DISTRIBUTION OF LEAD IN THE UPPER DEEP FORK RIVER SYSTEM OF OKLAHOMA

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Concentrations of lead in water, sediment, and biota of the Deep Fork River were determined by atomic absorption spectrophotometry. Highest concentrations of lead were found in sediment samples from the more densely populated areas where there was heavy traffic. Lower concentrations were found in water, biota, and sediment from the rural section of the drainage. Samples from urban lakes were higher in lead concentration than those from rural lakes.

Central Oklahoma has experienced rapid growth over the past twenty years which has had a profound effect on the quality and usefulness of water resources in the upper Deep Fork drainage basin. Storm water run-off from the Oklahoma City area may affect the possible use of this basin as a site for a multiple-purpose reservoir. A lack of suitable water for drinking and industrial uses could affect the growth and progress of Central Oklahoma.

Heavy metals, such as lead, are of concern because of their potential toxicity to biological forms. Lead is a natural component of the earth's crust and is found in soils, streams, and lakes. However, with rapid urban growth there has been an increase in the amount of lead introduced into the natural ecosystem from various sources including, in particular, storm run-off water. Lead is generally found in trace amounts in the water and in higher concentrations in the sediment and biota.

The investigation reported herein represented an attempt to measure the concentration of lead in the upper Deep Fork drainage basin. Objectives of this study were to: (a) determine if land use practices affected the lead levels in the drainage basin; (b) determine accumulations of lead in sediment of lakes throughout the basin; (c) make a comparison of concentrations of lead throughout the basin; and, (d) determine the concentration of lead in some of the organisms in the basin.

The Deep Fork River flows in a northeasterly direction across Oklahoma County to Arcadia, Oklahoma near a proposed damsite, then eastward to Lake Eufaula. The Deep Fork River receives much of its water as storm run-off water from the densely populated areas of Oklahoma City. At the present, the low flow in the river is almost entirely from municipal sewage treatment plant discharges. Plans have been made to remove these discharges because of the construction of an impoundment near Arcadia to receive waters from the upper Deep Fork drainage basin. The impoundment is proposed by the U.S. Army Corps of Engineers to serve as the drinking water supply for Edmond and as a recreational site for central Oklahoma. Concern for the water quality of the proposed lake has been expressed by the State Department of Health. With continued influx of people into the Oklahoma City area and increased motor vehicular travel, pollution by run-off waters is a major potential problem in the proposed reservoir.

METHODS AND MATERIALS

Selected components of Deep Fork River were sampled over a three-month period during the summer of 1974. Water and sediment samples were collected from 34 sampling stations in the drainage basin above the proposed damsite. Water samples were acidified (pH <2) with nitric acid within a few hours after collection. Analyses for lead were performed in accordance with the Environmental Protection Agency's method for total metals as follows: unfiltered samples were shaken until solid material was uniformly dispersed; a 100. ml aliquot was transferred to a 200. ml glass beaker; 5 ml concentrated nitric acid was added; solution was evaporated to dryness on a hotplate without boiling the solution; additional nitric acid was added as necessary to produce a light colored residue. The resi-

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due was dissolved in 5 ml of 5 percent nitric acid, and this solution was aspirated (after settling) into the atomic absorption spectrometer.

Lead was determined with a Perkin-Elmer 303 atomic absorption spectrometer using an air-acetylene flame at the 2170 angstrom absorption line; a deuterium arc background corrector was used during all measurements. For samples reported $\geq$ .05 mg/1 the error is $\pm$ 5 percent; for samples $<$ .05 mg/1, the error is $\pm$ .002 mg/1.

Sediment samples were collected by the core method, sampling down to hardpan. Sediment core samples were prepared for analysis by sectioning the core into 10-cm subsamples, which were then dried in an oven overnight at 125 C. Approximately a one gram aliquot (weighed to $\pm$ .0001 mg) was transferred to a 50 ml beaker and 10 ml of 5 percent nitric acid added by pipette. The beaker was covered with a watch glass and heated gently (with stirring) about 25 minutes. The solution was allowed to cool and settle; the supernatant was aspirated into the atomic absorption spectrometer; conditions were the same as for the water samples. For samples found to contain more than 40 mg/kg lead, the analysis was repeated using an 0.5 gram aliquot in order to verify that all the lead was being recovered. The error in the values reported for sediment is 5 percent.

Biological materials were prepared for analysis by drying in an oven at 105 C for 24 hours to obtain dry weight, digested with concentrated nitric acid to dryness, and ashed in a muffle furnace at 500 C for 24 hours. The residue was redissolved in 2N hydrochloric acid solution. Biota samples included plankton, algae, tubifex worms, detritus, and leaf samples, which were obtained throughout the upper drainage basin.

Figure 1 is a map of the basin with sampling station numbers enclosed in rings. In this study, the sampling stations were divided into five categories: (a) the head-

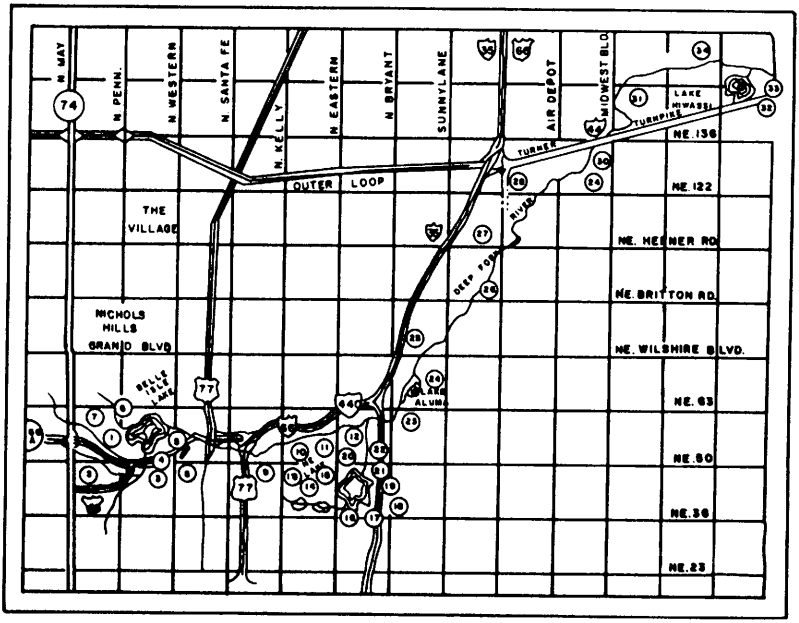

FIGURE 1. Map of Deep Fork River with collecting stations indicated by circled numbers.

water area west of Classen Blvd., stations 1-4 and 7, an urbanized area with a daily average traffic flow of 34,200 autos; (b) the mid-region area, stations 8-12, a lower level of urbanization with a traffic flow of 22,200 vehicles daily, located between Western Avenue and Highway I-35; (c) the rural area of the upper basin east of I-35 and northeastward to Arcadia, stations 25-32, 34 and 35, traffic flow was about 2,500 vehicles daily; (d) the Belle Isle Lake, stations 5 and 6, Upper and Lower Springlake Park lakes, stations 13-16, and the Northeast Lake, stations 17-22, areas of high traffic flow and heavy recreational use; and (e) Lake Aluma and Lake Hiwassee, stations 23-24 and 32-33, rural areas with very low traffic flow and low population density.

RESULTS AND DISCUSSION

Table 1 contains a summary of the data collected during this study. The highest lead concentrations were found in the headwaters of the Deep Fork, where the traffic flow was 34,200 vehicles daily in 1973 (1). The estimated daily vehicle travel in this area is approximately 1.3 million miles per day (2). The average total lead emission rate for automobiles is approximately 0.11 grams of lead per mile (2). Thus, approximately 143,000 grams of lead were emitted daily in this area (2).

Highest lead levels observed in water were measured at Stations 2, 3 and 19. Station 2, near the intersection of U. S. Highway 66 and Pennsylvania Avenue, had the highest lead level recorded during this study

TABLE 1. *Concentrations of lead in the sediments and water of the upper Deep Fork River basin*

		Components (mg/kg)						
			Sediment Depth (cm)					
Station No.	Location	Water (µg/l)	Surface	10	20	30	40	50
1	US 66 & Penn. Ave.	6	60	58	29	20	--	--
	Dry[a]		62	24	--	--		--
	Dry[a]		55	6				--
2	US 66 & Penn. Ave., s.s.	56	60	7	12	--		
3	US 66 & Penn. Ave., s.s.	73	206	7	--	--	--	--
4	Belle Isle L., s.s.	25	43	33	--		--	--
5	Belle Isle L., w. end	18	144	104	58	67	38	--
6	Belle Isle L., n.e.	14	20	11	6	--	--	--
7	Belle Isle L., Penn. Ave.	19	8	--		--	--	--
8	Broadway Extension	29	51	22	--	--	--	--
	Clay[a]	--	6	3	4		--	--
	Sand[a]	--	11	--	--	--	--	--
9	Lincoln Blvd.	15	46	17		--	--	
10	Kelly Ave.	14	8	7	7			--
11	Grand Ave.	13	13	9		--	--	
12	Eastern Ave.	11	13	16	19		--	
13	Upper Springlake, upper end	7	163	150	--	--	--	--
14	Upper Springlake, n. side	10	150	77	6	--	--	--
15	Lower Springlake, upper end	1	70	8	--		--	
16	Lower Springlake, lower end	5	101	67	19	11		--
17	Creek above N.E. Lake	34	15	10	--		--	--
18	N.E. Lake, upper end	34	180	142	101	100	66	34
19	N.E. Lake, east side	60	16	18	--	--	--	--
20	N.E. Lake, Zoo area	15	19	6	--		--	--
21	N.E. Lake, at dam	5	13	10	4	--	--	--
22	N.E. Lake, below spillway	11	12	4	--	--	--	--
23	Lake Aluma, upper end	6	9	2	--	--	--	--
24	Lake Aluma, at dam	18	7	1	--	--	--	--
25	Wilshire Blvd.	7	30	27	7	4	1	5
26	Britton Road	4	8	7	7	--	--	--
27	Hefner Road	25	154	9	2	2	--	
28	Sooner Road	5	3	3	3	--	--	--
29	US 66	7	2	2	--	--	--	--
30	Memorial Road	3	5	9	2	2	--	--
31	Midwest Blvd.	2	5	2	--	--	--	--
32	Hiwassee Lake, upper end	8	4	2	--	--	--	--
33	Hiwassee, Lake, dam area	5	3	1	--	--	--	--
34	Arcadia	3	2	1	--	--	--	--

[a] Dry sediment above the water line was collected.

at 73 μg/l. The water came from a storm sewer which drained an area of motels, cafes, and small businesses; daily traffic flow in the area was 26,300 vehicles in 1973 (1). High lead levels were detected in water from station 3, which was the north branch of this same storm sewer at the same intersection; the lead level was 56 μg/l.

The lake with the highest lead content in its waters was Northeast Lake. Water from the east side of the lake contained 60 μg/l lead. This area receives storm run-off from the area of the Lincoln Park golf course. Traffic flow in this area was 9,507 vehicles daily in 1973 (1).

Lowest levels of lead were found in water from lower Springlake (Station 15), which contained only 1 μg/l of lead. This lake received very little direct run-off because the waters that enter this lake must first flow through upper Springlake where it is postulated that most of the lead would settle out. Very low lead levels of 2 to 3 μg/l were recorded from rural stations 30, 31, and 34, all east of Highway I-35. This area had a low traffic flow of about 2,500 vehicles daily (1).

In general, higher lead concentrations were found in the sediment during this study. The highest concentration, 206 mg/kg lead, was found in the surface sediment sample from station 2. The only other high lead concentration measured from within the main river channel itself was at the intersection of the Deep Fork River and Hefner Road (station 27). This area received much of its run-off water from the intersection of Highway I-35 and Turner Turnpike. Daily traffic flow here was 34,600 vehicles (1). The lead concentration in the surface sediment was 154 μg/kg. The presence of bedrock in the bottom of the Deep Fork River main channel did not permit the accumulation of much sediment; therefore most of the sediment deposits in the main river were very shallow, usually less than 30 cm to the hardpan. The lack of deep deposits of sediment prevented the accumulation of lead within these sediments, probably owing to removal of these sediments by scouring during times of high flow. In general, the lead concentration decreased rapidly below the surface sediment.

The highest lead accumulations in the sediment were measured in samples taken from the upper ends of the lakes in the basin. One of the highest levels was found in sediment from station 18, located at the upper end of Northeast Lake. This area receives run-off from Eastern Avenue and parking lots at Springlake Park. The levels were 180 mg/kg at the surface, decreasing as the depth increased. Traffic flow in this area was 19,000 vehicles daily (1). Sediments from upper areas of the lakes in the headwaters of Deep Fork were usually higher in lead content than sediments from areas in the river channel. Lead tended to settle out once it entered lakes and, in most cases, lead levels were much lower in the areas closer to the dam.

Another lake with high lead concentrations in sediments was upper Springlake, where the surface sediment sample containen 163 mg/kg and at 10 cm measured 150 mg/kg of lead. Another station on this same lake but on the north side also exhibited lead levels of 150 mg/kg. This lake received storm run-off from the area and intermittently received raw sewage from an overflow of a sewage line.

Belle Isle Lake, at the intersection of Highway 66 and the Northwest Expressway, has a traffic flow of 34,200 vehicles daily (1) and in addition received run-off from a shopping center which served 10,500

TABLE 2. *Relationship of lead and sediment accumulations to traffic volume in area around Belle Isle Lake.*

Year	Sediment Depth	Traffic Flow (Daily)	Lead Accumulations mg/kg
1969[a]	50-40	29,300	38
1970	40-30	30,600	79
1971	30-20	29,500	66
1972	20-10	30,900	114
1973	10-0	34,200	153

[a] 1969 was the year the storm sewer was completed and sediment began to accumulate in the upper end of the lake.

vehicles daily. Sediments in the upper end of this lake also were high in lead. The surface lead levels were 135-153 mg/kg and at 10-cm from the top were between 95 and 114 mg/kg. The sediment accumulation in this lake was some 50 cm of sediment in a five-year period of time. Table 2 shows the relationship between the vehicle daily flow rate and accumulation of lead in these sediments. The concentration of lead is related to number of vehicles traveling in this area over the past five years.

The two lakes located in the rural section of the basin showed almost no accumulation of lead. The lead level in Lake Aluma, which is fed by springs, showed an accumulation of only 9 mg/kg in the upper end and 7 mg/kg near the dam in the sediment. Lake Hiwassee, which also had little urban drainage, contained very low lead concentrations in the sediments from both the upper end of the Lake and the area near the dam.

In most cases the accumulation of lead decreased as the sampling stations encompassed more rural drainage. In most of the sediment sampled from areas downstream, the sediment contained less than 15 mg/kg lead.

Aquatic organisms accumulated some lead in the upper Deep Fork River basin (Table 3). Green filamentous algae contained the highest lead concentration of the biota sampled. The highest lead levels were measured in green algae samples from the concrete storm sewer where Lincoln Blvd. crosses the Deep Fork River. The concentration of lead was 51 mg/kg on a dry weight basis. The traffic flow by this station was 21,000 vehicles per day in 1973 (1).

Lead concentrations in Deep Fork green algae were higher than the concentrations found in most of the water, sediment, and detritus samples. However, tubificids from the Hefner Road station had a much lower lead level than the sediments from the sample area.

Phytoplankton samples from the lower end of the Northeast Lake (station 5) had a higher lead concentration that the water sample from the same area, but this concentration was lower than that found in the water from the upper end of this lake.

The U.S. Public Health Service rejection limit for lead in water supplies is 50 μg/l. The U.S. Public Health Service recommended limit for lead in water supplies is 10 μg/l. Main stem waters throughout this basin tend to exceed the recommended limit. The accumulation of lead within the waters of certain lakes in this basin would indicate that it should be monitored closely if used as a drinking water supply. The difference between upper and lower lake sampling data would indicate that lead tends to settle and this could offset the potential problem. Water samples from this basin were usually higher in lead than those from Theta Pond (4) and those reported from Lake Thunderbird (5), however, sediment samples were much higher in lead in the Theta Pond study (4). In general the biota lead levels were lower in this basin than those in the Theta Pond studies (4).

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TABLE 3. *Concentrations of lead in biota from the Deep Fork River basin.*

Station	Biota	Lead Concentrations (mg/kg dry wt.)
12 Eastern Ave.	Organic debris	20.7
10 Kelly Ave.	Dead leaves	16.7
12 Eastern Ave.	Green filamentous algae	34.1
9 Lincoln Blvd.	Green filamentous algae (rocks)	48.1
9 Lincoln Blvd.	Green filamentous algae (concrete)	38.0
9 Lincoln Blvd.	Green filamentous algae (water)	51.0
10 Kelly Ave.	Green filamentous algae	21.8
27 Hefner Road	Tubifex worms	38.2
19 Northeast Lake	Phytoplankton (green algae)	12.5

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