SOME OBSERVATIONS ON THE LIMNOLOGY OF A POND RECEIVING ANIMAL WASTES[1]

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Limnological observations were made on a small pond in Oklahoma which receives runoff from a swine yard. Large populations of blue-green algae were dominant during the summer and *Chlorella* during the winter. Heavy runoff quickly decreased the concentration of ions on two occasions and also altered the size and composition of the community of phytoplankton. The concentration of major ions fluctuated markedly. Oxygen concentrations were often low and reduced nitrogen compounds predominated. The pond is similar to other bio-oxidation ponds in Oklahoma and probably would not be suitable for fish culture.

The problem of contamination of water supplies by animal wastes is currently receiving much attention. The most serious problems are oxygen depletion and eutrophication in surface waters and nitrate accumulation in subsurface waters.

Impounding runoff water from feedlots and heavily fertilized fields has been cited as a means to improve the quality of this water (1). In an effort to establish the occurrence of nitrogen fixation in impounded waters, the author conducted a study of a small pond receiving runoff from a swine yard during 1967 and 1968. Limnological observations were also made on phenomena which were thought to affect N_2 fixation. The purpose of this paper is to describe these observations, since these ponds receiving runoff from feedlots have not been studied extensively.

The environment studied (hog pond) has a surface area of 0.21 ha and a mean depth of about 50 cm when the surface is at the level of the spillway. It is located in the SW 1/4 NE 1/4 Section 16, Township 19 North, Range 2 East, Payne County, Oklahoma. The pond receives runoff from a swine yard and the overflow from a small septic pit above. The flow from the pit is channeled into a small creek which flows irregularly into the pond. The bottom of the pond is covered by a soft black ooze.

METHODS

Four samples of one liter each were taken at random and combined to form one composite sample of 4 liters. In each case, only the top 40 cm of the water column was sampled with a non-toxic water sampler. Water was filtered through cheesecloth to eliminate duckweed from the sample before it was analyzed.

Biological methods. Algae were identified on the day of sampling using keys of Drouet (2). Dr. Frances Drouet verified the identification of the blue-green algae at the Philadelphia Academy of Science. Chlorophyll *a* was determined by retaining particulate matter from 50 to 100 ml of the composite sample on 0.45 nm membrane filters, dissolving the filters in 90% acetone for 16 to 20 hours, and reading the absorbance in a one cm cell on a Beckman DB spectrophotometer. Chlorophyll *a* was calculated using the equations of Richards with Thompson (3). The pigment diversity ratio of Margalef (4) was calculated by dividing the absorbance at 430 mμ by the absorbance at 665 mμ. This ratio is useful in describing physiological states of populations and successional changes.

Chemical analysis. The micro-Kjeldahl technique was used to determine the total nitrogen concentration of the composite sample. The destruction mixture was that of Bruel, et al. (5). Either 50 or 100 ml of water from the composite sample was filtered through a 0.45 nm membrane filter and the total nitrogen content of this water was determined in the same way. The difference in total nitrogen content between filtered and unfiltered water roughly corresponds to the nitrogen content of the particulate matter.

Water from the composite sample, used for other chemical analyses, was poisoned with 2 mg $HgCl_2$ per liter, filtered through

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a 0.45 nm membrane filter and stored in acid-washed polypropylene bottles. The NH_4-N concentration was determined by direct nesslerization (6), while the concentration of NO_3-N was determined by the phenoldisulfonic technique described by Bremner (7).

Winkler oxygen determinations (Alsterberg modification) were accomplished following standard methods (6). Some difficulty was encountered in reaching a suitable endpoint because of the high concentration of organic matter in the water. The results are used only for comparative purposes.

All other analyses of water (as well as the nitrate analyses) were completed by the Soils Laboratory of the Oklahoma State University. A Beckman Model N pH meter was used for pH determinations. A Model R6-1B conductivity bridge (Industrial Instruments) was used to determine specific conductance. The concentration of certain cations (Na, Ca, Mg) was learned by using atomic absorption techniques.

The concentration of bicarbonates was determined by titrating a sample of 100 ml with 0.1 N HCl using methyl orange as an indicator. The concentration of chloride was determined by titrating 50.0 ml of sample with 0.1 N $AgNO_3$, while SO_4 concentration was determined turbidimetrically after addition of $BaCl_2$. Turbidity was measured in a 2.54 cm test tube with a colorimeter at 450 mμ.

RESULTS

Lemna sp. formed an extensive blanket over the surface of the pond between July, 1967, and the middle of January, 1968. *Lemna sp.* thus persisted well into the winter.

The phytoplankton consisted of *Oscillatoria rubescens, Spirulina sp.* and *Anacystis cyanea* during July, 1967. This bloom was diluted by a flood on 25 July and the former two species had disappeared by the end of August. At this time *Anacystis cyanea* still persisted on the surface, but phytoflagellates had increased markedly. Between the end of August and early December the composition of the phytoplankton did not change markedly, but the population decreased dramatically. On 18 December, microscopic examination did not reveal the presence of phytoplankton in the pond. Chlorophyll *a* could not be detected.

The weather during February was exceptionally cold and a thin ice cover formed on various nights, but such cover rarely persisted beyond noon of the next day. By 16 February, 1968, however, a massive bloom of *Chlorella sp.* had developed in the pond. The bloom persisted well into March, but was washed out of the pond by heavy runoff during late April. The dilution effect of the April runoff was marked; the pond was seemingly devoid of phytoplankton by 24 April.

Between April and May, *Anacystis cyanea* developed a bloom. The algae formed a thick blanket over the surface of the pond. A few pennate diatoms and many phytoflagellates were observed in subsurface water samples.

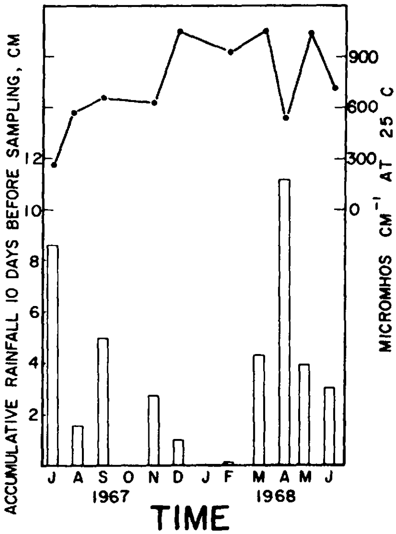

FIGURE 1. Conductivity of the hog pond water and total accumulative rainfall 10 days prior to date of sampling (Bar graph = rainfall measured at Stillwater, Oklahoma, by the U. S. Weather Bureau.)

By 10 June, *Anacystis cyanea* could be found as thin bands along the surface similar to those observed during the autumn of 1967. *Planktosphaeria* was the dominant genus. *Lemna sp.* did not appear again until late June, 1968. Blue-green algae were observed again during August, 1968, when *Anacystis cyanea, Oscillatoria rubescens* and *Arthrospira platensis* were the dominant plankters.

Heavy runoff not only washed out blooms of algae, but also altered the chemical composition of the pond water. Conductivity decreased markedly after heavy rainfall and then increased during periods of relatively little precipitation, probably due to concentration of ions by evaporation (Figure 1).

During the autumn of 1967, rainfall was low and dilution effects were negligible. Chlorophyll *a* rose dramatically during August and then decreased markedly afterwards until by December 18, none could be detected (Figure 2). Pigment diversity rose some time after the chlorophyll *a* peak and then decreased as in an ageing culture of algae.

The concentration of the major ions fluctuated considerably. For example, Na varied from 17 to 116 mg/l, Ca varied from 15 to 60 mg/l, and Cl varied from 7 to 147 mg/l (Table 1). Heavy rains during July, 1967, and April, 1968, caused a marked decrease in all the major cations (Table 1). Water temperatures and the pH of the water are also found in Table 1.

Oxygen concentrations during midmorning were never very high except at those

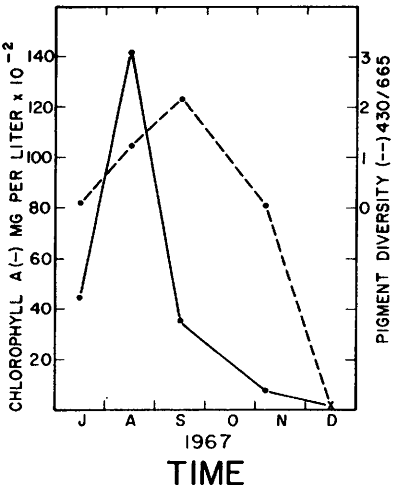

FIGURE 2. Chlorophyll *a* and pigment diversity of phytoplankton in hog pond during summer and fall, 1967. (Solid line = chlorophyll *a*; dashed line = pigment diversity; X = pigment not detected.)

TABLE 1. *Ionic composition, pH, surface temperature and major bloom-forming algae in hog pond water at the time of sampling (0600-0800 hrs CST).*

Date	Temp. (C)	pH	Cations (mg/l) Na	Ca	Mg	Anions (mg/l) Cl	SO_4	HCO_3	Bloom former
7/28/67	25	7.6	17	15	5	7	0	143	blue-greens
8/24/67	22	8.4	42	25	17	57	0	203	phytoflagellates
9/23/67	19	7.7	42	37	18	55	0	263	phytoflagellates
11/4/67	7	6.9	40	35	18	44	2	263	phytoflagellates
12/18/67	3	8.4	94	45	24	94	2	383	none
2/16/68	4	7.8	75	50	32	130	40	299	*Chlorella sp.*
3/21/68	9	7.7	116	40	26	147	48	329	*Chlorella sp.*
4/24/68	14	8.1	36	27	18	48	36	203	none
5/20/68	16	8.6	87	60	34	142	57	352	*Anacystis cyanea*
6/9/68	26	8.5	56	47	29	89	8	353	green algae
8/30/68	25	9.1	72	45	24	101	6	328	blue-greens

times when the pond supported a bloom (Table 2). On two occasions oxygen was not detectable or was present in a concentration of less than 0.2 mg/l.

TABLE 2. *Oxygen concentrations during mid-morning.*

Date	(mg/l) Oxygen Concentration
23 Sept. 1967	1.38
4 Nov. 1967	0.12
18 Dec. 1967	1.49
16 Feb. 1968	16.30
21 Mar. 1968	7.60
24 Apr. 1968	7.60
20 May 1968	4.35

Pond water, filtered through 0.45 nm membrane filters, was yellow in color and had a transmittance of 85 to 89% in a 2.54 cm cell at 450 mμ.

The concentration of NO_3-N was never greater than 0.172 mg/l on the day of sampling, and on several occasions it was barely detectable (Figure 3). The concentrations of NH_4-N were very high. There is no reason to expect nitrogen to be a limiting nutrient for the growth of algae.

High particulate nitrogen was observed during blooms and, as might be expected, the concentration of dissolved organic nitrogen tended to parallel particulate nitrogen (Figure 4). The exception was the relatively high concentrations of dissolved organic nitrogen during April and May, 1968, after a major flood caused dilution of a bloom. Water entering the pond as runoff may have contained a high concentration of soluble organic nitrogen. There is no evidence of a seasonal cycle in the concentration of any nitrogen compound measured.

DISCUSSION

The most striking feature of the lim-

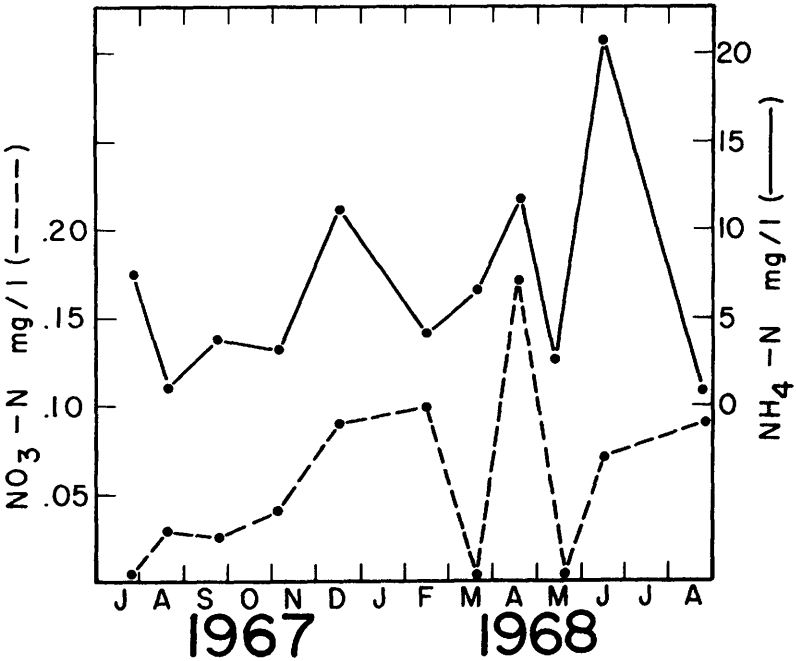

FIGURE 3. Concentrations of NO_3-N and NH_4-N on sampling day.

nology of this pond was the effect of dilution by heavy runoff from the watershed. This kind of perturbation quickly altered the composition of the phytoplankton community and significantly reduced cell numbers. Algal growth began again and bloom conditions developed if conditions were favorable, *e.g.*, after the July flood.

One unexpected phenomenon was the extreme fluctuation in the concentration of the major ions. The reason for this variation is not clear, but is important since many of the ions are nutrients which may have a stimulatory effect on algal growth (8). Seasonal changes in species composition of the flora, similar to those observed here, have been reported by Davis, Wilcomb and Reid (9) for some bio-oxidation ponds in Oklahoma. Populations of algae tend to be large and dominated by only a few species. Blue-green algae are characteristic of the summer, whereas green algae and phytoflagellates are dominant at other times (Table 1).

The hog pond studied would not be suitable for rearing fish, in spite of its high productivity. While oxygen concentrations were very high on three occasions, there were four instances where the oxygen concentration was less than 5 mg/l. Stroud (10) claims that no less than this concentration is necessary to maintain healthy populations of warmwater fishes. In addition, the high concentrations of NH_4-N may be toxic to fish, especially at high pH. Lloyd (11) showed that NH_4 was eight times as toxic to rainbow trout (*Salmo gairdnerii* Richardson) at pH 8.6 than at pH 7.0. The lower threshold at pH 8.6 was 7 mg/l NH_4-N. This does not mean that all ponds receiving domestic animal wastes would be unsuitable for rearing fish, but it does suggest the need for caution in using such environments for this purpose.

ACKNOWLEDGMENT

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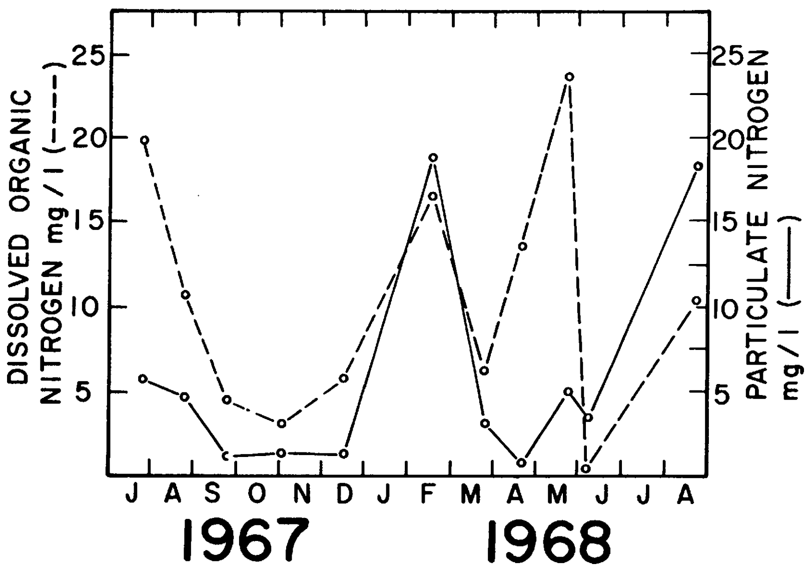

FIGURE 4. Concentrations of dissolved organic nitrogen and particulate nitrogen on sampling day.

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