SEASONAL CHANGES IN THE IRON, MANGANESE, AND ZINC CONCENTRATIONS IN THE SEDIMENTS, *CHAOBORUS PUNCTIPENNIS* (SAY), AND *CHIRONOMUS TENTANS* (FABR.) IN ARBUCKLE LAKE, OKLAHOMA

Ellen Cover, Department of Biochemistry
and
Jerry Wilhm, Department of Zoology, Oklahoma State University, Stillwater, OK 74078

The concentration of iron, manganese, and zinc of the sediments and of two species of macroinvertebrates were examined at depths of 15 and 26 m in Arbuckle Lake. The concentration of manganese was extremely high in the sediments, while the concentration of iron and zinc were low. Iron decreased in the sediments in summer. Populations of *Chaoborus punctipennis* and *Chironomus tentans* accumulated iron and zinc, but did not concentrate manganese.

INTRODUCTION

Iron, manganese, and zinc are essential micronutrients of plants and animals in aquatic systems (1). Iron and manganese influence the presence or absence of other substances in the water column and sediments by complexing and sorption reactions. They exhibit seasonal changes resulting from changes in oxidizing and reducing conditions in lakes that stratify in summer (2). Zinc does not change in solubility in response to stratification; however, it does accumulate in the bottom waters, in the hypolimnion (3). The concentration of trace elements has been related to other factors such as clay content and loss on ignition of the sediments (4), sediment texture (5), and depth of the overlying water (6, 7).

Many trace elements are concentrated by aquatic organisms. Iron and zinc were found to be concentrated by shallow-water in-fauna (8). Deposit feeders that are selective concentrated iron, while nonselective deposit feeders and omnivores concentrated zinc. Iron was higher in organisms from silty bays than those from sand and gravelly sands. In contrast, polychaete worms maintained constant concentrations of iron, manganese, and zinc (9). Trace element concentration in organisms has been related to variables such as salinity (10), temperature (11), and seasonality (12). Seasonal changes in the concentration of iron, manganese, and zinc in populations of benthic macroinvertebrates in Oklahoma lakes has received little attention.

Arbuckle Lake is located in south-central Oklahoma about 9.5 km SW of Sulphur (13). The lake was impounded in 1967 and has a surface area of 950 ha and a volume of 8930 ha-m. The deepest point in the lake is 26 m. Although the lake stratifies strongly in summer and thus undergoes seasonal changes in the profiles of temperature and concentration of dissolved oxygen, it does not appear to be eutrophic (13). Additional information and a sketch of the lake is given by Toetz (14).

It is the objective of this paper to present the seasonal changes of iron, manganese, and zinc in the sediments and concentrations in the tissues of *Chaoborus punctipennis* (Say) (Chaoboridae) and *Chironomus tentans* (Fabr.) (Chiromonidae) in Arbuckle Lake.

MATERIALS AND METHODS

Two stations were sampled at 26 m and one station in the Buckhorn Creek arm at 15 m in Arbuckle Lake. Samples were collected monthly from 4 March to 2 December 1978. Temperature, dissolved oxygen, and conductivity of the water and percent organic matter of the sediments were analyzed by Barker and Wilhm (15).

Water samples were collected from strata 1 m above the sediment with a 2.2-*l* plastic Van Dorn water bottle. Six 250-m*l* acid-rinsed plastic bottles were filled at each station, three each for determining soluble and total metals. Total metal samples were acidified with 3 m*l* of concentrated HNO_3. Sediment samples were obtained by inserting 2.5-cm-diameter polyethylene tubes into a filled 15 × 15 cm Ekman grab sampler. Organisms were collected with an Ekman grab sampler and a wash bucket. Concentrations of metals in water and organisms were measured by extracting with acid and in sediment by extracting with ammonium acetate (16), respectively, and measuring on a Varian Techtron atomic absorption spectrophotometer.

RESULTS

C. punctipennis was the most abundant benthic macroinvertebrate collected during the study, comprising 56% of the total numbers of organisms collected. Insufficient numbers of *C. punctipennis* were collected on 9 June and 11 July to permit analyses of the tissues of this species for metals. Sufficient numbers of *C. tentans* were collected only in spring. Monthly means of the concentration of iron, manganese, and zinc in Arbuckle Lake are presented in Table 1. Variation did not obscure seasonal trends.

Iron

Mean iron concentration in the water of Arbuckle Lake ranged from 269 to 903 ì g l^{-1} (Table 1). Soluble iron represented 28% of the total iron in the water and only total iron is presented in Table 1. The concentration of total iron increased abruptly on 15 August to a mean exceeding 900 ì g l^{-1}. Values decreased by 16 September.

Total iron of the sediments ranged from 0.4 to 12.9 ì g g^{-1}. Values decreased from 15 March to 9 June and subsequent variation was low. Minimum values were measured in late summer.

The concentration of iron in *C. punctipennis* increased from 287 to 2261 ì g g^{-1}. Values increased through summer with an abrupt increase measured on 15 August. The organisms accumulated iron from the sediments. The concentration factors were generally high and reached a maximum of 5652 on 15 August. Population density of *C. tentans* was generally low and the concentration of iron was only measured in spring. Concentrations averaged 441 μg g^{-1} for *C. tentans*, while concentration factors averaged 146.

TABLE 1. *Concentrations of heavy metals in the water, sediments, and* Chaoborus punctipennis *in Arbuckle Lake in 1978.*

Metal	Compartment	15 Mar	29 Apr	9 Jun	11 Jul	15 Aug	16 Sep	22 Oct	24 Nov
Iron	water[a]	411	316	430	269	903	250	260	402
	sediments[b]	12.9	3.5	1.1	1.0	0.4	0.4	1.1	1.2
	C. punctipennis[b]	287	468	—	636	2261	—	2173	—
	Conc. factor	22	134	—	636	5652	—	1811	—
Manganese	water[a]	24	72	793	306	1251	1274	148	65
	sediments[b]	316	327	361	360	348	348	339	288
	C. punctipennis[b]	34	34	—	106	458	436	248	—
	Conc. factor	0.1	0.1	—	0.3	1.3	1.2	0.8	—
Zinc	water[a]	25	19	14	12	16	4	15	4
	sediments	1.1	0.7	1.2	0.9	1.2	0.6	0.5	1.3
	C. punctipennis[b]	391	126	—	95	161	236	—	—
	Conc. factor	355	180	—	106	134	393	—	—

[a] $\mu g\ l^{-1}$
[b] $\mu g\ g^{-1}$

Manganese

Mean manganese concentration of the bottom water ranged from 24 to 1274 ì g l^{-1} (Table 1). Soluble manganese represented about 51% of the total manganese of the water; however, seasonal trends were similar in both soluble and total values. Maximum concentration of manganese was measured in Arbuckle Lake in summer (2).

Sorbed manganese of the sediments was relatively high and exhibited little seasonal fluctuation, ranging from 288 to 361 ì g g^{-1}; concentrations in *C. punctipennis* increased from 34 ì g g^{-1} on 15 March to 458 ì g g^{-1} on 15 August. Values decreased in fall. Concentration factors were small; the maximum was 1.2 on 16 September. Values in *C. tentans* ranged from 32 to 57 ì g g^{-1}.

Zinc

Total zinc in the bottom water ranged from nondetectable levels to 25.3 ì g l^{-1} . Soluble zinc represented 83% of total zinc. Values tended to decrease from 15 March to 16 September.

Sorbed zinc in the sediment was present in low concentrations varying from 0.6 to 1.3 ì g g^{-1}. Seasonal fluctuation was slight. In contrast, values in *C. punctipennis* were high and fluctuated seasonally. Values decreased from 391 ì g g^{-1} on 15 March to 95 ì g g^{-1} on 11 July. Concentration factors ranged from 106-393. Zinc in *C. tentans* ranged from 60 to 3126 ì g g^{-1}.

DISCUSSION

The concentration of sorbed iron in the sediments of Arbuckle Lake is lower than that reported in other reservoirs (3). However, an ammonium acetate extraction method was used in the present study to estimate the iron available to the organisms, and this typically produces lower values than acid extraction methods (16). The range in Ham's Lake, Oklahoma, was from nondetectable to 11.7 ì g g^{-1}, which is similar to the range in Arbuckle Lake. (17). Ammonium acetate extraction was also used in the Ham's Lake study.

Anoxic conditions developed in the hypolimnion in summer (18). Iron is released from the sediments under anoxic conditions (2). This resulted in a decrease in the concentration of sediment iron in summer and an increase in autumn after the fall turnover.

C. punctipennis and *C. tentans* accumulated large concentrations of iron in Arbuckle Lake. Although values for these species were not found in the literature, similar ranges have been reported for oysters and echinoderms (19, 20).

The concentration of total manganese in the water and sediments are higher than values in the literature (6, 21) and considerably higher than concentrations of iron in Arbuckle Lake. Although an increase in sediment manganese as well as iron under anoxic conditions has been reported (1), an increase in manganese was not observed in Arbuckle Lake.

Although the concentration of manganese in the sediment was considerably greater than that of iron, the benthic macroinvertebrates studied had considerably less manganese in the tissue. The maximum concentration factors were 1.3 for *C. punctipennis* and 0.1 for *C. tentans.* Harvey (22) reported that chironomids do not concentrate manganese.

The concentration of zinc found in water and sediments are similar to values reported in other studies (7, 23, 24). Both organisms concentrated zinc. Although no zinc concentrations were found in the literature for these organisms, the range is similar to that reported in fish and tipulid larvae (25, 26, 27).

In summary, the concentrations of iron in the sediments in Arbuckle Lake are relatively low, while high concentrations of manganese exist. Zinc values are low but similar to values reported in other lakes. The concentration of iron decreased in summer as the hypolimnion became anoxic; however, the manganese and zinc levels were relatively stable. The benthic macroinvertebrates, *C. punctipennis* and *C. tentans,* accumulated iron and zinc but not manganese.

ACKNOWLEDGMENT

This research was supported by the Office of Water Research and Technology and the Bureau of Reclamation.

REFERENCES

1. M. P. COUGHLAN, Sci. Progress (Oxford) 59: 1-23 (1971).
2. C. H. MORTIMER, J. Ecol. 30: 147-201 (1942).

3. R. C. WETZEL, *Limnology*, W. B. Saunders Co., Philadelphia, 1975, p. 735.
4. J. FITCHKO and T. C. HUTCHINSON, J. Great Lakes Res. 1: 46-17 (1975).
5. D. GRIEVE and K. FLETCHER, Estuar. Coast Mar. Sci. 5: 45-419 (1977).
6. J. J. DELFINO, G. C. BORTLESON, and G. F. LEE, Environ. Sci. Tech. 3: 1189-1191 (1969).
7. M. SIAS and J. WILHM, Proc. Okla. Acad. Sci. 55: 38-41 (1975).
8. D. K. PHELPS, R. J. SANTIAGO, D. LUCIANO, and N. IRIZARRY, *in:* D. J. NELSON and F. C. EVANS (eds.), *Symposium on Radioecology*, Ann Arbor, Mich., May, 1967.
9. F. A. CROSS, L. H. HARDY, N. Y. JONES, and R. T. BARKER, J. Fish. Res. Board Can. 30: 1287-1291 (1973).
10. O. H. PILKEY and H. G. GOODELL. Limnol. Oceanogr. 8: 137-148 (1963)
11. B. J. MATHIS, T. F. CUMMINGS, M. GOWER, M. TAYLOR and C. KING, Hydrobiologia 67: 197-206 (1979).
12. W. A. BLACK and R. L. MITCHELL, J. Mar. Biol. Assn., United Kingdom 30: 575-584 (1952).
13. E. M. CLAY and J. WILHM, Hydrobiologia 65: 33-38 (1979).
14. D. TOETZ, Hydrobiologia 63: 255-262 (1977).
15. D. M. BARKER and J. WILHM, Proc. Okla. Acad. Sci. 62: 000-000 (1982).
16. M. L. JACKSON, *Soil Chemical Analysis*, Prentice Hall, Inc. Englewood Cliffs, NJ, 1958.
17. E. C. COVER, and J. WILHM, Freshwater Ecol., in press.
18. E. C. COVER, *Caloric Content and Iron, Manganese, and Zinc Concentrations of Sediment Chaoborids, and Chironomids of Ham's and Arbuckle Lakes.* Ph.D. Dissert., Okla. State Univ., Stillwater (1980).
19. R. A. STEVENSON and S. L. UFRET, Limnol. Oceanogr. 11: 11-17 (1966).
20. H. L. WINDOM and R. A. SMITH, J. Fish. Res. Board Can. 29: 450-452 (1972).
21. P. L. BREZONIK, J. J. DELFINO, and G. F. LEE, J. Sanit. Eng. Div. Proc. Am. Soc. Civil Eng. SA-5: 929-940 (1969).
22. R. S. HARVEY, Health Physics 29: 613-616 (1971).
23. F. A. CROSS, T. W. DUKE, and J. N. WILLIS, Chesapeake Sci. 11: 221-234 (1970).
24. W. G. WILBER and J. V. HUNTER, Water Res. Bull. 13: 721-734 (1977).
25. A. BOHN and K. O. McELROY, J. Fish Res. Board Can. 33: 2836-2840 (1976).
26. M. I. ABUDULLAH, J. W. BANKS, D. C. MILES, and K. T. O'GRADY, Freshwat. Biol. 7: 161-166 (1976).
27. J. W. ELWOOD, S. G. HILDEBRAND, and J. J. BEAUCHAMP, J. Fish. Res. Board Can. 33: 1930-1938 (1976).