PAST AND CURRENT RESEARCH ON DAIRY WASTE MANAGEMENT

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Introduction

Dairy waste management continues to be a problem for Florida dairies. As the human population increases and as dairy milk production increases to meet the needs of the human population, proper management of wastes from Florida dairies can be expected to become even more important. Over the past twenty years, a great deal of research has been conducted in IFAS to address livestock waste management problems. Some of that research has dealt directly with dairy wastes. There has also been research with other wastes and materials which may be applicable to dairy waste problems in the future. This paper will summarize that research and will assess the current needs for research on dairy waste management in Florida.

Background

In the late 1960's, environmental quality became an issue across the United States. It marked the beginning of many of our environmental agencies at federal, state and county levels of government.

In Florida, dairies were the first livestock operations to come under the scrutiny of these new environmental agencies. The primary reason is easily understood. Because dairies were using large volumes of water, their effluents often left the property and became much more visible to the surrounding community.

The response to these problems was at first to use conventional sewage treatment technologies. There were numerous undocumented stories about those efforts. Most of them failed, and a large amount of money was undoubtedly wasted. It was obvious that the management of dairy farm wastes was very different from the management of municipal sewage and industrial wastewaters.

PAST RESEARCH

Spray Irrigation with Dairy Wastewater

The first research project in Florida on dairy waste management was conducted at the Dairy Research Unit (DRU) near Hague, Florida, using a spray irrigation system. The project was begun in 1969, and it was a cooperative effort between the Agricultural Engineering Department, the Dairy Science Department, the Soil Science Department, the Agronomy Department, and the Department of Microbiology.

The DRU at that time used a sprinkler cow wash system in a new milking parlor. This produced large volumes of wastewater which could readily run off of the property if not retained. The wastewater from the milking parlor and cow wash area was collected in a grated gutter. The wastewater flowed from the gutter into a sand trap and then into a 20,000 gallon underground, concrete storage tank. At the time, there was sufficient volume to store the wastewater from one day's operation. The wastewater was pumped through an underground line and through portable aluminum irrigation pipe to a nearby field with three gun-type sprinklers. Each gun was capable of covering approximately one acre. The results from this project are covered in several publications (Overman et al., 1970; Overman et al., 1971).

A well designed spray irrigation system is an excellent method for management of dairy wastewaters. However, if it is not operated properly, it can be a point source of pollution. Nutrient losses are minimized, and the nutrients can be efficiently utilized in crop production. However, it is a system which requires a high level of management. Adequate land area must be available, and the nutrients in the wastewater must be used in a well-planned nutrient management plan. This plan should include crop rotations and supplemental fertilization so that all of the nutrients are utilized to their full potential. Maintenance of equipment is also essential, since breakdown can result in a point source of pollution.

Anaerobic Lagoon Systems

Because the spray irrigation system required such a high level of management, interest had developed in lagoon systems for handling the large volumes of wastewater which were being generated by Florida dairy farms. Soon after the above research on spray irrigation systems for wastewater was underway, another project was initiated on anaerobic lagoon systems for handling of dairy farm wastewaters.

At that time, no design criteria existed for lagoons in Florida. Although lagoons had been used in other states, they had met with limited success. The cycle of freezing in the winter and thawing in the spring often resulted in some odor problems. In Florida's climate, it was known that higher loading rates could be used and that the lagoons would probably function throughout the year. Also, lagoons in northern climates often served a major storage function, since less water was used for flushing. The design criteria for lagoons in Florida would have to consider the large volumes of water which were used for flushing.

A careful analysis of information which was available in the literature on lagoons for both livestock wastes and for municipal sewage was conducted. Personnel from the Agricultural Engineering Department and the Soil Conservation Service developed a set of design guidelines for the construction of anaerobic lagoon systems in Florida. Those guidelines remain essentially unchanged today. The design guidelines include both a maximum organic loading rate and a minimum hydraulic retention time (Baldwin and Nordstedt, 1971).

A research project was initiated on a commercial dairy near Bradenton, Florida, which involved the construction of the first designed anaerobic lagoon system for dairy wastes in Florida. It was a cooperative effort of the Agricultural Engineering Department, the Soil Science Department, and the Bacteriology Department at the University of Florida, the Environmental Engineering Division of the Manatee County Health Department, the Soil Conservation Service, and the Florida Cooperative Extension Service. Experimental facilities were provided by John M. Hood, owner of Hood's Dairy, Inc.

The anaerobic lagoon system which was constructed was a three-stage system -- an anaerobic lagoon and two aerobic lagoons in series. Effluent from the third lagoon was discharged into a seepage irrigiation system in a pasture. The system was designed to handle 20 percent of the daily manure production of 800 cows which represented the portion of the day that the cows are on the paved areas from which manure, wash water and rainfall runoff would enter the system. Although most recommendations in the literature called for length to width ratios for the lagoons of no greater than 3:1, the lagoons were constructed with a width of 50 feet and lengths of 640, 700, and 850 feet for the anaerobic and two aerobic lagoons, respectively. The narrow width was chosen because of the common use of the dragline for excavation in Florida, particularly in high water table areas.

Results from this project indicated that the design criteria which had been developed were successful (Nordstedt et al, 1971). The narrow widths of the lagoons and the high length to width ratios worked very well. Nutrient losses in the wastewater passing through the system were quite high. As anticipated, the nutrient content of the effluents was too high to allow for discharge to surface waters. However, the system was designed to be a handling system for the wastewater and not to be a treatment system. It was found that the second lagoon in the series was not predominantly anaerobic or aerobic, but its function in a two stage lagoon system would be for storage of effluent until intermittent dispersal on pasture or cropland.

The choice of a three-stage lagoon system was at the insistence of the regulatory agencies. In fact, it was found that the third lagoon in the series exhibited extensive algal blooms, and the quality of the effluent from the second lagoon was in fact better than the quality of the effluent from the third lagoon.

As a result of this project, the design criteria which had been developed were put into widespread use (Nordstedt and Baldwin, 1973). Most systems since then have been designed as two-stage systems, i.e., an anaerobic lagoon followed by a storage pond. The use of seepage irrigation systems for dispersal of the effluent was employed in many cases, but management of the seepage systems was found to be a problem. If the effluent was permitted to flow continuously into the field, good dispersal was not obtained. This resulted in wet areas at the upper end of the system which caused maintenance problems in the ditches.

It was known at the beginning of the study that sludge would accumulate in the anaerobic lagoons. Thus, sludge accumulation rate and characteristics were monitored in the anaerobic lagoon for a period of fifty-six months. The results showed that there were two distinct layers of sludge, and at the loading rate and retention time in existence that the lagoon would need to have sludge removed every five years (Nordstedt and Baldwin, 1975a). An analysis of sludge management alternatives was also prepared (Nordstedt and Baldwin, 1975b). As more lagoons required sludge removal, an analysis showed that the value of the nutrients in the sludge was significant (Baldwin and Nordstedt, 1983).

A laboratory study was conducted in conjunction with the field study on anaerobic lagoon systems to investigate the physical and biological sealing mechanisms of anaerobic dairy wastewater ponded over a highly permeable Florida fine sand. The effects of hydraulic head, manure loading rate and inhibited microbial activity were studied. The columns receiving manure experienced a rapid reduction of flow rate. The flow rate was rapidly reduced to 0.12 percent of the original flow rate in the columns receiving the high loading rate of 0.007 lb VS/ft^3-day. However, after 113 days of manure loading, the flow rate returned to approximately 30 percent of the original flow rate in one of the two columns receiving the high loading rate.

Methane Collection from Anaerobic Lagoons

When prices of fossil fuels began to increase in the 1970's, the level of interest in generating methane from livestock wastes began to increase. Since an anaerobic lagoon is really an anaerobic digester with a very low loading rate, the feasibility of collecting methane from anaerobic lagoons was investigated. Based upon the work of Mahan (1972) which evaluated volatile acid levels and gas production in an anaerobic lagoon, several pilot-scale floating collectors were placed in lagoons. Mahan found that the rates of gas production were the highest in a lagoon near the inlet. The collectors could be placed where the gas production rates were the highest. The gas production rates were high enough that with certain costs of collector construction and energy prices, it would be economically feasible to collect methane from anaerobic lagoons (Nordstedt et al., 1976).

Anaerobic Digestion

The use of conventional anaerobic digesters, or stirred tank reactors, requires a higher level of total solids in the waste than in the wastewaters which are generated on most Florida dairies. However, dairies which do not use large quantities of flush water often use storage tanks for long-term storage of the wastes for application to cropland. Research in the Agricultural Engineering Department resulted in a new technique for anaerobic digestion which could utilize existing storage structures and thus lower capital costs for creating an anaerobic digestion system (Hill et al., 1981). The digester was called a continuously expanding reactor (CER). It was operated in a semi-batch mode so that the effluent would periodically be available for spreading on cropland. It was found to produce almost as much methane at ambient temperatures as at 95 ^{o}F. It was also very stable and not subject to disruption from shock loadings.

A type of reactor which may be applicable for methane generation from the dilute wastewaters which are generated on Florida dairies is the fixed film reactor. Although dairy wastewaters have not been utilized as feedstock, a great deal of research has been conducted in

IFAS on this type of reactor. The results will be useful whenever the need arises to anaerobically digest those wastewaters.

Flushing Devices

Although the drop gate flush tank was being used extensively on Florida dairies, there was a need for other types of flushing devices. Several demonstrations were conducted using small tilt tanks for flushing narrow alleys. Large tilt tanks were also used to flush wide alleys (Baldwin and Nordstedt, 1985). Several single and multiple siphon-type flush tanks were also developed (Baldwin and Nordstedt, 1977).

Effluent Quality and Irrigation

In addition to the land application of sludge from anaerobic lagoons for utilization of its nutrients, increasing interest was shown in irrigation of the effluents from anaerobic lagoon systems. Not only was it desirable from the standpoint of forage production, it was a way to utilize the effluents without causing environmental problems. The collection and analysis of effluents from several dairies resulted in recommendations for utilization of the effluents (Baldwin and Nordstedt, 1982).

CURRENT RESEARCH

Results of other research on environmental problems related to dairy wastes are elsewhere in these proceedings. Current research on waste handling includes two projects -- one on evaluation of a runoff control system in Okeechobee County, and another on production and characteristics of dairy waste.

Runoff Control Systems

A project is underway as part of the Lower Kissimmee River Project in the Rural Clean Water Program (RCWP). One of the best management practices (BMP) which are being implemented as part of the effort to reduce nutrient loadings into Lake Okeechobee is the installation of runoff control systems. This project involves wastewater flow and nutrient tracking through one of these systems.

The system was designed by the Soil Conservation Service using the best available information. However, since this type of system has never been installed on a Florida livestock operation, it is necessary to evaluate how well it functions. With this information in hand, it will be possible to devise improvements in future systems and to provide the data which is essential to proper management of the system.

In the system which is being evaluated, the wastewater from the milking parlor is collected in an anaerobic lagoon. A perimeter ditch around the holding pastures collects runoff which is then pumped into the anaerobic lagoon. The effluent from the anaerobic lagoon is pumped into a secondary lagoon, and then into a large impoundment used for storage of effluent. Irrigation water from the impoundment is pumped to two pivot irrigation systems. One pivot system is fixed, and the other system is towable between two sites.

A critical part of this system is the performance of the forage program in removing nutrients. Hence, a number of plot studies are being conducted under the permanent pivot irrigation system to evaluate forage varieties, yields, soil fertility, phosphorus uptake, and additional fertilizer requirements.

Samples of effluent are being collected regularly at several points throughout the system, including the pump stations, underneath the pivot irrigation systems, and the tile underdrains. Periodic plant tissue and soil analyses are also being conducted.

Dairy Waste Characteristics

A study in the Dairy Science Department on phosphorus levels in dairy rations has yielded an additional benefit. That benefit is some excellent information on dairy waste characteristics. Engineers and planners have been dependent for a long time on several data tables on livestock waste production and characteristics. Although this data has been suspect for some time, good information was not available to refute it.

Information from the current studies on P levels in rations is being evaluated with respect to waste production and characteristics. Preliminary results indicate that several changes may be justified. Total manure production per 454 kg cow was approximately 20 percent greater than published values (ASAE, 1983). This increase can be attributed to increased feed intake accompanying the increased milk production of dairy cows. An estimation of dry matter excreted per unit dry matter consumed may be a more useful tool than basing manure production on animal liveweight.

SUMMARY

A great deal of research has been conducted in the past twenty years on dairy waste management. As requirements change, more research will be needed. However, implementation of existing information and proper management practices are needed just as much as additional information from research.

Additional research needs at the present time include the following:

(1) More information on runoff quantity and quality. In terms of the perimeter ditches around confinement areas, surface flow and subsurface flow should be quantified.

(2) Evaluation of solids separation devices as part of recycled water systems and for nutrient removal.

(3) Development of nutrient management plans which will quantify nutrient movement through the systems, application rates, nutrient uptake, forage quality, supplemental irrigation requirements, supplemental fertilizer requirements.

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