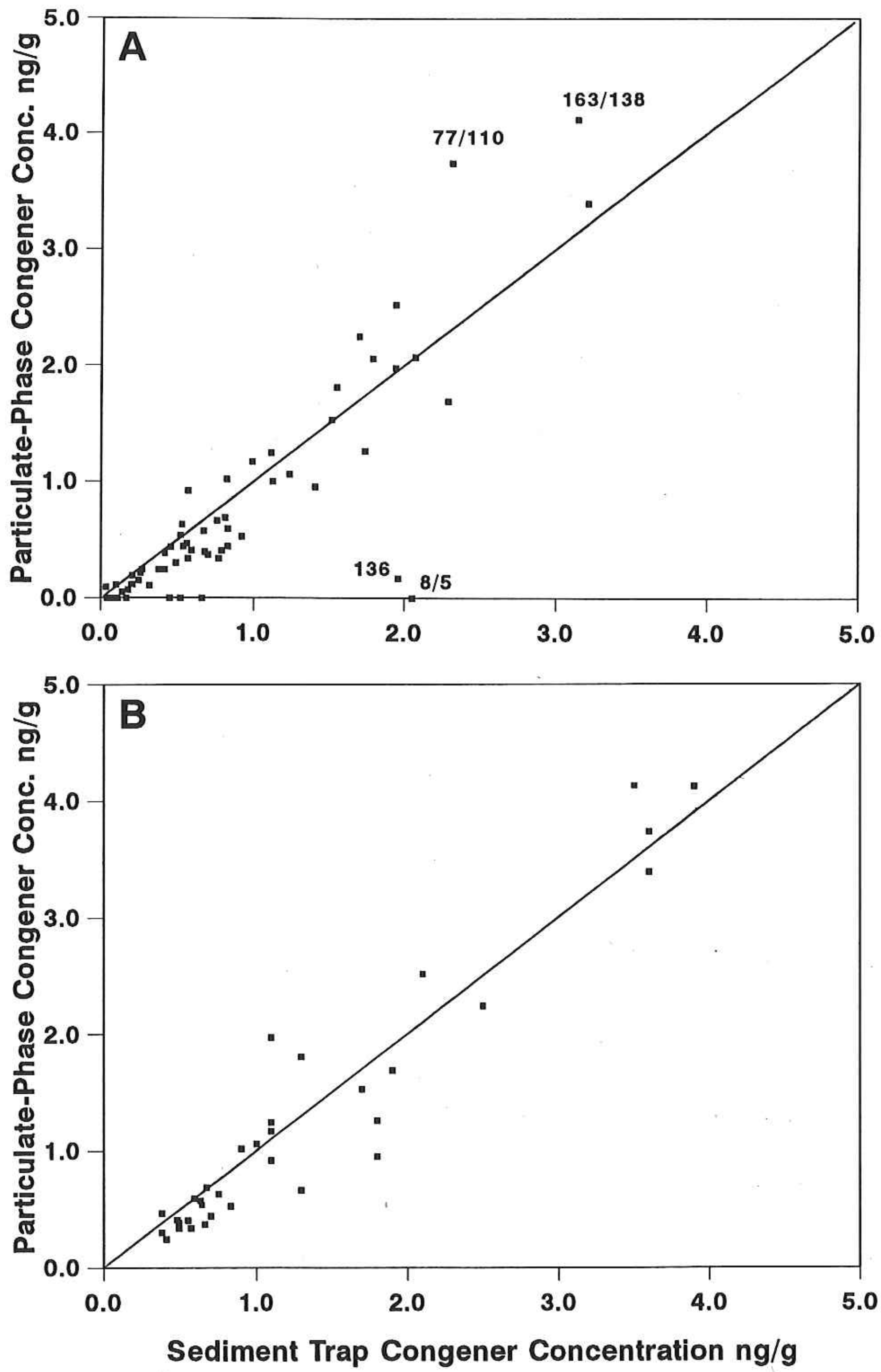

Figure 5. **A.** Comparison of polychlorinated biphenyl (PCB) congener concentrations measured in particulate-phase water samples (average of 3 samples) collected from the Mississippi River below Lock and Dam 3 during the spring of 1996 to congener concentrations measured in suspended material collected with sediment traps above Lock and Dam 3 during a similar period. Both matrices were quantified with the Mullin 1994 PCB standard. **B.** Same sample information except sediment traps were quantified with the Mullin 1985 PCB standard.

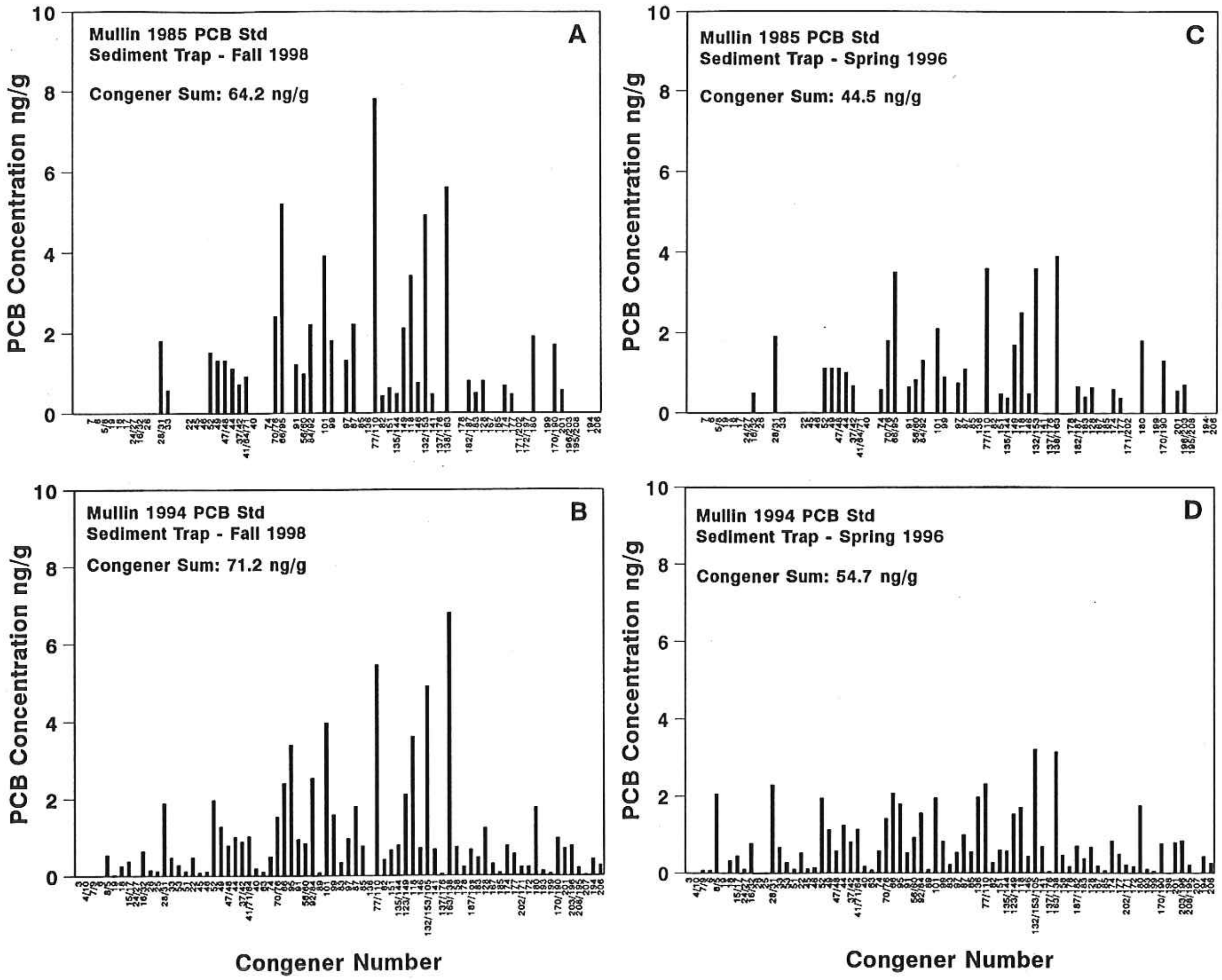

Figure 6. **A.** Polychlorinated biphenyl (PCB) congener concentrations measured in sediment trap samples deployed in the Mississippi River above Lock and Dam 3 in the fall of 1998 and quantified with the Mullin 1985 PCB standard. **B.** Fall 1998 sediment trap samples quantified with the Mullin 1994 PCB standard. **C.** Polychlorinated biphenyl (PCB) congener concentrations measured in sediment trap samples deployed in the Mississippi River above Lock and Dam 3 in the spring of 1996 and quantified with the Mullin 1985 PCB standard. **D.** Spring 1996 sediment trap samples quantified with the Mullin 1994 PCB standard.

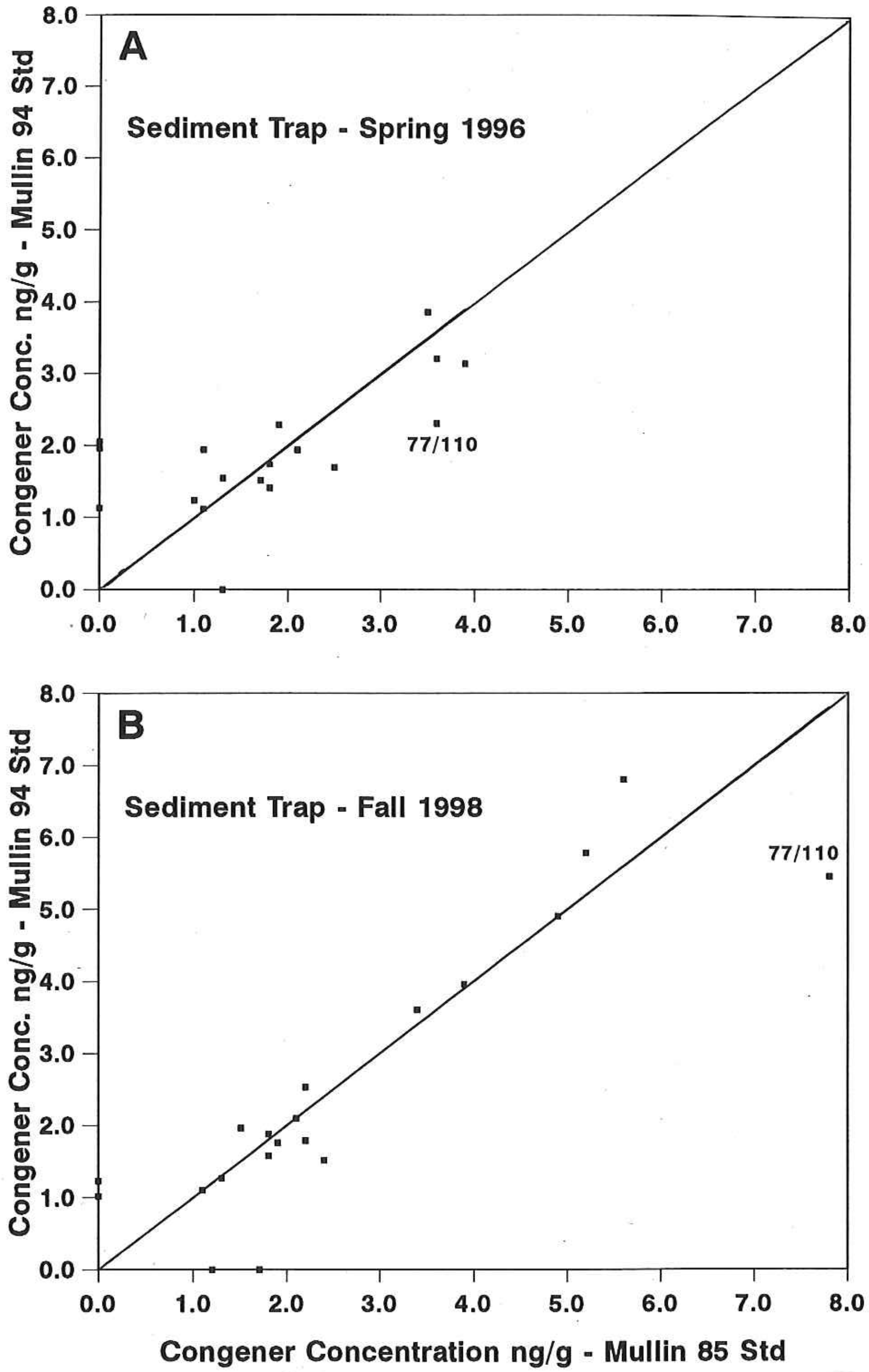

Figure 7. **A**. Comparison of dominant (> 1 ng/g) polychlorinated biphenyl (PCB) congener concentrations measured in sediment trap samples deployed in the Mississippi River above Lock and Dam 3 in the spring of 1996 and quantified with the Mullin 1994 versus 1985 PCB standards. **B**. Comparison of dominant polychlorinated biphenyl (PCB) congener concentrations measured in sediment trap samples deployed at Lock and Dam 3 in the fall of 1998 and quantified with the Mullin 1994 versus 1985 PCB standards.

Table 1. Summary of polychlorinated biphenyl (PCB), ancillary water quality and physical data for the Mississippi River measured near Lock and Dam 3 in the spring of 1996. PCB samples were quantified with the Mullin 1994 PCB standard.

Parameter	April 17	May 29	June 20	Average
Temperature C	4.5	16.2	21.5	14.1
Discharge cfs	66800	45500	29400	47233
Total Sus. Solids mg/L	32	54	63	50
Particulate Org. C. mg/L	1.4	2.6	1.9	2.0
Dissovled Org. C. mg/L	3.6	9.4	7.8	6.9
Total Carbon mg/L	5.0	12.0	9.7	8.9
Percent Organic Carbon in Particulate Fraction	4.4	4.8	3.0	4.1
Chlorophyll a ug/L	9.7	46.8	19.8	25.4
Particulate PCBs ng/L	0.7	3.1	3.9	2.6
Particulate PCBs ng/g	21.9	57.4	61.9	47.1
Particulate PCBs ng/g OC	498	1196	2063	1252
Dissolved PCBs ng/L	1.2	1.6	1.0	1.2
Dissolved PCBs %	62	34	20	39
Total PCBs ng/L	1.9	4.7	4.8	3.8
PCB load g/day	304	524	347	392

Table 2. Average dissolved, particulate and total PCB concentrations from rivers in Wisconsin. River flows and PCB loadings represent the average values for the dates of PCB sampling. Bed sediment PCB concentrations represent samples from upstream impoundments.

River	Period	Flow cfs	Sample size	Part. PCBs ng/L	Diss. PCBs ng/L	Diss. %	Total ng/L	Load g/d	Bed Sediment µg/g	Reference
Menominee River	April-June 1989	4265	13	1.5	1.5	50	3.0	31	na	House et al. 1993
Pestigo River	April-June 1989	980	3	6.1	3.7	38	9.8	24	na	House et al. 1993
Oconto River	April-June 1989	781	3	2.0	3.0	60	5.0	10	na	House et al. 1993
Fox River	April-June 1989	6068	13	56	16	22	72	1069	6 a	House et al. 1993
Milwaukee River	1993-94	360	4	19	7.7	29	27	24	0.3-100	Steuer et al. 1999a
Manitowoc River	1993-94	32	23	81	32	28	113	9	140	Steuer et al. 1999b
Mississippi River	April-June 1989	47200	3	2.6	1.2	32	3.8	439	0.04 b	This study

na - not available.
a - Steuer et al. 1995
b - Sullivan and Moody, 1996

Table 3. Dissolved (Diss.) and particulate (Part.) polychlorinated biphenyl (PCB) concentrations in the Mississippi River near Lock and Dam 3 during April to June 1996 based on 80-Liter water samples and sediment trap collections. Samples quantified using the Mullin 1994 PCB standard.

PCB No.	Chlorine Substitution	Laboratory Blank		80-Liter Composite Samples: April 17		May 29		June 20		Sediment Trap*: April 1 to June 5	
		Diss. ng/L	Part. ng/L	Diss. ng/L	Part. ng/L	Diss. ng/L	Part. ng/L	Diss. ng/L	Part. ng/L	Part. ng/g	Part. ng/L
3	4	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	na	na
4/10	2,2'/2,6	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	na	na
7/9	2,4/2,5	<0.011	<0.011	<0.011	<0.011	<0.012	<0.011	<0.011	<0.011	0.07	0.003
6	2,3'	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	<0.022	0.07	0.003
8/5	2.4'/2,3	<0.063	<0.049	0.056	<0.049	0.11	<0.049	0.058	<0.049	2.05	0.084
19	2,2',6	<0.007	<0.007	<0.007	<0.007	0.007	<0.007	<0.007	<0.007	na	na
18	2,2',5	<0.014	<0.014	0.033	<0.014	0.069	0.017	0.028	<0.014	0.32	0.013
15/17	4,4'/2,2',4	0.032	<0.032	0.036	<0.030	0.11	<0.030	0.039	<0.030	0.45	0.018
24/27	2,3,6/2,3',6	<0.007	<0.007	<0.007	<0.007	0.012	<0.007	<0.007	<0.007	0.09	0.004
16/32	2,2',3/2,4',6	<0.022	<0.022	0.045	<0.022	0.090	0.023	0.047	0.037	0.77	0.032
26	2,3',5	<0.014	<0.014	<0.014	<0.014	<0.031	<0.014	<0.014	<0.014	<0.17	<0.007
25	2,3',4	<0.012	<0.012	<0.012	<0.012	<0.015	<0.012	<0.012	<0.012	na	na
28/31	2,4,4'/2,4',5	<0.050	<0.050	0.11	0.041	0.18	0.11	0.073	0.11	2.29	0.094
33	2'3,4	<0.016	<0.015	0.042	<0.015	0.060	<0.020	0.020	<0.019	0.66	0.027
53	2,2',5,6'	<0.008	<0.008	0.008	<0.008	0.017	0.021	0.018	0.022	0.27	0.011
51	2,2',4,6'	0.020	<0.007	0.014	<0.007	0.017	0.009	0.016	0.011	0.10	0.004
22	2,3,4'	<0.022	<0.022	0.038	<0.022	0.056	0.023	<0.022	<0.022	0.52	0.021
45	2,2',3,6	<0.009	<0.009	<0.009	<0.009	0.011	<0.009	<0.009	<0.009	0.11	0.005
46	2,2',3,6'	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	0.009	0.14	0.006
52	2,2',5,5'	0.021	<0.015	0.100	0.042	0.11	0.12	0.079	0.15	1.94	0.080
49	2,2',4,5'	0.015	<0.010	0.034	0.021	0.053	0.084	0.046	0.096	1.12	0.046
47/48	2,2',4,4'/2,2'4,5	0.080	<0.018	0.031	0.018	0.056	0.066	0.039	0.061	0.57	0.023
44	2,2',3,5'	0.016	<0.013	0.062	0.023	0.074	0.069	0.041	0.075	1.24	0.051
37/42	3,4,4'/2,2',3,4'	<0.020	<0.020	0.030	<0.020	0.048	0.058	0.029	0.062	0.81	0.033
41/71/64	2,2',3,4/2,3',4',6/2,3,4',6	<0.020	<0.020	0.042	0.021	0.062	0.065	0.033	0.072	1.13	0.046
40	2,2',3,3'	<0.010	<0.010	0.010	<0.010	0.014	<0.010	<0.010	<0.010	0.17	0.007
63	2,3,4',5	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.07	0.003
74	2,4,4',5	<0.013	<0.013	<0.013	<0.013	0.013	0.028	<0.013	0.031	0.57	0.023
70/76	2,3',4',5/2',3,4,5	<0.025	<0.025	0.041	<0.025	0.043	0.078	0.027	0.089	1.41	0.058
66	2,3',4,4'	0.024	<0.023	0.048	0.035	0.062	0.13	0.036	0.17	2.07	0.085
95	2,2',3,5',6	0.019	<0.012	0.068	0.039	0.049	0.13	0.046	0.16	1.79	0.073
91	2,2',3,4',6	<0.011	<0.011	0.012	<0.011	0.011	0.042	0.012	0.053	0.52	0.021
56/60	2,3,3',4',/2,3,4,4'	<0.016	<0.016	0.030	<0.016	0.040	0.047	0.017	0.045	0.92	0.038
92/84	2,2',3,5,5'/2,2',3,3',6	<0.024	<0.024	0.049	0.032	0.041	0.11	0.041	0.15	1.55	0.064
89	2,2',3,4,6'	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.09	0.004
101	2,2',4,5,5'	0.012	<0.011	0.050	0.046	0.039	0.150	0.039	0.21	1.94	0.080
99	2,2',4,4',5	<0.008	<0.008	0.014	0.017	0.013	0.065	0.013	0.083	0.82	0.034
83	2,2',3,3',5	<0.009	<0.009	<0.009	<0.009	<0.009	0.015	<0.009	0.019	0.21	0.009
97	2,2',3'4,5	<0.006	<0.006	0.010	0.011	0.010	0.040	0.010	0.051	0.53	0.022
87	2,2',3,4,5'	<0.010	<0.010	0.024	0.022	0.020	0.075	0.019	0.090	0.99	0.041

Table 3. Continued.

PCB No.	Chlorine Substitution	QA - Blank		April 17		May 29		June 20		April 1 to June 5 Sediment Trap	
		Diss. ng/L	Part. ng/L	Diss. ng/L	Part. ng/L	Diss. ng/L	Part. ng/L	Diss. ng/L	Part. ng/L	Part. ng/g	Part. ng/L*
85	2,2',3,4,4'	<0.011	<0.011	<0.011	<0.011	<0.011	0.036	<0.011	0.042	0.54	0.022
136	2,2',3,3',6,6'	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	0.032	1.96	0.080
77/110	3,3',4,4'/2,3,3',4',6	<0.022	<0.022	0.050	0.064	0.052	0.240	0.052	0.30	2.31	0.095
82	2,2',3,3',4	<0.007	<0.007	<0.007	<0.007	<0.007	0.017	<0.007	0.021	0.26	0.011
151	2,2',3,5,5',6	<0.010	<0.010	0.014	<0.010	<0.010	0.032	<0.010	0.040	0.59	0.024
135/144	2,3',3,3'5,6'/2,2'3,4,5',6	<0.013	<0.013	<0.013	<0.013	<0.013	0.035	<0.013	0.047	0.56	0.023
123/149	2',3,4,4',5/2,2',3,4',5',6	<0.010	<0.010	0.027	0.029	0.015	0.096	0.014	0.12	1.52	0.062
118	2,3',4,4',5	<0.016	<0.016	<0.016	0.036	0.016	0.14	0.019	0.19	1.70	0.070
146	2,2',3,4',5,5'	<0.011	<0.011	<0.011	<0.011	<0.011	0.029	<0.011	0.039	0.42	0.017
132/153/105	2,2',3,3',4,6'/2,2',4,4',5,5'/2,3,3',4,4'	<0.020	<0.020	0.031	0.064	0.023	0.21	0.024	0.27	3.21	0.132
141	2,2',3,4,5,5'	<0.008	<0.008	<0.008	0.009	<0.008	0.030	<0.008	0.040	0.68	0.028
137/176	2,2',3,4,4',5/2,2',3,3',4,6,6'	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	0.03	0.001
163/138	2,3,3',4',5,6/2,2',3,4,4',5'	<0.022	<0.022	<0.022	0.070	<0.022	0.25	0.023	0.35	3.14	0.129
158	2,3,3',4,4',6	<0.015	<0.015	<0.015	<0.015	<0.015	0.032	<0.015	0.045	0.46	0.019
178	2,2',3,3',5,5',6	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	0.17	0.007
187/182	2,2',3,4',5,5',6/2,2',3,4,4',5,6'	<0.010	<0.010	<0.010	<0.010	<0.010	0.030	<0.010	0.035	0.70	0.029
183	2,2',3,4,4',5',6	<0.011	<0.011	<0.011	<0.011	<0.011	0.020	<0.011	0.023	0.38	0.016
128	2,2',3,3',4,4'	<0.009	<0.009	<0.009	0.009	<0.009	0.036	<0.009	0.049	0.67	0.027
167	2,3',4,4',5,5'	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	0.013	0.18	0.007
185	2,2',3,4,5,5',6	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	0.06	0.002
174	2,2',3,3',4,5,6'	<0.011	<0.011	<0.011	0.012	<0.011	0.038	<0.011	0.044	0.83	0.034
177	2,2',3,3',4',5,6	<0.012	<0.012	<0.012	<0.012	<0.012	0.024	<0.012	0.029	0.49	0.020
202/171	2,2',3,3',5,5',6,6'/2,2'3,3'4,4',6	<0.008	<0.008	<0.008	<0.008	<0.008	0.009	<0.008	0.011	0.21	0.009
172	2,2',3,3',4,5,5'	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.17	0.007
180	2,2',3,4,4',5,5'	<0.013	<0.013	<0.013	0.024	<0.013	0.081	<0.013	0.096	1.74	0.071
193	2,3,3',4',5,5',6	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	0.10	0.004
199	2,2',3,3',4,5,6,6'	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	0.04	0.002
170/190	2,2'3,3',4,4',5/2,3,3',4,4',5,6	<0.011	<0.011	<0.011	0.012	<0.011	0.041	<0.011	0.054	0.76	0.031
198	2,2',3,3',4,5,5',6	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015	na	na
201	2,2',3,3',4,5,5',6'	<0.018	<0.018	<0.018	<0.018	<0.018	0.034	<0.018	0.037	0.79	0.032
203/196	2,2',3,4,4',5,5',6/2,2',3,3',4,4',5,6'	<0.028	<0.028	<0.028	<0.028	<0.028	0.036	<0.028	0.042	0.83	0.034
208/195	2,2',3,3',4,5,5',6,6'/2,2',3,3',4,4',5,6	<0.008	<0.008	<0.008	<0.008	<0.008	0.009	<0.008	0.011	0.20	0.008
207	2,2'3,3',4,4',5,6,6'	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	na	na
194	2,2',3,3',4,4',5,5'	<0.011	<0.011	<0.011	<0.011	<0.011	0.020	<0.011	0.023	0.42	0.017
206	2,2'3,3',4,4',5,5',6	<0.007	<0.007	<0.007	<0.007	<0.007	0.012	<0.007	0.014	0.25	0.010
	Sum of detected values:	0.24	0.00	1.86	0.70	1.60	3.11	0.96	3.87	54.74	2.24

* - Method detection levels have not been established for this matrix. Water column particulate-phase concentrations estimated using an average total suspended solids concentration of 41 mg/L during the deployment period.

na - Not analyzed.

Table 4. Polychlorinated biphenyl (PCB) concentrations in sediment trap samples collected from Lock and Dam 3 during April 1 to June 6, 1996 and September 1 to November 3, 1998. Samples were qunatified using the Mullin 1985 and 1994 PCB standards.

Mullin PCB Std.		Spring 1996 Mullin PCB Std.		Fall 1998 Mullin PCB Std.	
1985 PCB No.	1994 PCB No.	1985 ng/g	1994 ng/g	1985 ng/g	1994 ng/g
3	3	na	nd	na	nd
4/10	4/10	na	nd	na	nd
7	7/9	<0.20	0.07	<0.20	nd
6	6	<0.45	0.07	<0.45	nd
5/8	8/5	<1.3	2.05	<1.3	0.54
19	19	<0.30	nd	<0.30	0.02
18	18	<0.35	0.32	<0.35	0.25
17	15/17	<0.30	0.45	<0.30	0.38
24/27	24/27	<0.30	0.09	<0.30	nd
16/32	16/32	0.49	0.77	<0.40	0.63
26	26	<0.35	<0.17	<0.35	0.15
25	25	na	nd	na	0.12
28/31	28/31	1.9	2.29	1.8	1.88
33	33	<0.45	0.66	0.57	0.47
53	53	na	0.27	na	0.28
51	51	na	0.10	na	0.12
22	22	<0.60	0.52	<0.60	0.47
45	45	<0.30	0.11	<0.30	0.08
46	46	<0.35	0.14	<0.35	0.11
52	52	1.1	1.94	1.5	1.96
49	49	1.1	1.12	1.3	1.27
47/48	47/48	1.1	0.57	1.3	0.79
44	44	1.0	1.24	1.1	1.10
37/42	37/42	0.67	0.81	0.72	0.88
41/64/71	41/71/64	<0.67	1.13	0.91	1.02
40	40	<0.30	0.17	<0.30	0.18
63	63	na	0.07	na	0.10
74	74	0.57	0.57	<0.66	0.49
70/76	70/76	1.8	1.41	2.4	1.52
66/95	66	3.5	2.07	5.2	2.39
95	95	r	1.79	r	3.39
91	91	0.64	0.52	1.20	0.94
56/60	56/60	0.83	0.92	0.97	0.83
84/92	92/84	1.3	1.55	2.2	2.53
89	89	na	0.09	na	0.08
101	101	2.1	1.94	3.9	3.96
99	99	0.90	0.82	1.80	1.58
83	83	na	0.21	na	0.34
97	97	0.75	0.53	1.30	0.96
87	87	1.1	0.99	2.2	1.79

Mullin PCB Std.		Spring 1996 Mullin PCB Std.		Fall 1998 Mullin PCB Std.	
1985 PCB No.	1994 PCB No.	1985 ng/g	1994 ng/g	1985 ng/g	1994 ng/g
85	85	<0.65	0.54	<3.0	0.77
136	136	<0.90	1.96	<3.0	<2.1
77/110	77/110	3.6	2.31	7.8	5.45
82	82	<0.30	0.26	0.42	0.41
151	151	0.48	0.59	0.62	0.66
135/144	135/144	0.38	0.56	0.47	0.79
149	123/149	1.7	1.52	2.1	2.10
118	118	2.5	1.70	3.4	3.60
146	146	0.49	0.42	0.74	0.71
132/153	132/153/105	3.6	3.21	4.9	4.90
141	141	<0.45	0.68	0.46	0.68
137/176	137/176	<0.30	0.03	<0.30	0.04
138/163	163/138	3.9	3.14	5.6	6.80
158	158	na	0.46	na	0.74
178	178	<0.40	0.17	<0.40	0.22
182/187	187/182	0.66	0.70	0.79	0.67
183	183	0.41	0.38	0.49	0.46
128	128	0.63	0.67	0.79	1.23
167	167	<0.50	0.18	<0.50	0.30
185	185	<0.30	0.06	<0.30	0.07
174	174	0.59	0.83	0.67	0.77
177	177	0.38	0.49	0.46	0.56
171/202	202/171	<0.30	0.21	<0.30	0.21
172/197	172	<0.50	0.17	<0.50	0.22
180	180	1.8	1.74	1.9	1.76
193	193	na	0.10	na	0.12
199	199	<0.30	0.04	<0.30	0.05
170/190	170/190	1.3	0.76	1.7	0.97
198	198	na	nd	na	nd
201	201	0.55	0.79	0.56	0.70
196/203	203/196	0.70	0.83	<0.70	0.77
195/208	208/195	<0.70	0.20	<0.70	0.20
207	207	na	nd	na	0.02
194	194	<0.50	0.42	<0.50	0.42
206	206	<0.40	0.25	<0.40	0.27
	Sum* :	44.5	54.7	64.2	71.2
	Sum > 1 ng/g :	34.4	34.1	54.6	50.2

na - Not analyzed. nd - Not detected. r - Reported with a co-euluting congener. * - Sum of all detected values.