Cadmium and Lead Levels in Palestine Lake, Palestine, Indiana[1]

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Abstract

Using an Atomic Absorption Spectrophotometer, cadmium and lead levels were determined for water, sediment, plant life and fish samples in Palestine Lake at Palestine, Indiana. Cadmium levels in the water in a ditch draining into the lake varied from 0.10-0.88 parts per million (ppm). Cadmium in the lake varied from 0.002-0.006 ppm. Lead levels in the ditch varied from 0.05-0.30 ppm and 0.001-0.070 ppm in the lake. The suspected source of these metals is an industrial plant discharging into the ditch approximately two miles from the lake. These values exceed the allowable levels (Water Quality Dept., Indiana Board of Health) for Indiana waters of 0.02 ppm for cadmium and 0.05 ppm for lead. Fish samples (wet weight) contained from 0.1-0.9 ppm of cadmium and 4-5 ppm of lead. Plant samples (dry weight) varied from 1-2800 ppm of cadmium and from 8-280 ppm of lead. Sediment samples (dry weight) contained from 3.2-2640 ppm of cadmium and 40-230 ppm of lead.

Introduction

Cadmium and lead are heavy metals that have wide uses in industry. Some 6 million pounds of cadmium (almost half the cadmium consumed) and 4 million pounds of lead are used annually in the electroplating industry (11). Although both metals accumulate in man, cadmium is found mainly in the kidney and liver, while lead is found in the long bones and to some extent in the soft tissues. Both metals in high concentrations can inhibit zinc or sulfhydryl containing enzymes (5, 9, 15). Durum *et al.* (7) found that 45% of the rivers in the Indiana region had cadmium levels exceeding 1 part per billion (ppb). The limit for cadmium in drinking water is 0.01 parts per million (ppm) or 10 ppb (1). Ettinger (8) analyzed drinking water samples for lead and found 90% were below 10 ppb. A limit of 0.05 ppm or 50 ppb has been set for drinking water (1).

This study was undertaken because of information received from the Water Quality Department of the Indiana State Board of Health that a plating plant was discharging cadmium into a ditch leading to Palestine Lake, Palestine, Indiana (Fig. 1). Palestine Lake, a state owned lake of 232 acres used for recreational fishing, drains into the Tippecanoe River. The objective of this study was to determine the levels of cadmium and lead in water, fish, plant and sediment samples along the ditch and in the lake.

Materials and Methods

As shown in Figure 1, five sites were chosen for sampling. Site 1 was located in a small ditch about one mile downstream from the electroplating plant suspected of discharging heavy metals into the

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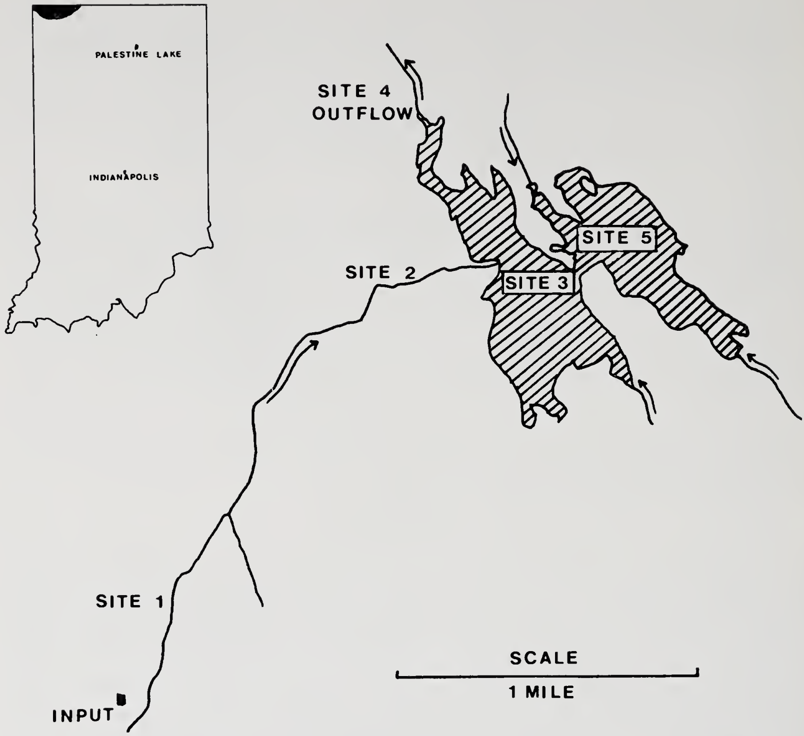

FIGURE 1. *Map of Palestine Lake illustrating location of collection sites and the flow of the water. The insert of the map of Indiana gives the location of Palestine Lake in reference to Indianapolis.*

environment. Site 2 was on the same ditch about one-half mile above its entrance into Palestine Lake. The ditch received several tributaries between sites 1 and 2 so the water at site 2 is representative of that entering the lake. Samples designated site 3 came from the main basin of the lake, and those designated site 4 came from the outlet stream. Site 5 samples came from the partially separated northeast lobe of the lake. The water movement in the lake was from site 5 toward site 3, and water coming in from site 2 probably did not mix with that entering the northeast lobe. Four collections were made between June 7, 1974 and August 13, 1974. Samples were analyzed with an atomic absorption spectrophotometer (AAS) using an air acetylene flame. Specific sample treatments are described below.

Water Analysis

One liter plastic bottles were used to collect water samples. The samples were immediately acidified with four ml. of concentrated nitric acid to keep the cadmium and lead in suspension. The samples were stored under refrigeration until analyzed. The samples were concentrated by boiling, filtered, and aspirated into the AAS.

Sample Analysis

Fish were collected by seining and aquatic plants were gathered by hand. Samples were placed in plastic bags and frozen until analysis. Plant and fish samples were analyzed by digestion in nitric acid as described in Yost *et al.* (19). The resulting fish and plant solutions were concentrated or diluted as necessary and aspirated into the AAS. Sediment samples were collected with a bottom sampler or by manual means and were analyzed in the manner described above.

Standards

Standards of cadmium and lead were made by measuring oven dried $CdCl_2$ and $Pb(NO_3)$ on a milligram balance, then acidifying with nitric acid and diluting with doubly distilled water using volumetric glassware. Calibration curves were constructed using standards at concentrations spanning the expected range in the unknown samples. Sample concentrations were then determined by interpolation in the calibration curves.

Results

Cadmium levels in acidified water samples are illustrated in Fig. 2. The range of cadmium for the four collections at each side was: site 1 (10 samples) from 0.156-0.888 ppm with an overall mean of 0.591 ppm; site 2 (11 samples) from 0.063-0.361 ppm with a mean of 0.248 ppm; site 3 (11 samples) from 0.003-0.007 ppm with a mean of 0.004 ppm; site 4 (9 samples) from 0.002-0.006 ppm with a mean of 0.004 ppm; site 5 (7 samples) from 0.001-0.002 ppm with a mean of 0.002 ppm.

Lead levels in acidified water samples are shown on Fig. 3. Over the four collections the range of lead levels at each site were: site 1 (10 samples) from 0.032-0.300 ppm with a mean of 0.113 ppm; site 2 (10 samples) from 0.049-0.114 ppm with a mean of 0.079 ppm; site 3 (10 samples) from 0.010-0.056 ppm with a mean of 0.035 ppm; site 4 (9 samples) from 0.013-0.074 ppm with a mean of 0.032 ppm; site 5 (7 samples) from 0.000-0.009 ppm with a mean of 0.005 ppm.

The concentration of cadmium and lead in the water samples decreased from site 1 through site 5. The cadmium concentration decreased 148 times from site 1 to site 3, while lead levels decreased only 3.2 times.

The range of cadmium in plant and sediment samples at the different sites is illustrated in Fig. 4. Four samples of aquatic grasses from the ditch were collected at site 1. The levels of cadmium ranged from 285-984 ppm with a mean of 564 ppm. Two samples of aquatic grasses were collected at site 2 and ranged from 112-522 ppm with a mean of 317 ppm. Also collected at site 2 were three samples of an unwashed algal mat (*Stigeoclonium stagnatile*) which ranged from 1971-2986 ppm with a mean of 2599 ppm. Nine samples of pond weed (*Potamogeton sp.*) and duckweed (*Limna sp.*) were collected from the lake at site 3 and ranged from 11-61 ppm with a mean of 42 ppm. Three samples of pond weed and algae collected from the outlet at site 4 had cadmium levels ranging from 13-82 ppm with a mean of

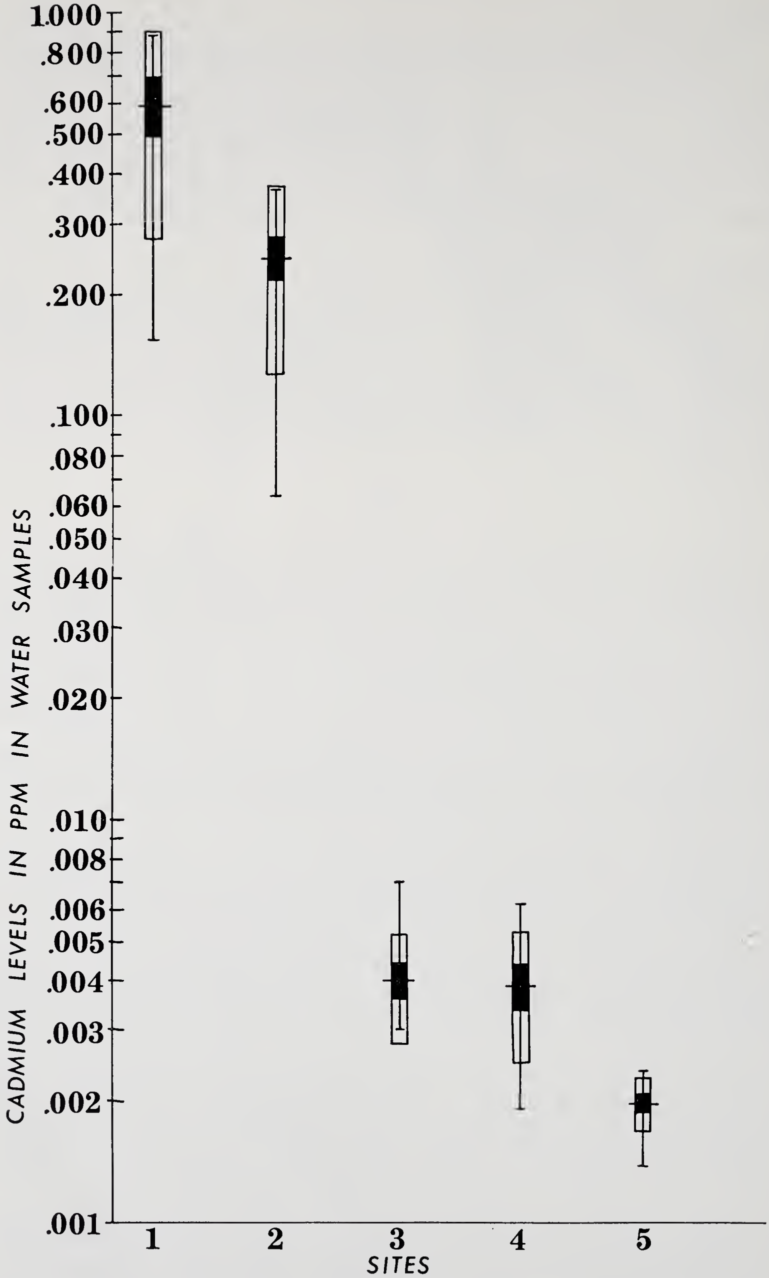

FIGURE 2. *Cadmium levels in ppm in water samples at each site. The horizontal line represents the mean, the shaded rectangle indicates two standard errors of the mean and the unshaded rectangle indicates two standard deviations.*

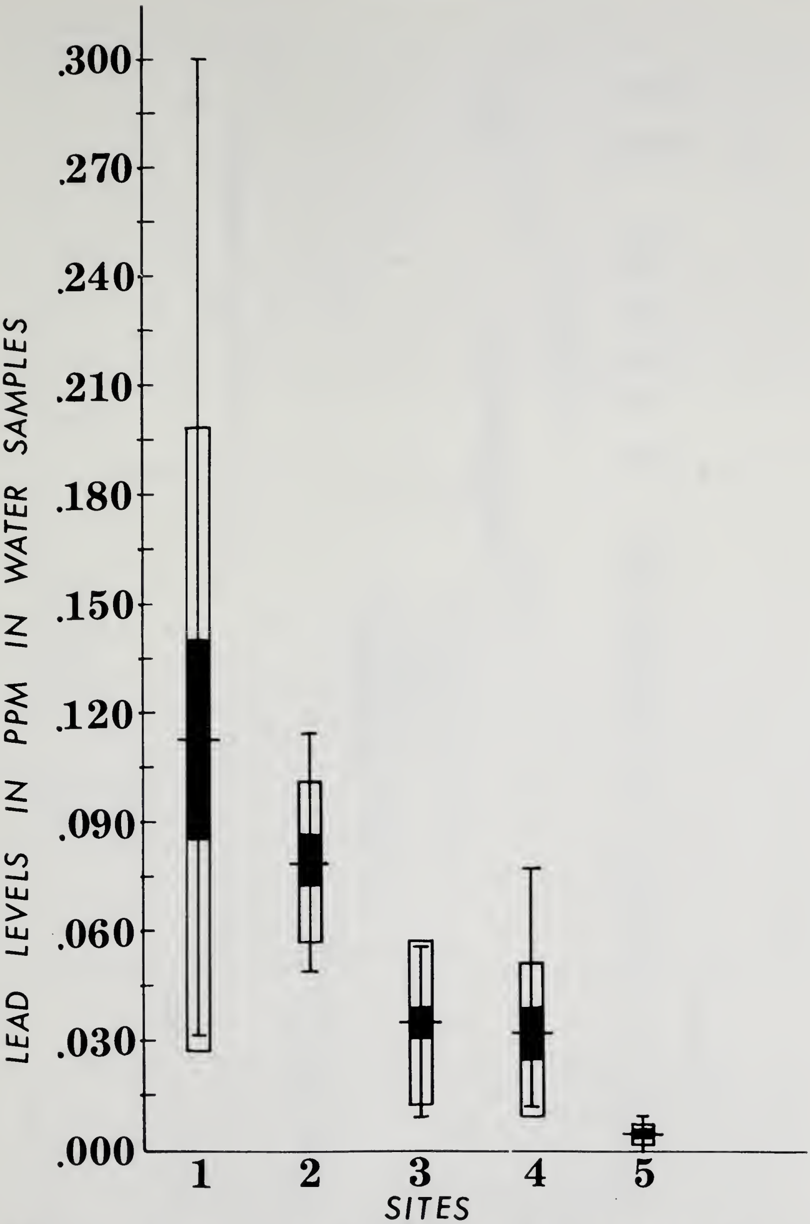

Figure 3. *Lead levels in ppm in water samples at each site. The horizontal line represents the mean, the shaded rectangle indicates two standard errors of the mean and the unshaded rectangle indicates two standard deviations.*

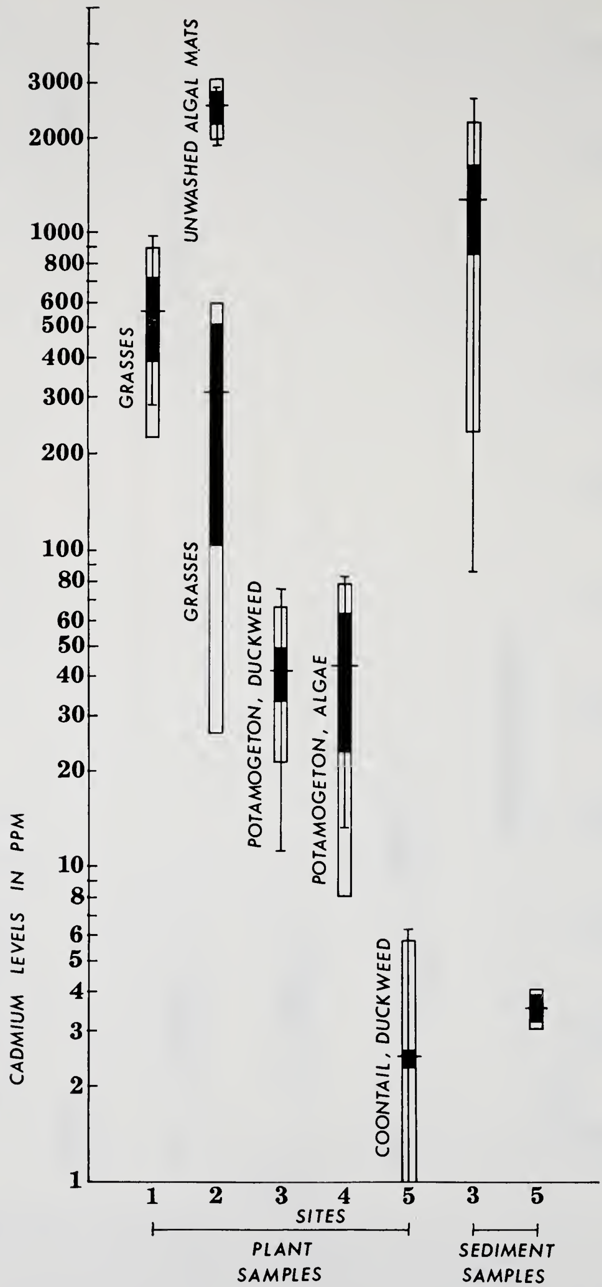

FIGURE 4. *Cadmium levels in ppm in plant and sediment samples at each site. The horizontal line represents the mean, the shaded rectangle indicates two standard errors of the mean and the unshaded rectangle indicates two standard deviations.*

43 ppm. Five samples of coontail (*Ceratophyllum demersum*) and duckweed were collected from site 5 and ranged from 1.0-6.3 ppm with a mean of 2.6 ppm. Cadmium levels in seven sediment samples from site 3 ranged from 86-2678 ppm with a mean of 1248 ppm. At site 5 levels for cadmium in two sediment samples ranged from 3.2-3.9 ppm with a mean of 3.6 ppm. The data on cadmium in plants in Fig. 4 shows a decline from site 1 through site 5. The unwashed algal mat gave the highest reading for cadmium.

The cadmium and lead data for whole fish samples are given in Table 1. The range for cadmium in fish is from 0.10-0.94 ppm with a mean of 0.44 ppm. The mean cadmium values for the two species studied [(red ear, *Lepomis microlophus* (Gunther); and black crappie, *Pomoxis nigromaculatus* (LeSuer)] did not differ significantly. The range of lead in fish samples was from 4.0-5.1 ppm with a mean of 4.7 ppm.

TABLE 1. *Cadmium and Lead in ppm in Fish Samples. A and B denote samples from the same fish.*

Fish			Date	Cadmium	Lead
Red Ear		1A	6/7	0.35	---
Red Ear		1B	6/7	0.94	---
Red Ear		2A	6/7	0.70	---
Red Ear		2B	6/7	0.10	---
Red Ear		3A	6/7	0.38	---
Red Ear		3B	6/7	0.24	---
	mean			0.45	---
Black Crappie		1	7/1	0.78	5.0
Black Crappie		2A	7/1	0.24	4.0
Black Crappie		2B	7/1	0.26	5.1
	mean			0.43	4.7
	overall mean			0.44	4.7
	standard deviation			±0.29	±0.6
	standard error of the mean			±0.10	±0.4

Discussion

Cadmium in water samples (see Fig. 2) decreased from site 1 through site 5. Site 1 was approximately one-half mile away from the input of the plant (the only industry on the ditch) and still had a mean concentration of 0.591 ppm, almost twenty times the allowable limit for wildlife of 0.03 ppm (2). The Water Quality Department of the Indiana State Board of Health (18) set limits for cadmium in Indiana waters at 0.02 ppm. The mean cadmium level at site 2 was less than half the concentration at site 1. This was predictable because another ditch joined the polluted ditch thus increasing the flow of the water (see Fig. 1) and some cadmium would be lost to plants and sediment. The large decrease in cadmium concentration at sites 3 and 4 is probably due to the large diluting factor of the lake. The mean cadmium levels in the water samples from sites 3 and 4 are both 0.004 ppm. They are similar because the flow of the water is from the main basin (site 3) to the outlet at site 4. Since Palestine Lake is only 232 acres, the discharge of cadmium into the ditch by the plating plant goes against the EPA proposal (3) that there should be no discharge of cadmium into a lake of less than 500 acres.

Site 5, the northeast lobe of the lake, can be considered a control or unaffected area. This is because the flow of the water is from site 5 into the main basin of the lake (site 3). The water from the polluted ditch should not mix with the water in site 5 (except possibly due to current set up by the wind). Also, the level of 2 ppb of cadmium in the water is close to the 1 ppb norm for natural waters and well below the 10 ppb limit in drinking water (1).

Friberg *et al* (9) has shown concern that concentrations of salt (NaCl) greater than 0.01 molar give elevated cadmium readings on the AAS when the sample is not extracted into an organic layer. This does not seem to have been a factor in the readings of the water samples in this study because samples from site 5 were concentrated the most (about 60 times) and the levels found do not seem elevated in relation to normal levels. In addition, in comparing acidic and organic techniques in biological materials, Lener and Bibr (12) found no difference between the two methods.

Lead concentrations in water samples (Fig. 3) for site 1 also exceed the 0.03 ppm limit for wildlife protection (2). The Water Quality Department of the Indiana State Board of Health (18) set a limit for lead in Indiana waters at 0.05 ppm. The decrease in lead levels from site 1 to site 2 is not as great as was the decrease for cadmium. This could be due to the greater solubility of the lead compound, or the ditch feeding into the polluted ditch (see Fig. 1) could be contributing the lead. The decrease in lead from site 2 to site 3 and 4 is also not as great as the decrease for cadmium. This could be due to lead pollution from another ditch, or to an infrequent release of lead by the plant into the ditch and therefore into the lake. The similar levels of lead in the main basin of the lake and in the outlet are again because of the flow of the water. The northeast lobe of the lake (site 5) can also be considered a control or unaffected area for lead. The mean value of 0.005 ppm for lead is well below the normal value of 0.01 ppm for lead in natural water (8) and below the 0.05 ppm limit for drinking water (1).

The levels of cadmium in plant and sediment samples (Fig. 4) at the different sites indicate a good correlation with the levels found in water samples. The mean value for cadmium in plant samples at sites 1, 2, and 5 are 564, 317, and 2.6 ppm respectively. These are all about one thousand times the concentration found in water samples at the same sites. Timofeeva-Resouskaya and Timofeeva-Resouskaya (17) studied 32 fresh water plants and found the average cadmium level in the plants to be 1620 times the cadmium levels in the water. Page *et al* (16) grew beets and turnips in 0.1 ppm cadmium solutions and found 280 ppm and 160 ppm, respectively, in the leaves. Normal levels for some vegetables ranged from 0.51-2.8 ppm cadmium (10) which seems to show that the 2.6 ppm of cadmium in plants at site 5 is probably normal. The unwashed algal mat collected at site 2 and the aquatic plants collected at sites 3 and 4 had values of 2599, 42, and 43 ppm, which were over ten thousand times the cadmium levels found in the water.

The difference between the sediment samples at site 3 and site 5 (1248 and 3.6 ppm of cadmium) seems to strengthen the assumption that there is minimal mixing between the main basin of the lake and the northeast lobe of the lake. Yost *et al* (19) studied three lakes in northern Indiana not known to be contaminated by cadmium and found cadmium levels in the sediment ranged from 0.1 to 6.6 ppm. In comparing Yost's values to the 3.6 ppm mean for cadmium at site 5, the latter value seems typical. The mean value of 1248 ppm of cadmium at site 3 indicates that cadmium is deposited in large amounts in the sediment. The high sediment value could be responsible for the higher concentration of cadmium in the aquatic plants at site 3. Haghiri (10) found that concentrations of cadmium in various vegetables increased ten times when the concentration in the soil was 10 ppm.

The data on cadmium and lead levels in fish in the main basin of the lake (Table 1) indicate that both are higher than in non-polluted water. In fish, cadmium and lead are both concentrated about 100 times over the concentration in the water. Cadmium levels in whole fish samples at Palestine Lake had a mean value of 0.44 ppm. The values at site 3 were greater than the values for whole fish samples of 0.020 ppm found in New York state (13). In whole fish samples from the Great Lakes, Lucas *et al* (14) found a mean value of 0.094 ppm. In Table 1 the difference in the content of cadmium between the two samples of the same fish could be due to the unequal distribution of the liver in the sample since Lucas *et al* (14) found that the liver concentrates cadmium in fish.

Lead levels in whole fish samples at site 3 had a mean value of 4.7 ppm. The values at Palestine Lake are greater than the 0.5 ppm norm for lead in fresh water fish (4). In marine fish an average of 1.7 ppm for lead has been found (6).

From the data it is obvious that cadmium and lead are building up in the fish and plant life. However, determining the effects on the fish and plant life requires more study on the lake. This study has set the basis for further research into specific effects of the metals on the Palestine Lake ecosystem.

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