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Swine Lagoon Effluent on a Soil-Plant Environment: An Impact Assessment

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TABLE OF CONTENTS

Abstract 1

Acknowledgments 2

Introduction 3

Objectives 4

Facilities Development and Experimental Procedure 5

Results 7

- I. Biological Treatment Units 7
- II. Disposal Plots 10

Conclusions and Summary 13

References. 15

Tables 17

Figures 37

LIST OF TABLES

1. Mean Concentration of Fecal Coliform in Waste Influent 18
2. Mean Concentration of TS and TVS in Waste Influent 18
3. Mean Concentration of (NO_3^- + NO_2^-) and NH_4^+ in Waste Influent. 19
4. Mean Concentration of Total N and P in Waste Influent 19
5. Mean Concentration of Na and Mg in Waste Influent 20

6. Mean Concentration of Cu and Zn in Waste Influent. 20

7. Mean Concentration of Ca and K in Waste Influent. 21

8. Mean Concentration of Mn and Cl in Waste Influent. 21

9. Mean Concentration of COD and pH of Waste Influent. 22

10. Estimated Lagoon Loading Rates 22

11. Mean Concentrations of Fecal Coliform and P in Effluent 23

12. Mean TS and TVS in Effluent 24

13. Mean Concentrations of (NO_3^- + NO_2^-) and NH_4^+ in Effluent 24

14. Mean Total Nitrogen in Effluent. 25

15. Mean Concentrations of Na and Mg in Effluent. 25

16. Mean Concentrations of Mn and Cu in Effluent 26

17. Mean Concentrations of Zn and Cl in Effluent 26

18. Mean Concentrations of K and Ca in Effluent. 27

19. Mean pH and COD of Effluent 27

20. Nutrients in Lagoon Effluent 28

21. Mean Soil Exchangeable N (as NO_3^- + NO_2^-) in Effluent Disposal Plots 28

22. Mean Exchangeable N (as NH_4^+) in Effluent Disposal Plots 29

23. Mean Soil P in Effluent Disposal Plots. 29

24. Mean Soil K in Effluent Disposal Plots 30

25. Mean Soil Na in Effluent Disposal Plots 30

26. Mean Soil Cu in Effluent Disposal Plots 31

27. Mean Soil Zn in Effluent Disposal Plots 31

28. Mean Soil Ca in Effluent Disposal Plots. 32

29. Mean Soil Mg in Effluent Disposal Plots 32

30. Mean Soil Mn in Effluent Disposal Plots 33

31. Mean Values of Soil Water Nutrients From Effluent Disposal Plots 34

32. Mean Total N, P, K, and Ca Content in Fescue From Plots Receiving Effluent. 35

33. Mean Na, Mg, Cu, and Zn Content in Fescue From Plots Receiving Effluent. 36

34. Mean Mn and Dry Matter Content in Fescue From Plots Receiving Effluent. 36

LIST OF FIGURES

1. Physical Layout of Animal-Soil-Plant Recycling System 38

ABSTRACT

This investigation studied the performance of two biological treatment units for a swine production unit. One unit was maintained as an anaerobic system, the other as a mixed aerated unit by means of a floating mechanical aerator. Wastes were flushed into each unit by recirculation of effluent. Analysis of the supernatant of both systems showed that, with time, accumulations of heavy metals and other elements increased.

Effluent from both treatment systems was irrigated on fescue plots, and effects on soil, soil water, and plant tissue then were determined. While no visible deleterious effects were noted over a period of one and one half years, both plant tissue and soils recorded accumulation or high uptake of Na, Cu, and Zn; over extended periods, these effects could be serious if not controlled. Nitrate leaching from plots was minimal. Other waste constituents measured did not appear to be limiting in land disposal of swine lagoon effluent.

Key Words: swine waste treatment, land disposal, swine waste irrigation.

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INTRODUCTION

Most industrial and municipal waste treatment systems are designed to provide sufficient treatment for discharge of effluent into receiving waters. The volume and high concentrations of wastes from swine confinement units would require treatment costs and management far beyond the capabilities of most farmers. Muehling [1969] and Loehr [1971] have noted the high strength of animal wastes as compared to municipal wastes, and have observed that it is unlikely that current liquid treatment systems will produce effluents that can be safely discharged into public waters. Loehr [1971] has suggested that such wastes be returned to land, but concluded that more information is needed on land disposal of animal wastes to avoid detrimental effects on the environment. Swine rations include not only feed ingredients of plant and animal origin, but also trace minerals, salts, and pharmaceuticals. Some of these materials are concentrated in manure and are further concentrated in lagoon fluids. There is a possibility of accumulation of certain materials in soils following application of manure wastes. Long-term repeated applications of swine lagoon effluent on agricultural lands may result in decreased productivity or "poisoning" of land application areas.

Numerous studies have been conducted or are in progress to determine effects of land spreading of agricultural waste materials. Koelliker et al. [1971] conducted studies to determine optimum land application rates of anaerobic swine lagoon effluent in Iowa. They concluded that total nitrogen is the constituent that will likely limit land application rates of effluents, and recommended a rate of 600 pounds of nitrogen per season under Iowa conditions.

Robbins et al. [1971] investigated the importance of animal wastes in agricultural land runoff, and concluded that the use of anaerobic lagoons as the sole means of treating animal waste is unsatisfactory in areas where rainfall exceeds evaporation. They suggested that research is needed to develop economical secondary treatment units such as effluent irrigation techniques and soil-plant filter systems.

Nordstedt et al. [1971] studied a three-stage dairy waste lagoon system in Florida. Effluent was disposed of in a seepage ditch irrigation system in 40 acres of permanent pasture. Quality of runoff from the disposal area was not investigated.

Swine lagoon systems were investigated by Humenik et al. [1972]. A nine-year old anaerobic lagoon was monitored for one year to determine treatment performance prior to construction of a second-stage unit. Considerable work was devoted to developing criteria for land application of swine wastes. Indications were that heavy metal feed additives can approach levels in soil-plant systems which are toxic to sheep and other animals. However, lagoons may function as a trap for such constituents prior to land application of effluent [Overcash et al., 1977].

Cummings et al. [1975] reported the effects of swine lagoon effluent applied to Coastal Bermuda grass in North Carolina. Although effluent rates increased soil reserves of several elements, no detrimental effect of effluent application upon plants or soils was noted. However, they observed that more years of application would be needed to evaluate long-term effects, and that optimum loading rate may vary with climate and nature of the wastes.

Much information remains to be developed regarding plant toxicity, uptake, and accumulation of nutrients and other elements from swine wastes. In particular, plant covers for waste disposal areas must be identified for Virginia conditions which will promote good infiltration characteristics and nutrient removal. Leaching characteristics of nutrients through the soil profile and effects of soil structure as a result of repeated applications of lagoon wastewaters must be better understood. Effluent application rates which will minimize runoff must be determined for a variety of field conditions. Secondary pollution effects of precipitation runoff from disposal areas must also be established.

OBJECTIVES

A broad study was initiated to provide some of the preceding information needed by Virginia swine producers and regulatory agencies in making reasonable and sound decisions in the future. Specific objectives of this project were:

1. To develop facilities necessary to support research planned in the following objectives.
2. To compare two systems of biological treatment for swine wastes in Virginia.

3. To monitor wastes from two confinement swine production facilities and effluent from their companion waste treatment systems to determine the degree of biological treatment afforded and fate of mineral feed constituents.

4. To measure effects of application of lagoon effluent from the above systems on the soil-plant environment in the effluent disposal areas.

An auxiliary objective of the project was to provide a demonstration of the principles of good lagoon-land application technology for farmers and other interested persons who visit the Virginia Polytechnic Institute and State University campus for various purposes. Full exploration of all objectives of the project would be productive over a period of many years. This report describes progress and trends established to date.

FACILITIES DEVELOPMENT AND EXPERIMENTAL PROCEDURE

Two separate sealed concrete treatment tanks, 6.7 m in diameter and 3.6 m deep, were constructed at the VPI&SU swine center *(Figure 1).* These units have a drain cross-connection so that they can be operated as a two-stage lagoon system or maintained as separate systems. An existing swine research building was modified slightly and included in the waste management research facility. Each of two underslat pits in this building was remodeled to provide a uniformly sloping floor of two percent grade. Tipping-bucket flush tanks were installed at the upper end of each pit. Drainage from the research building pits can be consolidated and channeled into one treatment tank for two-stage treatment, or divided for direct flow to separate treatment tanks. In this study, pits were connected to separate tanks. One unit was operated as an anaerobic system based on design volumes required by the USDA Soil Conservation Service Virginia Standards (80.2 kg of VS per 1000 m^3). The other unit was equipped with a 3-horsepower floating aerator operated on a percentage timer to provide aeration at a rate equivalent to twice its estimated daily BOD_5. Each treatment tank contained a small submersible pump for recycling effluent from the tank to flush its companion waste collection pit. Pits were flushed five times daily.

A permanent waste irrigation system was installed to distribute treatment tank effluent on 6 m by 6 m (20-ft. by 20-ft.) soil-plant disposal plots.

Area available for disposal was relatively small, permitting space for only two plots for each treatment. Applications of anaerobic lagoon effluent, aerobic lagoon effluent, and a control constituted the experimental treatments. Since the amount of effluent available for disposal was limited, only one rate of effluent application was attempted.

The entire waste treatment-land application system was part of an animal production unit committed to other programs. Therefore, there were limitations on the degree of control which could be exercised over loading and management of both treatment units and associated disposal schemes. Some variations in animal population occurred during the study, but care was taken to always maintain loading rates of both treatment units about equal. The irrigation system was designed to apply effluent at a rate of 0.56 cm (0.22 inches) per hour. However, equipment malfunction caused application of rates as high as 3.91 cm (1.54 inches) per hour on occasion. At no time, though, was the percolation rate of the soil exceeded. Varying rates of effluent accumulation in the anaerobic and aerobic treatment units dictated slight differences in total effluent application for the two systems. Irrigation was applied to plots as required to maintain acceptable level control in treatment units. Forty-six to 91 cm (18 to 36 inches) of effluent was removed from each unit with each irrigation event.

Higher evaporation from the aerated unit left less effluent for irrigation than from the anaerobic unit. During the period reported, a total of 20.75 cm of anaerobic and 17.88 cm of aerobic effluent was applied to plots.

Slope of the disposal area ranged between 0 and 10 percent, with an average slope around 4 percent. Soil was a clay-like material of the Groseclose series, and was well-drained in most areas and moderately-drained over a minor part of the field. Percolation rate ranged between .5 and 5 cm per hour, and tended to decrease as the soil became wet. Drying cycles tended to raise the percolation rate within this range. Plots were seeded with Kentucky 31 Tall Fescue grass, and were arranged so that runoff from both irrigation and precipitation events could be sampled. Each plot also was equipped with porous cup lysimeters at depths of 15, 61, and 122 cm for sampling soil water and its constituents.

Production pens were populated with equivalent live weights of pigs, and wastes were loaded into treatment systems beginning in November, 1974. Samples of waste influent and treatment tank effluent were taken regularly commencing in December, 1974. Waste influent was taken at the inlets to the lagoon, and consisted of wastes collected in each pit between flushings, and the effluent recycled from the treatment unit for flushing. Fecal coliform, pH, COD, minerals, $NO_3^- + NO_2^-$ - N, TKN, Total N, and combinations of total, settable, dissolved, and volatile solids and ash were determined according to Standard Methods [1971], FWPCA Methods [1969], and Banwart et al. [1972]. Soil cores and plant tissue from the disposal plots were taken prior to commencing irrigation to establish baseline conditions. Irrigation of plots was begun in late winter, 1975, and after that time sampling included soil cores, vegetation soil water, and plot runoff. Plot runoff was checked for the same constituents as treatment unit influent and effluent. Plot soils were sampled at 15 and 30 cm depths for fecal coliform, Ca, P, K, Na, Mn, Cu, Zn, NH_4^+, NO_3^- plus NO_2^-, total N, and pH. Soil water was checked at 15, 61, and 122 cm depths for fecal coliform, Ca, P, K, Na, Mg, Mn, Cu, Zn, Cl, NO_3^- plus NO_2^-, NH_4^+, and pH. Fescue plant tissue was analyzed for fecal coliform, Ca, P, K, Na, Mg, Mn, Cu, Zn, total N, and percent dry matter.

RESULTS

More data were available for analyses on biological treatment units than on effluent disposal plots. Little data could be obtained on effects of plot application until treatment units had stabilized and excess effluent was generated.

I. Biological Treatment Units

Both treatment tanks (lagoons) were filled to design level with fresh water, and waste loadings were begun in November, 1974. Sampling of waste loadings and lagoon effluent was begun in December, 1974. As previously noted, samples of loadings included recycled effluent used to flush waste collection pits. Characteristics of influent to each lagoon are included in *Tables 1-9.* Volatile solids loading rates have been estimated by computing the difference between effluent and influent values on given sampling dates, and are included in *Table 10.*

Treatment units were designed to provide 1000 m^3 of lagoon dilution volume for each 80.2 kg of VS loading. *Table 10* indicates wide variation in actual loading rate, with the mean rate approximately 65 kg per 1000 m^3. Both units performed satisfactorily without noticeable odors even during periods of heavy loading. Uniform waste loading by frequent flushing could be expected to improve tolerance of either system to heavier loadings.

Lagoon 2 was mechanically aerated by a 3-hp floating unit operating in a cycle of two minutes ON, eight minutes OFF. This procedure was estimated to provide approximately twice the daily BOD_5 requirement of the loaded wastes. Lagoon 1 was maintained as an anaerobic system typical of most swine waste lagoons.

Both lagoons apparently operated mainly as low-activity anaerobic systems during the first four to six months of use *(Table 13).* Similar high levels of NH_4^+ were observed in both lagoons along with low levels of $NO_3^- + NO_2^-$. As average temperature began to rise during spring months, each system began to assume characteristic values; NH_4^+ levels remained about the same in Lagoon 1, but dropped sharply in Lagoon 2. At the same time, $NO_3^- + NO_2^-$ levels in the aerobic system rose drastically, indicating establishment of an aerobic environment. Additional evidence that both treatment units stabilized is reflected in pH levels recorded after December, 1974 *(Table 19).* Levels recorded are desirable for both types of biological treatment. The low pH recorded in June for the aerobic lagoon denote the transformation to, and progress of, aerobic digestion.

Total nitrogen values *(Table 14)* for both lagoons were statistically different at the 99 percent level, with Lagoon 2 yielding lower values than Lagoon 1 once desired biological activity was established. Although rates of waste loading varied, total input to both systems was about equal. The difference in total N could have been related to the ON-OFF cycle of the mechanical aerator in Lagoon 2. Dissolved oxygen may have dropped rapidly during the 8 minutes that the aerator was not operating, resulting in sufficient conditions for denitrification. Additional nitrogen losses probably occurred because of the turbulent mixing caused by the aerator.

Statistically significant differences among sampling dates and lagoon were recorded for effluent Cu, Zn, Ca, Mn, and Mg *(Tables 15, 16, 17, and 18).* Levels of these elements were consistently higher in Lagoon 2, and indicate a trend of increasing concentration with time. Although sludges were not sampled, work reported previously [Overcash et al., 1977] shows that Cu and Zn may be retained in lagoon bottom sludge. It is reasonable to expect that Cu and Zn levels, as well as levels of Ca, Mn, and Mg, would be higher in the mixed environment of Lagoon 2. Data presented in *Tables 15, 16, 17, and 18* indicate that concentrations of the above materials continued to rise in both Lagoon 1 and 2, but the increase was more pronounced in the aerated unit.

High concentrations of fecal coliform would be expected in any livestock waste treatment lagoon, and the units reported herein were no exception *(Table 11).* However, the aerated treatment unit was slightly more effective in reducing coliform populations.

Values of effluent total P were significantly different between Lagoon 1 and Lagoon 2. After indicating approximately equivalent concentrations between units for the first six months of operation, the aerated unit showed a sharply increasing P concentration. This phenomenon is likely due to increased agitation and suspension of solids in Lagoon 2.

No significant difference in concentration of Na and K was observed between Lagoon 1 and Lagoon 2. However, increasing levels of these cations were observed with time in both units.

Given the approximately equal loading of wastes into both systems, Lagoon 2 apparently achieved better organic waste reduction than Lagoon 1. Effluent COD levels in Lagoon 2 were significantly different from Lagoon 1.

Better nitrogen conservation was evident in the anaerobic unit, although considerable nutrient value was contained in the aerobic effluent. However, the mixed aerobic effluent had an important potential disadvantage because of increased concentrations of Cu and other heavy metals; evidence has been reported indicating that these materials can accumulate in soil-plant systems to levels toxic to sheep and other animals. Mean nutrient values, as determined from this study, for both types of effluent are present in *Table 20.*

Failure of effluent recycling/flushing equipment was a minor problem. Although effluent recycling pipes were protected at exposed points, if ice plugs were allowed to form they were difficult to dissipate. Tipping bucket flush tanks were used inside the animal housing and, even though well-painted, the tanks showed signs of corrosion within two years of use. Hair accumulation in Lagoon 2 was also becoming a problem toward the end of the study. Hair, which was suspended in the lagoon supernatant by the aerator, occasionally clogged the effluent recycling pump, requiring attention from farm personnel.

The lagoons used in this study were closed systems, with little opportunity for dilution by lot runoff, roof water, or other external sources. Results discussed previously indicate a rising trend in concentration of certain constituents which can ultimately hinder operation of the biological systems. Evidence has been reported [Booram et al., 1973] suggesting that, in typical swine lagoon supernatant with concentrations above 48 ppm Mg, 375 ppm NH_4^+ and 250 ppm PO_4, deposition of $Mg(NH_4)PO_4$ on pumping equipment and pipes may be expected. This was not a problem during the study, but the above concentrations were approached only in the most recent samplings. It may be advisable, even under high rainfall conditions as found in Virginia, to consider periodic removal of larger quantities of lagoon effluent during irrigation and refilling to design level with fresh water. This would have a diluting effect on the lagoon and would minimize the problems of rising concentrations of constituents.

II. Disposal Plots

Irrigation of wastes on plots was begun in February, 1975. Soil cores were collected six times from plots receiving effluent from Lagoons 1 and 2, and control plots receiving no wastes. Soil water samples were obtained five times. However, with exception of the first two samplings, complete sets of soil water samples could not be extracted because of high soil moisture tension. Available data were analyzed with regression techniques to reveal treatment effects on soil water. Plant tissue was sampled eight times during the study.

Mean values for important parameters in soil cores, soil water, and fescue plant tissue are shown in *Tables 21-34.* Fecal coliform indicators were zero or at negligible levels, and are not presented.

Nitrate N is the form of nitrogen that is most mobile and is of the greatest concern from the standpoint of leaching losses and movement into water supplies. Plots receiving Lagoon 1 effluent (Treatment 1) received accumulative application of 1,797 lbs. total N per acre, while Lagoon 2 plots (Treatment 2) received 784 lbs. total N per acre. Even though most of the N applied in Treatment 1 was in the NH_4^+ form, and most applied in Treatment 2 was in the NO_3^- form, no significant difference among NH_4^+ levels was found in either soil cores or soil water among Treatment 1, Treatment 2, or Treatment 3 (Control). Significant differences in $(NO_3^- + NO_2^-)$ levels in soil and soil water were found between treatments, with Treatment 1 ranking highest, followed by Treatment 2, and Treatment 3. Apparently, the NH_4^+ in Treatment 1 effluent was volatilized, utilized by plants, fixed on soil or humus particles, or nitrified to NO_3^-. In any case, levels of NO_3^- in soil and soil water were low in all treatments, and would not be important as far as leaching or transport is concerned.

The enriching effect of the nitrogenous wastewater was evident in plant tissue samples from the three treatment areas. Highly significant differences in total N were observed among treatments, with highest values recorded for Treatment 1, followed by Treatment 2, and Treatment 3. More lush growth was obtained on plots from Treatment 1 and 2 than from Treatment 3. Highly significant differences in percent dry matter (DM) were observed, with Treatment 3 yielding highest values, followed by Treatment 2, and Treatment 1. There appeared to be little difference in percent (DM) between treatments until after waste application was begun. At that point, more lush growth developed on plots receiving wastewaters and the plant tissue on those plots included less dry matter.

Even though effluent-applied P in Treatment 2 was higher than in Treatment 1, little difference was observed in soil or soil water P among the three treatments. Also, P levels in plant tissue from all three treatments revealed no differences among treatments and was highly variable. It is possible that, if the study were continued, treatment effects would be evident.

Comparable levels of K were applied in Treatments 1 and 2, but none was applied in Treatment 3. However, statistically different levels of K were found in soil cores, with Treatment 3 showing the highest levels. Conversely, statistically different levels of K were found in plant tissue, with Treatments 1 and 2 recording higher values than Treatment 3. Apparently soil K was better utilized in Treatments 1 and 2 because of the increased growth promoted by nutrients and water applied, thereby preventing accumulation of K in the soil. No differences were determined for soil water, but limited data were available due to lack of samples. Leaching of K would not be expected because of the high cation exchange capacity of the Groseclose soils.

Sodium concentration in animal wastes may be of major concern, since high accumulations can destroy soil structure and contribute to non-productivity. As noted earlier, both Lagoon 1 and Lagoon 2 became increasingly higher in Na concentration during the study. Statistically, no difference was detectable in soil Na among the three treatments. There appeared to be a difference in Na in soil water, with plots receiving wastes yielding higher soil water Na than was observed in the control plots.

However, soil water samples were limited, as explained earlier, and must be considered with caution. Once waste application was begun, Na recorded in plant tissue was much higher in Treatments 1 and 2 than in Treatment 3. This is indicative of high plant uptake of Na in the waste application plots, although no detrimental effects on plant growth were observed during the study. Plant tissue also showed increasing concentrations of Na corresponding to increasing concentrations in lagoon effluent.

Interest in heavy metals concentration and uptake in soil-plant disposal systems is an important part of most studies of land application of waste materials. Values of soil water Cu and Zn were low and not statistically different among all treatments. Clear inferences cannot be drawn from soil Cu and Zn data; statistically significant differences among depths or treatments were not observed for soil Zn. Increasing levels of Cu were observed in both waste application plots and control plots. Control plots were initially abnormally high in soil Cu which make comparison of treatment values difficult. Data for plant tissue Cu is more clear. Even though initial values of plant tissue Cu were highest in control plots, statistically significant differences in Cu content were observed after 8 waste applications. Effluent applied to Treatment 2 was highest in Cu content, and Cu content of tissue from this treatment was also highest among the three treatments. Lower values of soil Cu at 15 cm depth than at 30 cm probably reflects uptake of Cu by the crop. Although some increase in plant tissue Zn was observed, values were not statistically different among treatments in this study. During the study, plant Cu and Zn did not reach levels which would be dangerous when fed to livestock. However, only long-term studies can provide definitive answers for how to best manage metal-enriched wastes to prevent danger to plant-consuming animals.

Although wastewater applied in Treatment 2 was higher in Ca, no differences were observed in Ca levels of soil cores or plant tissue. Statistically different values for soil water Ca among treatments was observed, with highest values recorded for waste-treated plots. Soil water at shallow depths also yielded higher Ca concentrations than at the 122 cm depth. Variability in Ca values for all samples could be related to effects of rainfall leaching which was not considered in the study.

Rising levels of Cl in soil water were evident in Treatments 1 and 2. Limited data revealed decreasing concentrations from 15 cm to 122 cm in depth. Concentrations of Cl in plant tissue were not measured, but no Cl effects on plants were visible.

Statistical differences in soil Mg levels were observed, with the control plots always yielding higher values. Two explanations may be advanced. First, initial soil Mg levels were higher for the control plots. Secondly, while there were no differences in plant tissue Mg among the three treatments, plant growth on Treatments 1 and 2 was more lush, and higher Mg uptake could have occurred but may not have been evident on a percentage basis. Soil water Mg levels are included in the Tables but are based on limited samples and inferences have not been made. In any case, levels, of Mg in soil cores and plant tissue remained relatively low and constant, and do not appear to be of major concern.

Provisions were made in the disposal field for collection of runoff of irrigation and precipitation from each plot. Funds were not available for automated sampling, but some limited "grab" sampling of runoff was attempted. However, because of good vegetative cover which aided in promoting infiltration, and dry weather during much of the study, no runoff data was available for the study.

CONCLUSIONS AND SUMMARY

Two systems of biological treatment of swine wastes have been studied since December, 1974, at Virginia Tech's facilities for animal-soil-plant recycling and waste handling. Effluent from both systems has been recycled to fescue disposal plots since June, 1975, to determine fate of certain constituents which may accumulate to hazardous levels in soil-plant systems.

The two treatment systems studied were an anaerobic lagoon, designed according to U.S.D.A. Soil Conservation Service standards for Virginia, and a mechanically aerated lagoon with an aeration rate of twice its estimated daily BOD_5. Both units were found to perform satisfactorily as designed, although the stable activity desired was not achieved until late spring of the first year. Both lagoons were used in conjunction with recycling of effluent for transporting wastes from the confinement buildings. During their second winter season, once desired activity was established, both units performed well.

Waste characteristics for both types of systems were established and fertilization values for effluent determined. The aerated lagoon recorded higher values of Cu, Zn, Ca, Mn, Mg, and P than did the anaerobic lagoon, and showed increasing concentrations of these materials with time. Both lagoons showed equivalent levels of Na and K, and demonstrated increasing concentrations with time. Where significant amounts of fresh water are not introduced, it may be desirable to withdraw large amounts of effluent at one time and dilute the lagoon with fresh water to prevent development of high concentrations of these materials.

Irrigation of waste effluents on fescue plots has not caused deleterious effects on the soil-plant environment. Nitrate leaching from disposal plots was not significant, and plants showed evidence of good nitrogen utilization. Both plants and soils in disposal plots showed evidence of accumulation or high uptake of Na, Cu, and Zn; over a long period, these effects could be serious if not controlled. Their effects in this study did not appear to be deleterious. Other waste constituents measured did not indicate they would be limiting factors in land disposal of swine lagoon effluent. However, extended studies are necessary to learn more about maximum soil sorption of such materials, and to develop good management techniques for waste disposal sites.

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TABLES

TABLE 1

Mean Concentration of Fecal Coliform in Waste Influent (MPN/100 ml)

Date	Anaerobic	Aerobic
1-9-75	1,907,500	131,800
2-12-75	1,750,000	239,773
4-1-75	7,342,860	13,366,670
5-6-75	2,020,000	1,770,000
6-5-75	5,826,087	28,933,333
8-27-75	9,058,800	1,735,300
10-21-75	9,534,900	3,527,270
1-12-76	6,702,700	9,951,200
3-3-76	15,333,333	2,144,445
5-26-76	12,232,560	8,129,030
7-20-76	1,020,000	2,611,111
9-29-76	46,818,182	5,080,460
12-14-76	6,771,084	18,803,721

TABLE 2

Mean Concentration of TS and TVS in Waste Influent (mg/l)

	Anaerobic		Aerobic	
Date	TS	TVS	TS	TVS
1-9-75	7,087.00	5,329.00	4,059.00	2,735.00
2-12-75	4,333.00	2,965.00	4,453.00	2,931.00
4-1-75	8,024.00	5,805.00	9,175.00	5,976.00
5-6-75	4,769.00	3,115.00	6,583.00	4,148.00
6-5-75	3,563.90	1,952.80	4,415.80	2,494.40
8-27-75	13,283.40	10,003.00	6,584.00	4,125.30
10-21-75	6,614.10	3,777.20	6,796.50	3,804.40
1-12-76	11,647.00	7,929.00	19,329.30	13,338.10
3-3-76	10,267.00	6,752.90	4,929.30	1,703.60
5-26-76	10,463.30	6,927.60	21,012.00	13,746.80
7-20-76	10,175.50	6,712.90	16,687.30	10,050.90
9-29-76	16,954.30	12,124.40	18,346.30	11,078.60
12-14-76	10,910.40	7,713.20	15,814.70	10,189.60

TABLE 3

Mean Concentration of $(NO_3^- + NO_2^-)$ and NH_4^+ in Waste Influent (ppm)

	Anaerobic		Aerobic	
Date	$NO_3^- + NO_2^-$	NH_4^+	$NO_3^- + NO_2^-$	NH_4^+
1-9-75	6.24	467.60	5.23	393.80
2-12-75	6.33	554.50	6.10	545.60
4-1-75	8.40	693.00	16.25	906.00
5-6-75	10.03	699.80	331.10	158.00
6-5-75	12.50	667.70	200.80	133.00
8-27-75	13.41	673.00	72.00	148.80
10-21-75	5.89	921.40	47.95	170.00
1-12-76	16.32	1171.50	10.47	395.90
3-3-76	9.72	1164.30	19.12	183.56
5-26-76	15.60	1372.90	7.03	198.00
7-20-76	22.85	1300.80	61.70	90.20
9-29-76	32.30	1355.20	3.20	63.30
12-14-76	27.60	963.30	11.40	222.30

TABLE 4

Mean Concentration of Total N and P in Waste Influent

Date	Total N, ppm	P, mg/100 ml	Total N, ppm	P mg/100 ml
1-9-75	738.10	10.10	702.20	8.95
2-12-75	732.70	2.74	712.80	8.63
4-1-75	957.40	15.23	1314.00	19.22
5-6-75	867.90	10.79	722.40	19.08
6-5-75	840.30	9.52	351.30	13.32
8-27-75	1097.00	21.41	433.70	15.98
10-21-75	1248.00	10.23	576.70	21.76
1-12-76	1568.00	23.95	1227.00	51.93
3-3-76	1480.00	26.26	272.00	13.80
5-26-76	1628.00	15.02	1220.00	70.73
7-20-76	1548.00	16.42	845.40	52.73
9-29-76	1956.00	27.38	715.70	55.65
12-14-76	1421.00	20.47	898.40	50.76

TABLE 5

Mean Concentration of Na and Mg in Waste Influent (ppm)

	Anaerobic		Aerobic	
Date	Na	Mg	Ma	Mg
1-9-75	––	80.20	––	68.20
2-12-75	––	25.00	––	56.70
4-1-75	––	87.60	––	99.85
5-6-75	––	66.10	––	104.40
6-5-75	235.30	54.20	216.80	86.90
8-27-75	254.00	171.70	286.00	122.00
10-21-75	284.00	63.80	252.00	135.20
1-12-76	406.80	100.00	412.00	268.80
3-3-76	383.10	104.80	387.20	134.80
5-26-76	394.00	74.00	424.00	298.20
7-20-76	346.00	78.00	384.00	211.20
9-29-76	224.00	137.60	296.00	256.00
12-14-76	332.00	94.80	404.00	247.20

TABLE 6

Mean Concentration of Cu and Zn in Waste Influent (ppm)

	Anaerobic		Aerobic	
Date	Cu	Zn	Cu	Zn
1-9-75	0.326	6.870	0.408	7.640
2-12-75	0.227	1.830	0.394	4.720
4-1-75	0.325	3.170	0.710	7.990
5-6-75	0.225	2.540	0.805	7.830
6-5-75	0.515	1.330	1.490	5.080
8-27-75	0.766	1.250	0.970	5.800
10-21-75	2.620	16.200	2.480	19.400
1-12-76	0.886	4.360	2.434	18.350
3-3-76	0.940	5.960	0.166	1.270
5-26-76	1.120	2.900	4.140	25.900
7-20-76	0.540	2.550	2.010	15.700
12-14-76	1.280	9.200	2.460	21.000

TABLE 7

Mean Concentration of Ca and K in Waste Influent (ppm)

	Anaerobic		Aerobic	
Date	**Ca**	**K**	**Ca**	**K**
1-9-75	175.00	350.00	176.00	335.00
2-12-75	58.00	320.00	128.50	417.00
4-1-75	213.50	465.00	278.50	570.00
5-6-75	124.00	505.00	317.00	514.00
6-5-75	102.00	413.60	235.00	455.00
8-27-75	360.00	617.60	276.00	642.80
10-21-75	148.00	637.60	384.00	584.00
1-12-76	443.90	909.60	946.80	920.00
3-3-76	446.80	923.90	177.20	874.00
5-26-76	234.00	1052.00	1136.00	1178.00
7-20-76	176.00	914.00	756.00	996.00
9-29-76	476.00	940.00	756.00	1104.00
12-14-76	312.00	808.00	765.00	972.00

TABLE 8

Mean Concentration of Mn and Cl in Waste Influent (ppm)

	Anaerobic		Aerobic	
Date	**Mn**	**Cl**	**Mn**	**Cl**
1-9-75	1.519	394.60	1.722	368.40
2-12-75	0.688	374.50	1.584	482.50
4-1-75	1.878	526.90	3.533	704.60
5-6-75	0.585	535.80	3.560	373.70
6-5-75	0.420	416.10	2.280	218.60
8-27-75	3.434	657.90	2.830	574.90
10-21-75	1.250	677.70	4.280	502.50
1-12-76	2.612	917.70	8.712	741.60
3-3-76	2.490	1197.20	0.518	785.80
5-26-76	1.500	1033.35	12.600	922.21
7-20-76	1.400	918.00	8.000	783.00
9-29-76	7.800	1446.00	11.400	1234.00
12-14-76	3.860	681.00	9.540	712.00

TABLE 9
Mean Concentration of COD and pH of Waste Influent

	Anaerobic		Aerobic	
Date	COD, mg/l	pH	COD, mg/l	pH
1-9-75	9,065.00	7.57	5,288.00	8.16
2-12-75	2,262.00	7.33	2,936.00	8.54
4-1-75	6,331.00	7.57	6,646.00	8.39
5-6-75	4,622.00	7.21	3,935.00	6.71
6-5-75	3,254.00	7.66	3,776.00	7.39
8-27-75	13,496.00	7.23	3,746.00	7.72
10-21-75	6,378.00	7.66	4,632.00	8.07
1-12-76	12,988.00	7.46	20,833.00	7.33
3-3-76	28,602.00	7.61	1,775.00	7.92
5-26-76	12,142.00	7.30	14,680.00	7.63
7-20-76	13,005.00	7.17	11,743.00	7.93
9-29-76	29,349.00	7.17	22,583.00	7.53
12-14-76	15,966.00	6.97	45,479.00	7.08

TABLE 10
Estimated Lagoon Loading Rates
(kg VS/1000 m^3)

Date	Anaerobic	Aerobic
1-9-75	105.0	22.5
2-12-75	47.2	36.3
4-1-75	113.6	112.2
5-6-75	29.2	42.1
6-5-75	6.3	9.3
8-27-75	219.4	84.1
10-21-75	9.3	20.1
1-12-76	103.0	184.7
3-3-76	86.8	16.7
5-26-76	6.3	87.2
7-20-76	23.1	59.4
9-29-76	63.2	73.5
12-14-76	72.1	89.9
Mean	68.1	64.5

TABLE 11

Mean Concentrations of Fecal Coliform and P in Effluent

	Anaerobic		Aerobic	
Date	Fecal Coliform MPN/100 ml	P Mg/100 ml	Fecal Coliform MPN/100 ml	P Mg/100 ml
12-9-74	72,972	4.27	91,111	3.58
1-9-75	363,556	5.59	370,169	3.85
2-12-75	351,111	5.46	64,481	5.33
4-1-75	356,410	6.32	986,666	7.05
5-6-75	949,444	8.11	1,129,018	14.94
6-5-75	1,520,000	7.56	211,111	12.50
8-27-75	142,979	9.46	10,817	5.78
10-21-75	584,050	10.45	144,911	18.91
1-12-76	4,723,810	11.94	812,196	31.29
3-3-76	805,697	11.79	420,477	9.14
5-26-76	3,118,518	12.73	266,410	51.56
7-20-76	239,682	14.21	50,264	40.68
9-29-76	1,177,977	21.15	358,388	47.23
12-14-76	1,711,503	13.21	378.314	43.15
*3-14-77	543,984	15.73	33,189	9.30

*Aerator frozen since January, both systems anaerobic.

TABLE 12
Mean TS and TVS in Effluent (mg/l)

	Anaerobic		Aerobic	
Date	TS	TVS	TS	TVS
12-9-74	1,760.00	1,107.00	2,083.00	1,394.00
1-9-75	2,210.00	1,351.00	2,872.00	1,881.00
2-12-75	2,318.00	1,179.00	2,710.33	1,554.33
4-1-75	2,994.00	1,499.00	3,414.00	1,720.33
5-6-75	3,552.00	2,007.00	4,684.00	2,550.67
6-5-75	3,191.90	1,713.52	3,840.37	2,143.37
8-27-75	3,519.47	1,682.63	2,823.63	939.20
10-21-75	5,508.63	3,427.23	5,923.93	3,040.80
1-12-76	6,709.97	4,024.57	10,446.17	6,334.80
3-3-76	6,022.13	3,459.80	3,947.93	1,073.43
5-26-76	10,168.77	6,688.43	16,789.50	10,443.57
7-20-76	9,092.97	5,836.77	13,763.07	7,763.23
9-29-76	13,993.90	9,726.10	15,164.27	8,289.47
12-14-76	7,551.83	4,982.90	11,737.63	6,781.83
*3-14-77	8,252.47	2,613.17	4,663.27	2,672.60

*Aerator frozen since January, both systems anaerobic.

TABLE 13
Mean Concentrations of ($NO_3^- + NO_2^-$) and NH_4^+ in Effluent (ppm)

	Anaerobic		Aerobic	
Date	Nitrate + Nitrite	NH_4^+	Nitrate + Nitrite	NH_4^+
12-9-74	3.32	306.10	4.35	227.83
1-9-75	3.75	403.50	3.11	339.13
2-12-75	6.38	494.15	5.33	391.00
4-1-75	4.27	609.00	6.28	435.33
5-6-75	4.17	707.40	355.23	125.47
6-5-75	13.18	637.57	238.17	24.20
8-27-75	4.98	661.20	93.74	2.77
10-21-75	5.76	851.27	109.23	6.18
1-12-76	5.67	1019.07	239.21	31.14
3-3-76	9.54	1008.37	73.31	32.78
5-26-76	19.03	1313.37	54.15	40.12
7-20-76	18.03	1250.53	125.03	4.90
9-29-76	18.03	1285.07	171.53	5.62
12-14-76	6.60	893.93	163.90	51.27
*3-14-77	6.92	974.53	2.35	238.33

*Aerator frozen since January, both systems anaerobic.

TABLE 14

Mean Total Nitrogen in Effluent (ppm)

Date	Anaerobic	Aerobic
12-9-74	374.10	375.10
1-9-75	491.97	478.60
2-12-75	549.40	531.37
4-1-75	706.60	611.60
5-6-75	791.87	611.10
6-5-75	735.63	300.53
8-27-75	729.07	128.13
10-21-75	1066.00	302.53
1-12-76	1233.67	694.33
3-3-76	1166.67	126.67
5-26-76	1590.67	831.37
7-20-76	1436.67	708.10
9-29-76	1788.33	699.93
12-14-76	1122.00	655.50
*3-14-77	1199.67	314.27

*Aerator frozen since January, both systems anaerobic.

TABLE 15

Mean Concentrations of Na and Mg in Effluent (ppm)

	Anaerobic		Aerobic	
Date	Mg	Na	Mg	Na
12-9-76	36.60	––	26.40	––
1-9-75	46.10	––	29.80	––
2-12-75	46.75	––	39.97	––
4-1-75	45.45	––	44.08	––
5-6-75	50.93	––	92.97	––
6-5-75	49.50	222.07	79.00	194.37
8-27-75	78.00	214.67	91.80	246.00
10-21-75	65.20	278.00	136.93	273.33
1-12-76	56.00	360.67	190.33	355.33
3-3-76	46.67	368.73	123.67	358.27
5-26-76	65.80	382.67	241.33	404.67
7-20-76	66.67	318.00	199.73	367.33
9-29-76	108.93	206.67	246.67	280.00
12-14-76	65.20	278.67	214.53	353.33
*3-14-77	75.93	268.67	60.93	318.00

*Aerator frozen since January, both systems anaerobic.

TABLE 16

Mean Concentrations of Mn and Cu in Effluent (ppm)

	Anaerobic		Aerobic	
Date	Mn	Cu	Mn	Cu
12-9-74	0.285	0.055	0.596	0.160
1-9-75	0.360	0.073	0.675	0.240
2-12-75	0.311	0.073	1.090	0.296
4-1-75	0.319	0.104	1.509	0.382
5-6-75	0.417	0.170	2.600	0.597
6-5-75	0.313	0.135	1.650	0.458
8-27-75	0.600	0.203	0.347	0.163
10-21-75	1.210	0.493	3.273	1.147
1-12-76	1.185	0.563	5.672	1.546
3-3-76	1.021	0.497	0.176	0.090
5-26-76	1.390	0.717	9.967	2.520
7-20-76	1.103	0.513	7.000	1.830
9-29-76	6.667	2.453	10.533	2.300
12-14-76	2.820	1.100	8.220	2.180
*3-14-77	2.767	0.943	0.933	0.227

*Aerator frozen since January, both systems anaerobic.

TABLE 17

Mean Concentrations of Zn and Cl in Effluent (ppm)

	Anaerobic		Aerobic	
Date	Zn	Cl	Zn	Cl
12-9-74	1.99	221.50	4.34	227.00
1-9-75	1.82	265.70	4.09	292.00
2-12-75	1.29	278.50	4.30	277.87
4-1-75	0.80	418.30	4.18	398.33
5-6-75	0.84	491.37	5.46	340.50
6-5-75	0.45	328.17	3.48	244.43
8-27-75	0.62	427.50	0.72	442.70
10-21-75	2.04	612.53	7.17	480.60
1-12-76	2.50	237.33	12.57	584.67
3-3-76	2.53	910.30	0.60	691.87
5-26-76	3.34	1011.29	15.07	685.16
7-20-76	1.99	978.67	14.13	675.00
9-29-76	15.20	1549.67	18.00	1214.00
12-14-76	7.53	562.00	17.40	541.67
*3-14-77	7.17	595.80	2.67	646.63

*Aerator frozen since January, both systems anaerobic.

TABLE 18
Mean Concentrations of K and Ca in Effluent (ppm)

	Anaerobic		Aerobic	
Date	K	Ca	K	Ca
12-9-74	201.00	52.00	190.00	74.00
1-9-74	269.00	65.50	240.00	69.00
2-12-75	323.33	68.83	336.00	92.33
4-1-75	412.67	80.33	311.67	109.67
5-6-75	476.67	94.00	495.33	226.33
6-5-75	482.87	94.00	400.53	192.67
8-27-75	487.73	109.33	515.87	84.67
10-21-75	622.93	146.00	575.60	320.40
1-12-76	792.93	237.33	792.93	522.00
3-3-76	877.47	204.00	836.73	120.00
5-26-76	990.00	222.67	1084.67	858.00
7-20-76	818.00	157.33	928.67	685.33
9-29-76	874.67	413.33	1089.33	673.33
12-14-76	688.00	230.67	876.00	648.00
*3-14-77	654.00	208.67	764.67	120.00

*Aerator frozen since January, both systems anaerobic.

TABLE 19
Mean pH and COD of Effluent

	Anaerobic		Aerobic	
Date	pH	COD mg/liter	pH	COD mg/liter
12-9-75	7.86	1955.0	8.23	1548.0
1-9-75	7.73	2671.0	8.27	1365.0
2-12-75	7.24	2392.3	8.39	1462.7
4-1-75	7.46	2992.7	8.41	1709.3
5-6-75	7.32	2421.0	6.07	2232.7
6-5-75	7.57	3164.3	5.47	1439.7
8-27-75	7.23	4590.0	7.59	406.0
10-21-75	7.67	5550.7	8.10	3122.7
1-12-76	7.80	5794.7	6.99	6324.7
3-3-76	7.84	8247.7	8.62	420.7
5-26-76	7.34	10821.3	7.74	11331.0
7-20-76	7.12	10770.7	7.89	9268.7
9-29-76	7.36	20767.0	7.49	16181.3
12-14-76	7.19	11040.3	7.21	5598.0
*3-14-77	6.91	11650.3	7.25	2641.1

*Aerator frozen since January, both systems anaerobic.

TABLE 20
Nutrients in Lagoon Effluent

Lagoon Type	Available N*	Total N	Total P	Total K
		-----g/1000 l. effluent-----		
Anaerobic	693	825	82	499
Mixed Aerated	102	418	163	509

*N as NH_4^+

TABLE 21
Mean Soil Exchangeable N (as $NO_3^- + NO_2^-$) in Effluent Disposal Plots (ppm)

Treatment Depth	Date					
	1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	1.9300	8.1900	14.2400	8.0700	6.3675	21.4300
30 cm	2.6750	5.0300	8.7550	4.4850	5.8125	28.0450
Aerobic						
15 cm	4.3100	6.5150	3.5450	4.8750	5.1050	10.2300
30 cm	3.1500	4.5850	3.4800	5.2750	7.2600	10.0850
Control						
15 cm	0.9650	6.3850	2.5600	6.3500	4.1100	10.1600
30 cm	3.9100	5.5700	2.4850	4.8500	1.8500	8.8850

TABLE 22

Mean Exchangeable N (as NH_4^+) in Effluent Disposal Plots (ppm)

Treatment Depth	1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	3.4500	9.3600	14.1650	7.5200	16.3850	10.9950
30 cm	2.2700	2.4300	7.2550	4.4900	9.8250	10.2900
Aerobic						
15 cm	2.2300	6.4000	13.6850	6.4850	9.5500	13.2950
30 cm	0.7300	4.3300	6.9550	3.6950	6.3400	9.5050
Control						
15 cm	1.6800	9.5400	7.1600	6.8800	6.4050	9.9600
30 cm	4.0100	5.9600	3.9750	3.2550	9.8800	9.4900

TABLE 23

Mean Soil P in Effluent Disposal Plots (percent)

Treatment Depth	1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	0.082	0.069	0.079	0.090	0.079	0.064
30 cm	0.057	0.029	0.066	0.050	0.047	0.032
Aerobic						
15 cm	0.077	0.063	0.076	0.079	0.085	0.073
30 cm	0.063	0.040	0.061	0.040	0.047	0.034
Control						
15 cm	0.063	0.061	0.066	0.078	0.072	0.064
30 cm	0.050	0.041	0.059	0.048	0.051	0.034

TABLE 24
Mean Soil K in Effluent Disposal Plots (percent)

Treatment Depth	Date 1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	3.310	3.115	3.235	3.705	3.050	3.245
30 cm	3.285	3.120	3.360	3.645	3.140	3.195
Aerobic						
15 cm	3.210	3.305	3.575	3.570	3.190	2.970
30 cm	3.420	2.980	3.090	3.570	3.020	2.885
Control						
15 cm	3.800	3.880	4.655	3.810	4.320	3.895
30 cm	4.125	3.065	4.360	4.230	5.430	4.095

TABLE 25
Mean Soil Na in Effluent Disposal Plots (percent)

Treatment Depth	Date 6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic					
15 cm	0.1235	0.3235	0.2980	0.2015	0.6375
30 cm	0.1225	0.2645	0.2685	0.3220	0.6000
Aerobic					
15 cm	0.1410	0.3145	0.2925	0.3080	0.4935
30 cm	0.1315	0.3420	0.3205	0.4530	0.3300
Control					
15 cm	0.1390	0.3005	0.3275	0.4780	0.2365
30 cm	0.1475	0.3240	0.3385	0.6600	0.2755

TABLE 26

Mean Soil Cu in Effluent Disposal Plots (ppm)

Treatment			Date			
Depth	1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	11.7050	14.7600	11.7400	14.8000	20.4050	16.0500
30 cm	11.4400	14.7300	15.7450	13.1050	17.4900	19.9500
Aerobic						
15 cm	14.1800	15.8650	13.1350	16.2350	17.2900	19.8500
30 cm	16.4250	23.8300	17.6450	21.8800	21.3150	46.3500
Control						
15 cm	15.9400	17.0850	15.8250	37.4650	16.0250	30.6500
30 cm	19.6800	22.1450	18.3300	32.7750	29.4800	39.1000

TABLE 27

Mean Soil Zn in Effluent Disposal Plots (ppm)

Treatment			Date			
Depth	1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	34.1250	30.3300	35.6800	38.2050	58.4550	35.9000
30 cm	29.8650	23.5250	31.1800	31.0900	44.3750	23.9500
Aerobic						
15 cm	36.7700	39.6600	35.5350	34.6950	50.2150	34.3500
30 cm	34.8550	35.7600	34.8300	37.2250	50.3600	72.8000
Control						
15 cm	35.6350	33.2600	34.5600	35.4800	22.8650	59.0500
30 cm	33.4100	36.2700	33.7650	40.5450	24.1650	59.9500

TABLE 28

Mean Soil Ca in Effluent Disposal Plots (ppm)

Treatment Depth	1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	1916.59	2061.95	1979.65	1820.50	1017.20	1328.15
30 cm	828.10	774.75	806.50	761.10	464.35	590.05
Aerobic						
15 cm	2495.91	2290.00	2426.10	1955.25	1049.60	1883.20
30 cm	766.64	1045.00	1005.60	468.35	631.65	819.70
Control						
15 cm	2240.81	2744.05	1712.15	1799.75	1094.15	1650.65
30 cm	851.44	1103.10	766.40	838.30	548.40	704.65

TABLE 29

Mean Soil Mg in Effluent Disposal Plots (percent)

Treatment Depth	1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	0.3355	0.3085	0.3140	0.3330	0.3230	0.3000
30 cm	0.3060	0.2575	0.3460	0.3255	0.4086	0.3695
Aerobic						
15 cm	0.3645	0.3300	0.3400	0.3025	0.3565	0.3300
30 cm	0.3045	0.4685	0.3895	0.5170	0.4670	0.5465
Control						
15 cm	0.5455	0.4885	0.3425	0.5310	0.5690	0.4935
30 cm	0.6795	0.6915	0.5105	0.9215	0.9465	0.8895

TABLE 30

Mean Soil Mn in Effluent Disposal Plots (ppm)

Treatment Depth	Date 1-8-75	6-3-75	9-24-75	1-7-76	3-2-76	7-8-76
Anaerobic						
15 cm	1202.50	881.20	929.75	832.25	999.30	711.90
30 cm	1064.25	572.10	739.45	617.35	366.35	223.85
Aerobic						
15 cm	1586.00	1272.50	1386.15	1174.60	1199.20	1135.30
30 cm	1329.75	906.05	1042.55	743.30	955.65	365.75
Control						
15 cm	1098.75	895.50	878.20	916.60	920.60	701.60
30 cm	744.50	506.05	848.90	340.40	369.85	230.60

TABLE 31

Mean Values of Soil Water Nutrients From Effluent Disposal Plots

Nutrients Depth	Anaerobic (20.75 cm applied)	Aerobic (17.88 cm applied)	Control (no application)
P (mg/l)			
15 cm	45.554	53.725	105.025
61 cm	19.987	29.000	29.000
122 cm	29.000	29.000	29.000
K (ppm)			
15 cm	12.060	12.717	8.358
61 cm	9.154	3.530	3.849
122 cm	16.312	4.187	3.624
Ca (ppm)			
15 cm	67.788	57.876	22.833
61 cm	73.136	23.592	7.919
122 cm	19.225	10.914	7.119
Na (ppm)			
15 cm	19.509	26.589	1.956
61 cm	33.711	10.902	3.292
122 cm	12.767	8.011	4.144
Mg (ppm)			
15 cm	34.494	17.736	8.573
61 cm	23.879	6.673	7.0438
122 cm	23.163	7.709	5.556
Cl (ppm)			
15 cm	65.713	57.096	9.078
61 cm	63.289	22.278	8.194
122 cm	29.640	18.833	8.938
$NO_3^- + NO_2^-$ (ppm)			
15 cm	2.438	0.636	0.428
61 cm	1.335	0.273	0.739
122 cm	2.784	1.566	2.630
Cu (ppm)			
15 cm	0.026	0.017	0.021
61 cm	0.018	0.012	0.016
122 cm	0.008	0.011	0.016
Zn (ppm)			
15 cm	0.129	0.126	0.120
61 cm	0.143	0.055	0.075
122 cm	0.088	0.071	0.157

TABLE 32
Mean Total N, P, K, and Ca Content in Fescue from Plots Receiving Effluent (percent)

	Anaerobic		Aerobic		Control	
Date	Total N	P	Total N	P	Total N	P
1-8-75	2.118	0.2085	2.075	0.1905	1.853	0.1905
6-3-75	3.662	0.5335	4.158	0.4565	3.774	0.5725
8-27-75	3.519	0.4055	3.021	0.3540	2.955	0.3390
10-21-75	3.857	0.3715	3.573	0.3615	3.413	0.3720
3-2-76	4.153	0.3735	3.880	0.4125	3.282	0.2600
4-28-76	3.993	0.3625	3.221	0.3920	2.795	0.2850
6-23-76	––	0.3785	––	0.4035	––	0.3505
8-12-76	––	0.3520	––	0.4190	––	0.4250
	K	Ca	K	Ca	K	Ca
1-8-75	0.9730	0.5305	0.8255	0.4740	0.8640	0.4620
6-3-75	1.7520	0.4690	1.3135	0.4555	1.8905	0.4845
8-27-75	3.7005	0.6490	3.3320	0.6805	3.2680	0.6280
10-21-75	3.4870	0.5040	3.2020	0.5685	3.3760	0.5475
3-2-76	2.1860	0.5775	2.3245	0.5955	1.8630	0.6105
4-28-76	2.1440	0.4490	2.2625	0.3365	2.000	0.3215
6-23-76	2.1065	0.5625	2.0000	0.4380	1.8565	0.4675
8-12-76	3.6875	0.6285	3.2250	0.5950	2.8925	0.6525

TABLE 33

Mean Na, Mg, Cu, and Zn Content in Fescue from Plots Receiving Effluent

	Anaerobic		Aerobic		Control	
Date	Na	Mg	Na	Mg	Na	Mg
			----------Percent----------			
1-8-75	66.56	0.2630	59.93	0.2510	74.51	0.2450
6-3-75	66.56	0.3285	59.93	0.3450	74.51	0.3500
8-27-75	296.88	0.4155	203.13	0.4085	109.38	0.4120
10-21-75	171.88	0.2455	128.13	0.2705	90.63	0.2995
3-2-76	371.90	0.1925	356.30	0.1980	146.90	0.1890
4-28-76	509.38	0.1985	265.63	0.1755	356.25	0.1585
6-23-76	293.75	0.3555	125.00	0.3450	284.38	0.3640
8-12-76	826.88	0.3555	400.00	0.3450	339.38	0.3640
	Cu	Zn	Cu	Zn	Cu	Zn
			----------PPM----------			
1-8-75	6.995	28.480	7.6150	28.900	8.5600	24.815
6-3-75	8.6650	59.550	8.1550	33.415	10.6350	40.155
8-27-75	10.3450	37.845	9.4100	38.030	7.7550	32.280
10-21-75	7.1900	27.940	7.3750	28.595	7.1850	30.880
3-2-76	6.4150	32.315	10.2150	37.090	5.5000	25.065
4-28-76	4.5650	27.125	5.1900	24.250	4.1250	24.500
6-23-76	5.6300	27.125	5.8750	24.250	4.4400	24.500
8-12-76	8.9300	37.625	7.8400	51.125	6.3400	43.325

TABLE 34

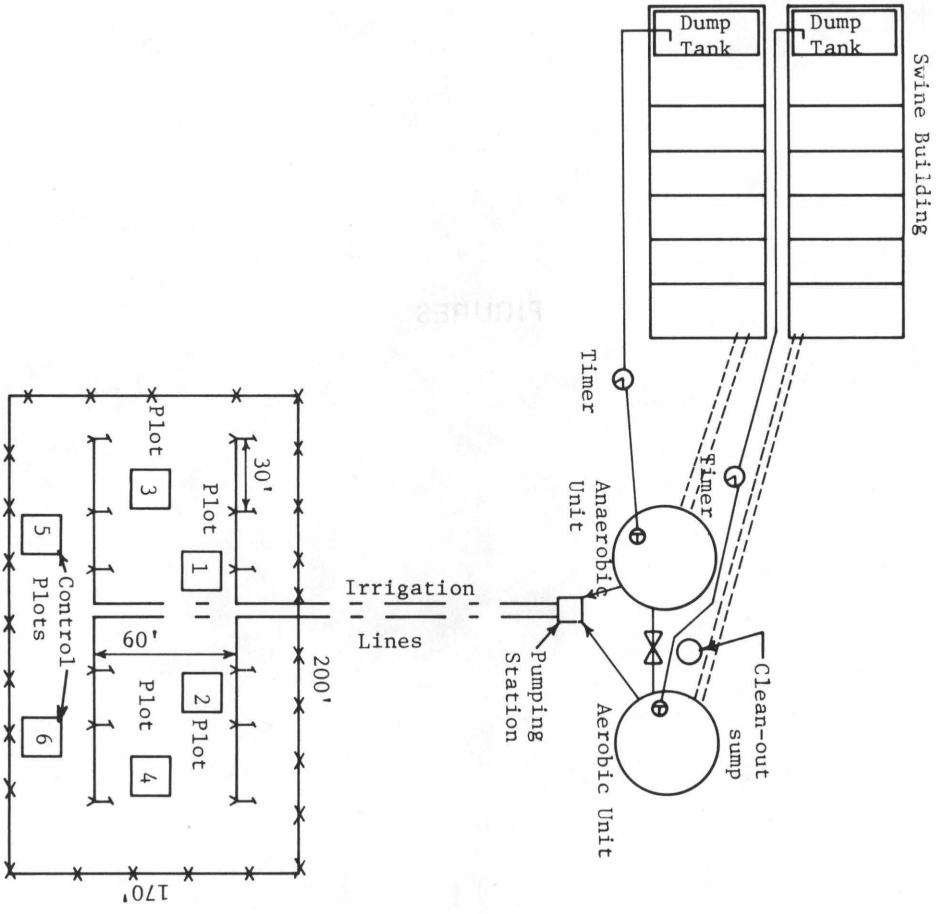
Mean Mn and Dry Matter Content in Fescue from Plots Receiving Effluent

	Anaerobic		Aerobic		Control	
Date	Mn, ppm	DM, %	Mn, ppm	DM, %	Mn, ppm	DM, %
1-8-76	225.700	29.235	216.15	31.350	189.90	33.845
6-3-75	268.450	23.205	168.90	23.195	246.85	23.420
8-27-75	177.550	21.705	236.90	25.805	206.10	26.725
10-21-75	85.550	23.360	173.80	26.540	203.80	26.715
3-2-76	118.050	51.920	136.95	45.560	152.80	53.205
4-28-76	75.315	24.940	65.94	26.525	60.94	30.495
6-23-76	89.065	18.770	93.44	22.670	100.01	25.090
8-12-76	124.400	16.840	121.65	21.860	132.05	24.850

FIGURES

FIGURE 1

Physical Layout of Animal-Soil-Plant Recycling System



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