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# Selected physical and chemical properties of an alkaline bog lake

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## SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF AN ALKALINE BOG LAKE

Mud Lake is located in Ozaukee County, Wisconsin, on land adjoining the UW–Milwaukee Field Station. It is surrounded by Cedarburg Bog, the most extensive bog in southeastern Wisconsin. This lake is unusual among bog lakes in being alkaline. Some work has been done on the chemistry of acid bog lakes (Malins Smith, 1942; Gorham, 1956; Gorham and Pearsall, 1956; Hayward, 1957), but none of these authors sampled sites with pH values approximating those of Mud Lake. The primary purpose of this study was to begin a data bank of chemical analyses of Mud Lake water samples. The availability of such data should stimulate further research on this unique lake.

During the summer of 1974, selected physical and chemical properties of this lake were studied. Briefly, this project entailed sampling at three major stations in the lake at intervals of approximately three weeks. Three other stations were sampled sporadically throughout the summer. One 24-hour diurnal study was also done. Samples from 0, .25, .5, .75, and .9 meters were analysed for pH, color, turbidity, alkalinity, dissolved oxygen, nitrogen and phosphorus. Surface temperature was measured and an accurate bathymetric map of Mud Lake was constructed.

### PROCEDURE

The map of Mud Lake was drawn from aerial photographs of the area taken by the Wisconsin Department of Natural Resources (DNR) in 1967. Depth contours were constructed by anchoring a premeasured, marked rope at both ends and taking depth measurements to the silt and clay bottom at predetermined distances along this rope. Morphometric analysis was carried out using the system devised by Olson (1949). (See Appendix A*, Table 1.)

Six sampling stations were included in this study. Stations 1 and 2 were located in the western-most portion of the lake near the stream that drains Mud Lake. Both were in regions of high density emergent aquatic plants. Stations 3, 4, and 5 were along an open water transect in the deepest region of the lake. Station 6 was in the region of the stream feeding Mud Lake. It is in this area that the rising and sinking mats of decaying matter characteristic of bog lakes are the most prevalent.

Air and surface water temperatures were measured with a mercury-glass thermometer. Equipment failure made it impossible to measure temperature at other depths.

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*Appendix A is available upon request from the authors.

Water samples for chemical analysis were obtained with a glass sampler designed specially for procuring water from a very narrow depth range (Appendix A, Figure 1).

Nitrate, phosphate, and alkalinity were determined according to procedures in *Standard Methods,* 1971.

Color and turbidity measurements were made with a Hach kit (Hach Chemical Company, Model DR-EL). Each sample was allowed to settle until all visible particles were at the bottom of the container before an aliquot was inserted into the Hach meter. Since samples were not centrifuged, color values are reported as apparent color rather than true color.

pH was measured in the field using the Hach kit. Samples were also transported back to the lab at 0°C where the pH was again measured with a Beckman pH meter after the sample had warmed to room temperature.

The specific conductance of samples was measured with an Industrial Instruments conductivity meter (Model RB3 338, ref. temp. 25°C) and a YSI electrode (Series 3400). Readings were made as soon as possible to avoid conductance changes caused by changes in pH.

Dissolved oxygen was measured with a modification of the Carritt and Carpenter technique (1966). The reaction was carried out in 300 ml BOD bottles with polished glass stoppers instead of the long-tapered glass stoppers recommended by the authors. While this necessitated transferring aliquots to titration flasks, it proved more reliable than using the recommended flasks.

## RESULTS

A detailed bathymetric map of Mud Lake is illustrated in Appendix A (Figure 2). The depth at certain points in the lake was subject to change due to mats of decaying material that periodically floated to the surface and sunk to the bottom depending upon the gas concentration of the mat. In these cases, depths used are maximum depths. Measurements involving mats which have floated to the surface were disregarded when depth contours were drawn.

Summarized data for color, turbidity, pH, temperature, phosphate, nitrate, specific conductance, and dissolved oxygen are listed in Table 1 of this report. Values are reported as the mean of all samples taken on a single date ± the standard error of the mean.

Color results from dissolved materials in the water. In the case of Mud Lake, much of its tea-brown color is due to humic acids. Some of these humic acids probably originate in the bog and flow into the lake, as color tests near the stream inlet show higher color values than anywhere else in the lake. Over the course of the summer a distinct decrease was noted in mean color values from 97.7 ± 2.4 color units on June 6 to 83.0 ± 3.6 color units on August 6. However, on June 27 there was a significant increase in color to 122.0 ± 3.7 color units, the highest measured value for the summer. According to Juday and Birge (1933) seasonal and annual variations in color are due mainly to the amount of drainage water flowing into the lake. Bleaching of color may also occur, but this action decreases rapidly with depth. This bleaching effect was not noted during our sampling period, possibly due to the fact that the lake is 1.3 meters at its deepest depth. During the diurnal study (Appendix A, Table 3) a decrease in color of 22 units at 2000 hours (8 p.m.) and an increase in color of 11.5 units at 600 hours (6 a.m.) was noted. In terms of drainage or bleaching effects this night-time decrease cannot be explained.

Complete sets of turbidity data are included in Appendix A (Tables 2 and 3). As with color, a distinct increase in turbidity to 33.45 ± 3.68 turbidity units was noted on June 27. There was no discernable summer trend in turbidity as was seen with color. Diurnally, turbidity exhibited a decrease from the daytime mean of 33.03 ± 3.44 units to 28.68 ± 1.36 units between 2000 and 600 hours.

All pH measurements made during the summer were alkaline, ranging from 7.4 to 8.8 with a mean of 8.2. Over the summer there was a very slight increase from a mean of 7.93 on June 6 to 8.02 on August 6. However, the highest observed pH of 8.82 was obtained on June 6 at station 3. The diurnal fluctuation of pH showed a slight increase at 2000 hours from the daily mean of 7.97 to 8.20 and a subsequent decrease at 600 hours at station 3.

On any given day, alkalinity values showed no appreciable differences between stations or depths (Appendix A, Table 6). A steady increase was observed over the summer from a minimum value of 126.9 ± 0.9 mg/l $CaCO_3$ on June 6 to 168.5 ± 3.7 mg/ l $CaCO_3$ on August 6. The high alkalinity that makes Mud Lake such a unique bog lake is probably due to the dolomite in the watershed. There were no appreciable diurnal differences indicated in the data (Appendix A, Table 7).

Complete data tables for summer dissolved oxygen trends are in Appendix A (Tables 8 and 9). In early June oxygen values for open water stations (Stations 3, 4, and 5) were low, with a mean of 5.97 ± 0.03 mg/l $O_2$. Oxygen values increased to the maximum of 9.30 ± 0.09 mg/l $O_2$ in mid-July and then decreased to the seasonal minimum of 5.76 ± 0.24 mg/l $O_2$ in early August. However, in mid-July when maximum oxygen values were exhibited in open water, oxygen concentrations approaching aerobic conditions were found in a weed bed near the outlet of the lake. No significant differences were found between station, time, or depth during the diurnal study.

Soluble reactive phosphorus (SRP) was the only category of phosphorus measured during theis study. Complete data are given in Tables 10 and 11 of Appendix A. A definite seasonal trend was observed at the open-water sampling stations. Maximum SRP concentrations of 6.87 ± 0.90 µg P/l were found in early June following the end of the spring diatom bloom. This value decreases to the seasonal minimum of 1.55 ± 0.20 μg P/l in mid-July and then increases to 3.67 ± 0.47 μg P/l in the first part of August. SRP concentrations may reflect productivity levels in Mud Lake, as bog lakes are well known for having very low concentrations of most ions (Ruttner, 1963). If this is the case in Mud Lake, then the lowest SRP concentrations would reflect periods of greater productivity than those times with the higher SRP concentrations. Daily fluctuations in SRP concentrations were very pronounced, with a concentration maximum of 3.50 ± 0.49 μg P/l appearing at 2000 hours and a concentration minimum of 1.28 ± 0.18 μg P/l appearing at 1600 hours.

Nitrate-nitrogen was the only form of nitrogen tested for during the study. Complete data lists corrected for color and blank reactions are in Appendix A (Tables 12 and 13). A fluctuation paralleling that of SRP is noted with nitrates. Nitrate concentration declined from 0.285 ±.005 mg/l on June 6 to 0.006 ±.001 mg/l on June 27, the lowest observed value for the summer. An increase was noted on the next two dates, increasing to its greatest concentration on August 6 of 0.299 ±.005 mg/l. Station 6, located near the entrance of the stream feeding Mud Lake, exhibited the greatest observed nitrate concentrations, indicating a possible outside source of nitrogen.

Specific conductance as a measure of resistance provides information on the total amount of ionic material in a water sample. Increasing specific conductance reflects increasing ionic concentration and decreasing resistance of a sample. Complete data for the summer are given in Appendix A (Tables 14 and 15). A general increasing trend from a minimum of 276.67 ± 4.42 μmhos on June 6 to a maximum of 672.86 ± 6.62 μmhos on July 18 and a subsequent decrease to 637.00 ± 12.51 μmhos was noted. This trend nicely parallels those for both nitrate and phosphate measurements.

Mid-July measurements were made of calcium and total hardness and of iron and silica concentrations. Values for calcium hardness (90 mg/l $CaCO_3$) subtracted from total hardness (140 mg/l $CaCO_3$) give magnesium hardness (50 mg/l $CaCO_3$). Surface iron was measured at 0.13 ppm Fe and surface silica was measured at 4.5 ppm $SiO_2$. Measurements were taken at station 3 using surface water samples.

## DISCUSSION

Eutrophication is generally defined as the accumulation of nutrients. While this is an acceptable definition, a working definition has to be developed. Presently, no one universal working definition has been agreed upon. Lueschow et al (1970) have developed a characterization of Wisconsin lakes on the basis of nitrogen and phosphorus levels, the nutrients that are generally considered to be limiting nutrients. They do not go as far as to state that their classification indicates the trophic nature of the lake, but rather the probability of the occurrence of algal and weed nuisances during the summer months which is in itself an indicator of the trophic nature of a lake.

Nitrogen in water is present in four forms – organic nitrogen, nitrate nitrogen, nitrite nitrogen, and ammonium nitrogen. Organic nitrogen is bound by biological processes and is generally not available to photosynthetic organisms. The inorganic fraction, comprised of the three other forms of nitrogen, is available to photosynthetic organisms and consequently is the fraction important in trophic considerations. Lueschow et al (1970) found that lakes with an annual mean greater than 0.03 mg/l inorganic nitrogen have general algal nuisances during the summer while lakes with less than this amount did not have summer nuisance blooms. Total inorganic nitrogen was not measured during this study, but nitrite nitrigen can be used as an estimate of inorganic nitrogen as the nitrite fraction is unstable and the ammonium fraction is oxidized by nitrifying bacteria in the presence of oxygen to yield nitrate in both cases. In Mud Lake the summer mean falls below this critical value, although two out of the four summer values came close to 0.03 mg/l.

| Data | 6/6 | 6/27 | 7/18 | 8/6 |
|---|---|---|---|---|
| Surface Temperature ($^{o}$C) | 18.3 | 24.5 | 25.0 | 23.0 |
| Color | 97.7 ± 2.43 | 122.0 ± 3.73 | 91.5 ± 6.82 | 83.0 ± 3.65 |
| Turbidity | 20.3 ± 0.51 | 33.5 ± 3.68 | 17.8 ± 2.34 | 22.8 ± 2.26 |
| pH | 7.96 ± 0.13 | 7.93 ± 0.04 | 7.87 ± 0.19 | 8.02 ± 0.10 |
| Specific Conductance (μmhos/cm) | 276.67 ± 4.42 | 568.57 ± 6.70 | 672.86 ± 6.62 | 637.00 ± 12.51 |
| Alkalinity (mg/l $CaCO_3$) | 126.9 ± 0.42 | 138.8 ± 3.29 | 155.1 ± 2.80 | 168.5 ± 3.67 |
| Dissolved Oxygen (mg/l $O_2$) | 5.97 ± 0.03 | 6.24 ± 0.30 | 9.30 ± 0.09 | 5.76 ± 0.2 4 |
| Nitrate (mg/l $NO_3$-N) | 0.285 ± .005 | 0.006 ± .001 | 0.166 ± .081 | 0.299 ± .005 |
| Phosphate (SRP) (μg P/l) | 6.87 ± 0.90 | 2.60 ± 0.67 | 1.55 ± 0.20 | 3.67 ± 0.47 |

Table 1. Summarized Physical and Chemical Data for Mud Lake Collected During the Summer of 1974.

Lueschow et al (1970) also considered total phosphorus. They found that lakes with an annual mean less than 0.03 mg P/l were free from aquatic nuisances, with between 0.03 and 0.05 mg P/l were essentially free of algal nuisances, and with greater than 0.1 mg P/l were experiencing nuisance weed growths or algal blooms during most of the growing season. Unfortunately, we did not measure total phosphorus during the summer and Lueschow et al (1970) could not come up with any significant concentration levels of soluble reactive phosphorus, so no predicitions can be made on the trophic nature of Mud Lake based on soluble reactive phosphorus concentrations.

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