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The use of Periphyton as a Monitor of Trace Metals in Two Contaminated Indiana Lakes

George D. Johnson[1], Alan W. McIntosh, and Gary J. Atchison
Bionucleonics Department, School of Pharmacy and Pharmacal Sciences, Purdue University, West Lafayette, Ind. 47907

Introduction

In recent years, there has been much interest generated concerning the uptake of trace metals by aquatic organisms. Numerous investigators (BLUM, 1956; PATRICK, 1957; CAIRNS et al., 1968) have demonstrated that aquatic macrophytes, algae and periphyton (defined herein as attached algae and other algal species which have become affixed to the periphyton forms) can concentrate trace metals to high levels, while others have noted that many forms can survive in highly metal-contaminated waters.

HUTCHINSON (1973) used growth as an indication of algal response to a variety of metals and found that *Chlorella vulgaris* was the most sensitive and *Chlamydomonas* sp., the least sensitive, to cadmium (Cd) of the algal species studied. WHITTON (1970) suggested that *Cladophora*, the most sensitive form to lead (Pb), copper (Cu), and zinc (Zn) among the genera he tested, might be used as an indicator of trace metals in stream waters. GALE et al. (1973) found that relatively high concentrations of Pb and Zn in stream sediments had little effect on algal growth in naturally hard waters. In the current study, the utility of periphyton as a monitor of trace metal contamination in two highly impacted lakes was assessed.

Materials and Methods

Site Description

Two highly contaminated northern Indiana lakes, both receiving effluents from nearby electroplating facilities at the time, were chosen for study. Little Center Lake is a small (less than 11 ha), privately owned, highly eutrophic system near Angola, Indiana. Preliminary analyses conducted by MCINTOSH and BISHOP (1976) showed that all components of the lake sampled, including water and sediment, had high levels of Cd and Zn (Table 1). Palestine Lake, 93 ha in size, is a highly eutrophic lake near Warsaw, Indiana. The system is naturally divided into an east

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[1] Current address: Peabody Coal Co., Department of Environmental Quality, 301 N. Memorial Drive, St. Louis, MO 63102.

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and west basin; the west basin has received substantial burdens of Cd and Zn via Williamson Ditch (Fig. 1) for a number of years. Data presented in Table 1 indicate the extent of metal contamination in the sediment and water of both Little Center Lake and the west basin of Palestine Lake.

TABLE 1

Cd and Zn levels in sediment and water of several lakes.

Investigator	System Studied	Component: Filterable Fraction of Water (ppb) Cd	Zn	Sediment (ug/g, dry wt) Cd	Zn
McIntosh & Bishop	Little Center Lake, Angola, Indiana	N.D.- 1.3[a]	5-92	4-860	120-18,000
Iskandar & Keeney	Various Wisconsin Lakes	....[b]	....	3	182
Shephard	Palestine Lake, Warsaw, Indiana	17[c] (0.9)[d]	73[c] (36)[d]	140-800[c]	1800-13,000[c]

[a]N.D. - Not detectable
[b]Component not studied
[c]West basin
[d](East basin)

Experimental

Six sampling sites were established in each lake (Figs. 1 and 2). Two periphyton racks were placed at each site with each rack carrying five 5 cm x 5 cm x 0.3 cm plexiglass slides.

Since the authors were most interested in the western basin of Palestine Lake, especially the area where trace metals enter the system, sampling sites were fixed rather than randomly selected, with the majority of sites located near the mouth of the ditch (Fig. 1). Sites were chosen in the east basin (#2 in Fig. 1) to act as a control and near a dam (#6 in Fig. 1) to monitor metals in water leaving the lake.

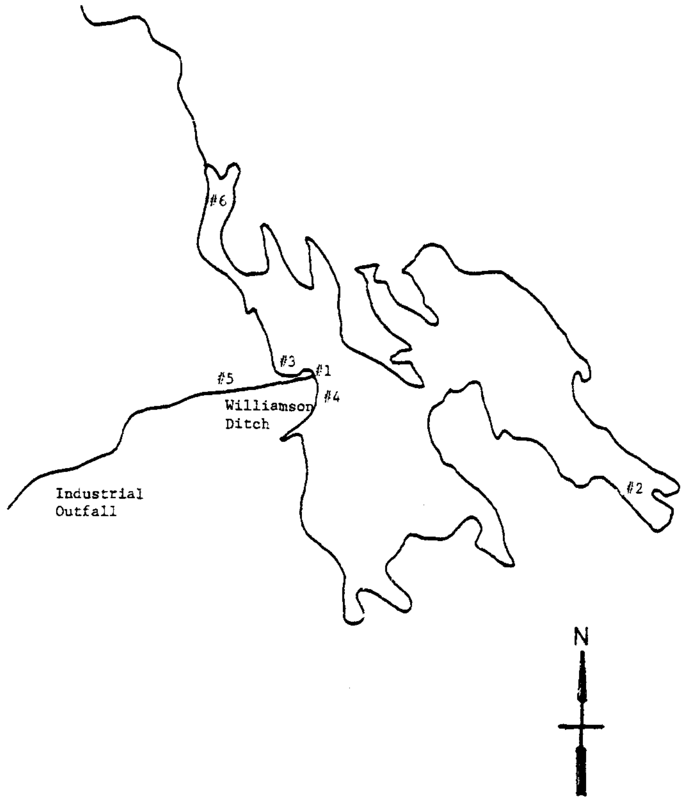

Figure 1. Diagrammatic map of Palestine Lake indicating locations of sample sites and industrial input of metals.

It was felt that Little Center Lake, being so small, might have a more uniform distribution of metals in its waters. Thus, one site was established in the ditch and five were situated in the lake itself, with each margin and the center of the system monitored.

Both water and algae samples were collected from all stations in both lakes at intervals of approximately 3 weeks during a 12-week period in the summer of 1975.

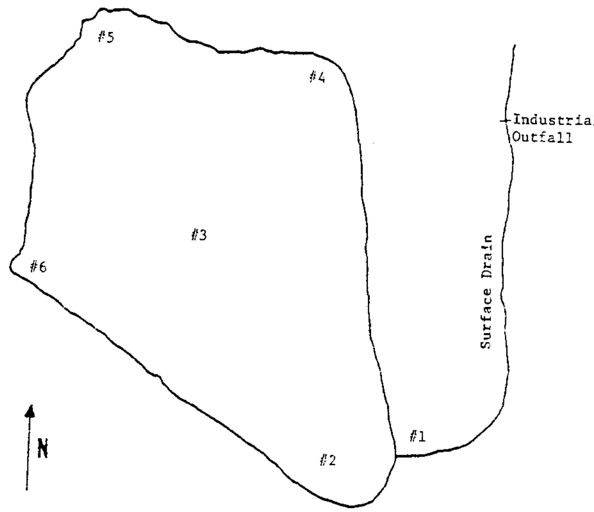

Figure 2. Diagrammatic map of Little Center Lake indicating location of sample sites and industrial input of metals.

Subsurface water samples (900-1000 ml) were collected at each station in narrow-mouth polyethylene bottles which had been washed in 10% HNO_3. All samples were filtered through 0.45 μ membrane filters in the field, acidified with 5 ml HNO_3/liter of water and returned to the laboratory for subsequent analysis. Approximately 500 ml was taken from each filtered water sample, evaporated to less than 5 ml, filtered and brought to volume with 1:1 HNO_3 for analysis. Filter pads were digested in 15 ml HNO_3 and treated in a manner similar to filtered water samples.

Algal populations growing on the plexiglass slides were collected at each station. One slide per rack was stored for later estimation of algal diversity; identification to genera was performed. The remaining four slides per rack were frozen for later biomass determination and trace metal analysis. Periphyton on two slides per rack was scraped into 200 ml Berzelius beakers and dried to a constant weight. After cooling, 15 ml HNO_3 was added and approximately 4-8 hours were allowed for frothing to subside. Samples were heated slowly until the material was dissolved. The solution was then evaporated to less than 10 ml and brought to volume with 1:1 HNO_3. All analyses were performed on a Perkin-Elmer Model 306 Atomic Absorption Spectrophotometer.

Prior to initiating the analysis for metal content of algae, a recovery study was performed (TWEETEN and KNOECK, 1976) yielding the following average percent recoveries for the metals tested: Cd, 100.4% and Zn, 123.9%.

Statistical Analysis

The main goal of this study was to determine whether or not Cd and Zn levels in water can be monitored by algae and whether the location or time of year affects metal levels. The relationship between the trace metal content of the water and that of the periphyton was investigated by regression analysis. Algae metal concentrations were analyzed by analysis of covariance (ANCOVA) using time and location as factors and dry weight as a covariate.

Results and Discussion

Sample site selection was based on the hypothesis that site location would affect the amount of metals taken up by the periphyton. This theory was supported by data from both Palestine and Little Center Lakes (Tables 2 and 3). Levels of Cd and Zn in both water and algae in Little Center Lake were highest at station 1, located closest to the source of the metals, and were generally similar at the other five stations. In Palestine Lake, Cd and Zn concentrations were again highest in areas of greatest exposure, station 5 in Williamson Ditch and station 1 in the inlet (Fig. 1); levels attained at stations 3, 4, and 6 were intermediate, while at station 2, in an area of no known metal exposure, algae exhibited lowest levels.

Concentrations attained in algae and water at sites of greatest exposure in both systems were high, with maximum readings of 430 ppm Cd (stations 1 and 5 in Palestine) and 13,000 ppm Zn (station 1 in Palestine) in algae (dry wt. basis) and 9.8 ppb Cd and 270 ppb Zn (both at station 1 in Palestine) in the filtered water samples.

TABLE 2

Trace metal concentrations in the filterable fraction of water (ppb) and algae (ppm dry wt.) from Palestine Lake. Numbers represent means of samples from 4 sampling periods.

	Site 1	2	3	4	5	6
			Cd			
Water (ppb)	9.8	1.8	4.8	4.5	7.2	2.2
Algae (ppm)	430	5.6	8.8	230	430	80
			Zn			
Water (ppb)	270	30	66	78	100	46
Algae (ppm)	13,000	330	1800	3100	8700	2900

TABLE 3

Trace metal concentrations in the filterable fraction of water (ppb) and algae (ppm dry wt.) from Little Center Lake. Numbers represent means of samples from 4 sampling periods.

	Site 1	2	3	4	5	6
			Cd			
Water (ppb)	2.7	1.9	1.2	0.7	0.7	0.9
Algae (ppm)	56	27	34	28	27	32
			Zn			
Water (ppb)	87	74	37	36	39	32
Algae (ppm)	9700	1300	1500	1200	900	1300

The results of the regression analyses run on the data from Little Center Lake yielded correlation coefficients all close to zero. Thus, no significance is attached to the relationship between metal concentrations in the water and those in the periphyton at a particular site at a specific time.

In Palestine Lake, however, a correlation significantly greater than zero ($\alpha = .05$) was found between metal concentrations in the water and those in the periphyton, with $r = .71$ for Cd and .82 for Zn. It should be pointed out that the 95% confidence interval for Zn was only .25 to .91.

The results of the ANCOVA indicated that both time and location had a significant effect on metal concentrations in algae in Little Center Lake. Similarly, as a covariate, dry weight was a highly significant variable. Time and location were also highly significant in Palestine Lake.

Data from Palestine Lake support the use of periphyton as a monitor of trace metal pollution, particularly in systems where large differences in the concentrations of available metals exist. The ANCOVA results also indicate a highly significant correlation between time, location and dry weight and the uptake of trace metals by periphyton.

Analysis of algae genera distribution indicated that the diatoms *Fragilaria* and *Synedra* were dominant in Little Center Lake at stations 2 through 6 throughout the summer. At station 1, limited diatom growth and the dominance of green filamentous genera, such as *Pseudoulvella*, *Ulothrix*, and *Stigeoclonium*, were noted. The mean filterable Cd and Zn levels, 2.7 ppb and 14.2 ppb, respectively, found in water samples from station 1 indicated that these filamentous algae flourished in spite of the relatively high metal levels.

In Palestine Lake, the diatom *Navicula* dominated at all six stations at sampling period 1. At periods 2 through 4, however, the filamentous genus *Stigeoclonium* assumed dominance along with the diatom *Navicula* at stations 2 through 6. Thus several genera, including *Pseudoulvella*, *Ulothrix*, *Stigeoclonium* and the diatom *Navicula* appeared to be tolerant of high concentrations of Cd, Zn and possibly other metals, such as chromium.

Other investigators have noted the existence of metal tolerant algae. PATRICK (1977) indicated the tolerance of certain algal species to high concentrations of trace metals in water. Specifically the green algae *Stigeoclonium lubricum* was found to grow in the presence of trace metals. GALE et al. (1973) also noted extensive blooms of *Cladophora* in one hardwater stream where the concentration of Pb associated with the filaments exceeded 5,000 ppm.

Conclusion

The results of this study are inconclusive as to whether or not periphyton is a reliable biological indicator of trace metal pollution in all lentic ecosystems. However, evidence from Palestine Lake indicates that where great differences exist in metal levels in water, periphyton may be a useful monitor. The presence of certain species in both lakes in areas of highest contamination may indicate a tolerance on the part of those species.

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