A Preliminary Description of the Physcio-Chemical Characteristics and Biota of Three Strip Mine Lakes, Spencer County, Indiana.

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Abstract

Physico-chemical characteristics and biota of three Spencer County strip mine lakes, all within the same immediate area and all about 30 years old, were studied. Physico-chemical values were significantly higher for Lakes II and III than for Lake I; values for Lake III were slightly higher than for Lake II. Lake I was by far the most fertile, both as to number of genera and density of organisms; Lakes II and III were comparatively sterile. Differences might be explained by variations among the area/volume ratios, slopes of basins, and watersheds. These lakes appeared to be similar to strip mine lakes studied in Missouri and Illinois and can be considered to be in the alkaline stage of recovery. All results reinforced the theory that each strip mine lake is modified chemically, physically, and biotically at its own rate.

During the past 60 years, nearly 100,000 acres of land in Indiana have been strip mined, and it is estimated that at least as many acres could be profitably stripped in the future. There are about 12,000 acres of strip mine lakes now in Indiana, or about 1 acre of water for each 8 acres of land stripped.

These lakes represent an extremely harsh physico-chemical environment immediately after formation and are typically biologically sterile for a number of years. Research on such lakes has been done in Illinois (7), Missouri (4), Pennsylvania (5), and Ohio (9). The first detailed research on Indiana strip mine lakes, in Pike County, was completed in 1971 by Ronald Smith of Indiana University (12).

This preliminary description of three lakes in Spencer County, a B.S. research project, was supported by a grant from the Indiana Academy of Science.

Location and Description of the Lakes

The three lakes selected were among the 20 of varying sizes in a 150-acre area strip mined from 1937-1942, 1 1/2 miles east of Mariah Hill, Harrison Township, Spencer County, Indiana (SW 1/4 Sec. 7 and NW 1/4 Sec. 18, T4S, R4W). The area lies near the eastern margin of the Pennsylvanian zone. The stratum of workable coal averages 3 feet thick, overlain by 45-70 feet of sandstone, shale, and fire-clay.

Table 1 presents the estimated physical dimensions of the three lakes. The basin of Lake I was gently sloping with a thick layer of organic debris; the basins of Lakes II and III were steeply sloping with little organic deposit.

The spoil banks, generally steep, had a variety of native deciduous trees scattered among the pines planted shortly after the mining was completed, as well as a sparse cover of annuals and perennials, with some extensive bare exposures remaining.

TABLE 1. *Dimensions of Lakes I-III.*

Lake	Surface Area (acres)	Ave. Depth (feet)	Volume (acre feet)	Area/Vol.
I	6	8	48	0.12
II	1.5	14	21	0.07
III	7	15	25	0.08

Lakes I and III received some drainage from nearby farmland. Only Lake II has never successfully been stocked with game fish. Little modification of the area has been done, except for an access road for fishermen.

Procedure

The three lakes were selected because of visible differences: abundant aquatic vegetation in Lake I, limited watershed of Lake II, the greenish water color of Lake III.

Field data were collected between September 20 and November 15, 1971. Water samples for chemical analyses were taken with a Meyer sampler at a depth of 5 feet. Dissolved oxygen was determined by Ohle procedure (1, 8). Calgon Corporation of Evansville was contracted for more accurate and sensitive tests for dissolved ions and compounds. Temperature measurements, by standard Centigrade thermometer (±0.1°), and measurements of depth of effective light penetration, by 8-inch Secchi disc, were made on the same day near noon.

The plankton samples (6 x 16 inches, No. 20 cloth) was towed horizontally at depths of 1-4 feet and vertically from 1 foot of the bottom to the surface. A Carribean-type dredge (12 x 10 x 24 inches) was used for benthic samples. Specimens were preserved in 5% formalin.

TABLE 2. *Chemical and physical characteristics.*

	Lake		
	I	II	III
pH	7.4	6.4	7.0
Total hardness (mg/l)	104.0	172.0	260.0
Calcium (mg/l)	29.0	39.0	50.0
Magnesium (mg/l)	7.2	18.0	32.5
Dissolved oxygen, 23 °C (mg/l)	8.01	5.98	6.82
Total iron (mg/l)	0.08	0.35	0.66
Sulfates (mg/l)	30.0	185.0	275.0
Sulfide (mg/l)	<0.1	<0.1	<0.1
Average depth of effective light penetration (ft.)	11.75	10.25	2.75
Specific conductance, 23 °C (microhms)	250.0	340.0	490.0
Dissolved solids (mg/l)	104.0	240.0	410.0

Results and Discussion

Young strip mine lakes are generally highly acidic, due to the action of air and water on marcasite (FeS_2) in the overburden, producing iron sulfates and sulfuric acid (3, 9, 13). These compounds leach out in time, the iron compounds precipitating as "sulfur mud." The rate of recovery from acid pollution depends on the amount of acid-producing materials in the spoil and the nature of the watershed. The pH values of these three lakes (Table 2) indicated that they could be considered in the alkaline stage (pH 6.1-8.2) of recovery (2).

Oxidation of marcasite is responsible for the low oxygen concentration in young strip mine lakes (10, 11). As oxidizable materials decrease and phytoplankton appear, oxygen increases. The higher value for dissolved oxygen in Lake I (Table 2) reflected the relatively greater abundance of phytoplankton (Table 3) and the higher aquatic plants found there. *Lemma* spp. and *Najas minor* were abundant, and *Ludwigia palustris* was present in both Lakes I and III. Lake II, with the lowest dissolved oxygen, had the least amount of phytoplankton and no higher aquatics, had the smallest surface area, and was the most sheltered from wind action.

TABLE 3. *Phytoplankton in limnetic samples. (A = abundant; C = common; R = rare).*

	Lake				Lake		
	I	II	III		I	II	III
Chlorophycophyta				Chrysophycophyta			
Chroococcus spp.	A	—	—	*Cymbella* spp.	R	—	—
Cosmarium porrectum	A	—	C	*Diatoma* spp.	C	R	R
C. punctulatum	R	—	—	*Navicula* spp.	R	—	R
C. rectangulare	R	R	—	*Nitzchia* spp.	R	—	—
Cosmarium spp.	A	R	C	Euglenophycophyta			
Dictyosphaerium spp.	R	—	—	*Euglena* spp.	R	R	R
Dimorphococcus spp.	C	R	C	*Trachelomonas* spp.	R	—	—
Gloeocystis spp.	R	—	—	Cyanophycophyta			
Micrasterias spp.	—	R	—	*Anacystis* spp.	C	R	R
Pandorina spp.	C	—	—	*Lyngbya* spp.	C	R	C
Pleurotaenium spp.	—	R	—	*Merismopedia* spp.	C	—	—
Selenastrum spp.	R	—	—	*Oscillatoria* spp.	R	—	—
Spirogyra spp.	C	—	R	*Phormidium* spp.	R	—	R
Staurastrus alternans	C	—	—	Phyrrhophycophyta			
S. gracile	C	—	R	*Dinobryon* spp.	R	—	—
Staurastrus spp.	C	—	R	*Ceratium* spp.	A	—	C
Volvox spp.	C	—	—	*Peridium* spp.	R	—	—

The values of the other chemical data were, by far, lowest for Lake I (Table 2). This was to be expected from the greater dilution factor involved (*cf.* Area/vol. ratio, Table 1) in a climate where direct precipitation on the lake exceeds the evaporation from the surface. Lakes II and III, more similar chemically, had approximately the same area/volume ratio. The higher values for Lake III probably represent differences of input from spoil drainage. Sulfate was the predominate anion in each of the lakes. The minute amount of iron indicated that most of the iron sulfate had precipitated out. Total hardness and the amounts of calcium and magnesium indicated that most of the sulfate was present in the form of magnesium, calcium, and a small number of other metal sulfate compounds. The amount of arsenic ($<10\ \mu g/l$, composite sample of all lakes), sometimes associated with shale, probably was equivalent to levels found in freshwater lakes generally (1). The depth of effective light penetration corresponded to the amount of dissolved solids.

The temperature values did not indicate a clear thermal stratification at the time the data were gathered. Temperatures through the first 9 feet were slightly higher in Lakes II and III with the higher concentration of dissolved solids, which can increase heat absorption (6).

The values for specific conductance fell within the range expected from the concentrations of salts found in such alkaline lakes and within the range exhibited by most freshwater lakes (1, 3).

Lake I was biologically the most productive of the three. Twenty-four genera of phytoplankton were found in Lake I, compared to 8 and 11 genera in Lakes II and III, respectively (Table 3). The pH of Lake II and high turbidity of Lake III might have been limiting factors (11, 14).

TABLE 4. *Limnetic zooplankton and benethic invertebrates. (A= abundant; C = common; R = rare).*

	Lake				Lake		
	I	II	III		I	II	III
Protozoa				Insecta (larvae)			
Paramecium spp.	C	—	R	Diptera			
Stentor spp.	R	—	—	Chironomidae	C	R	—
Difflugia spp.	R	—	R	Culisidae	R	C	R
Rotifera				Other families	R	R	—
Kertella spp.	A	—	C	Coleoptera	—	R	—
Other spp.	—	—	R	Crustacea: Ostracoda	A	R	C
Crustacea				Mollusca: Pelecypoda	R	—	R
Copedoda				Nematoda	R	—	—
Cyclops spp.	C	C	C				
Other spp.	C	A	A				
Nauplii	—	R	—				
Cladocera	A	A	A				

No rotifers of the genus *Branchionus*, associated with acid waters, were found (9). *Kertell*a spp. were abundant in Lake I (Table 4). Copepods and Cladocera were the common zooplankton in each of the lakes. Ostracods were the most abundant benthic form found (Table 4). Shells of mollusk *Lampsilis radiata siliquoidae* were found on the banks of Lake I, and shells of *Anodonta grandis* were found at both Lakes I and III.

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