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Major emphasis of this research study involved the evaluation of nutrient transport by overland flow. Samples gathered at various distances relative to a swine-waste spray irrigation system were used for the nutrient evaluation.

As a result of this study, the following conclusions are made:

1. It is improbable that the spray irrigation system contributes to the nutrient content of Oak Creek.
2. In nearly all cases the nutrient concentration at station 2 was nearer that of the two control stations (3 and 4) than to that of the freshly applied waste at station 1.
3. The applied liquid waste for the most part was absorbed by the soil prior to reaching station 2 (150 feet down slope from the nozzles). Only prolonged high-intensity rainfall, in addition to spraying, would cause liquid accumulation behind dam

number two (station 2). The only agent causing a reservoir at stations 3 and 4 was rainfall.

4. The soil does not appear to be overloaded since the pasture cover crop flourishes. During the rainy season the grass within the "throw" of the sprinklers is higher than that in the surrounding area, while in summer the same grass is shorter and appears burned. Although growth is somewhat inhibited during the dry season, application of toxic or inhibitory matter has not been great enough to destroy the grass or cause cattle to reject it for grazing.

Nutrients in Runoff from Spray Irrigation of Swine Wastes

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NUTRIENTS IN RUNOFF FROM SPRAY IRRIGATION OF SWINE WASTES

INTRODUCTION

It has been said that "agricultural runoff is the greatest single contributor of nitrogen and phosphorus to water supplies (60).

Increasing public demands for clean water coupled with new water quality requirements have caused the search for effective treatment schemes which are economically available. Although the environment can be preserved through proper management of liquid waste disposal, Dubos adds a note of caution:

> Technological fixes are of course needed to alleviate critical situations, but generally they have only temporary usefulness. More lasting solutions must be based on ecological knowledge of the physiochemical and biological factors that maintain the human organization in a viable relationship with the environment (17).

Soil systems have been used to treat wastewaters since man conceived the idea of collecting and treating waste discharges. The various systems range in complexity from the original pit "out behind the cabin" to the modern and elaborate systems of infiltration basins, ridge-and-furrows, and spray irrigation.

When land is available and climatic conditions are favorable, sprinkler irrigation is an effective method for removing nutrients as well as oxygen demanding compounds. Of primary importance is an application rate of nutrients such that it will be in harmony with and at optimum utilization-efficiency for crop production.

The soil-vegetation complex is the link which holds greatest promise for recycling waste material nutrients. Nutrients such as nitrogen, phosphorus, potassium, calcium and magnesium are made readily available to plants through chemical and bacterial decomposition in the soil of the organic compounds of the waste material (45). In addition to its nutrient value, animal waste will increase water holding capacity and infiltration and lesson soil erosion (31).

The importance of this type system for animal waste disposal is suggested by Jensen (33) when he reports that one hog produces as much waste as two humans. Loehr (37) says that hog wastes exceed human wastes, in terms of population equivalents, in seven states.

PURPOSE AND SCOPE

The purpose of this research was to determine the nutrient contributions from swine waste spray irrigation to an adjacent stream.

Major emphasis of the study involved the evaluation of nutrient transport by overland flow. Samples gathered at various distances relative to a sprinkler irrigation system were used to evaluate the nutrient concentration of the runoff. The significant parameters of measurement were nitrogen and phosphorus forms with temperature, pH, BOD, and coliforms also analyzed periodically.

LITERATURE REVIEW

A general knowledge of the various reactions and processes important to this study is necessary for an adequate background. This information, generated by a review of the literature, has been segregated herein according to subject. Nutrients and their effects are first discussed followed in turn by sections devoted to swine waste characteristics, anaerobic lagoons, spray irrigation systems, and soil loadings and cover crops.

Nutrients

In addition to the principal elements such as carbon, nitrogen, phosphorus, and sulfur that are needed for the synthesis of organisms, the nutritional requirements include many quantitatively minor elements including iron, manganese, copper, cobalt, zinc, boron and molybdenum. Furthermore, organism growth may be stimulated by minute quantities of organic growth factors, for example, thiamine, biotin, niacin and vitamin B_{12}.

Eutrophication, while requiring these various elements and growth factors, in most cases is subject to the concentrations of nitrogen and/or phosphorus. When reaching surface water these elements are important in the balance between photosyntheses (P) and respiration (R). A steady state between P and R is a prerequisite for the maintenance of a constant chemical composition in an aquatic ecosystem. The condition $P > R$ is characterized by a progressive accumulation of algae which ultimately leads to an organic overloading. When $R > P$, the dissolved oxygen may become exhausted and thus anoxic conditions prevail. Figure 1 schematically illustrates the interaction between the activities of producer and consumer organisms (P and R).

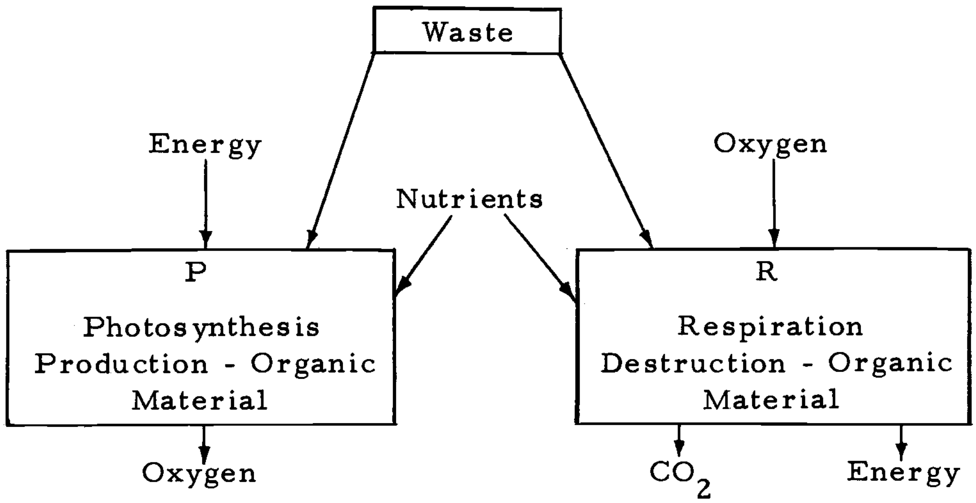

Figure 1. Photosyntheses and respiration interaction.

When mineral forms of nitrogen (NO_2 and NO_3) reach the soil, either directly or after nitrification (biological transformation from $NH_4 \rightarrow NO_2 \rightarrow NO_3$) occurs, and are in excess of vegetation requirements, they are subject to leaching due to their negligible adsorbance by the soil complex (13, 31, 34, 39, 62).

Nitrification can also at times produce oxygen depletions in water bodies. Since 80 to 90 percent of the total nitrogen present in animal waste is in the form of ammonia and urea (urea -- NH_3 CO_2), these depletions can be significant (26). Stoichiometrically, the reactions of nitrification show that for each gram of ammonia oxidized to nitrate, 3.56 grams of oxygen are consumed.

"Nitrogen pollution" can lead to serious consequences such as affecting the health of infants and animals (methemoglobinemia) at concentrations of 10 mg/l - N as nitrates in water (62), poisoning of livestock which have consumed forage containing nitrates in excess of 0.3 percent dry weight (27) and contributing to eutrophication with concentrations in excess of 0.30 mg/l (54).

Phosphorus appears to play a major roll in influencing productivity (eutrophication) in that any incipient deficiency in nitrogen could be obliterated by nitrogen fixation (53). It is worth noting, however, that if proper land disposal of wastes is practiced, phosphorus will not be a problem since it is absorbed by soil particles and will not migrate any great distance (22, 34, 39, 45); it will only reach surface waters if the soil itself is transported by runoff. Effective erosion control will minimize this problem. The phosphorus applied to the soil surface is readily fixed in most soils, either as organic complexes, as Fe or Al phosphates, or Ca phosphates in alkaline soils. The degree of phosphorus absorption will relate mostly to concentrations of Fe and Al and the original phosphorus level (8, 35, 57).

If phosphorus is the limiting factor, each additional milligram allows the synthesis of approximately one-tenth gram algae biomass (dry weight assuming algae protoplasm consistency of $C_{106}H_{263}O_{111}N_{16}P_{1}$). This biomass after settling exerts a biochemical oxygen demand of approximately 140 mg for its mineralization (57). The influence of phosphorus discharges can be further demonstrated by simple calculation. A domestic waste discharge (20-100 mg organic matter per liter) may be small in comparison to the organic matter that is biosynthesized from a phosphorus discharge (5-8 mg P per liter can yield 500-800 mg organic matter per liter).

Figure 2 depicts some of the phosphorus exchange processes in an aquatic environment. The critical level for phosphorus with respect to algal blooms (eutrophication process) has been established as somewhere near 10 μg-P per liter (53). One of the primary sources of phosphorus is domestic waste effluent which contributes approximately 3 mg/l inorganic P (soluble orthophosphorus is the principle P source for algae) and 1 mg/l organic P (53).

Swine Waste Characteristics

The physical and chemical properties of swine waste vary with the hog's feed, water, environment, and age and weight. Average daily weights of manure (feces and urine) produced per 100 pound animal, as reported by Muehling (42), Taiganides (58), and Hart (28)

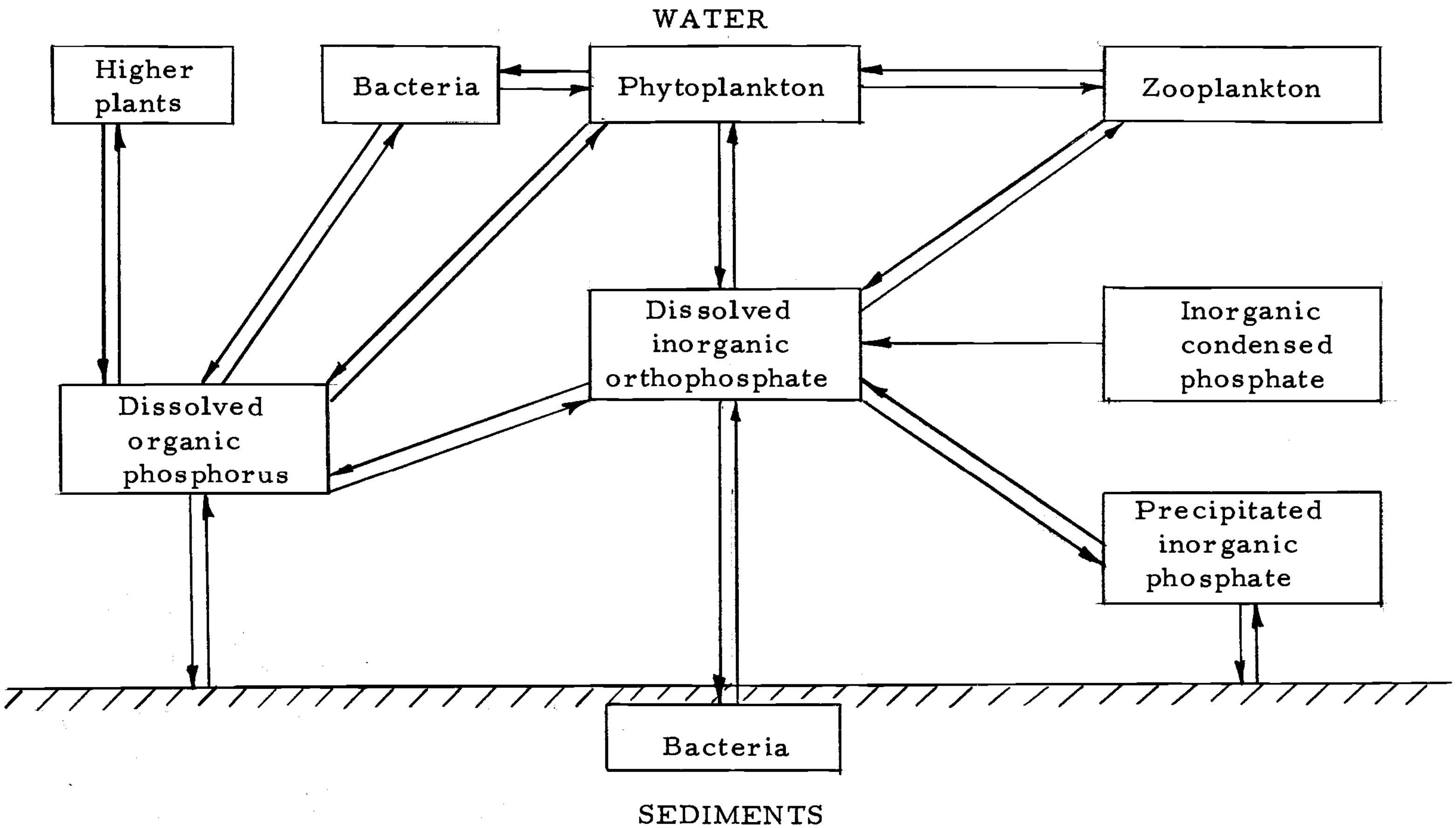

Figure 2. Phosphorus transformations (48).

are 7.7 lb, 5.0 lb, and 8.6 lb respectively. Research in Ireland (52) produced data indicating total solids production of 5.6 lb to 9.5 lb per day depending upon feeding regime. Loehr (38) considers six percent of the animals live weight to be the value when estimating swine waste production. On a dry weight basis solids produced amount to about one pound per day per 100 lb animal of which approximately 80 percent is volatile (36). Okey and Balakrishnan (44) state that the average liquid volume, including flushing water, per 100 lb hog to be 1.07 gal/day. In terms of cubic feet of waste per day per 100 lb animal, Windt used 0.8 when designing an oxidation ditch (67). Willrich (66) considers 0.8 to 1.2 cubic feet/day/1000 lb animal weight to be normal manure production for swine breeders and feeders respectively.

On a dry weight basis 1000 pounds of swine waste would contain about 7 lb nitrogen, 4 lb P_2O_5, and 4 lb K_2O (42, 44). In terms of feces and urine the percent values for nitrogen, phosphorus and potassium are 0.9, 0.4, 0.4 and 0.9, 0.1, 0.2 respectively (36). It is important again to stress that the concentrations of waste products generated are primarily a function of feed ration and type, animal age, and housing conditions.

The BOD_5 values observed ranged from 0.21 lb/day to 0.44 lb/day per 100 lb animal (32, 36, 42, 59). O'Callaghan (43) suggests that the BOD_5 can be expressed as four percent by weight of the meal consumed. The BOD_5/COD ratio cited ranged from 0.34 to 0.65 (43, 44).

Care must be taken when expressing results of BOD analyses conducted on swine wastes. Clark (12), after investigating erratic BOD results, observed that large quantities of antibiotics were being fed to the animals and suggested that this should be considered when using BOD data. Ariails investigations revealed that 75 percent of the antibiotic chlortetracycline was excreted in the feces (5). Copper, in the form of copper sulfate or copper oxide, is fed to hogs as a growth stimulant. Zinc is also fed to the animals for the same purpose. It is estimated that 80 percent of the ingested copper is excreted (5). During Ariails study he found that BOD_5 values decreased as the amount of sample and, consequently, amount of inhibitory substances increased in the assay bottle. He also found that the minimal inhibitory concentration (MIC) of chlortetracycline was not reached but that of copper was. Perhaps more emphasis should be directed toward usage of the chemical oxygen demand (COD) test in order to obtain technically sound oxygen-demand data.

Bromel et al. (9) state that antibiotics have been extensively used in every major livestock-producing country since 1954. The major benefits of increased growth rate and feed conversion by suppressing or controlling subclinical or nonspecific diseases are not warranted by all. Goldberg (21) said that the same results may be achieved by good housekeeping. Armour and Smith as well as the World Health Organization warn that serious health hazzards for humans may develope as a direct result of prolonged usage of antibiotics for disease control. They have shown the emergence of antibiotic-resistant strains of bacteria.

Anaerobic Lagoon

The literature surveyed indicates that anaerobic lagooning of swine wastes is the most widely accepted and most commonly used method of treating those wastes. It is the most economic method with the possible exception of direct spreading of the waste on fields. There must however, be some additional treatment of the effluent from these ponds since it remains unsuitable for discharge to natural waters (40, 51, 55). Of the methods used for additional treatment irrigation seems to be the most practical.

One of the major problems with an anaerobic system is that of malodorous conditions. Literature suggests that the odors involved, including hydrogen sulfide, methyl and ethyl mercaptan, ammonia, methane, amines, carbonyls, alcohols, and other sulfur compounds, originate within the pen waste-holding sumps and/or the lagoon and not during sprinkling (11, 23, 30, 42). The atmosphere in confined swine buildings is frequently disagreeable to the operator, can be toxic to him or the animals, and may be sufficiently offensive to prompt legal action by neighbors (30, 46). Bates (6) recommends that if abundant ventilation is not available, exhaust fans of at least 200 cubic feet/minute/1000 lb animal weight be installed and placed in operation when manure is being agitated or pumped.

Although many parameters seem to affect the level of odors most sources agree that proper design and management will reduce the severity of the problem. They state first that the pen waste-holding sumps be emptied at least daily; second, design of lagoons should be determined on the basis of BOD loading per unit volume or lagoon volume per animal, 75-100 cubic feet/100 lb animal (14), 130-170 cubic feet/100 lb animal (16); third, lagoon depth as deep as economically possible without being below the water table (thus providing a minimal surface area for oxygen transfer), 8-12 feet (29, 42); fourth, continuous or at least daily lagoon loading with the influent pipe extending to the center and discharging two feet above the lagoon bottom (29); and fifth,[1] proper management such that the accumulated solids are removed periodically. Authors seem to agree also that the length to width ratio of a lagoon should be at least 3 to 1.

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[1]There are existing anaerobic lagoons which, after several years of operation, have reached an apparent fixed solids volume. Included in the causes for no further buildup of solids are losses from gaseous products of anaerobic decomposition and effluent solids carry-over. Willrich (66) suggests that inert benthic solids are suspended by gas bubbles and thus are carried out of the system.

A few more costly methods of odor control are listed. Those include polyethylene covers, lime additions to reduce hydrogen sulfide production, chlorine addition to deter formation of hydrogen sulfide, ammonia, methane and other gases (25). Also mentioned are methods of burning, absorption, adsorption and masking (42).

One other interesting note is reported by Willrich (65). When experimenting with anaerobic lagoons he found organisms which were identified as anaerobic photosynthetic red and purple sulfur bacteria. Since these organisms oxidize hydrogen sulfide, which in turn cause a detectable reduction in odors, they may be of benefit when in large numbers.

Spray Irrigation

Spray irrigation systems require large land areas and have been utilized where economic benefit can be attained from irrigation. Successful operation of a spray irrigation arrangement is dependent upon the capacity of the receiving site to absorb the wastewater. Among the variables influencing soil receiving capacity are type of soil, stratification of soil, depth to ground water, initial moisture content, and cover crop. Wastewater characteristics are also of prime importance.

This type of waste disposal system has been adapted and developed to suit a quite varied range of applications. These modifications include improved crop yield, where barley, oats, wheat, corn and hay are reported to be improved in both yield and quality (15, 56); and soil stabilization, where in Israel shifting sands have been converted into crop fields (50). Also included are water conservation, where the Flushing Meadows project in Arizona (3) and studies by the U.S. Department of Agriculture and Pennsylvania State University (19) have shown that plant-soil filters can be used successfully to recharge ground water with no harmful effects; and for treatment of animal wastes (2, 49), domestic wastes (13, 18, 36), and industrial wastes (7, 10, 24). Weeks et al. (63) report a general favorable effect on cultivation and workability for soils with manure applications.

Problems can sometimes be generated by land disposal of large quantities of wastes. These problems include potentially harmful effects to crops, soil, surface and ground water, and possible nuisance conditions. Problems usually are the result of excessive or improper land disposal.

Plant life can be inhibited by high phosphorus levels, which reduce plant uptake of metallic trace elements (1); high carbonaceous levels, causing reduced oxygen and increased CO_2 content of soil air which in extreme cases (low D.O.) can retard plant growth (4); and high carbon to nitrogen ratios, which affect the amount of nitrogen, in the short run, which is available for plant synthesis. Readily available nitrogen will be assimilated by soil bacteria and bound in organic complexes. Also, problems associated with accumulations of soluble salts in the soil can occur in arid regions where leaching is negligible.

Soil properties can be altered by the accumulation of various ions. Sodium and potassium, for instance, have caused reductions in percolation characteristics of certain soils.

Possibly the greatest potential hazard of land application of wastes is related to surface and ground water pollution. The degree of this problem as well as the other potential problems is solely dependent upon system design and operation. As stated previously, few problems exist with well designed and well managed operations.

Soil Loadings and Cover Crops

Biologically, physically, and chemically active surface soil and associated agronomic and forest crops do an excellent job of removing and assimilating nutrients contained in the effluent during summer months (31). Crop and grazing lands have the added advantage that the nutrients taken from the wastewater and used by the crops are removed from the disposal area.

Nutrient utilization declines with increasing waste application rates as well as during the winter time when physical-chemical adsorption is relied upon to a greater extent (31). Nutrient losses from winter-applied wastes are extremely variable and depend upon factors such as soil adsorptive capacity, ammonia volatilization, denitrification, temperature, application rate, soil erosion, vegetation, slope, etc. An adequate cover crop is probably a more important factor than the soil type in determining the water-absorptive capacity of the land. In addition to the benefits mentioned, the crops themselves prosper from waste application (8). Improved crop yields have been reported for alfalfa, fescue, brome and ryegrass. Oats measured up to those grown with inorganic fertilizer in chemical composition, palatability and digestibility (35, 45). It was found that Midland Bermudagrass was most tolerant, compared to wheat, cotton, rye and grain sorghum, to undiluted feedlot runoff in a Texas experiment (41). Regardless of the handling method, manure increased corn yields (31). Blosser and Owens (7) found that Alta fescue had a high moisture resistance and reasonably high salt tolerance. There is apparently no danger of plant toxicity due to nutrient buildup under normal loading conditions (13, 31). It should be noted that a cultivated crop such as corn exposes the soil to maximum erosion.

No clear guide can be given for the amount of land necessary as this will depend entirely on local conditions as mentioned previously. System design factors include amount of liquid to be disposed of, type of sprinklers, commonly 0.15-0.5 inches per hour, absorptive capacity of soil, rate of application, continuous or eight hour/day pumping, weather, and cycle of application-rest for the soil (64).

Common practice employs an application rate of 1/4 inch per hour with a maximum of 2 inches of waste per week (47). Overman (45) states that by utilizing the concepts of classical fertility a rational design for the management of animal waste can be carried out. In his soil-plant experiments he found that optimum utilization of nutrients by sorghum-sudangrass occurred with an application rate of one inch per week. When the rate was doubled the nutrient uptake reduced by about 40 percent.

Foster (20) sprayed secondary domestic waste until the forest soil was saturated, 2-3 days, then rested the plot for 4 days before the next application. Koelliker (35) suggests the application of 600 lb per acre of nitrogen per season. He assumes that 25 percent of the total nitrogen is lost be desorption during application, that the growing crop will remove from 150 to 300 lb per acre of nitrogen and that denitrification in the soil profile can remove the remaining nitrogen. His conclusions concerning phosphorus leaching echo those of other researchers in that phosphorus presented no problem as it was readily fixed in the soil. He did repeat, however, that each particular type of soil has a definite capability for phosphorus removal and that leaching may occur with increased application rates.

When considering the fertilization value of animal wastes, care must be taken to include the losses through the system. Losses can be contributed by storage, gravitational settling, precipitation, volatilization, denitrification, leaching and runoff.

It has been estimated that from 45-60 percent of the waste nitrogen is removed by various mechanisms in an anaerobic lagoon. Another source suggests a 15-30 percent loss of nitrogen from sprinkler nozzle to ground (66). This is most likely the result of desolubilization of ammonia.

Another factor of note is the actual availability of the nutrient to the crop. Willrich (66) states that for an equal effect the amount of inorganic fertilizer required is 33 percent ammonium sulfate, 67 percent superphosphate, and 75 percent potash for nitrogen, phosphorus and potassium respectively.

PROCEDURES

A method of treating swine wastes by a combination of two processes; a biological treatment process and a physical-chemical-biological process was investigated. Biological stabilization was accomplished using an anaerobic lagoon. Additional reduction of organic matter as well as reduction in nutrients was caused by the application of the lagoon effluent to the plant-soil complex by sprinkler irrigation.

Swine Facility Operation

The swine facility at Oregon State University is located approximately one mile west of the campus center and is composed of four main buildings. These buildings as well as the lagoon and sprinkler irrigation system are shown in Figure 3. A potential problem exists in that the irrigation system is relatively close to Oak Creek, a stream of less than 0.5 cubic feet per second flow during the summer months.

Sows and boars are housed in the gestation building. In the grower barn, swine from the just weaned stage to the final market stage (220 lb) are raised and cared for. Feeding experiments are conducted in the nutrition building.

The grower barn is subdivided into five collection areas as

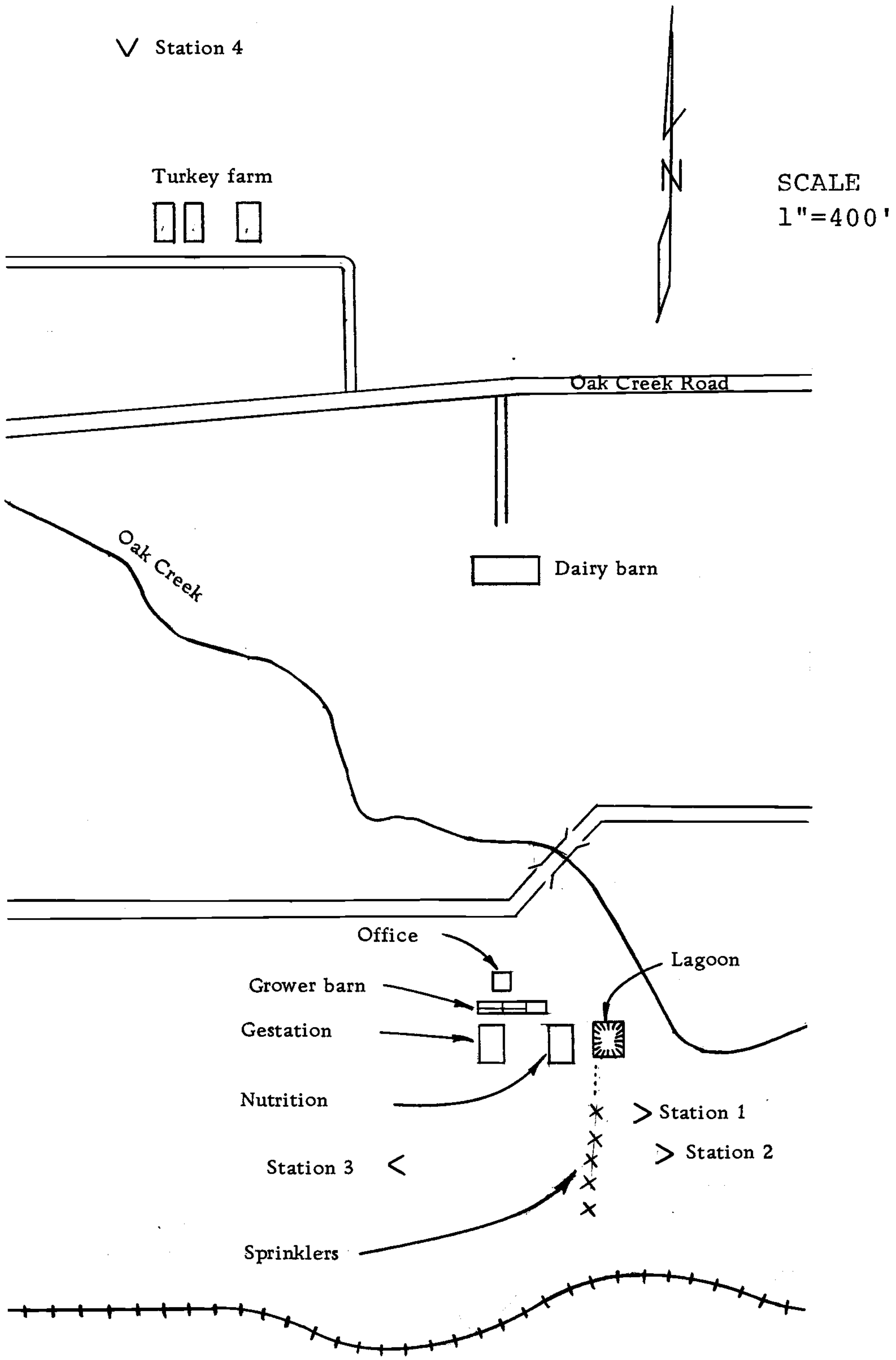

Figure 3. Swine facility and spray irrigation system.

shown in the figure. Waste storage is provided by 6-foot-wide by 3-foot-deep holding tanks which extend the entire length of the barn and are located beneath slotted floors. The tanks are drained each day to prevent the production and accumulation of toxic atmospheric conditions within the barn. Throughout the 15 minute draining period, 3/4-inch water valves are opened above each of the five drains to augment solids flushing.

Waste enters the lagoon by gravity flow. Theoretical detention time of the lagoon is approximately 250 days. The 50-foot by 100-foot by 6-foot deep anaerobic lagoon has been in continuous service since 1965. No solids have been removed during this time. Pumping from the lagoon is primarily dependent upon weather conditions since little storage is available. During the rainy season, pumping to the spray irrigation system is nearly continuous. Table 1 contains pumping data.

Lagoon effluent enters the irrigation system through the three-foot deep pump intake. The pump then transports the liquid through three-inch diameter aluminum irrigation pipe delivering it approximately 100 yards to the first sprinkler. In theory the throw of each nozzle is 20 feet. Seven sprinkler heads located 40 feet apart distribute the effluent over an area of 0.2 acres. Frequent unpulugging of the sprinkler heads is required to maintain even distribution.

Table 1. Lagoon pumping data.

Pumping data (Feb. 1, 1970 - April 5, 1970)	
February 1970	6 days @ 8 hr/day 5 days @ 24 hr/day
March 1970	16 days @ 8 hr/day 3 days @ 12 hr/day
April 1970	4 days @ 8 hr/day
Pumping data (Dec. 1, 1970 - April 12, 1971)	
December 1970	All days @ 24 hr/day
January 1971	All days @ 24 hr/day (two sprinklers added to system on January 8, 1971 9 total)
February 1971	14 days @ 24 hr/day
March 1971	2 days @ 12 hr/day 29 days @ 24 hr/day
April 1971	2 days @ 12 hr/day 7 days @ 24 hr/day

The normal irrigation practice was to pump so as to maintain a nearly constant level in the lagoon. This required from eight to twenty-four hours per day during the rainy season tapering off to from two to three times a week for eight hours in the summer.

Table 1 is a log of lagoon pumping frequency. The increased time and frequency of pumping in 1971 was in part due to increased swine population and decreased lagoon volume (caused by solids build-up).

Pump air-locking and sprinkler clogging among other factors caused the abandonment of efforts to determine actual waste application rates. Using the literatures waste concentrations and design criteria and the actual swine population, the following calculations of waste application rate and lagoon loading can be made:

Animal Number	400 @ average weight 112 lb	- 44800 lb
	70 @ average weight 450 lb	- 31500 lb
	Total swine weight	- 76400 lb
Waste Production (30, 84)		
Dry weight (1 lb/100 lb animal)		- 800 lb/day
Total weight (6% of animal weight)		- 4800 lb/day
Liquid volume (1.07 gal/100 lb animal)		- 856 gal/day
Nutrient Production (65, 84)		
N (7 lb/1000 lb animal weight)		- 5.6 lb N/day
P (1.7 lb/1000 lb animal weight)		- 1.4 lb P/day
K (3.4 lb/1000 lb animal weight)		- 2.7 lb K/day
Biochemical Oxygen Demand (65)		
0.3 lb/day/100 lb animal weight		- 240 lb/day
Nutrient Application Rate[2]		
Nitrogen 5.6 lb/0.2 acres		- 28 lb/acre/day
Phosphorus 1.4 lb/0.2 acres		- 7 lb/acre/day
Potassium 2.7 lb/0.2 acres		- 13 lb/acre/day

Lagoon Size (considering no solids accumulation)
50 ft x 100 ft - 5000 ft^2
depth - 6 ft
total volume - 30000 ft^3

Dornbush and Andersen (16) consider 150 cubic feet per 100 lb animal to be optimum for design purposes for an anaerobic lagoon.

[2] These numbers represent maximum values. As stated in the literature review, researchers suggest using 50 percent of the nutrient concentration generated for the amount that actually reaches the soil surface.

Using this criterion and the total swine weight (80,000 lb) a lagoon of 120,000 cubic feet would be optimum. The actual lagoon has one-quarter (30,000 cu ft) of this volume. This implies that further stabilization of organics may be obtained with a larger lagoon. The final destination of a lagoon's effluent must, however, be considered. In this case the lagoon operation may be sufficient while it would certainly not be if discharged directly to surface water.

During this study from 65 to 70 adult animals and approximately 400 adolescent animals, average weight 450 and 112 pounds, were present. The maturing animals, up to 140 pounds, are fed ASP-250 as a feed supplement. Aureomycin-Sulfamethazine-Penicillin is an antibiotic used to increase growth rate and feed conversion. Animals also have a zinc supplement in their feed.

Experimental Design

Small dams located at various distances away from the spray irrigation system were used for accumulation of surface runoff.

The operational plan consisted of the analysis of four simultaneously collected samples whose locations are shown on Figure 3. The four sample stations represented runoff from natural through swine waste influenced conditions.

Dams were constructed of 0.02" by 14" by 25' pieces of aluminum sheeting. An edging spade was employed to open a groove approximately five inches deep in the soil so that the aluminum could be secured. Extending beyond the ends of the aluminum were six-inch high and fifteen foot long sections of plastic garden edging. The edging increased the "catch" area of the dams. There was a one foot elevation difference between the apex of the dams and each exterior point. Holes plugged with rubber stoppers were located at ground level in each dam. Removal of the plug allowed the reservoir to be drained thus permitting the collection of a fresh sample. Figure 4 depicts the design of the dams.

The four dams were all placed on similar 6 to 10 percent sloping terrain. Soil in all cases was Steiwer silt loam.

Station one was located immediately outside the sprinkler's range, approximately 50 feet down slope from the nozzles. The second was 150 feet below the first while the third and fourth were completely removed from the waste spray influence. The location of the third, 200 yards west, was on pasture land of similar fesque ground cover. Station four was located on an undisturbed remote hill one mile north. Again the soil type was similar but in this case the ground cover was of natural origin.

Whenever practicable the accepted methods for the analysis of samples as described in Standard Methods for the Examination of Water and Waste Water were employed. It is understood that some of these methods were written only for use in water supply, e.g.,

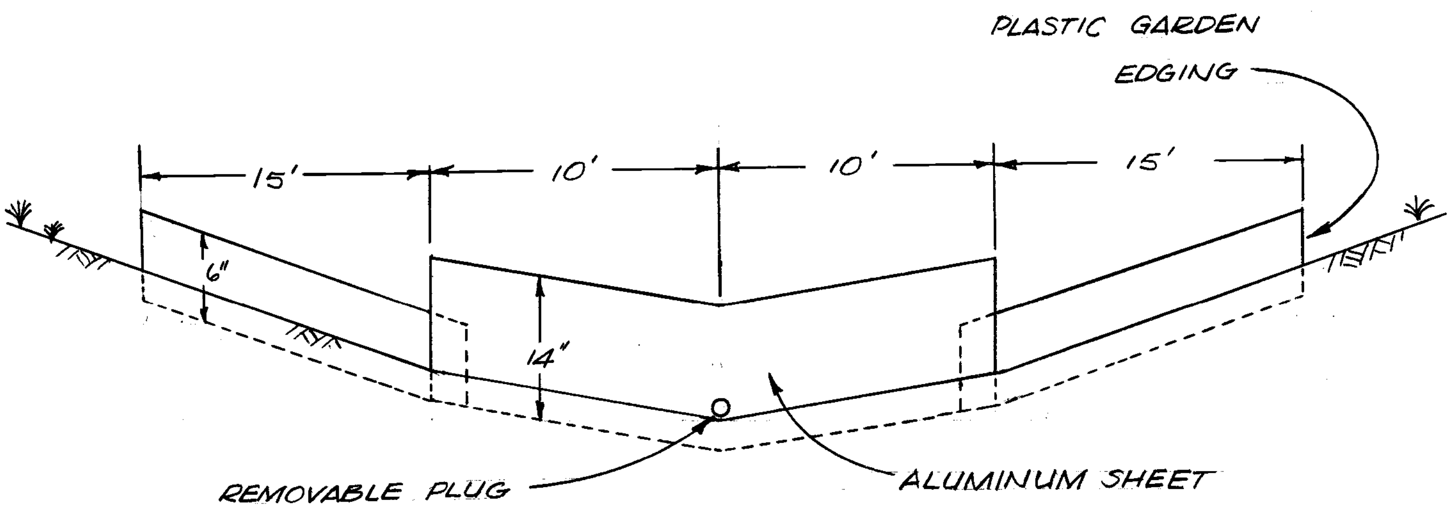

Figure 4. Typical runoff collection dam.

stannous chloride method for orthophosphate, and not for waste streams.

The deviations from standard methods occurred during some nitrogen and coliform analyses. Those nitrogen values differing were obtained by using the Pacific Northwest Environmental Research Laboratory's Technicon AutoAnalyzer. The samples were preserved by the addition of 40 milligrams $HgCl_2$ per liter and refrigeration at 5° centigrade. The deviation from standard practice in the analyses of coliforms incorporated the use of syringe mounted Millipore swinnex filters.

RESULTS

The following tables and figures depict the results of sample analyses. Included are samples collected from the lagoon and runoff stations as well as from Oak Creek above and below the irrigated area. Discussion of these results is the substance of the next section of this thesis.

Missing values signify that insufficient sample was present for analysis. The letter T represents trace. Trace means that a detectable quantity of the parameter was present, however, the concentration of it was below the limit of the test.

Tables 2 through 6 list the concentrations of the various forms of nitrogen at the four collection stations.

Table 2. Ammonia concentrations (mg/l-N).

Date	Station 1	Station 2	Station 3	Station 4
1-14-70	28.5	1.60	2 40	0.50
1-24-70	22.0	1.27	0.40	0.37
2-16-70	3.30	0.16	0.05	0.16
3-15-70	18.6	--	--	--
7-12-70	0.01	T	0.01	0.13

Table 3. Nitrate concentrations (mg/l).

Date	Station 1	Station 2	Station 3	Station 4
1-14-70	7.10	27.6	0	T
1-24-70	7.50	27.6	T	T
2-16-70	3.10	27.5	0.01	T
3-15-70	5.33	--	--	--
7-12-70	T	T	0.21	T

Table 4. Nitrite concentrations (mg/l).

Date	Station 1	Station 2	Station 3	Station 4
1-14-70	T	0	0	0
2-16-70	0.08	0.02	0.01	0.02
3-15-70	T	--	--	--
7-12-70	T	T	T	0.01

Table 5. Total organic nitrogen concentrations (mg/l).

Date	Station 1	Station 2	Station 3	Station 4
1-14-70	3.18	2.47	0.16	T
1-24-70	3.68	2 14	0.47	--
2-16-70	6.60	0.01	1.10	1.20
3-15-70	4.63	--	--	--
7-12-70	T	0	T	T

Table 6. Total Kjeldhal nitrogen (mg/l).

Date	Station 1	Station 2	Station 3	Station 4
1-14-70	31.68	4.07	2.56	0.50
1-24-70	25.68	3.41	0.87	--
2-16-70	9.90	0.17	1.15	1.36
3-15-70	23.23	--	--	--
7-12-70	0.01	T	0.01	0 13

Figures 5 and 6 plot concentration versus sample station for ammonia and nitrate respectively. The data are composed of simultaneously collected samples on four separate dates.

Tables 7 and 8 show the magnitudes of orthophosphate and total inorganic phosphate at each station for five samples.

Table 7. Orthophosphate concentrations (mg/l as P).

Date	Station 1	Station 2	Station 3	Station 4
1-16-70	2.80	3.20	1.67	2.00
1-21-70	11.3	3.46	0.21	0.04
2-16-70	8.90	1.57	0.12	0.02
3-15-70	7.11	--	--	--
7-12-70	T	T	0	T

Table 8. Total inorganic phosphate (mg/l as P).

Date	Station 1	Station 2	Station 3	Station 4
1-16-70	3.67	4.00	2.00	2.67
1-21-70	23.3	4.30	0.22	0.07
2-16-70	23.7	2.35	0.26	0.15
3-15-70	18.2	--	--	--
7-12-70	0.03	0.03	0.01	0.08

Figures 7 and 8 are graphic representations of the data contained in Tables 7 and 8. Figure 7 depicts the relative magnitudes of orthophosphate at the four stations while Figure 8 does the same for total inorganic phosphate.

Table 9 contains a listing of solids and nutrient analyses of samples collected from the anaerobic lagoon.

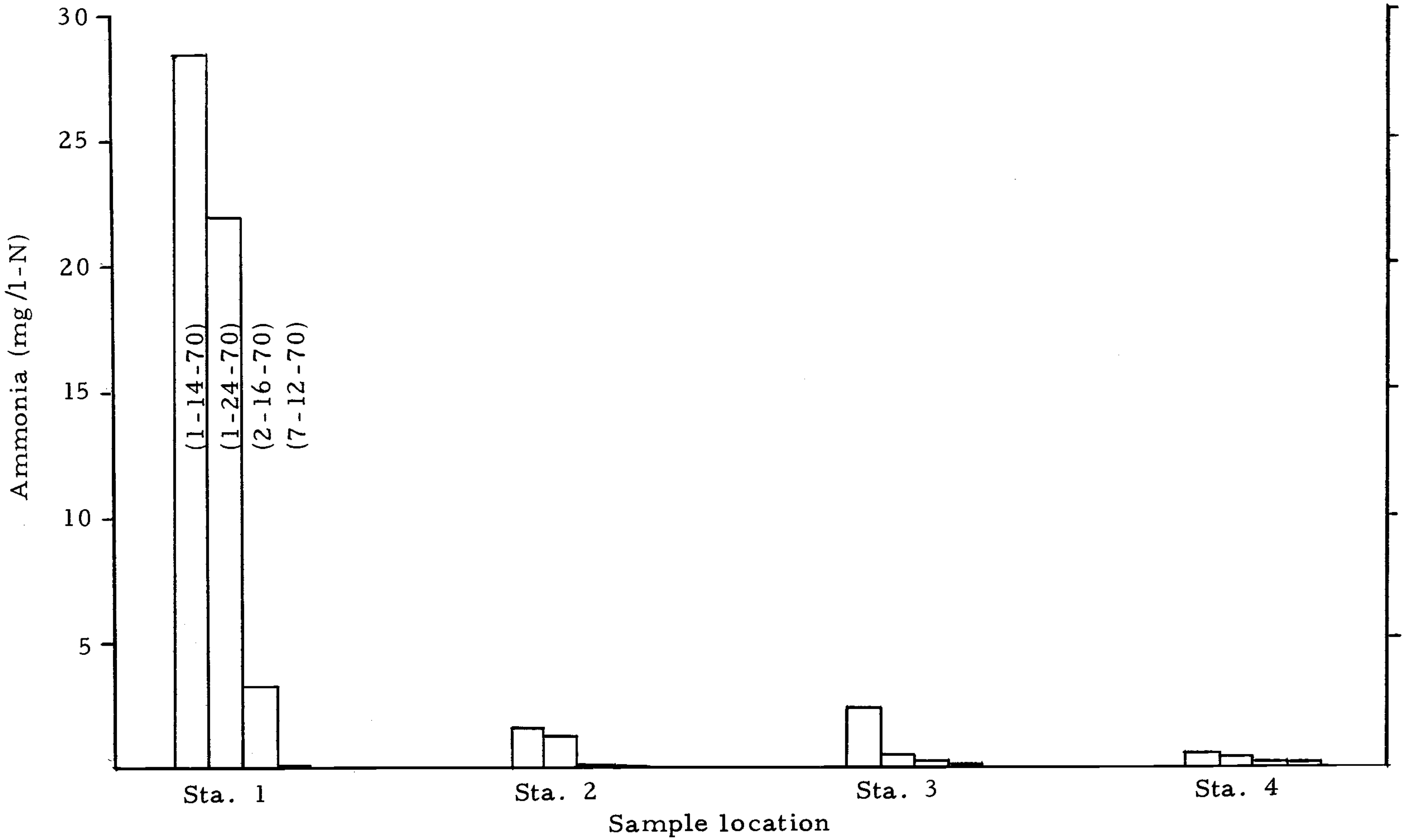

Figure 5. Ammonia-N versus sample station.

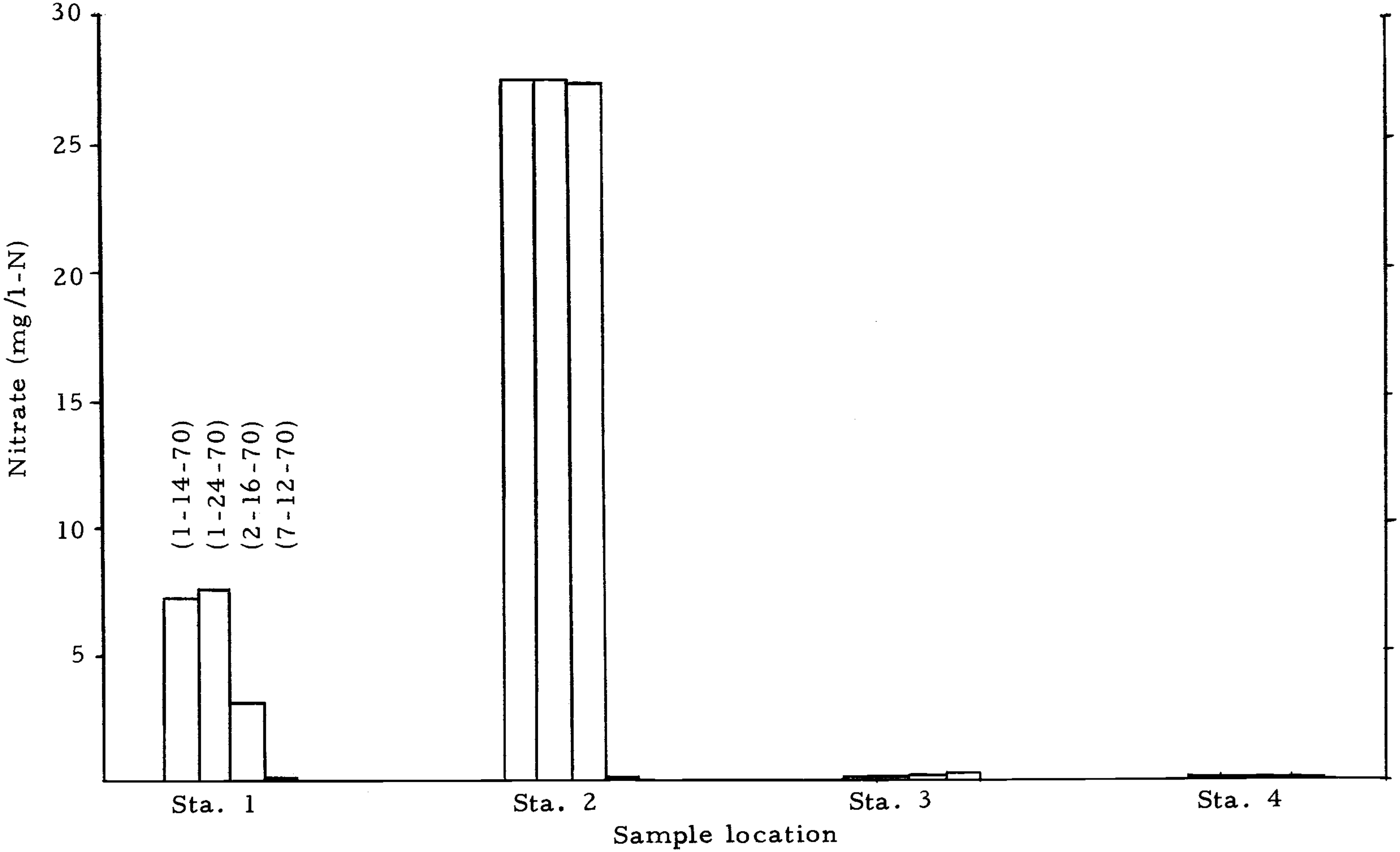

Figure 6. Nitrate-N versus sample station.

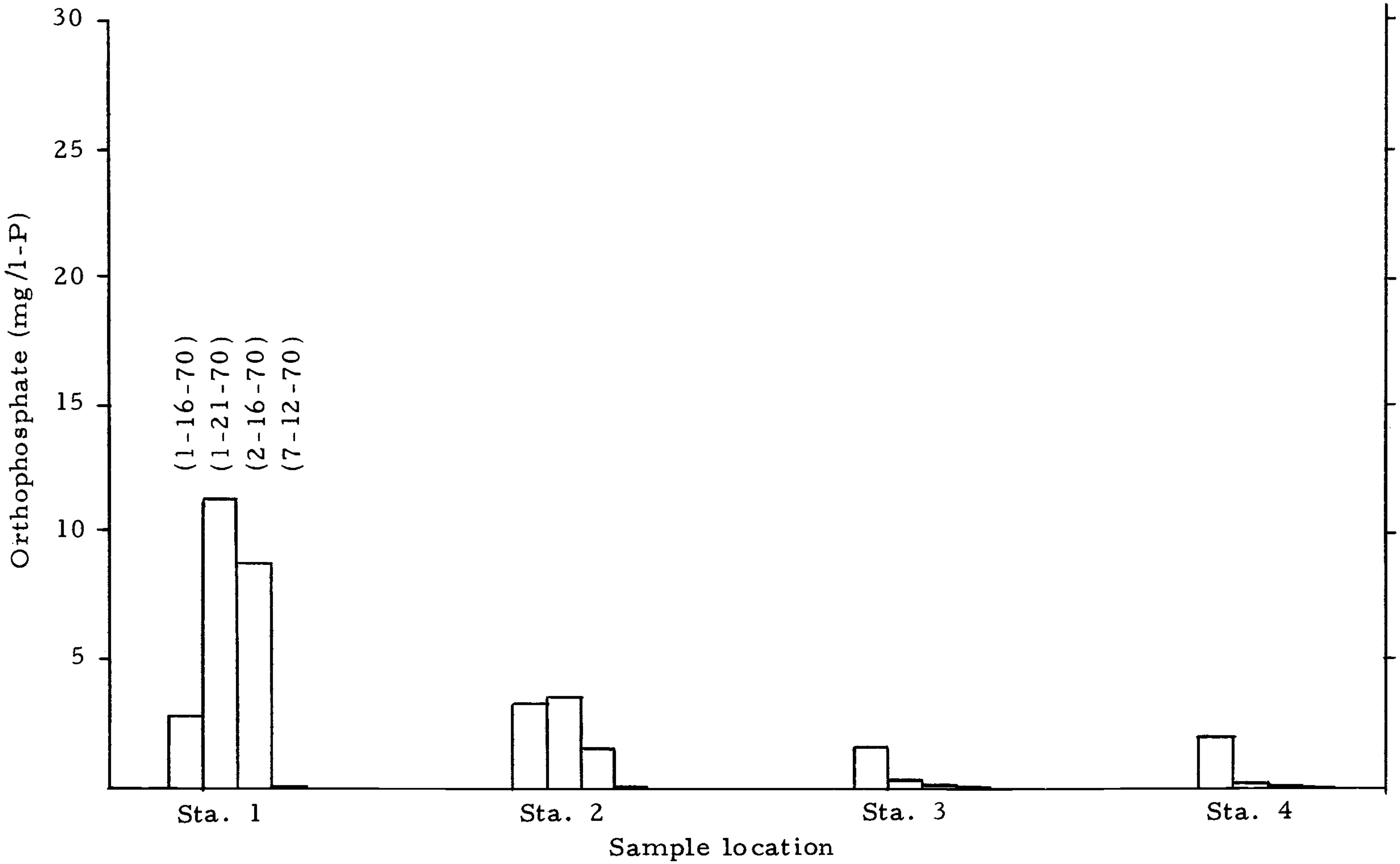

Figure 7. Orthophosphate-P versus sample station.

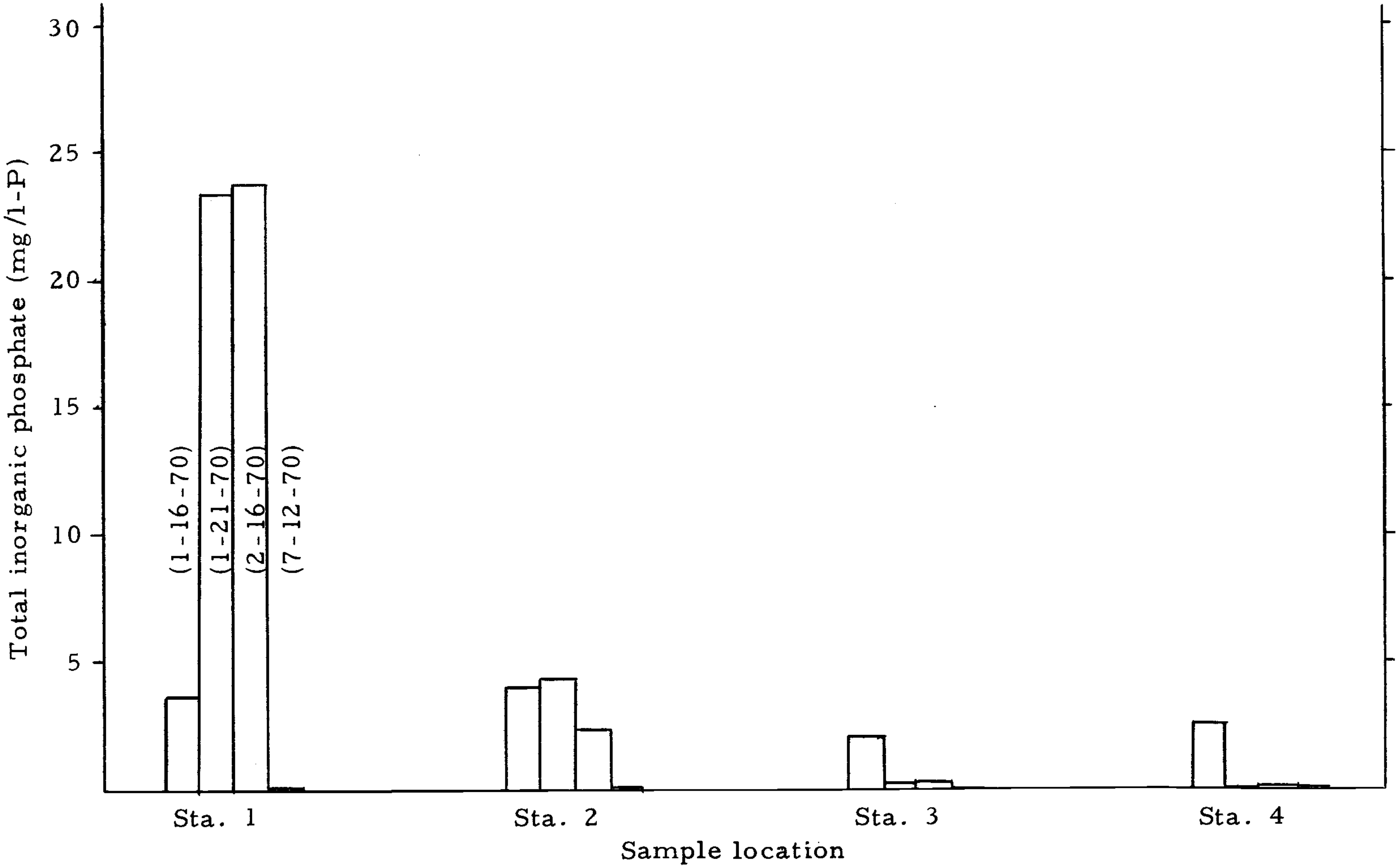

Figure 8. Total inorganic phosphate-P versus sample station.

Table 9. Anaerobic lagoon data.

Date	Sample Location	Suspended Solids (mg/l)	Volatile Suspended Solids (%)	pH	NH_3 (mg/l-N)	NO_2 (mg/l-N)	NO_3 (mg/l-N)
2-23-70	lagoon	68	81.4	7.1	192	0.11	0.11
7- 7-70	lagoon						
	influent			6.5	72.0	0.30	0.10
	lagoon*			7.4	530	0.10	0.10
	effluent			7.3	520	0.10	0.10

*Sample taken below scum layer.

The remaining four tables contain data relating to BOD, temperature, pH, and coliform bacteria. Table 10 compares five-day and twenty-day BOD results at the various stations. Table 11 shows temperature recordings and Table 12 lists pH values.

Table 10. BOD results (mg/l).

Date	Station 1		Station 2		Station 3		Station 4	
	5 day	20 day	5 day	20 day	5 day	20 day	5 day	20 day
12-11-69	50	-	--	--	--	--	--	--
1-14-70	80	190	60	80	10	20	0	10
1-24-70	70	240	20	20	10	10	10	--

Table 11. Temperature results (°C).

Date	Station 1	Station 2	Station 3	Station 4
12-11-69	10.9	-	-	-
1-14-70	9.0	8.5	8.5	9.0
1-24-70	9.3	9.5	9.3	10.0
2- 6-70	-	-	-	9.0
3-15-70	11.0	-	-	-
4- 9-70	13.0	-	-	-

Table 12. pH results.

Date	Station 1	Station 2	Station 3	Station 4
1-14-70	7.4	6.4	6.9	6.8
1-21-70	7.8	6.2	7.4	6.8
1-24-70	7.7	5.8	6.5	6.4
2- 6-70	-	-	-	6.2
3-15-70	7.7	-	-	-
4- 9-70	6.9	-	-	-

In the last table total and fecal coliform bacteria results are shown. The Millipore filter method of determining fecal coliforms was used for the first sample series. The standard fermentation tube procedure was followed in the second sample series. The validity of the fecal coliform analyses is questionable. The consistent values of zero for all tests may indicate errors in test procedure.

Table 13. Coliform bacteria results (MPN).

	Station 1		Station 2		Station 3		Station 4	
Date	total	fecal	total	fecal	total	fecal	total	fecal
1-14-70		0		0		0		0
1-21-70	91800	0	4900	0	1300	0	2300	0

DISCUSSION

The numbers derived by this study are intended for qualitative rather than quantitative usage. Relative magnitudes are represented. Although an attempt was made to monitor pumping rates, mechanical failures, air locking and sprinkler clogging were among the factors which inhibited quantitative exploration.

Runoff Samples

The total nitrogen relationship obtained from an analysis of the data (Table 6) indicated an average reduction of 85 percent between station 1 and station 2. Ammonia nitrogen decreased an average of 95 percent (Table 2) over the same 150 foot distance.

Increased nitrate nitrogen suggests that much of the ammonia nitrogen was oxidized as expected. Accumulated data show an increase in nitrate nitrogen of about 400 percent (Table 3) between the stations. Although nitrate nitrogen is extremely soluble it is likely that most, if not all, is chemically or physically bound, utilized by vegetation or lost by denitrification prior to reaching Oak Creek. Nitrate nitrogen was rarely detectable at the control stations.

Values of ammonia nitrogen as well as total organic nitrogen for station 2 approximated those of the control samples (stations 3 and 4). Nitrite nitrogen values were similar at all four stations.

Phosphorus reductions were as expected and in agreement with the literature. Eighty to 90 percent of the ortho and total phosphorus was "fixed" between the two stations (Tables 7 and 8).

In nearly all cases the nutrient concentration at station two was nearer that of the two control stations than to that of the freshly-applied waste at station one.

No fecal coliforms were detected and the BOD analyses indicated significant oxidation of the organic matter over the 150 feet traveled (Tables 10 and 13). The dilution factor as well as possible antibiotic residuals add possible sources of error to the BOD values.

It should be noted that some of the reductions of the various parameters may have occurred as a result of dilution by rainfall. Rainfall should, however, have had nearly the same effect upon all stations.

Oak Creek Samples

Samples were taken from Oak Creek for the purpose of determining, if possible, any change in nutrient concentration due to swine waste irrigation. The major problem encountered was the spray irrigation of dairybarn wastes directly across the creek. It was thought that some method of differentiating the contributions of each might be devised if a significant change was found. Results of sample analysis are listed in Table 14.

Table 14. Oak Creek data.

Sample	Date	Flow (cfs)	TKN (mg/l)	NO_2-N (mg/l)	NO_3N (mg/l)	NH_3-N (mg/l)	ORT-P (mg/l)	TOT-P (mg/l)
A	*7-14-69	0.5			0.40	0.14	0.10	0.13
C	*7-14-69	0.5			0.70	0.27	0.19	0.76
A	11-18-71	3.5	0.5	0.01	0.11	0.04	0.08	
B	11-18-71	3.5	0.6	0.01	0.17	0.03	0.08	
C	11-18-71	3.5	0.6	0.01	0.26	0.03	0.08	

*1969 data extracted from reference 61.

Sample Code:

A Directly above swine and dairy irrigation.
B Directly below swine and dairy irrigation.
C One mile below (Parker Stadium) swine and dairy irrigation.

Due to the small change across this area only one other sample was taken. It represented winter conditions when, due to soil saturation, maximum runoff should occur. Analysis of the second set of samples indicated even less change in nutrient concentration through the area. It is also interesting to note that the difference between the 1971 results of samples B and C is greater than that of A and B. This indicates that a portion of the increase in nutrients of the 1969 samples could conceivably be due to activities below the swine area (below sample B).

CONCLUSIONS

As a result of this research study, the following conclusions are made:

1. It is improbable that the spray irrigation system contributes to the nutrient content of Oak Creek.
2. In nearly all cases the nutrient concentration at station 2 was nearer that of the two control stations (3 and 4) than to that of the freshly applied waste at station 1.
3. The applied liquid waste for the most part was absorbed by the soil prior to reaching station 2 (150 feet down slope from the nozzles). Only prolonged high-intensity rainfall, in addition to spraying, would cause liquid accumulation behind dam number two (station 2). The only agent causing a reservoir at stations 3 and 4 was rainfall.
4. The soil does not appear to be overloaded since the pasture cover crop flourishes. During the rainy season the grass within the "throw" of the sprinklers is higher than that in the surrounding area, while in summer the same grass is shorter and appears burned. Although growth is somewhat inhibited during the dry season, application of toxic or inhibitory matter has not been great enough to destroy the grass or cause cattle to reject it for grazing.

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