A PRELIMINARY CONTAMINANT AND TOXICOLOGICAL SURVEY OF ILLINOIS RIVER SEDIMENTS

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A PRELIMINARY CONTAMINANT AND TOXICOLOGICAL SURVEY OF ILLINOIS RIVER SEDIMENTS

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by

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ABSTRACT

Sediments from 6 sites on the Illinois River and its tributaries were analyzed for organic and inorganic contaminants. Relative toxicity of sediments was determined using bioassays. Concentrations of contaminants were extremely high in the Chicago River and declined with increasing distance from Chicago. Ammonia appears to be the factor most significantly affecting aquatic life, but levels of polynuclear aromatic hydrocarbons and heavy metals are also of concern. Recommendations for further study and improving water quality are made.

INTRODUCTION

The Illinois River, before it became highly polluted, was one of the most biologically productive riverine systems in the United States. Over 2 million migrating scaup (*Aythya* spp.) used the river valley annually until the 1940's. However, when fingernail clams, their primary food, began to disappear in the 1950's, diving duck use also declined (Bellrose et al. 1979). The ducks moved to feeding grounds on the Mississippi River where fingernail clams remained abundant. Environmental conditions continue to be toxic to fingernail clams on an extensive reach of the Illinois River and populations have remained depressed (Blodgett et al. 1983). As a consequence, diving duck use of the Illinois River has also remained low over the past three decades.

Use of the Illinois River valley by dabbling ducks has also decreased. Aquatic plants, their preferred food source, declined in the Illinois River almost to a point of extinction between 1936 and 1976 because of altered water levels and increased turbidity (Bellrose et al. 1979). The only plants now present are those tolerant of low water quality, which are poor duck foods. Use of the upper Illinois by migratory dabbling ducks is now primarily limited to moist soil units and areas where waste corn is available.

The Illinois River was one of the most productive freshwater fisheries in the country until World War II, being second only to the Columbia River in value of commercial catch in American Rivers. Fish catches on the Illinois River have shown a steady decline since 1950 (Sparks et al. 1983). By the 1970's, water quality declined to such an extent that fish were no longer present in the upper Illinois River. Presently, fish populations in the river fluctuate in relationship to flow volume, with fish numbers increasing when high flow volumes are available to dilute pollution and decreasing following years of low flow volume. Conditions in the Illinois River tributaries in the Chicago area are even worse than in the Illinois River. Carp, goldfish and hybrids are the only fish present in the Des Plaines River and most of these are diseased (Sparks 1977). The North Branch of the Chicago River does not sustain a year-around fish population

The decline in water quality in the Illinois river can be directly attributed to the discharge of sewage effluent into the Chicago River and other Illinois River tributaries in the Chicago area. These tributaries originally flowed into Lake Michigan from which Chicago withdraws its drinking water. Therefore, in 1871, the flow of the Chicago River was reversed into the Des Plaines and Illinois Rivers to divert the high sewage load away from the city's drinking water supply. As Chicago continued to grow, discharges into the Illinois River increased. However, the amount of water available for diluting additional sewage has remained the same, increasing pollution problems.

Despite attempts to regulate industrial and sewage effluent, the Illinois River has failed to recover. The cumulative effects of a large number of discharges, as well as illegal discharging, continue to significantly impact water and habitat quality. Water and habitat quality are further degraded by high rates of sedimentation. Fingernail clam bioassays conducted on the Illinois River by the Illinois Natural History Survey in the early 1980s indicated that sediments along a 290 km (180-mile) reach of the river downstream from Chicago were toxic (Blodgett et al. 1983). The exact cause of toxicity was not determined, although elevated concentrations of ammonia were suspected.

Contaminants in the Illinois River and its tributaries are of concern to the U.S. Fish and Wildlife Service for a number of reasons. Chautauqua National Wildlife Refuge and Swan Lake on the Calhoun Division of the Mark Twain National Wildlife Refuge are located on the Illinois River. The direct impacts of contaminants on waterfowl and the abundance of waterfowl foods such as the fingernail clam, and the possible effects of contamination of the food chain on waterbirds such as herons and egrets are also of Service concern.

In 1987, the U.S. Fish and Wildlife Service conducted a preliminary evaluation of the toxicity of sediments on the Illinois River. The objectives of this study were to identify contaminants in sediments, quantify levels of contamination, determine the toxicity of these contaminated sediments to aquatic biota, and identify sites in need of further study. The ultimate purpose would be to reduce or eliminate inputs of contaminants, and to clean up those sites creating water quality problems on the Illinois River.

STUDY AREA

The area evaluated on the Illinois River extended from the North Branch of the Chicago River in downtown Chicago downstream approximately 526 km (327 miles) to the Swan Lake National Wildlife Refuge near Grafton, Illinois, which is 8 km. above the confluence of the Illinois and Mississippi Rivers (Fig. 1).

Sediment samples were collected from the following locations on the Illinois River (Fig. 1):

1. North Branch of the Chicago River in downtown Chicago; river km 524.5 (river mile 326).
2. Des Plaines River near Joliet, Illinois; river km 460.2 (river mile 286).
3. Pool above Starved Rock lock and dam; Illinois River km 371.7 (river mile 231).
4. Turner Lake at Spring Valley, Illinois; Illinois River km 345.9 (river mile 215).
5. Chautauqua Lake on the Chautauqua National Wildlife Refuge near Havana, Illinois; Illinois River km 205.5-206.4 (river mile 127.7-128.3).
6. Swan Lake on the Mark Twain National Wildlife Refuge near Grafton, Illinois; Illinios River km 8-10.5 (river mile 5-6.5).

METHODS

In December, 1987, composite sediment samples consisting of four to six subsamples were collected with a 50 cm by 10 cm stainless steel core sampler. Two composite sediment samples, one from 0 to 15 cm (0 to 6 in) depth and another from the 30 to 46 cm depth (12 to 18 in), were collected from each station except at Chautauqua Lake. At Chautaqua Lake, an additional set of cores were collected from the original lake bed lying under the more recently deposited sediment layer. Original lake bed sediments were identified by their hard consistency and by the presence of remnant fingernail clam shells.

Sediments in the North Branch of the Chicago River, the Des Plaines River, Chautauqua Lake and Swan Lake are flocculant and watery, making it difficult to collect samples from exact depths. Attempts were made to collect samples at the depths reported although, at some locations, limited amounts of highly flocculent sediment were observed passing through the coring device and escaping through the water relief valve on top. Therefore, the river kilometer sampling locations are precise but the actual sediment sampling depths may vary somewhat from those reported.

Bioassays were used to determine the relative toxicity of the sediments, although this technique did not identify the compounds

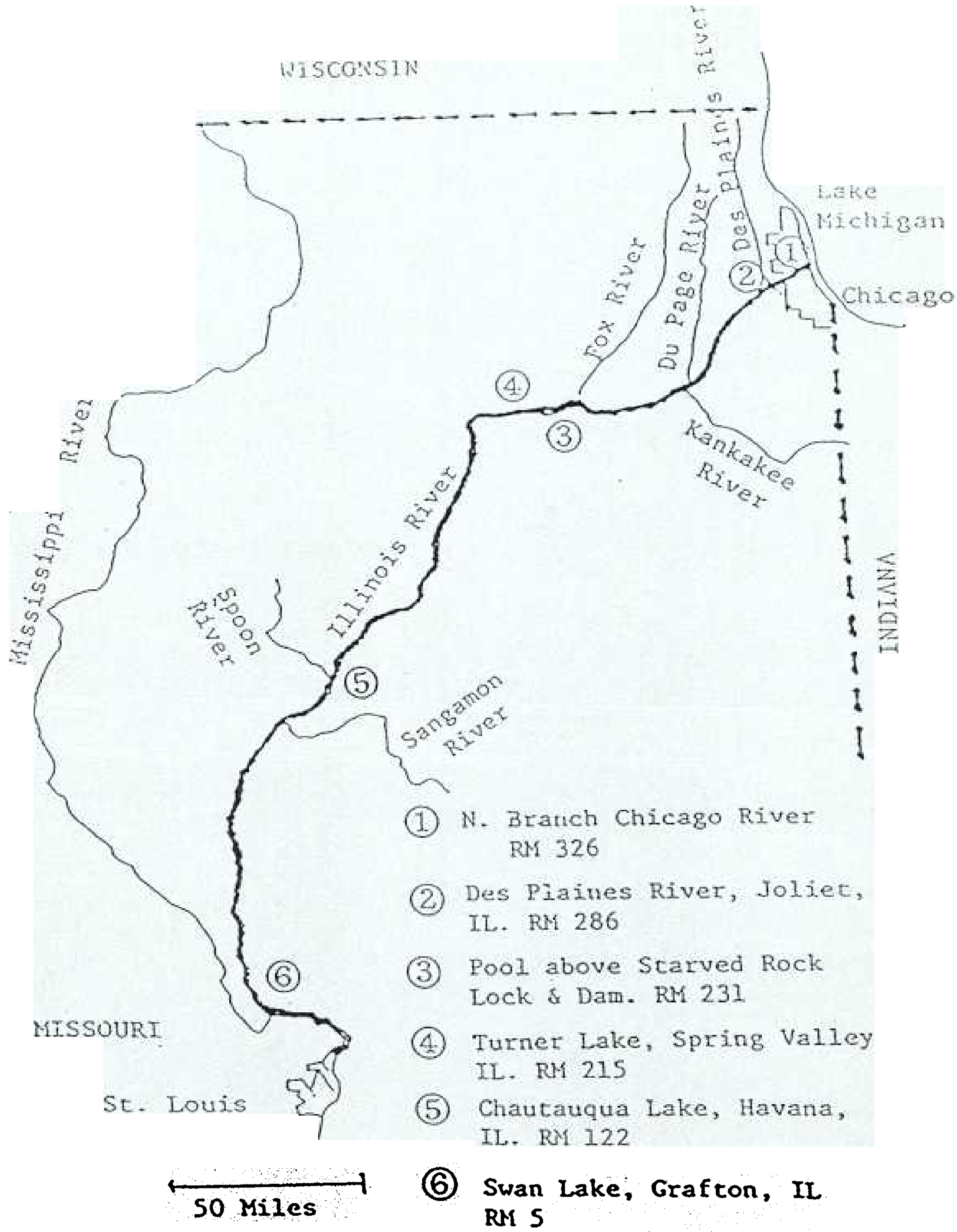

Figure 1. Sediment collection locations on the Illinois River and tributaries.

responsible. Bioassays were conducted by the University of Iowa Hygienic Laboratory using the standard Daphnia magna and larval fathead minnows (Pimephales promelas) technique. The number of test organisms in each bioassay ranged between 19 and 24.

Bioassays were conducted by exposing each test species to each sediment sample. A control bioassay using well water without sediment was conducted simultaneously with each sediment bioassay. One part sediment was diluted with three parts water to prepare the bioassay solution. The mixture was stirred and allowed to settle for 24-hr to 48-hr before the test organisms were added. An aliquot of water for chemical analyses was removed from the container immediately before starting the bioassays. The water was analyzed to insure that pH and oxygen concentrations were satisfactory for organism survival. The water sample was analyzed for: dissolved oxygen, pH, total ammonia, nitrate nitrogen, nitrite nitrogen and organic nitrogen Un-ionized ammonia concentrations were calculated from these data.

Sediment samples were analyzed for carbofurans, PAH's and organochlorines including Aroclor specific polychlorinated biphenyls (PCBs). A gas chromatograph-mass spectrometer was used to analyze for organics in the sediments. Zinc, lead, cadmium, copper, nickel and chromium were analyzed for using atomic absorption. A complete priority pollutant analysis was performed on one sediment sample from the Chicago River, which had been determined, based on the bioassay results, to be the most toxic.

RESULTS

In the bioassays, 100% of the larval fathead minnows died within 24 hours when exposed to sediments collected from the Chicago River, the Des Plaines River and the deeper sediments from Starved Rock on the Illinois River (Table 1). Fish mortality decreased progressively as distance downstream from Chicago increased. However, 25% of the fish died when exposed to Chautauqua Lake sediments collected at the 30 to 46 cm (12 to 18 inch) depth. The lowest fish mortality occurred with Swan Lake sediments, the station farthest downstream.

Daphnia had a much higher survival rate than fathead minnows. With one exception, mortality was always less than 16% and, in the majority of bioassays, no mortality was observed. The sole exception were bioassays conducted with the deeper sediments collected from the Chicago River, where mortality was 100% (Table 1).

High concentrations of ammonia were present in Illinois River sediments. Un-ionized ammonia concentrations ranged between 1.6 and 6.7 mg/L in bioassays conducted with sediments collected from the three stations closest to Chicago where 100% of the fish died

Table 1. Total and un-ionized ammonia concentrations in bioassay water, (mg/l), un-ionized and ammonia nitrogen concentrations in bulk sediments (mg/kg dry weight) and percent mortality of fathead minnows and Daphnia in 96-hour bioassays conducted with Illinois River sediments.

Parameter	RM[1] 326 Chicago River		RM 286 Brandon Road Des Plaines River		RM 231 IL River Starved Rock		RM 215 IL River Turner Lake		RM 127.7-128.3 IL River Chautauqua Lake		RM 127.7-128.3 IL River Chautauqua Lake	RM 5-6.5 IL River Swan Lake	
Depth-cm	0-16	30-46	0-16	30-46	0-16	30-46	0-16	30-46	0-16	30-46	Old River Bed	0-16	30-46
<u>Bioassay Water</u>													
Total Ammonia	43.7	105.7	19.4	48.6	9.5	29.2	11.1	9.6	1.8	4.3	3.6	3.8	5.0
Unionized Ammonia	1.8	6.7	0.51	2.6	0.39	1.6	0.75	0.52	0.11	0.27	0.12	0.26	0.27
<u>Bulk Sediments</u>													
<u>$-NH_4$ Dry Weight</u>													
Un-ionized Ammonia	3.3	3.46	0.66	0.92	<0.02	0.38	0.49	0.36	<0.02	0.06	0.74	0.50	0.58
Ammonia Nitrogen	320	530	160.0	280	<1.0	46.0	60.0	22.0	<1.0	2.4	57.0	31	45
Fish Mortality													
24-hour	100	100	100	100	16	100	10	5	0	0	0	0	
48-hour	-	-	-	-	21	-	20	10	0	10	5	0	
72-hour	-	-	-	-	26	-	25	15	0	15	5	0	
96-hour	-	-	-	-	47	-	60	35	15	25	10	5	
Total Mortality	100	100	100	100	47	100	60	35	15	25	10	5	
Daphnia Mortality													
24-hour	0	100	0	0	0	0	0	0	0	0		0	
48-hour	0	-	0	0	5	0	0	0	0	0		5	
72-hour	0	-	0	0	10	0	0	0	0	0		25	
96-hour	0	-	0	0	16	10	10	0	0	0		25	
Total Mortality	0	100	0	0	16	10	10	0	0	0		25	

[1]River Miles

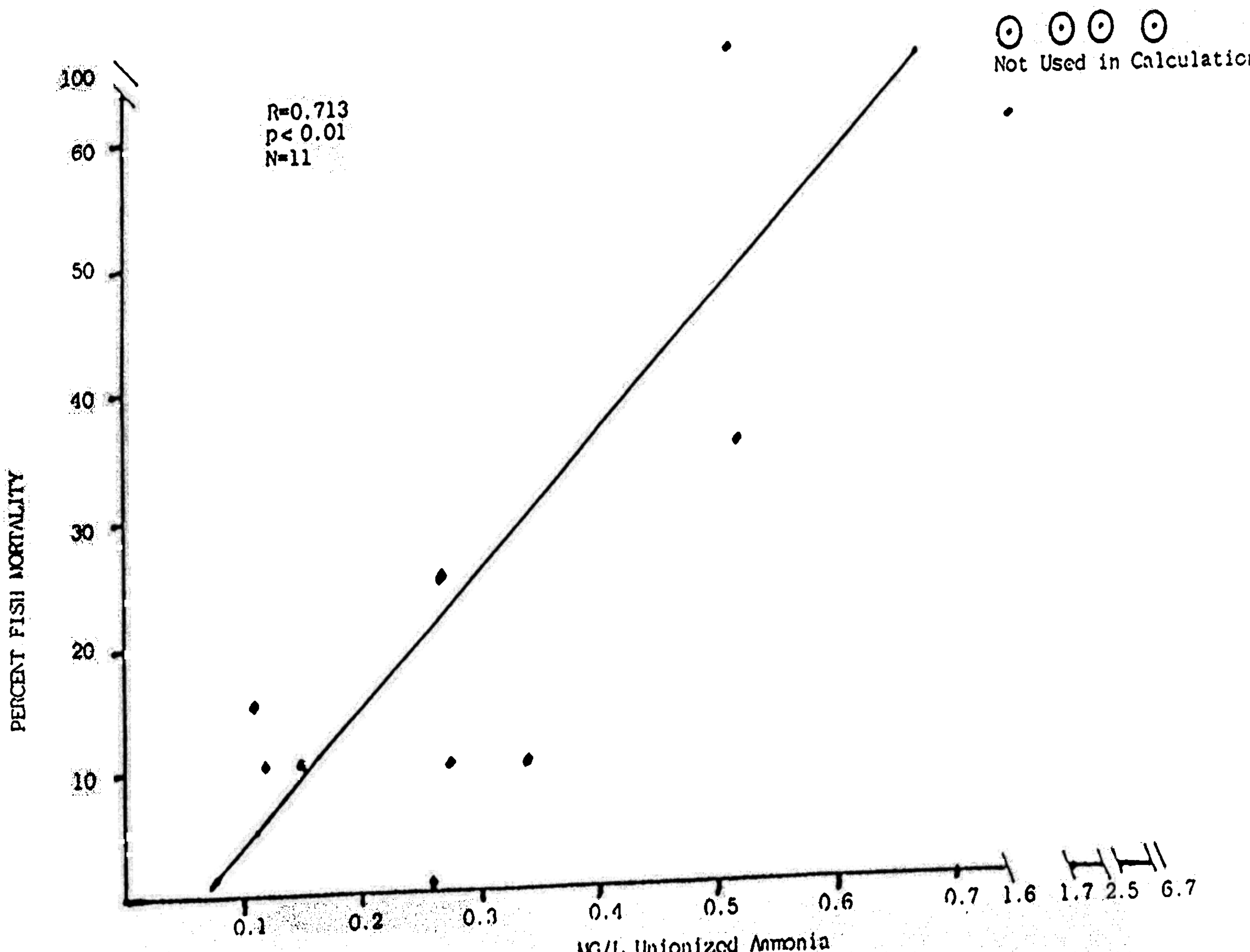

Figure 2. Percent mortality in larval fathead minnows exposed in bioassays to unionized nia present in Illinois River and tributary sediments.

within 24 hr. There was a significant correlation ($r=0.71$, $p<0.01$) between the concentration of un-ionized ammonia present in the bioassay waters and percentage of fathead minnow mortality (Figure 2). In bioassays where fish mortality occurred, total ammonia and un-ionized ammonia concentrations in bioassay water were elevated and were suspected as the main cause of mortality (Table 1).

In samples from the Chicago and Des Plaines Rivers, polynuclear aromatic hydrocarbons (PAHs) were present in the sediments at elevated concentrations (Table 2). Low levels of PCB's and organochlorine pesticides were detected at the same sites (Table 2). The highest concentrations were detected in the deeper sediments collected from the Chicago River. None of the organic compounds for which analyses were conducted were detected in the Illinois River sediments at Turner Lake, located approximately 90 miles from Chicago, or at sites located farther downstream.

Elevated concentrations of inorganic contaminants such as cadmium, chromium, copper, nickel, lead and zinc were detected in sediments collected in, or immediately downstream, from Chicago (Table 3). Inorganic contaminant concentrations declined as the distance downstream from Chicago increased and approached background levels at Starved Rock, approximately 121 km (75 miles) from Chicago.

DISCUSSION

The results of this study strongly implicate un-ionized ammonia as a major factor affecting aquatic life in the of the Illinois River watershed as far downstream as Lake Chautauqua. Reported 96-hour LC50's range from 0.14 to 4.60 mg/L NH_3 for non-salmonid fish species (EPA, 1986). These are comparable to values of 0.51 to 6.7 mg/L NH_3 in those bioassays with 100% mortality in this study. In addition, concentrations from 0.0017 to 0.612 mg/L NH_3 can have chronic effects on fish such as reduction in hatching success, reduction in growth rate and morphological development, and pathologic changes in gill, liver and kidney tissue. Invertebrates, with the exception of fingernail clams, tend to be less sensitive to NH_3 (EPA, 1986). Fingernail clams, however, experienced 100% mortality in experimental streams at concentrations of 0.48-1.17 mg/L NH_3(Zischke and Arthur 1987). Sparks et al. (1983) also suspected that ammonia was the cause of fingernail clam mortality which was observed during bioassays using raw Illinois River water.

Presently, ammonia is probably the most significant pollutant affecting aquatic life on the upper Illinois River. Large quantities of ammonia continue to be released into the Illinois River system by industrial sources and municipal sewage treatment plants, and from non-point sources. Due to ammonia's solubility, it impacts water quality from a point source for a much greater

Table 2. Organic Contaminant concentrations (ug/kg, dry weight) detected in Illinois River and Tributaries sediment core samples. Samples were collected from 0 to 16 cm and 30 to 46 cm depths. One deep sample was collected from the old river bed at Chautauqua Lake. RK indicates river Kilometer. ND indicates not detected.

	RM 524.5 Chicago River		RM 460.2 Des Plaines River		RM 371.7 IL River Starved Rock		RM 345.9 IL River Turner Lake		RM 205.5-206.4 IL River Chautauqua Lake		Old River Bed Chautauqua Lake	RM 5-6.5 IL River Swan Lake	
Parameters Depth-cm	0-16	30-46	0-16	30-46	0-16	30-46	0-16	30-46	0-16	30-46		0-16	30-46
Naphthalene	1000	600	950	1000	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorene	1100	1270	2500	1400	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	8700	8900	10900	7500	ND	470	ND	ND	ND	ND	ND	ND	ND
Anthracene	1600	2600	4900	4500	ND	210	ND	ND	ND	ND	ND	ND	ND
Fluoranthrene	10200	13800	22900	16300	ND	1400	ND	ND	ND	ND	ND	ND	ND
Pyrene	9100	9200	19900	17200	1300	1200	ND	ND	ND	ND	ND	ND	ND
Benz(a)anthracene	7300	8800	22400	16500	580	780	ND	ND	ND	ND	ND	ND	ND
Chrysene	9700	11300	13600	20000	870	1100	ND	ND	ND	ND	ND	ND	ND
Benzo(b)fluoranthrene	6000	6000	23000	11200	ND	970	ND	ND	ND	ND	ND	ND	ND
Benzo(k)fluoranthrene	4700	6200	9900	13300	ND	660	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	6200	8100	15500	15500	ND	850	ND	ND	ND	ND	ND	ND	ND
Dibenz(a,h)anthracene	ND	ND	1100	2000	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(g,h,i)perylene	7500	9400	5300	14400	ND	680	ND	ND	ND	ND	ND	ND	ND
Aroclor 1242	4000	7000	2000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aroclor 1254	3000	10000	1000	1000	500	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	2000	2000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDD	200	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DDE	200	200	100	100	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno(1,2,3-CD)pyrene	6000	7400	5800	13300	ND	560	ND	ND	ND	ND	ND	ND	ND

Table 3 Inorganic Contaminant concentrations (mg/kg, dry weight) detected in Illinois River and Tributaries sediment core samples. Samples were collected from 0 to 16 cm and 30 to 46 cm depths. One deep sediment composite sample was collected from the Old River Bed at Chautauqua Lake. RK indicates river Kilometer.

Parameters	RM 326 Chicago River		RM 286 Des Plaines River		RM 231 IL River Starved Rock		RM 215 IL River Turner Lake		RM 127.7-128.3 IL River Chautauqua Lake		RM 127.7-128.3 IL River Chautauqua Lake	RM 5-6.5 IL River Swan Lake	
Depth-cm	0-16	30-46	0-16	30-46	0-16	30-46	0-16	30-46	0-16	30-46	Old River Bed	0-16	30-46
Cadmium	67	99	29	44	5.3	9.8	4.4	4.1	<2	<2	<2	<2	<2
Chromium	460	620	260	350	52	86	58	55	46	40	36	44	44
Copper	570	590	260	340	39	66	55	42	34	30	25	31	30
Nickel	220	200	180	200	31	36	37	37	35	29	24	30	31
Lead	1200	1200	400	460	65	96	79	65	43	39	24	37	36
Zinc	1700	2000	1100	1500	190	310	260	270	160	130	86	110	110

RM = River Miles

distance than many other pollutants. Even when it is tied up in sediments, it continues to be bioavailable to benthos, and toxic amounts of non-ionized ammonia could be released from the highly flocculant sediments by water turbulence associated with barge traffic or wave action.

Polynuclear aromatic hydrocarbons (PAH's) and heavy metals potentially interact with the effects of the un-ionized ammonia. Concentrations of a number of these contaminants are elevated, but their concentrations in the water column and their bioavailability to different aquatic organisms would be expected to vary. Bottom-dwelling organisms such as fingernail clams or bottom feeding fish would be most greatly affected.

Although no criteria or standards have presently been established for PAH's, it is now evident that many PAHs are acutely toxic to aquatic life at concentrations of 50 to 1000 ug/l and sublethal effects may be observed 0.1 to 5.0 ug/ (Eisler 1985). Toxicity to fish may be significantly enhanced by exposure to sunlight (Landrum et al 1985). Due to low solubility, PAHs tend to be deposited near point sources, being incorporated into sediments where they degrade very slowly. High levels of PAH's in sediments have been established as the cause of liver tumors in brown bullheads in the Black River in Ohio (Baumann and Harshbarger 1985) and liver lesions in English sole in Puget Sound, Washington (Malins et al. 1984; Varanasi et al 1984) and have been correlated with thyroid, gonad, skin and liver tumors in fish at a number of sites. Baumann (Pers. Comm.) has summarized the data on PAH levels in sediments at sites where tumor occurrences have been recorded in fish. The levels of PAHs at sites on the North Chicago and Des Plaines River are comparable, with the exception of the Black River, Ohio, to levels at the most contaminated sites summarized by Baumann. The concentrations observed at these sites on the Illinois River would indicate that it is very likely that they cause cancer in benthic feeding fish. Baumann (Pers. comm.) has also suggested that there may be increases in fungal and bacterial lesions, due to immune system suppression.

Concentrations of heavy metals in the Chicago River, the Des Plaines River, Starved Rock and the Turner Lake site on the Illinois River are at levels defined as highly contaminated (Warren 1981). Concentrations at the most heavily contaminated sites ranged from 1-2 orders of magnitude greater than concentrations in non-industrial use streams in Illinois evaluated by Mathis and Cummings (1973). Concentrations at Chautauqua Lake are of intermediate value and are of Service concern because of their presence on refuge lands.

The toxicity of heavy metals in sediments to aquatic life in the Illinois River sediments is difficult to establish. It is generally recognized that there is little correlation between metal concentrations in sediments and toxicity to benthos (Thurston et al. 1979). Attempts to correlate concentrations of trace elements in sediments with toxic concentrations or bioaccumulation in fish have also met with limited success (Wiener et al. 1984). This lack of correlation may be due to a number of factors. There are different forms of metals and they vary in their bioavailabity. Some forms are actually insoluble in water and not bioavailable. For example, chlorides, nitrate and sulfate of cadmium are water soluble, while carbonate and hydroxide are insoluble. Trace elements also typically adsorb very rapidly onto particulate matter and become incorporated into sediments. The duration of time that aquatic life is exposed to trace metals from a source is dependant on how rapidly this process takes place. This process may be influenced by current velocity, water and sediment chemistry and particle size. Once incorporated into the sediments, the availability of trace elements to aquatic organisms is greatly reduced. The actual toxicity of a specific level of a trace element is also affected by water hardness and synergistic and/or antagonistic effects between trace elements. However, contaminated sediments will continue to act as a sink and they may become bioavailable at some future time. For example, sediment may serve as a source of metals through the uptake into roots and foliage of aquatic macrophytes (Buhl and McConville 1984). However, regardless of the difficulty in establishing correlations, the extremely high levels of trace elements which were recorded should be of concern.

Cadmium is the most toxic of the metals detected in Illinois River sediment. At concentrations of 0.47-5.0 ppb in water, all freshwater biota show decreases in standing crop, decreases in growth, inhibition of reproduction, immobilization and population alterations. Aquatic organisms, fish in particular, are very sensitive to cadmium, while birds and mammals are relatively resistant (Eisler 1985). Potential for teratogenic, mutagenic and carcinogenic effects are also greater for cadmium than for other metals (Eisler 1985).

Concentrations of lead are of concern because they are present at high concentrations in sediments. However, most lead is precipitated to sediments and is mobilized from sediments only when pH decreases or ionic composition changes. Some Pb^{+2} may be transformed to tetraalkyllead compounds, a highly toxic form of lead, by microbial or chemical processes.

Copper is of concern in the Illinois River because of its toxicity to larval freshwater clams (Harrison et al. 1984) and impacts on phytoplankton (Ibragim and Patin 1975). It is generally less toxic to adult organisms. However, copper is significantly more toxic when it occurs in solution with zinc (Doudoroff 1952).

CONCLUSIONS AND RECOMMENDATIONS

This preliminary study provides data on the distribution of contaminants in the Illinois River, and suggests what further study is needed prior to proposing solutions. The toxicity of sediments was observed to decrease downstream from Chicago and the conclusion was reached that un-ionized ammonia is probably the immediate cause of mortality. Other contaminants, which are interacting in unknown ways, probably are having chronic effects on aquatic life. This suggests that identifying sources of ammonia inputs and seeking means to reduce inputs would have the most immediate benefits to fish and wildlife, particularly where ammonia inputs are already diluted. However, other sources of contaminants would also need to be cleaned up. To implement any cleanup plan, it will be necessary to target specific sources of contaminants, describe the relative impacts of significant contaminants on fish and wildlife and identify sites where the potential benefits to fish and wildlife are the greatest. At a minimum, from a Service perspective, a followup study will be necessary to more thoroughly investigate contaminant hotspots and determine contaminant levels in sediments, effluents and biota where impacts to migratory bird habitat and refuge lands could occur. However, a multi-agency evaluation and cleanup of the Illinois River would be desirable because of the human health and fish and wildlife resources at risk.

It is evident that the present laws and procedures for regulating discharges are not adequate, if water quality in the Illinois River is to be improved. The following recommendations need to be implemented:

1. Limits for contaminant parameters defined in permits must be sufficiently low to protect the environment. The words "they didn't violate their permit" or "we have a permit to discharge these wastes" are a frequent response to water quality problems resulting from point discharges. The permit limitations usually were not exceeded because the contaminant concentrations allowed in the discharge were excessively high to begin with.

   Municipal and industrial effluents should be brought into compliance by establishing standards resulting in cleaner effluents. Raising the contaminant concentrations allowed under the permit should not be used to bring effluents into compliance.

2. Bioassays on effluents and mixing zone sediments should be a standard NPDES permit monitoring requirement on discharges of questionable quality.

   Restrictions placed on the concentrations of toxic materials do not always provide adequate protection to aquatic organisms. The monitoring method of collecting grab samples of effluents for analyses provides only short-term information on effluent quality, and does not ensure that the receiving water will support a balanced biotic community. Periodic monitoring of effluents does not detect slugs of toxicants being released between periods of scheduled sampling. When bioassays are a required part of the permit requirement, only effluents are evaluated. In addition, it is recommended that bioassays exposing standard sensitive organisms be conducted on stream sediments, as well as effluents. If it is determined through bioassays that the effluent or sediments are toxic to aquatic organisms, tighter restrictions should be placed on the toxic materials allowed in the effluent.

3. Models alone should not be relied upon to predict adverse environmental impacts to receiving waters.

   Models that are well designed can be successfully used to predict environmental impacts to receiving waters from effluents. However, results can be heavily influenced by model assumptions and constants. Model predictions are only useful if the constants are realistic and unbiased. Past modeling attempts have predicted no adverse biological impacts from a discharge, when in fact analyses and bioassays conducted with sediments revealed the presence of toxic materials. Models should not be entirely relied upon for predicting environmental impacts from effluents.

4. Cumulative impacts from all discharges to entire river basins need to be considered when reviewing existing and issuing new permits.

   Evaluating the impacts of individual discharges on a stream that receives multiple discharges does not give a true picture of adverse effects on the receiving waters.

   The combined cumulative impacts of all discharges to the entire river basin needs to be considered when reviewing NPDES permits. Many streams are lined with outfalls. The assumption that adding one more discharge won't hurt is unrealistic. In addition, the assumption that high volume streams have the capability of diluting the input from an unlimited number of discharges also needs to be changed. Many streams with multiple outfalls along their banks are biologically dead. The fact that a stream does not support significant biological life is often used as an excuse to be lenient toward allowing more contaminants to be discharged into the system.

5. The permit objectives should be to maintain or improve receiving water quality. Objectives can be achieved by placing realistic restrictions on existing discharges so that polluted streams can recover or by thoroughly reviewing new discharge

applications on high quality streams so that existing water quality can be maintained.

6. Permit parameters monitored need to include all toxicants potentially in the effluent and should include periodic testing for all process chemicals.

   Toxic materials are often present in the effluent but are not included in the permit monitoring criteria. A thorough review of processing chemicals used and waste by-products produced by the applicant is the most economical method of insuring that all toxic parameters are included in the monitoring plan. Another good, but more expensive method of detecting unknown toxicants in suspect effluents and sediments, is to have them analyzed for a wide variety of priority pollutants.

LITERATURE CITED

Bauman, P.C., W.D. Smith and M. Ribick. 1982. "Hepatic tumor rates and polynuclear aromatic hydrocarbon levels in two populations of brown bullhead (Ictalurus nebulosus)." Pages 93-102 In: Polynuclear aromatic hydrocarbons: Sixth international symposium on physical and biological chemistry. Battelle Press, Columbus, Ohio. M.W. Cooke, A.J. Dennis and G.L. Fisher (ed). 1982.

Bauman, P.C. 1985. Frequencies of liver neoplasia in a feral fish population and associated carcinogens. Mar. Environ. Res 17: 324:324-327.

Bellrose, F.C., F.L. Paveglio Jr., and D.W. Steffeck. 1979. "Waterfowl populations and the changing environment of the Illinois River Valley." Illinois Natural History Survey Division, Vol. 32, Article 1.

Blodgett, K.D., R.E. Sparks, A. A. Paparo, R.A. Cahill and R.V. Anderson. 1983. Distribution of Toxicity in the Sediments of the Illinois Waterway. Pages 293-308 In: W. Blake-Coleman (Ed). Conference Proceedings on urban effects on water quality and quantity. Urbana, Illinois.

Dourdoroff, P. 1952. Some recent developments in the study of toxic industrial wastes. Proc. 4th Ann. Pacific N.W. Ind. Waste Conf., State College (Pullman, Washington). Vol. 21.

Eisler, R. 1985. Cadmium hazards to fish, wildlife and invertebrates: a synoptic review. U.S. Fish and Wildlife Service-Biological Report 85(1.2).

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service-Biological Report 85 (1.11)

Environmental Protection Agency. 1986. Water quality criteria for water. Washington, DC.

Harrison, F.L., J.P. Knezovich and D.W. Rice, Jr. 1984. The toxicity of copper to the adult and early life stages of the freshwater clam, Corbicula manilensis. Arch. Environ. Contam. Toxicol. 13: 85-92.

Ibragim. A.M. and S.A Patin. 1975. Effect of mercury, lead, cadmium, and copper on primary production and phytoplankton in some coastal regions of the Mediterranean and Red Seas. Oceonology 15:589-591.

Landrum, P.F., J.P. Giesy, J.T. Orix and P.M. Allred. 1986. "Photoinduced toxicity of polycyclic aromatic hydrocarbons to aquatic organisms." Pages 304-318 In: Oil in freshwater, chemistry, biology, countermeasure technology. John Van Der Meulen and Steve Hrudey (ed) Pergamon Press, New York.

Malins, D.C., McCain, B.B., Brown, D.W., Chan, S., Myers, M.S., Landahl, J.T., Prohaska, P.G., Friedman, A.J., Rhodes, L.D., Burrows, D.G., Gronlund, W.D., and Hodgins, H.O. 1984. Chemical pollutants in sediments and diseases of bottom-dwelling fish in Puget Sound, Washington, Environ. Sci. Technol. 18:705-713.

Mathis, B.J. and T.F. Cummings. 1973. Selected metals in sediments, water and biota in the Illinois River. J. Water Poll. Cont. Fed. 45:1573-1583.

Sparks, R.E. 1977. Environmental inventory and assessment of Navigation Pools 24, 25, and 26, Upper Mississippi and Lower Illinois Rivers. Special Report No.5, Water Resources Center, University of Illinois, Urbana, Illinois.

Sparks, R.E., M.J. Sandusky and A.A. Paparo. 1983. Identification of the water quality factors which prevent fingernail clams from recolonizing the Illinois River, Phase III. Research Report No. 179, Water Resources Center, University of Illinois, Urbana, Illinois.

Thurston, R.V., R.C. Russo, C.M. Fetterolf, T.A. Edsall, Y.M. Barber. 1979. A review of the EPA Red Book: Quality criteria for water. American Fisheries Society, Bethesda, Maryland.

Varanasi, U. M. Nishimoto, and J. Stover. 1984. Analyses of biliary conjugates and hepatic DNA binding in benso(a)pyrene-exposed English sole. Pages 1315-1328 in M. Cooke and A.J. Dennis (Eds). Polynuclear aromatic hydrocarbons: mechanisms, methods and metabolism. Batelle Press, Columbus, Ohio.

Warren, L.J. 1981. Contamination of sediments by Lead, Zinc, and Cadmium; A Review. Environ. Pollut., Series B 26:401-436.

Wiener, J.G., G.A. Jackson, T.W. May and B.P. Cole. 1984. Longitudinal Distribution of Trace Elements (As, Cd, Cr, Hg, Pb and Se) in Fishes and Sediments in the upper Mississippi River. Pages 139-170 In J.G. Wiener, R.V. Anders, D.R. McConville (Eds). Contaminants in the Upper Mississippi River. Butterworth Publishers, Boston, Massachussetts.

Zischke, J.A. and J.W. Arther. 1987. Effect of elevated ammonia levels on the fingernail clam, Musculium transversum, in outdoor experimental streams. Arch. Environ. Contam. Toxicol. 16: 225-231.