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THREE YEARS OF EVALUATING A MIDWEST ANAEROBIC DAIRY LAGOON

1. INTRODUCTION

Anaerobic lagoons are an important component of many animal waste management systems in Missouri because they provide long term storage and partial treatment of livestock wastes at a reasonable cost. Current lagoon design recommendations are based on the biological oxygen demand (BOD) or volatile solids entering the lagoon per day per unit lagoon volume [1]. Some adjustment of this lagoon design volume is made to account for different climatic conditions (primarily temperature) in different geographic areas and to account for the kind of animal waste. Although properly designed and managed anaerobic lagoons generally perform satisfactorily in Missouri, little is known of their physical, chemical, and biochemical parameters.

The objective of this research was to monitor the performance of an anaerobic lagoon to determine the suitability of current design recommendations and to establish certain parameters that are characteristic of properly operating lagoons.

2. EQUIPMENT AND PROCEDURES

An anaerobic lagoon at the University of Missouri Columbia (UMC) Foremost Dairy Farm was monitored in this study. The lagoon receives animal waste from the milking parlor, holding pen, and feeding-loafing areas. Wastes from the milking parlor and holding pen are flushed into the lagoon, and wastes from the feeding-loafing areas are moved to the lagoon by a combination scraping-flushing operation (fig. 1). At fullpool level, the lagoon has a liquid volume of about 24,670 m^3 (20 acrefeet) and a liquid surface area of about 8093 m^2 (2 acres). The design and as-built dimensions of the lagoon are shown in fig. 2. The design was based on 275 mature dairy cows, and an 8000 m^2 runoff area, and six pumpdowns — the wettest year in 10 years.

Two sampling locations were established in the lagoon (fig. 1). The sampling apparatus consisted of two 25-mm-diameter black polyethylene hoses, of which one was attached to pressure preservative-treated poles in the lagoon and the end of the other one to a manifold on the bank of the lagoon. The

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hoses were arranged so that they would draw a sample of lagoon liquid at eight predetermined depths (fig. 3). The highest sampling port was usually above the surface of the lagoon liquid. The only time it was in the liquid was when the lagoon was at pumpdown volume. The sampling procedure consisted of closing the valves on all the hoses except the one representing the depth at which the sample was to be drawn. Then as a vacuum was applied to the manifold, liquid from the lagoon was drawn through the hose whose valve was open. After sufficient liquid was drawn through the hose to insure that the hose was adequately flushed, a sample was collected. This procedure was repeated for each depth and both locations in the agoon.

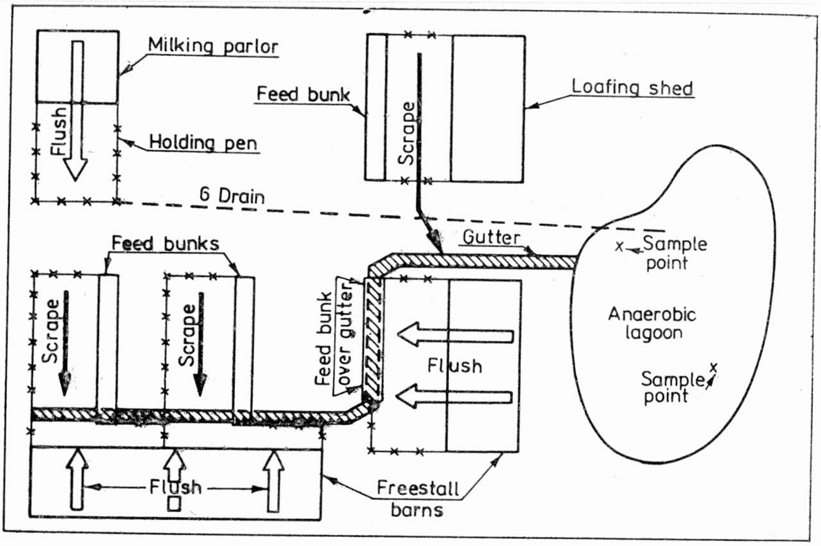

Fig. 1. Layout of lagoon and buildings at the University of Missouri-Columbia Foremost Dairy Farm

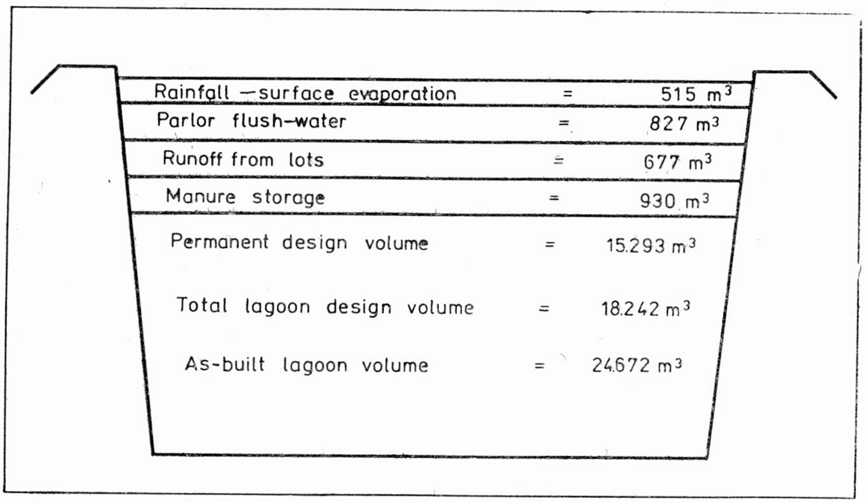

Fig. 2. Design specification for University of Missouri-Columbia Foremost Dairy Lagoon

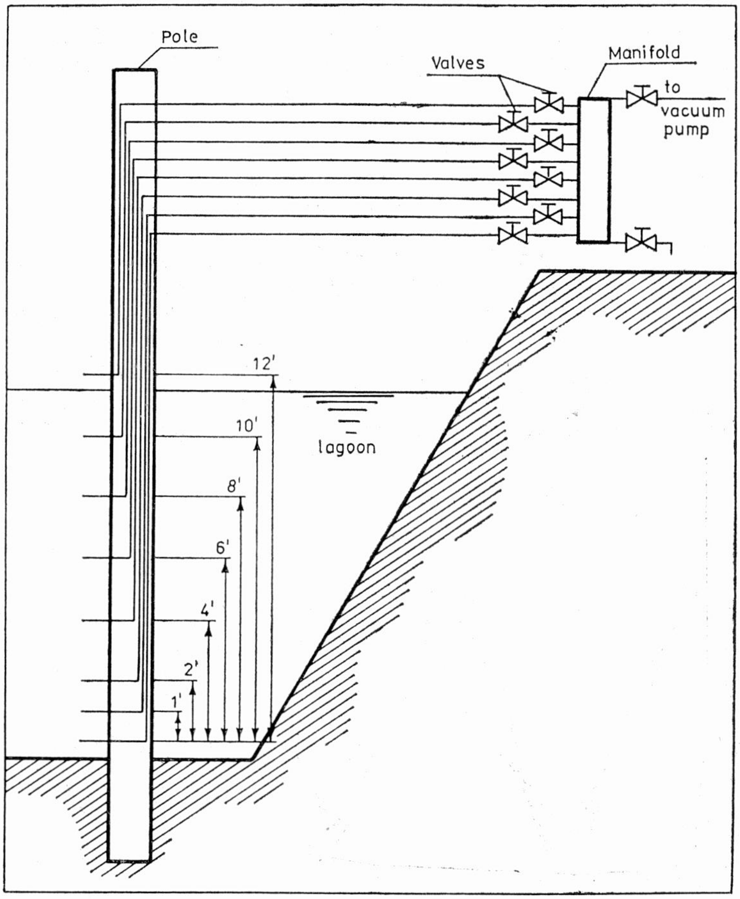

Fig. 3. Lagoon sampling apparatus

Thermocouples were attached to each sampling post to determine the temperature at which the sample was drawn. Thermocouple input was processed and tabulated as temperature by recording potentiometers.

At the beginning of the study, an attempt was made to sample the waste input to the lagoon. A flume at the discharge end of the flush gutter was used to measure the flow of waste into the lagoon, and a rotating-arm "grab" sampler was constructed so as to automatically collect a sample of the waste at the flume discharge. Extreme difficulty was experienced in the attempt to sample waste input to the lagoon. Various foreign objects such as cattle whips, pieces of two-by-four, dead rats, and plastic syringes, as well as occasional frozen chunks of manure and bunches of straw, tended to arrive at the sampling point with considerable momentum. The result was often a plugged and ineffective flume and a damaged rotating-arm sampler. After several destruction–reconstruction operations on the sampling apparatus, measurement of waste input to the lagoon was terminated.

Liquid samples were collected on a nominal once-per-month basis. Temperature data were recorded during three 2-hour intervals each day. These intervals were 12:00 p.m. to 2:00 a.m., 8:00 a.m. to 10:00 a.m., and 4:00 p.m. to 6:00 p.m. The readings were then averaged over a 30-day period to obtain monthly averages.

Sampling was begun in July 1974, and terminated in July 1977. Since waste input to the lagoon could not be measured, it was assumed that about two-thirds of the waste production from 100 cows constituted the manure load on the lagoon. The lagoon had been working under partial load until the flush systems became operable in 1976.

Liquid samples were analyzed for total solids (TS), volatile solids (VS), total Kjeldahl nitrogen, ammonia nitrogen, pH, electrical conductivity, and alkalinity.

3. RESULTS AND DISCUSSION

The results of the laboratory analysis and temperature data are presented in figs. 4–10.

Solids values (figs. 5 and 6) varied little with depth, indicating that solids distribution within the liquid portion of the lagoon was uniform. The increase in solids in June 1976 was caused by initiation of a flushing system operation. The ratio of VS to TS in the lagoon vs. time is shown in fig. 11. The VS/TS ratio was variable and indicates no particular seasonal relationship. The VS/TS ratio of about 0.4 was typical for the major portion of the testing period; however, it increased slightly during the last 6 months of testing. This increase could be due to the increased loading when the flushing system was in full operation.

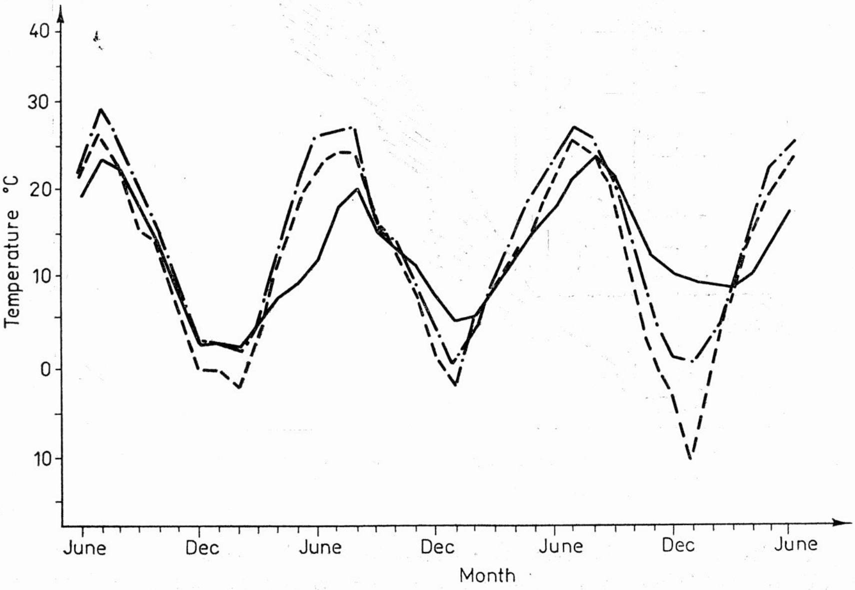

Fig. 4. Temperature of lagoon and ambient air versus time
— — ambient temp., —— bottom temp., —.— top temp.

An estimate of the reduction of volatile solids in the lagoon was made by assuming that the input waste exhibited a VS/TS ratio of 0.8.

With no loss of ash in the lagoon, the following relationship holds true

$$R = \frac{VS_l}{VS + 0.2},$$

where

R — ratio of VS to TS in lagoon,

VS_l — fraction of raw manure volatile solids in lagoon at sampling time.

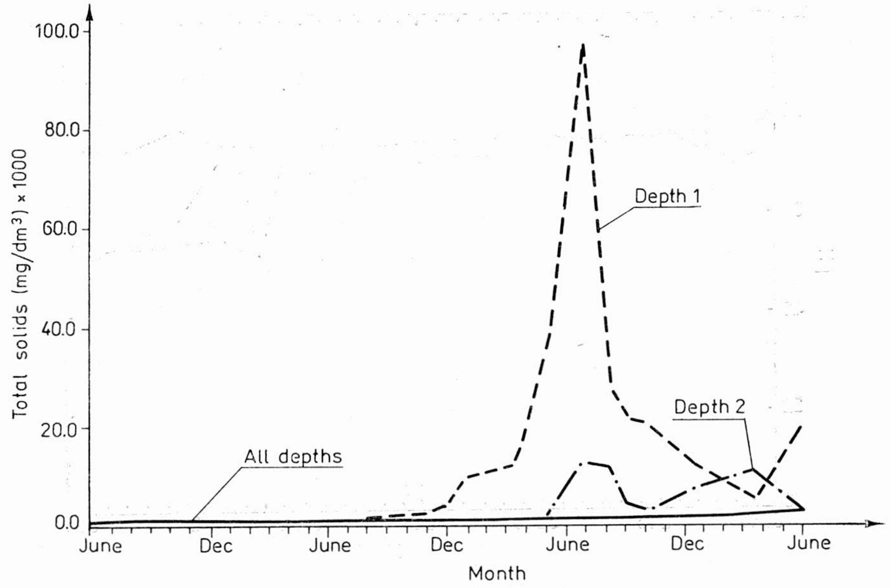

Fig. 5. Total solids concentrations in the lagoon versus time

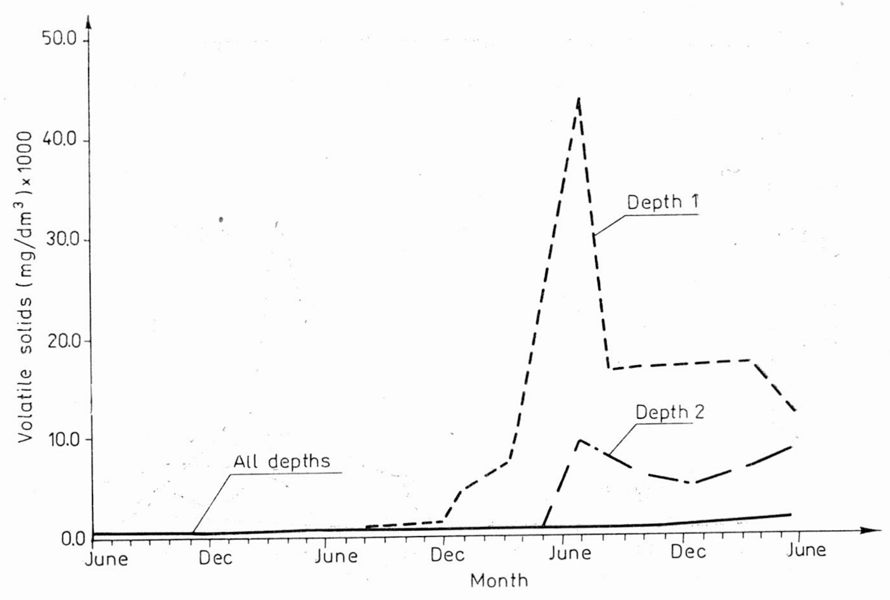

Fig. 6. Volatile solids concentration in the lagoon versus time

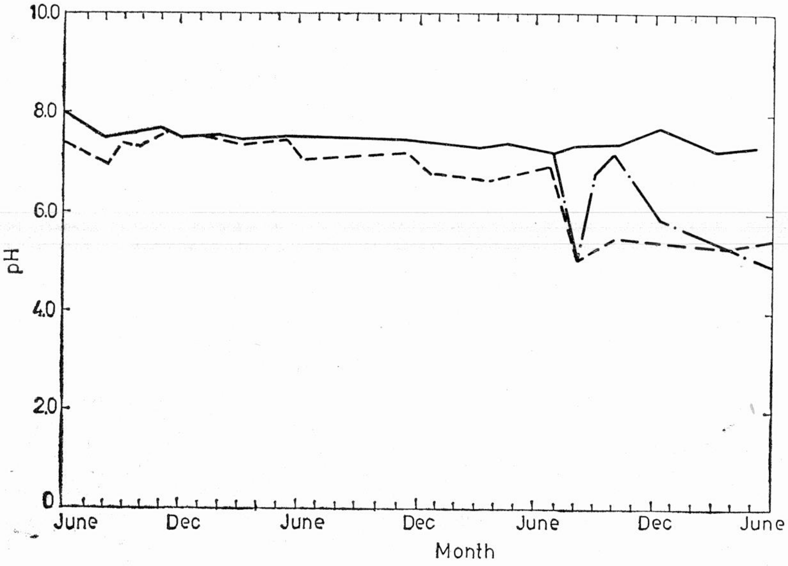

Fig. 7. pH of lagoon versus time

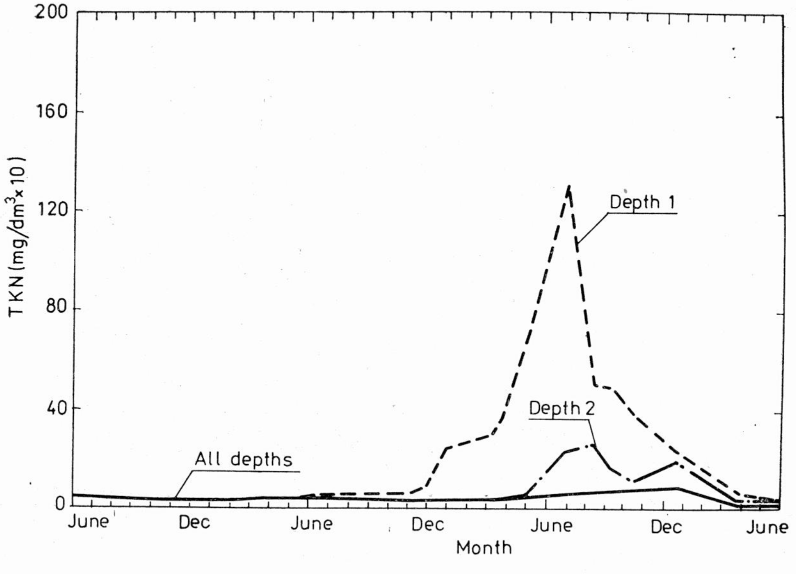

Fig. 8. Total Kjeldahl nitrogen (TKN) concentration in the lagoon versus time

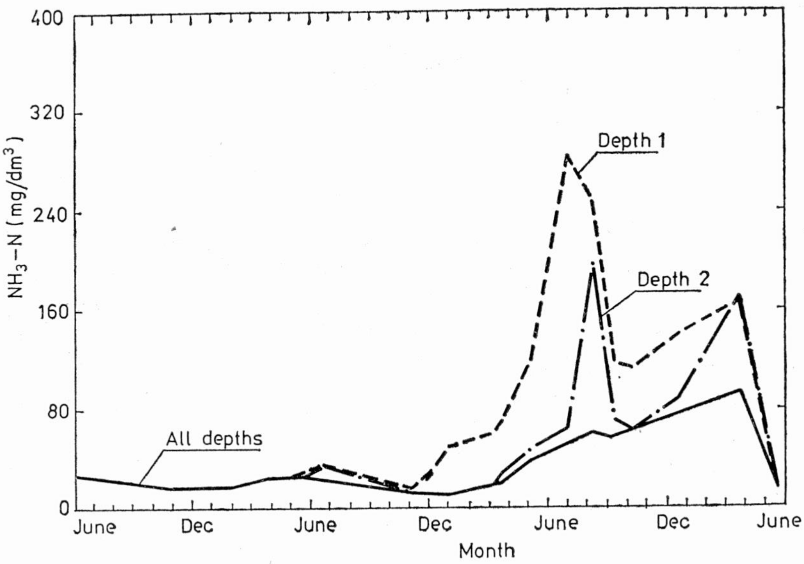

Fig. 9. Ammonia concentration (NH_3-N) in lagoon versus time

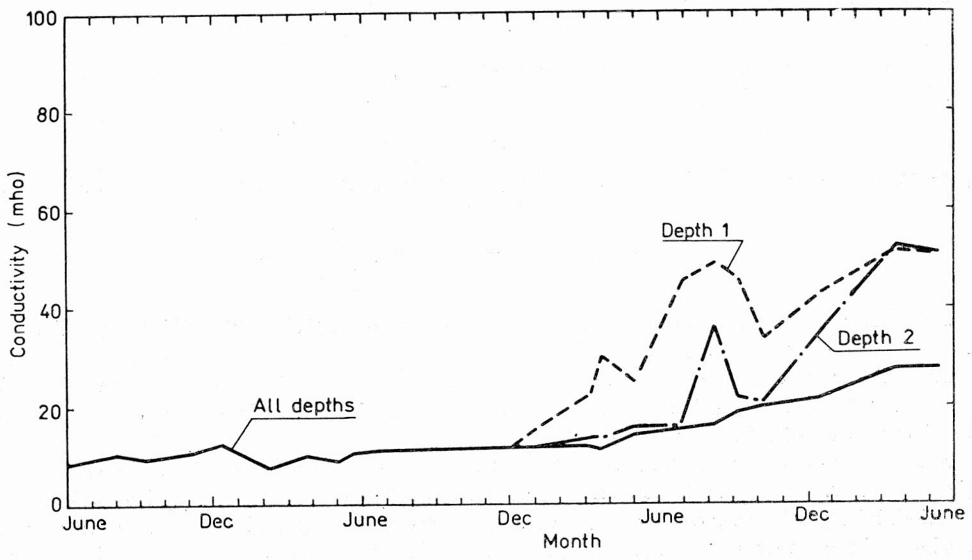

Fig. 10. Conductivity of the lagoon versus time

Solving for VS_l, we have

$$VS_l = \frac{(0.2)R}{1-R}.$$

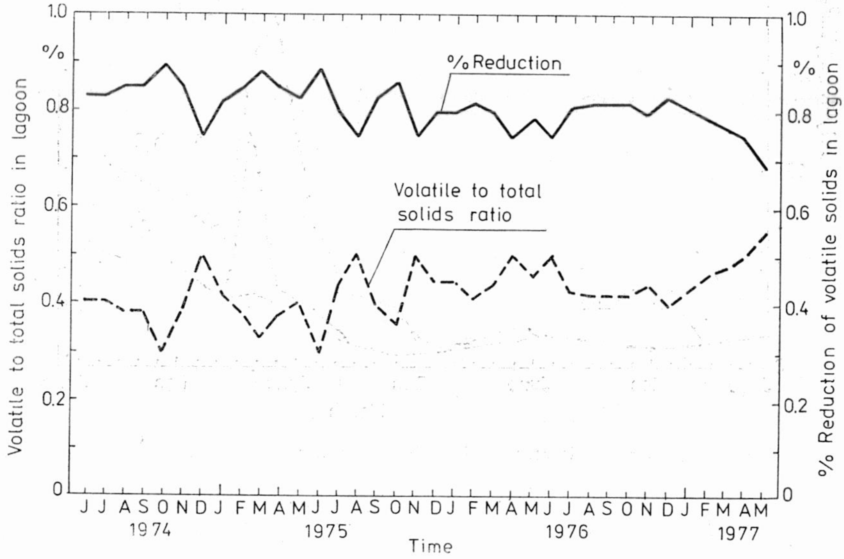

Fig. 11. Ratio of volatile solids to total solids and the percentage reduction of volatile solids in the lagoon

The ratio of volatile solids in the lagoon to the volatile solids in the raw manure is

$$\frac{VS_l}{VS_{rm}} = \frac{\frac{(0.2)R}{1-R}}{0.8},$$

where

VS_{rm} — raw manure in volatile solids, and the percentage of reduction in volatile solids is

$$\text{percentage reduction} = 100\left(1 - \frac{0.2R}{(1-R)/0.8}\right).$$

The percentage of reduction in volatile solids is also shown in fig. 11. Volatile solids reductions of 80% were typical throughout the sampling period.

Temperature data are shown in fig. 4. (Temperature typically exhibited a differential of 6 °C or less from top to bottom, except during the spring and early summer months of 1975 when temperature differentials of as much as 14 °C were recorded.)

Nitrogen data are shown in figs. 8 and 9. The ratio of ammonia nitrogen to total Kjeldahl nitrogen is given in fig. 12. Ammonia nitrogen accounted for about 50% to 80% of the total nitrogen during the test period. Nitrogen losses through ammonia desorption have been reported to be as high as two-thirds of the input nitrogen to anaerobic lagoons [2]. Total ammonia nitrogen is the sum of nitrogen in the ammonium (NH_4^+) form and nitrogen in the ammonia (NH_3) form. These two forms of nitrogen exist in equili-

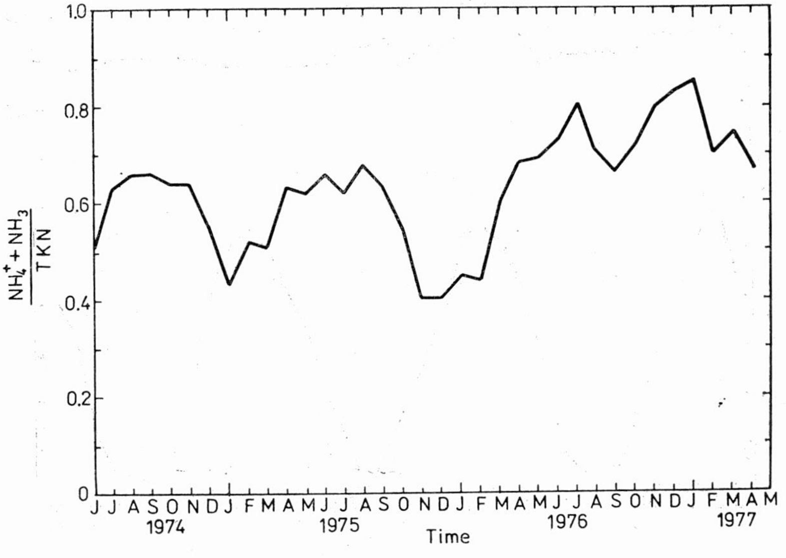

Fig. 12. The ratio of ammonia (NH_3) plus ammonium nitrogen (NH_4^+) to total Kjeldahl nitrogen (TKN) versus time

brium, and the relative amounts of each form are governed by temperature and pH (fig. 13). Average lagoon temperature at the surface temperatures in the summer was generally 20 °C or greater, and pH levels ranged from 7.4 to 7.8 throughout the test period (fig. 14). Based on the information in figs. 13 and 14, it is conl cluded that, in the summer months, nitrogen in the ammonia form will comprise 2% to 4% of the tota-ammonia nitrogen. KOELLIKER and MINER [2] demonstrated that as much as 65% of the nitrogen introduced into an anaerobic lagoon may be lost through ammonia desorption under these conditions. This loss ot nitrogen allows the land area required for disposal to be significantly reduced when lagoons are a componenf of the waste management system.

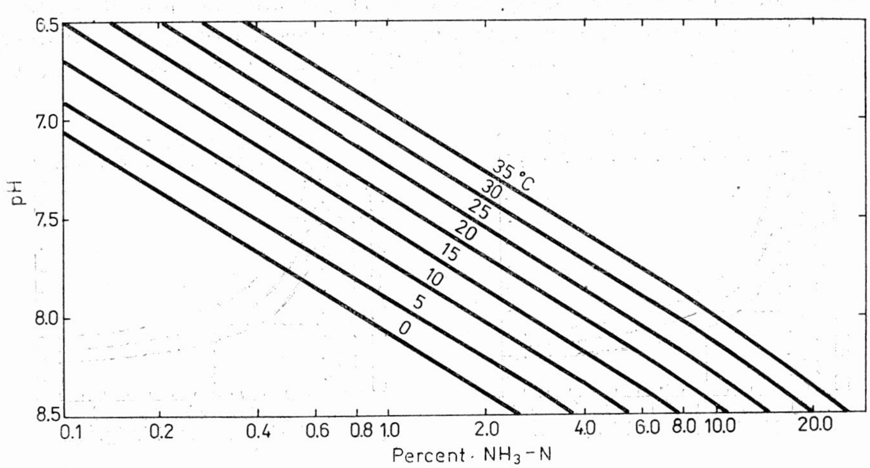

Fig. 13. Percentage of total ammonia nitrogen in solution that is in ammonia form at equilibrium at various expected conditions in an anaerobic manure lagoon

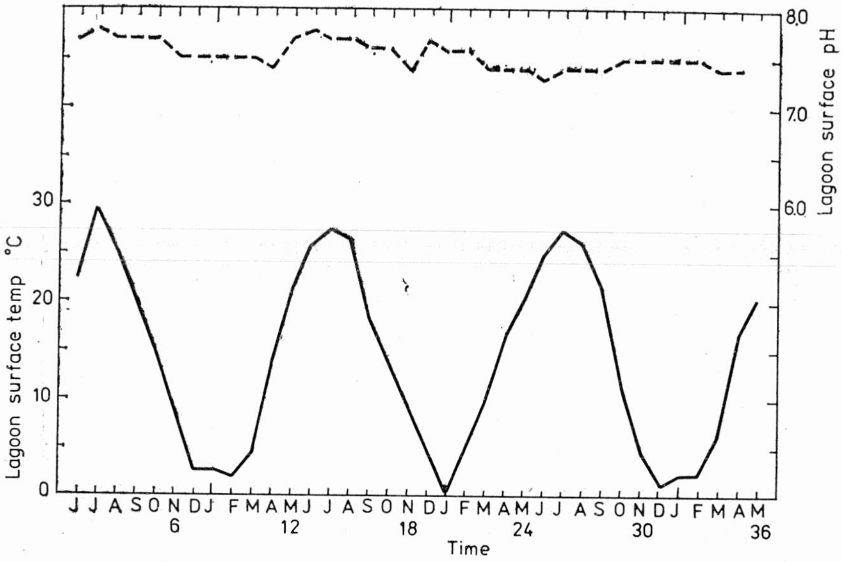

Fig. 14. Surface lagoon temperature and pH versus time

Electrical conductivity data are shown in fig. 10. Conductivity is a measure of salts (dissolved solids) in the lagoon, and these salts are a limiting factor for the land application of lagoon water [3]. High salt levels can cause soil aggregates to disperse and become impermeable to infiltration. Hence, if nitrogen or another plant nutrient does not limit the application of lagoon water to land, the soil texture and electrical conductivity should be evaluated together to determine the potential salt hazard. The maximum annual application of lagoon water to soils with low and medium salinity hazards is shown in fig. 15. Salt levels in the test lagoon were low (conductivity less than 1700 mho/cm) during the first 24 mo. of the test period due to the presence of dilution water in the lagoon at the beginning of the test period and to a relatively light manure load on the lagoon initially. An increase in conductivity to a level of about 2800 mho/cm was observed in the latter stages of the test period. According to fig. 15, irrigation applications of this lagoon water should be limited to about 3, 5, and 6 in./yr for light-medium- and heavy-textured soils if a low salinity hazard can be tolerated by the cover crop. If a medium salinity hazard can be tolerated, yearly applications of 7 in. or greater could be allowed.

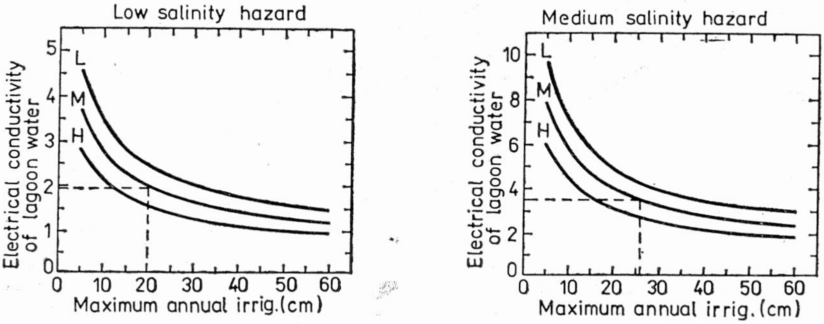

Fig. 15. The maximum amount of undiluted lagoon water that can be added to light-, medium- or heavy-textured soil and maintain a low or medium salinity hazard (KOELLIKER and MINER, 1971)
Soil textures; L – light, M – medium, H – heavy

4. SUMMARY

An anaerobic dairy lagoon was monitored for 3 years at various lagoon depths. The solids content in the lagoon was less than 1000 mg/dm^3 for all depths. Except on one occasion, the depth closest to the bottom of the lagoon increased to 100,000 mg/dm^3 during a period of increased loading. Solids in the lagoon were reduced about 80%. The pH of the lagoon averaged 7.6. The conductivity of the lagoon increased with lagoon age, but little seasonal variation in conductivity was observed.

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