Pond Water Quality in a Claypan Soil

Elbert C. Dickey
University of Nebraska-Lincoln, edickey1@unl.edu

J. K. Mitchell
University of Nebraska-Lincoln, jkmitche@illinois.edu

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E. C. Dickey, J. K. Mitchell
ASSOC. MEMBER ASAE MEMBER ASAE

BACKGROUND

IN many areas of the midwestern United States, a safe and plentiful supply of groundwater is a primary concern. Groundwater is sporadic, unreliable, shallow, and often polluted, even though these same areas often have an annual rainfall in excess of 1 m.

The pollution problems associated with these groundwater supplies are both chemical and bacterial. Older wells are often the most dangerous. Linings made of open brick near the surface, cracked casings and covers, and nearby privy, septic tank, and barnyard sites accentuate the problems in shallow groundwater aquifers. High levels of nitrates frequently present in the shallow domestic well water of Illinois were recognized as a health problem by Weart (1948).

A preliminary study by Smith et al. (1970) in Washington County, Illinois, of 213 dug wells (2.1-9.2 m deep), 31 drilled wells, and 72 farm ponds showed that water from 73.4 percent of the dug wells exceeded the U.S. Public Health Standard of 10 mg/l nitrate nitrogen. Only 19.3 percent of the drilled wells exceeded the standard for safe drinking water. All the ponds sampled were found to be well below the U.S. Public Health Standard for nitrate content.

Pryor (1956) has reported that because of the geology of the area groundwater supplies in most of Washington County, Illinois, are inadequate. The geologic situation makes successful drilled wells almost nonexistent. Existing low-quality and low-yielding wells are being supplemented by cisterns, transported water, and some ponds.

An economic analysis of farm water supplies in Washington County by Moore (1972) revealed that present well water systems are the least costly available, but the quality and quantity make most of these sources unreliable. Alternatives considered by Moore included farm ponds, municipal water supplies, transported water, and various combinations of these potential sources. Moore concluded that farm ponds with a treatment system could be one of the more satisfactory sources of water provided storage is available to meet demands during a prolonged drought.

The data reported by Smith et al. (1970) concerning nitrate levels in Washington County ponds were from samples collected during late spring. Hill et al. (1962) reported an average maximum level of 3.1 mg/1 of nitrate nitrogen occurred in 14 Ohio ponds with a mean value of 0.17 mg/1. Hill also reported that maximum values for some chemical parameters occurred during early spring months. The authors felt that ponds in Washington County could potentially exceed the public health limit for nitrate because contamination could occur from the same sources causing widespread goundwater contamination. Also, it was felt that differences in watershed types could influence the quality of pond water.

Pryor (1956), Smith (1970), and Moore (1972) have shown that Washington County needs an alternate water supply to existing low-quality wells. A project was initiated in December 1970 to determine seasonal and monthly fluctuations of several water quality parameters in farm ponds having different watershed types. Additionally, the premise that Washington County farm ponds could provide water of acceptable quality to repace existing low-quality wells was considered.

STUDY AREA DESCRIPTION

In November, 1970, a field inspection was made of Washington County ponds having three basic types of watersheds:

1 Those containing ungrazed pasture or trees.

2 Those having cultivated land.

3 Those consisting primarily of a livestock exercise area.

The ten watersheds described in Table 1 were selected for this study.

The watersheds are predominately in the Cisne-Hoyleton and Bluford-Wynoose soil association areas (Smith and Smith 1937). These soils are mainly silt loams characterized by an almost impervious subsoil. The soil drains very slowly and often remains wet and cold in the spring. Sheet and rill erosion on the more rolling slopes in cultivated fields is a serious problem. Slick spots (sodic soils) frequently occur in conjuction with the major soil groups in Washington County.

Washington County has a long time average precipitation of 1,009 mm, with 565 mm occurring between April 1 and September 30. The rainfall in Nashville, Illinois, for the calendar years of 1971 and 1972 was 882 mm and 1037 mm, respectively. Roberts and Stall (1967) re-

TABLE 1. DESCRIPTION OF PONDS USED IN STUDY.

Pond	Watershed management	Watershed area (hectares)	Average slope (percent)	Pond surface area (hectares)	Maximum depth (meters)
A1	Woodlot	9.9	3.5	0.55	3.7
A2	Grassed	1.3	6.7	0.32	3.7
A3	Grassed	28.6	4.9	3.68	4.6
B1	Cultivated	3.5	1.0	0.24	2.1
B2	Cultivated	8.1	4.0	0.85	3.0
B3	Cultivated	4.5	2.0	0.08	3.7
B4	Cultivated	4.9	2.6	0.10	6.1
C1	Livestock (dairy)	3.2	1.8	0.08	1.5
C2	Livestock (sheep)	1.7	1.0	0.53	3.0
C3	Livestock (hogs)	0.4	1.5	0.08	2.4

Article was submitted for publication in July 1974; reviewed and approved for publication by the Soil and Water Division of ASAE in November 1974. Presented as ASAE Paper No. 74-2038.

The research in this report was conducted with the cooperation of the Illinois Agricultural Experiment Station, USDA, SCS, in Illinois and the Illinois Natural History Survey. Funds were provided through the Illinois Agricultural Experiment Station and Rockefeller Foundation.

The authors are: E. C. DICKEY, Research Assistant, and J. K. MITCHELL, Assistant Professor, Agricultural Engineering Dept., University of Illinois, Urbana.

This article is reprinted from the TRANSACTIONS of the ASAE (Vol. 18, No. 1, pp. 106, 107, 108, 109, 110, 1975)
Published by the American Society of Agricultural Engineers, St. Joseph, Michigan

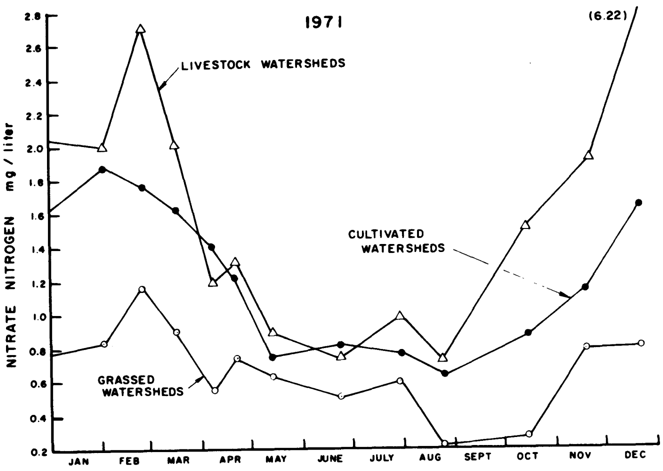

FIG. 1 Changes in the average nitrate nitrogen concentrations during 1971 for three watershed types.

ported that lake evaporation for the area is 908 mm. The mean temperature is 14.3 C with January being the coldest month (1.5 C) and July being the hottest (26.4 C).

PROCEDURE

Several measurements were made on water samples from each pond during the 2-yr study period of November 1970 to November 1972. Those measurements discussed in this paper are:

- Biochemical oxygen demand
- Coliform bacteria
- Soluble ortho-phosphate
- Nitrogen
  - a. Ammonia
  - b. Nitrate
- Dissolved oxygen
- Hardness
- Rainfall
- Temperature

All measurements were taken at approximately monthly intervals throughout the study period except coliform bacteria and B.O.D., which were discontinued in March, 1971. Water samples were taken at one location in the pond at depths of approximately 20 cm below the water surface and 20 cm above the bottom at that location using the sampling device desicribed by Mitchell and Dickey (1973).

Nitrate nitrogen concentrations were measured with an Orion nitrate ion-selecting electrode using the procedure described by Dickey (1974). Nitrate concentrations were checked frequently with the chromotropic acid method as described in Standard Methods (1971). Biochemical oxygen demand and coliform bacteria were measured using procedures described in Standard Methods (1971). Soluble ortho-phosphate, hardness, nitrite nitrogen, and ammonia nitrogen were determined by the Illinois Natural History Survey using a Technicon Auto-Analyzer (Model CSM-6). Dissolved oxygen was measured at the time of collection with a Yellow Springs Instrument (Model 54).

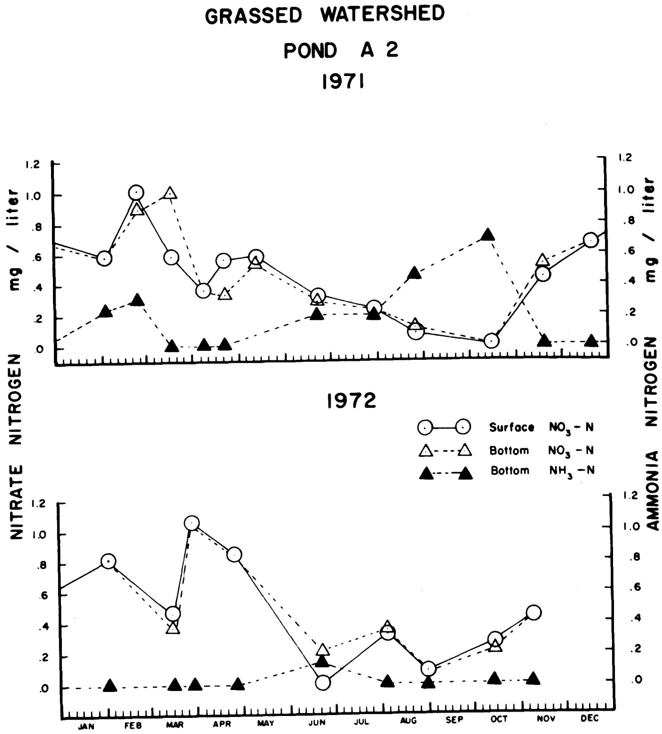

FIG. 2 Nitrate and ammonia nitrogen concentrations measured in a typical pond having a grassed watershed.

BACTERIAL QUALITY

Coliform bacteria levels were highest in those ponds having livestock on the watershed, but all ponds studied had positive coliform tests. Mean fecal coliform counts were 14.7 per 100 ml on grassed watersheds, 145 per 100 ml on cultivated watersheds, and 982 per 100 ml on livestock watersheds. However, after manure was applied to a cultivated watershed, counts went as high as 7,200 per 100 ml. During an intense runoff period, a coliform bacteria count of 16,000 per 100 ml was recorded for a pond having a livestock concentration on the watershed of approximately 50 milk cows per hectare. Fecal streptococci counts were also made, and the results essentially paralleled the fecal coliform counts.

These coliform counts showed a potential health hazard for humans unless water is properly treated. However, if the ponds are to be used as a drinking water supply for animals, treatment may not be necessary. For example, the pond having the highest coliform count in this study was used to supplement a water supply for dairy cows and fecal coliform counts frequently exceeded 1,000 per 100 ml. The farmer has not detected any problems in using the bacteria-laden water after the animals have adjusted to it.

NITRATE AND AMMONIA NITROGEN

Fig. 1 shows that the average nitrate values were highest in ponds having livestock on the watershed. The lowest level of nitrate occurred in ponds having grassed or wooded watersheds. The maximum level of nitrate nitrogen found in any specific pond at any time was 1.38 mg/l for grassed watersheds, 2.84 mg/l for cultivated watersheds, and 22.0 mg/l for livestock watersheds. The maximum level of 2.84 mg/l occurred on a cultivated watershed which had some hogs near the pond. Ponds having only cultivated watersheds with no livestock in the vicinity had a maximum level of 2.22 mg/l.

Additionally, Fig. 1 shows that the nitrate levels in farm ponds were highest during the cooler months of the year. Nitrate values were lower during the warmer months, reaching the lowest level during August. Subsequent data have shown that high peaks can occur during summer months for short periods of time.

Figs. 2, 3, and 4 are nitrate and ammonia plots over time from a typical pond in each watershed type. The A2 pond (grassed watershed) had a maximum nitrate nitrogen level of 1.06

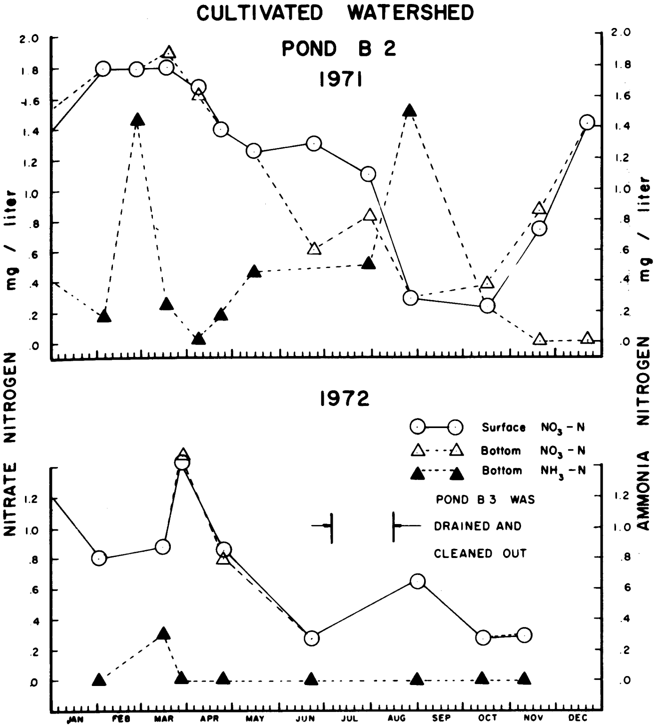

FIG. 3 Nitrate and ammonia nitrogen concentrations measured in a typical pond having a cultivated watershed.

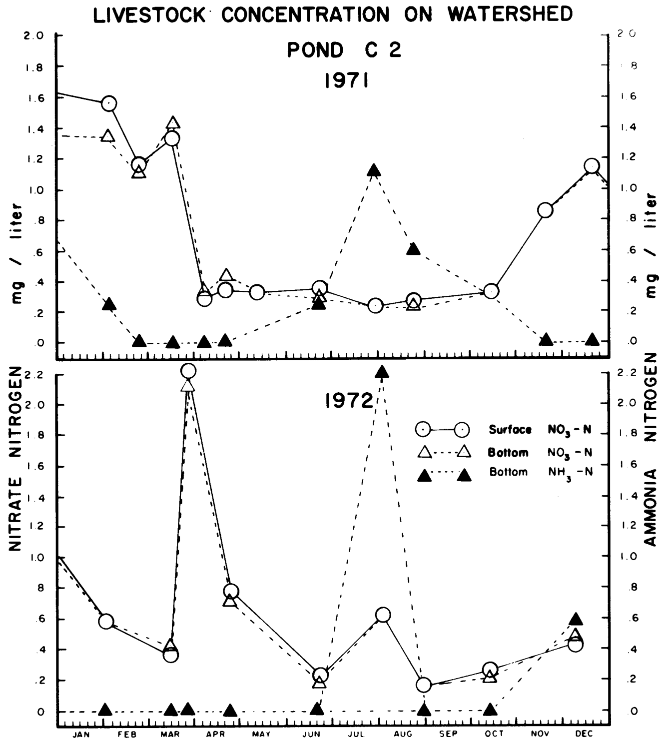

FIG. 4 Nitrate and ammonia nitrogen concentrations measured in a typical pond having a livestock concentration on the watershed.

mg/l. Pond B3 (cultivated watershed) reached a maximum nitrate level of 1.88 mg/l, while pond C2 (livestock watershed) had a maximum of 2.22 mg/l. These maximums occurred in early spring.

As the nitrate level decreased in the spring, the ammonia tended to increase. Again the watersheds with more nutrients had higher ammonia levels in the ponds. The maximum ammonia levels occurred near the bottom of the ponds where anaerobic conditions existed during portions of the year. Extremely high levels of ammonia (more than 15 mg/l) were observed in the ponds having

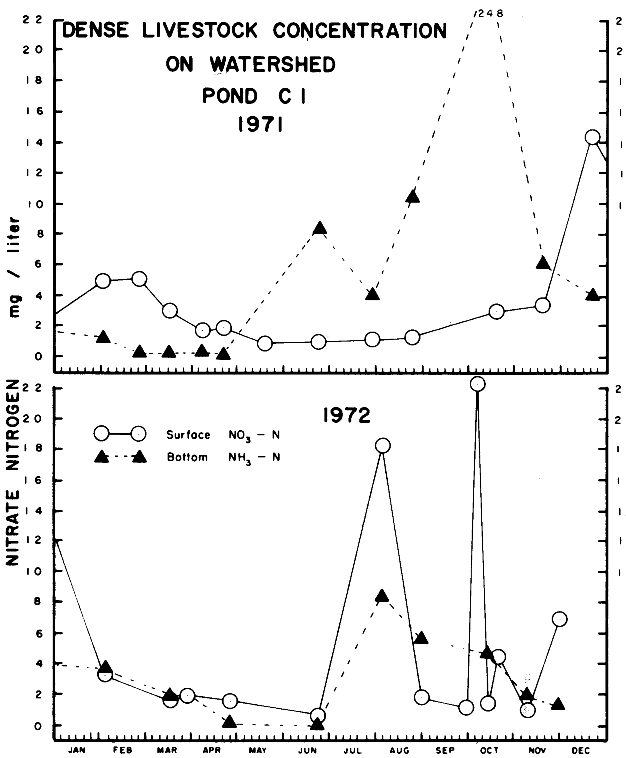

FIG. 5 Nitrate and ammonia nitrogen concentrations measured in a typical pond having a dense livestock concentration on the watershed.

a dense livestock population on the watershed and in cultivated watersheds receiving manure on an annual basis.

Lack of oxygen and decomposition of organic nitrogen in the anaerobic portion of the pond can cause the ammonia concentration to increase during the warmer months. Without oxygen, ammonia released during decomposition (Sawyer and McCarty 1967) will remain in the ammonia form until oxidation can occur.

The reduction in the nitrate level during the summer may be explained by either denitrification or algae growth. The farm ponds studied have enough nutrients to sustain an abundant algae growth. As the growth occurs, nitrate may be removed directly by the ponds vegetation. Nitrate nitrogen may also be lost to the atmosphere through denitrification under favorable conditions.

During the first year of study, there were no measurements of nitrate above the U.S. Public Health Standard of 10 mg/l. In December, 1971, there was a sharp rise of nitrate-nitrogen in pond C1, as shown in Fig. 5. The level reached 14 mg/l, and by February, 1972, the level had returned to 3 mg/l. In August, 1972, the nitrate-nitrogen level in this same pond rose to 18 mg/l, and in October another peak of 22 mg/l occurred. Such a rise in nitrates could have been caused directly by the addition of nitrates via runoff from a watershed with an accumulation of nitrates or

TABLE 2. MAXIMUM AND MINIMUM OXYGEN LEVELS, NOVEMBER, 1970, TO NOVEMBER, 1972.

	Maximum D.O.	Minimum D.O.	Range
	(mg/l)	(mg/l)	(mg/l)
Grassed watersheds			
A1	9.5	4.4	5.1
A2	10.0	2	8.0
A3	10.5	5.6	4.9
Cultivated watersheds			
B1	11	3	8
B2	9.5	2.5	7
B3	10.5	1.5	9
B4	13.5	1.5	12
Livestock on watershed			
C1	20.5	2	18.5
C2	12.5	2.4	10.1
C3	11.5	1	10.5

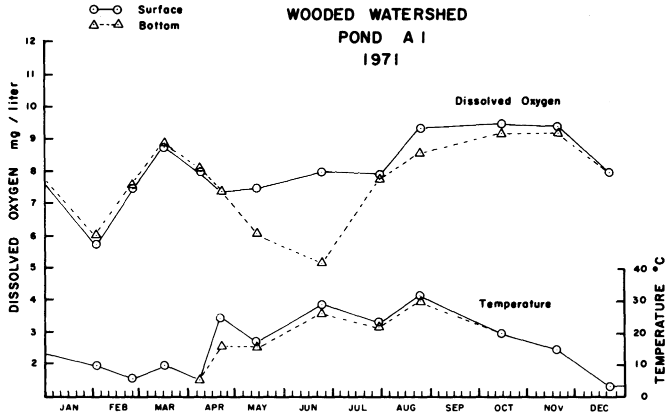

FIG. 6 Temperature and dissolved oxygen concentrations measured in a typical pond having a grassed watershed.

indirectly through the oxidation of pond water that had a large amount of nitrogen present in a reduced form.

Unpaved cattle lots, when dry, exhibit high nitrate concentrations on or near the surface. The soil analysis was made using a Bray (1945) color test without a quantitative determination. Cool, wet lots have exhibited low nitrate levels when tested with the Bray procedure.

In the cases involving the excessively high nitrates in pond C1, the nitrates have appeared immediately following a period of high-intensity rainfall on a dry lot surface. There was, in each case, a large amount of runoff into the pond with an initially low water level. Since there was very little time between the runoff event and sampling time, the authors concluded that oxidation of reduced nitrogen probably was minimal. The large increase in nitrate is more likely due to the runoff which contained nitrates from the dry, unpaved cattle lot. Miner et al. (1966) also found high levels of nitrate only in the runoff from previously dry, warm beef feedlots.

OTHER PARAMETERS

The lush growth of vegetation in the ponds with higher levels of nutrients often results in poor water quality. Photosynthesis by vegetation during daylight hours and respiration during the night often results in a wide diurnal fluctuation in the dissolved oxygen content. The oxygen level near the surface may become supersaturated while the bottom remains anaerobic.

Ruttner (1963) reported that minimum level of oxygen usually occurs in the early morning, while the maximum oxygen content normally occurs in late afternoon. Table 2 lists the maximum and minimum oxygen levels in the ponds during this study. Samples were taken in late morning and early afternoon. Consequently, values of dissolved oxygen levels in the ponds were probably more extreme than is listed in Table 2. The range of the D.O. levels indirectly shows differences of nutrient levels for different types of pond systems. The ponds having livestock on the watershed had an average range of 13 mg/l while the cultivated watershed and grassed watershed had average ranges in D.O. of 9 mg/l and 6 mg/l, respectively. For the pond water from livestock watersheds, the wide range between maximum and minimum oxygen levels was primarily a function of algae growth stemming from an abundance of nutrients.

The maximums and minimums listed in Table 2 occurred almost entirely during the period between June and September. While algae blooms and intense runoff followed by low oxygen levels occurred during other times of the year, the extreme D.O. levels occurred during the months with high water temperatures. As shown in Fig. 6, 7, and 8, the water temperatures were above 25 C. for these months, which would promote algae growth.

If there is ice on a pond for an extended period of time, low oxygen levels can occur during winter. The only month when sampling was conducted through the ice was in January. Consequently, there was no extended period

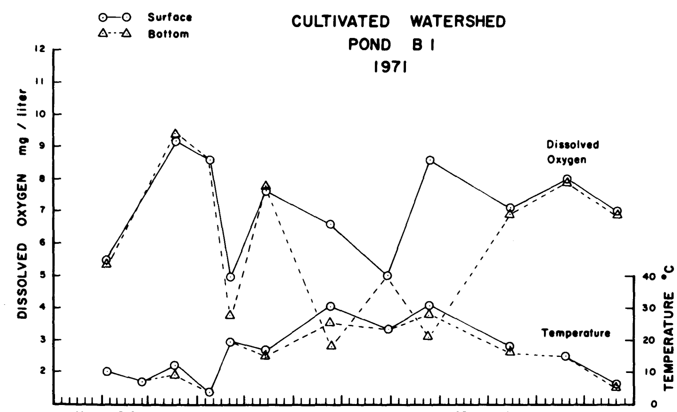

FIG. 7 Temperature and dissolved oxygen concentrations measured in a typical pond having a cultivated watershed.

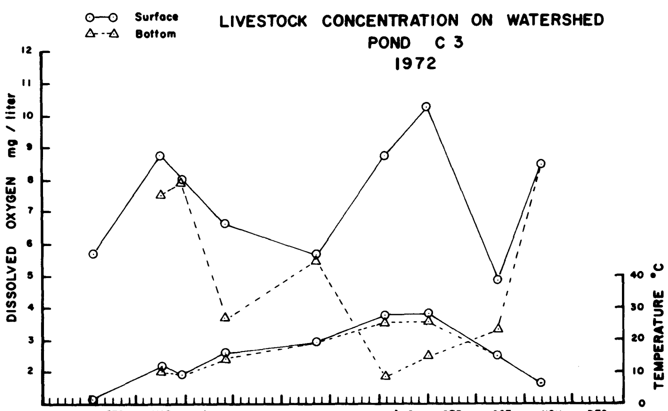

FIG. 8 Temperature and dissolved oxygen concentrations measured in a typical pond having a livestock concentration on the watershed.

of ice cover to determine this effect. Weather records for southern Illinois show that it is unusual for average temperatures during any month to be below 0 C. Thus, low oxygen levels in these farm ponds may be expected to occur primarily during the summer, and the effect of ice cover on oxygen levels will be very small.

Only the ponds with grassed watersheds met a water quality standard of less than 7 mg/l B.O.D. at any time. Two of the livestock watersheds exceeded 20 mg/l on occasion. One of the ponds with a cultivated watershed had a B.O.D. level of 18 mg/l after runoff carried recently spread manure into the pond. Average B.O.D. levels observed in ponds for grassed watersheds was 0.77 mg/l and cultivated watersheds averaged 4.85 mg/l. Because of the large variability of the B.O.D. in ponds having livestock on the watershed and the short period of record, averages for such ponds are inconclusive.

Data from the phosphorus measurements were somewhat more erratic than the other data. Some of the maximum levels of phosphorus in the pond waters occurred after a runoff event, especially in the watersheds having more nutrients. The average level of soluble ortho-phosphate in the water samples from ponds having grassed watersheds was 0.18 mg/l. The maximum level observed for grassed watersheds was 1.35 mg/l. Pond water samples from cultivated watersheds had an average level of 1.71 mg/l of soluble ortho-phosphate with a maximum of 10.2 mg/l. However, this maximum level occurred on a cultivated watershed which had received some manure.

The phosphate levels in the pond water from livestock watersheds appear to be largely influenced by the runoff. A maximum of 36.0 mg/l occurred in pond C1 after a 45-mm rainfall. Another peak of 26.2 mg/l was also observed after a rainfall event. The average level of phosphate for ponds having livestock watersheds was 5.82 mg/l, which was 32 times the average level occurring in grassed watersheds.

Pond water in Washington County, being mainly surface water, was relatively soft. The hardness, expressed as $CaCO_3$, averaged 37 mg/l for grassed watersheds, 58.8 mg/l for cultivated watersheds, and 80 mg/l for livestock watersheds. Soft water is normally defined as less than 70 mg/l according to Sawyer and McCarty (1967).

These ponds, although grouped into watershed types, were found to have individual characteristics which made each perform quite differently from others of the same classification. For example, while cultivated watershed ponds were generally less polluted than ponds with livestock watersheds, B4 was more polluted than C3 as evidenced by the extent of aquatic life. The owner of C3 has a successful fish business while there are no fish in B4. These individual characteristics make averages between ponds inconclusive in some cases. Trends may be readily observed, but a quantitative measurement is very hard to define.

CONCLUSIONS

Watershed types greatly influence the amount of nitrate nitrogen occurring in farm pond water. Grassed and cultivated watershed pond water reached a maximum nitrate nitrogen level of 2.84 mg/l. Ponds having livestock on the watershed exceeded the public health standard of 10 mg/l nitrate nitrogen with one pond reaching a maximum level of 22.0 mg/l on one occasion. Ponds having few nutrients applied in the form of animal wastes on the watershed reached maximum levels of nitrate during early spring. Ponds with dense livestock concentrations on the watershed reached maximum levels in late fall after intense runoff events.

Pond water for human consumption would need some type of treatment for bacteria. Pond water is at present the most reliable source for drinking water for animals in Washington County. Farm ponds having grassed or cultivated watersheds could provide water of acceptable quality to replace existing high-nitrate wells or low-yielding wells.

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