NUTRIENT COMPOSITION OF KANSAS SWINE LAGOONS AND HOOP BARN MANURE [1]

J. D. DeRouchey, R. D. Goodband, J. L. Nelssen, M. D. Tokach, S. S. Dritz [2], and J. P. Murphy [3]

Summary

A total of 236 lagoon and 35 hoop barn manure samples were collected during 2000 from Kansas swine operations to determine the effects of production phase and season of the year on their nutrient concentration. Lagoon analyses revealed that nitrogen concentrations were lower during the summer and fall seasons compared to winter and early spring. In addition, levels of nitrogen were highest in nursery, wean to finish, and finishing lagoons compared with sow and farrow-to-finish lagoons. Phosphorus levels for all lagoons increased from February until June, but then declined steadily throughout the remainder of the year. The concentration of phosphorus also was highest for wean-to-finish and finishing lagoons and the lowest for farrow-to-finish lagoons. No seasonal changes in nitrogen and phosphorus concentrations were observed in manure from hoop barns. Therefore, season and type of production phase affects the nutrient content of Kansas swine lagoons, and producers will benefit from obtaining individual analyses from their lagoons when developing nutrient management plans rather than utilizing published reference values.

(Key Words: Pig, Lagoon, Hoop Barn.)

Introduction

Environmental stewardship by livestock producers throughout the world has become an emerging issue to help preserve and maintain the environment. To ensure proper management of livestock waste, nutrient profiles of various forms and types of manure have been established to help livestock operators accurately apply manure to land. This practice allows crops or forages to utilize the nutrients from the manure thereby decreasing the need for chemical fertilizers. Thus, accurate and detailed nutrient profiles must be obtained to correctly distribute manure so that a deficiency or excess of a given nutrient does not occur. Currently, many sources of nutrient reference values are available to provide average concentrations of various types of manure from different livestock species. Published values are a source of information that producers can use to determine the amount of land needed for manure application or for comparison to their on-farm manure analysis. However, these reference values represent manure samples from across the United States and are from samples compiled during the past two decades. The majority of these published values may not reflect manure nutrient profiles from Kansas swine operations from the recent changes in management practices (phase feeding, use of phytase, reduced particle size) or differences in nutrient concentrations associated with different types of production phases or manure handling systems. In addition, published values do not account for differences that may occur with the season of the year, which may lead to a misrepresentation of the actual nutrient profile for producers. Therefore, it was our objective to determine the effects of produc-

[1]The authors would like to thank KCARE for partial funding of this project.
[2]Food Animal Health and Management Center.
[3]Department of Biological and Agricultural Engineering.

tion phase and season of the year on nutrient concentration of swine lagoons and hoop barn manure from Kansas swine operations.

Procedures

Lagoons. Samples from five different types of production systems were taken six times over the year 2000 to determine changes in nutrient and mineral concentrations. The different operations were classified as: 1) sow; 2) nursery; 3) wean to finish; 4) finish; and 5) farrow to finish, with a total of 9, 8, 7, 10, and 8 lagoons sampled from each phase of production, respectively. Our classification was based on the type of facility sending effluent into the lagoon. The lagoons used collected waste from only gestation and farrowing facilities (sow), from only nursery facilities (nursery), from only nursery and finishing facilities (wean to finish), from only finishing facilities (finishing), or from combined gestation, farrowing, nursery and finishing facilities (farrow-to-finish). Lagoons were sampled in February, April, June, August, October, and December.

The lagoons used were in different geographic locations across Kansas. Because our goal was to develop average nutrient concentrations from lagoons within a classification, we did not distinguish between waste handling systems within a classification.

We provided an on-farm demonstration of the technique used to sample lagoons. Thus, all swine operations had employees that were trained in proper sampling technique. In addition, all participants collected samples at a uniform time (2nd Tuesday of the month sampled). For collecting samples from lagoons, we designed and constructed a sampler that was distributed to all participants in the project. The sampler contained two separate pieces of 1 inch PVC pipe. First, a 6 inch piece was capped at one end, filled to volume with sand, and attached via a ½ inch threaded solid-centered coupler to the second piece of pipe, which was 12 inches in length (Figure 1). This portion held the liquid from the lagoon during collection. In addition, a 1 inch threaded screw cap was attached to the top of the 12 inch pipe, with five 11/32 inch holes drilled into the cap to allow liquid to enter the pipe once it was submerged in the lagoon. A 40 ft nylon rope was attached via a galvanized metal clamp just below the screw cap. Positioning the rope in this manner was to prevent loss of the liquid once it was retrieved from the lagoon. The sampler was weighted with sand so that it would sink approximately 6 to 8 ft before being filled to volume of liquid. Four samples were taken from different locations throughout each lagoon and combined. The combined samples were then thoroughly mixed and sub-sampled for chemical analysis. No samples were taken within 40 ft of any inlet pipes entering the lagoon from the production facilities. All samples were shipped to the laboratory the same day in which they were taken.

Hoop Barns. Samples from six hoop barn sites were collected at the same time as lagoons. All manure from the production sites used in this study originated from growing and/or finishing pigs. A least 5 samples were collected approximately 18 inches from the outside of the manure pile to reduce the incidence of weather effects. The samples were combined and mailed to the laboratory on the day of collection for analysis. The manure piles sampled throughout the year ranged from newly removed manure from the hoop barn to manure piles that had been stored for more then one year.

Sample Analysis. All manure samples were analyzed at Platte Valley Laboratories, Inc., Gibbon, NE through AOAC procedures. All lagoon and hoop barn samples were analyzed for nitrate, ammonium, and total nitrogen. Organic nitrogen was calculated by subtracting ammonium and nitrate nitrogen from the total nitrogen. In addition, concentrations of phosphorus, potassium, calcium, sodium, chloride, magnesium, sulfur, copper, zinc, iron, and manganese were analyzed. Phosphate and potash were calculated from the concentrations of phosphorus and potassium, respectively. In addition, percentage solids, pH, and electrical conductivity were measured. Carbonate and bicarbonate concentrations also were measured on lagoon samples, but not hoop barn samples.

Statistical Analyses. Statistical analyses were performed using the MIXED procedures of SAS. Individual samples were used as the experimental unit, with month used as a repeated measure to determine seasonal difference. Orthogonal contrasts were used to determine linear and quadratic effects of nutrient concentrations from February to December. In addition, the least square means test was applied to determine statistical differences between production phases. No phase by month interactions occurred, thus main effects of production phase and month of analysis results are reported.

Results and Discussion

Lagoon Concentration by Production Phase. Nutrient concentrations from lagoons on wean-to-finish and finishing operations were higher for the majority of nutrients compared to sow and farrow-to-finish operations (Table 1). Samples from nursery lagoons usually had intermediate values; except for trace minerals, for which they had the highest concentrations.

For total nitrogen, lagoons from finishing and wean-to-finish facilities had greater concentrations ($P<0.05$) compared to sow and farrow-to-finish lagoons (Table 1). In addition, lagoons from sow and farrow-to-finish operations had approximately 39 and 48% less total nitrogen compared to nursery lagoons, respectively, although the differences were not significant ($P>0.05$). For ammonium nitrogen, farrow to finish lagoons had lower ($P<0.05$) levels than wean-to-finish and finishing lagoons. Furthermore, the level of nitrate nitrogen was less than 1 ppm for all production phases, thus indicating that concentrations of nitrates is low in the liquid portion sampled from the lagoons.

Phosphorus concentrations in farrow-to-finish lagoons were lower ($P<0.05$) by approximately 65% compared to lagoons from wean-to-finish operations (Table 1). Although not significantly different ($P>0.05$), phosphorus concentrations from nursery (223 ppm) and finishing (246 ppm) lagoons were higher while concentrations from sow farms had levels (141 ppm) below that of the overall average of 203 ppm for all samples. Phosphate levels followed an identical pattern as that of phosphorus, as it was calculated from the phosphorus levels. For potassium, sow lagoons contained lower ($P<0.05$) concentrations then wean-to-finish and finishing lagoons, while levels in nursery and farrow-to-finish lagoons were intermediate. Potash concentrations were calculated from the analyzed potassium concentrations, thus, differences followed the same pattern as potassium. Farrow-to-finish lagoons had lower ($P<0.05$) concentrations of calcium then nursery, wean-to-finish, and finishing lagoons, while sow lagoons had lower ($P<0.05$) levels then finishing lagoons. For sodium, no differences between phases of production were detected. However, sow lagoons had a lower concentration ($P<0.05$) of chloride and magnesium compared to wean-to-finish and finishing lagoons, with nursery and farrow-to-finish lagoons having intermediate concentrations. In addition, sulfur concentrations were dramatically reduced ($P<0.05$) in lagoons from sow and farrow-to-finish operations compared to the other three types of production phases.

For the trace minerals (copper, zinc, iron, and manganese), sow and farrow-to-finish lagoons had the lowest concentrations compared to the other production phases (Table 1). In addition, concentrations of all minor nutrients except manganese were the highest in nursery lagoons. For copper and iron concentrations, nursery lagoons had a higher level ($P<0.05$) compared to sow and farrow-to-finish lagoons. In addition, the zinc concentration in nursery lagoons was higher ($P<0.05$) then all other phases of production, being approximately 59% higher (40.7 vs. 16.8 ppm) than the combined mean of all phases. For manganese, sow and farrow-to-finish lagoons contained lower ($P<0.05$) concentrations compared to lagoons from the other three production phases.

Bicarbonate, which is an indicator of dissolved carbon dioxide when the pH of the sample is between 6.4 and 10.2, was significantly lower ($P<0.05$) for sow and farrow-to-finish lagoons compared to the other production phases (Table 1). However, the carbonate level was less than 1 ppm for all samples, which would be logical, as it is an indicator of dissolved carbon dioxide when the pH of the sample is over 10.2. Average pH values ranged from 7.7 to 7.8 for the samples from the different production phases. Electrical conductivity, which measures the ability of a substance to carry an electrical current and is directly correlated to the amount of dissolved salts in the sample was higher ($P<.05$) for wean-to-finish and finish lagoons compared with farrow-to–finish lagoons. The percentage of solids in the samples was higher ($P<0.05$) for wean-to-finish and finishing lagoons than sow and farrow-to-finish lagoons.

Differences in nutrient concentrations between production phases may be associated with different management, nutrition, and lagoon types associated with each phase. For the farrow-to-finish operations, many of the locations utilized both a primary and secondary lagoon system, or one large lagoon. Use of these types of lagoons may have resulted in decreased concentrations of nutrients, which would be correlated with the percentage solids, also reduced compared to nursery, wean-to-finish, and farrow-to-finish lagoons. In addition, sow lagoons were also typically lower in nutrient concentration than the other production phases, which may be because the breeding herds produce less manure per animal body weight than growing-finishing pigs. This would help explain the reduction in percentage solids with sow and farrow-to-finish lagoons compared to the other phases of production as well. Furthermore, as swine increase in age they become less efficient in the utilization of nutrients when fed ad libitum. This may help explain the increased level of nutrients found in wean-to-finish and finishing lagoons. Also, improper management (feeder adjustment) and nutrition (overformulation of diets) may have increased nutrient levels for these two production phases. Increased concentrations of certain trace minerals in nursery lagoons, especially for zinc and copper, would be associated with nutrition practices that use these minerals as growth promoters for pigs during this stage of growth. Finally, due to extreme variation among and within classifications, there were few significant differences ($P<0.05$) among classifications, although there were wide differences in mean values. The level of variation demonstrated in the lagoons in this study reemphasizes the importance of obtaining individual analysis from each lagoon before land application.

Lagoon Concentration by Season. Seasonal differences in the lagoon samples were determined for a large number of nutrients and other properties. Overall effects of season will be discussed (Table 2) as a uniform pattern was present for all nutrients, regardless of production phase (Tables 3 through 7).

For nitrogen characteristics, the amount of ammonium and total nitrogen concentrations decreased (linear, $P<0.05$) from February until December (Table 2). However, the largest decline occurred between June and August, with a moderate increase from October to December. In addition the concentration of organic nitrogen varied with season (quadratic, $P<0.05$) with the months of December and February having the lowest, while June and August had the highest levels. The decrease in nitrogen during the warmer season can be explained by an increase in activity of bacteria in lagoons during this time, which convert the nitrogen into ammonia that is volatilized.

Phosphorus and phosphate concentrations were influenced (quadratic, $P<0.05$) by season, with the highest levels occurring during June and August, and the lowest during February and December. Also, the concentrations of potassium, potash, and chloride increased (linear, $P<0.05$) during the year. A quadratic effect ($P<0.05$) for all other major (calcium, sodium, magnesium, and sulfur) and minor (copper, zinc, iron, and manganese) nutrients was demonstrated. This response was indicated by an increase in nutrient concentration during warmer months followed by a decrease in the cooler months, except for sodium, which had the opposite response. The concentration of bicarbonate (linear and quadratic, $P<0.05$), percentage solids (quadratic, $P<0.05$), pH (linear, $P<0.05$), and electrical conductivity (linear and quadratic, $P<.05$) was influenced by season.

The rise in nutrient levels during the summer months may be associated with the increased agitation of solid materials from the lagoon bottom caused by an increase bacteria level associated with warmer temperatures. Furthermore, less rainfall that is typically associated with the summer months may allow the lagoon to become more concentrated with nutrients. These theories would be supported by the fact that the percentage solids were highest during the warmer while lowest in the cooler months in this study.

Hoop Barn Manure Concentrations. All hoop barns sampled in this study housed growing-finishing pigs, therefore, no effects of production phase could be determined. However, seasonal alterations in manure were analyzed (Table 8.)

No seasonal differences (P>0.05) for nitrogen characteristics, phosphorus, potassium, calcium, magnesium, and sulfur were detected (Table 8). However, sodium (linear and quadratic, P<0.05) and chloride (linear, P<0.05) were influenced by season. For trace minerals, zinc and iron were not affected, but copper (quadratic, P<0.05) and manganese (linear, P<0.05) were influenced by season. Percentage solids, pH, and electrical conductivity were not affected by month of sampling.

Nutrient values for hoop barn manure that were determined in this study are the first to be published for Kansas. One striking observation from these results is the higher nutrient concentration associated with hoop barn manure compared to other published values of swine manure with bedding. However, the percentage solids for hoop barn manure is much higher compared to those values (57 vs. 18%), which would contribute to higher nutrient concentrations.

Table 1. Effects of Production Phase on Mean Nutrient Concentration of Kansas Swine Lagoons for 2000[a]

Item	Sow	Nursery	Wean to Finish	Finish	Farrow to Finish	SEM	Overall Mean
Number of samples	50	44	41	56	45		236
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	.33	< 1
Ammonium, NH_4^+-N	841[fg]	1,252[fg]	1,506[f]	1,469[f]	643[g]	250	1,142
Organic N[b]	125[h]	312[fg]	346[f]	351[f]	166[gh]	86	260
Total N	967[g]	1,563[fg]	1,852[f]	1,820[f]	810[g]	420	1,402
Major nutrients, ppm							
Phosphorus, P	141[fg]	223[fg]	302[f]	246[fg]	106[g]	80	204
Phosphate, P_2O_5[c]	320[fg]	503[fg]	686[f]	559[fg]	241[g]	185	462
Potassium, K	856[g]	1,351[fg]	1,750[f]	1,786[f]	1,125[fg]	432	1,374
Potash, K_2O[d]	1,030[g]	1,625[fg]	2,106[f]	2,150[f]	1,354[fg]	517	1,653
Calcium, Ca	225[gh]	463[fg]	465[fg]	500[f]	198[h]	120	370
Sodium, Na	284	282	437	439	281	90	345
Chloride, Cl	509[h]	647[fgh]	994[fg]	1,013[f]	671[fgh]	219	767
Magnesium, Mg	30[h]	89[fgh]	112[f]	97[fg]	43[gh]	30	74
Sulfur, S	30[g]	105[f]	110[f]	94[f]	36[g]	30	75
Copper, Cu	1.0[g]	6.1[f]	3.1[fg]	3.7[fg]	1.5[g]	1.6	3.1
Zinc, Zn	3.1[g]	40.7[f]	20.2[g]	16.2[g]	4.0[g]	9.7	16.8
Iron, Fe	14.8[gh]	58.0[f]	41.0[fg]	35.4[fgh]	10.7[h]	13.9	32.0
Manganese, Mn	1.3[g]	4.2[f]	4.4[f]	4.4[f]	1.2[g]	1.3	2.5
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	.1	< 1
Bicarbonate, HCO_3	4,840[g]	7,380[fg]	8,817[f]	9,199[f]	4,645[g]	1,830	6,976
Solids, %	0.5[g]	1.2[fg]	1.3[f]	1.3[f]	0.6[g]	.3	1.0
pH	7.8	7.7	7.8	7.8	7.7	.1	7.8
EC[e], mmho cm^{-1}	6.9[gh]	9.0[fgh]	9.5[f]	9.1[fg]	6.4[h]	1.3	8.1

[a]A total of 236 samples representing 42 lagoons sampled from February through December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}. [fgh]Means in same row with different superscripts differ (P<0.05).

Table 2. Effects of Season on Nutrient Concentration of Kansas Swine Lagoons for 2000[a]

Item	February	April	June	August	October	December
Number of samples	42	42	41	42	40	29
Nitrogen, ppm						
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N[f]	1,348	1,303	1,315	953	894	1,041
Organic N[bg]	223	275	321	286	255	201
Total N[f]	1,571	1,579	1,635	1,239	1,151	1,241
Major Nutrients, ppm						
Phosphorus, P[g]	152	199	287	240	212	131
Phosphate, P_2O_5[cg]	344	453	651	546	482	297
Potassium, K[f]	1,286	1,284	1,353	1,343	1,604	1,370
Potash, K_2O[df]	1,549	1,547	1,624	1,617	1,933	1,649
Calcium, Ca[g]	309	411	390	440	413	258
Sodium, Na[g]	393	305	318	321	391	339
Chloride, Cl[f]	754	647	774	784	891	748
Magnesium, Mg[g]	38	80	102	115	73	39
Sulfur, S[g]	46	85	95	99	77	47
Copper, Cu[g]	1.3	3.2	5.1	4.0	2.8	2.0
Zinc, Zn[g]	8.2	16.8	23.1	26.6	18.5	8.0
Iron, Fe[g]	18.0	30.4	40.9	55.5	34.3	12.9
Manganese, Mn[g]	1.6	3.1	4.7	4.5	3.3	1.4
Other Constituents						
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3[fg]	7,039	7,013	8,288	6,814	6,460	6,244
Solids, %[g]	0.8	1.0	1.2	1.1	1.1	0.8
pH[f]	7.7	7.5	7.8	7.7	7.9	7.9
EC[efg], mmho cm^{-1}	4.8	8.5	8.9	8.7	10.1	8.2

[a]A total of 236 samples representing 42 lagoons sampled from February through December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}. [f]Linear effect, ($P<0.05$). [g]Quadratic effect, ($P<0.05$).

Table 3. Effects of Season on Mean Nutrient Concentration of Kansas Sow Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	9	9	8	9	9	6	50
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	1,034	1,203	889	639	595	687	841
Organic N[b]	103	149	147	104	139	108	125
Total N	1,137	1,352	1,037	743	747	797	969
Major Nutrients, ppm							
Phosphorus, P	138	139	158	135	196	80	141
Phosphate, P_2O_5[c]	313	316	357	306	445	182	320
Potassium, K	867	861	892	855	951	707	856
Potash, K_2O[d]	1,044	1,037	1,070	1,029	1,146	851	1,030
Calcium, Ca	217	418	183	163	268	100	224
Sodium, Na	348	261	272	254	298	274	285
Chloride, Cl	476	429	524	554	576	497	509
Magnesium, Mg	20	32	34	33	50	13	19
Sulfur, S	23	47	35	22	44	8	30
Copper, Cu	0.3	1.2	2.0	0.5	1.0	1.0	1.0
Zinc, Zn	1.6	3.9	4.2	2.0	6.4	.7	3.1
Iron, Fe	11.6	20.0	23.0	13.4	18.3	2.6	14.8
Manganese, Mn	0.7	1.4	2.4	1.1	2.1	0.4	1.4
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	5,337	5,162	5,977	4,405	4,127	4,035	4,841
Solids, %	0.5	0.6	0.6	0.5	0.6	0.3	0.5
pH	7.7	7.6	7.8	7.7	7.9	8.0	7.8
EC[e], mmho cm^{-1}	4.5	7.4	7.6	7.1	7.9	6.7	6.9

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}.

Table 4. Effects of Season on Mean Nutrient Concentration of Kansas Nursery Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	8	8	8	8	7	5	44
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	1,356	1,370	1,449	1,143	1,117	1,077	1,252
Organic N[b]	226	307	342	520	294	186	312
Total N	1,582	1,676	1,791	1,664	1,409	1,257	1,563
Major Nutrients, ppm							
Phosphorus, P	145	217	257	396	250	67	223
Phosphate, P_2O_5[c]	328	492	582	899	569	151	503
Potassium, K	1,233	1,328	1,369	1,282	1,550	1,315	1,351
Potash, K_2O[d]	1,486	1,599	1,675	1,544	1,867	1,582	1,625
Calcium, Ca	317	410	431	875	562	183	463
Sodium, Na	328	262	257	263	308	274	282
Chloride, Cl	561	554	662	741	706	656	647
Magnesium, Mg	43	90	82	212	94	15	89
Sulfur, S	54	123	117	213	106	16	105
Copper, Cu	2.4	6.5	7.8	9.9	6.6	3.2	6.1
Zinc, Zn	16.2	41.0	41.5	85.7	51.1	8.9	40.7
Iron, Fe	22.0	50.0	54.7	152.5	59.8	9.1	58.0
Manganese, Mn	1.5	3.7	4.7	10.6	4.5	0.6	1.3
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	6,873	7,618	8,911	7,761	7,141	5,979	7,380
Solids, %	0.8	1.2	1.2	1.8	1.3	0.7	1.2
pH	7.5	7.4	7.8	7.8	7.9	7.9	7.7
EC[e], mmho cm^{-1}	4.8	9.5	9.8	9.2	11.0	9.6	9.0

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}.

Table 5. Effects of Season on Mean Nutrient Concentration of Kansas Wean-to-Finish Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	7	7	7	7	7	6	41
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	1,740	1,625	1,735	1,137	1,452	1,350	1,506
Organic N[b]	304	327	441	317	493	190	346
Total N	2,004	1,952	2,175	1,455	1,945	1,543	1,852
Major Nutrient, ppm							
Phosphorus, P	205	271	452	299	384	200	302
Phosphate, P_2O_5[c]	466	616	1,026	1,680	874	454	686
Potassium, K	1,513	1,575	1,703	1,688	2,152	1,866	1,750
Potash, K_2O[d]	1,823	1,898	2,043	2,033	2,592	2,245	2,106
Calcium, Ca	352	523	443	441	673	357	465
Sodium, Na	466	391	404	404	514	442	437
Chloride, Cl	954	845	1,012	949	1,234	968	994
Magnesium, Mg	51	133	166	143	123	57	112
Sulfur, S	68	103	140	115	137	99	110
Copper, Cu	1.4	3.0	3.9	3.4	4.1	2.5	3.1
Zinc, Zn	12.0	19.7	21.9	26.2	24.7	17.0	20.2
Iron, Fe	28.1	38.4	43.7	56.3	56.4	24.3	41.0
Manganese, Mn	2.4	4.5	6.0	5.0	6.2	2.4	4.4
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	8,578	8,732	10,607	7,973	9,576	7,440	8,817
Solids, %	1.0	1.2	1.6	1.3	1.7	1.2	1.3
pH	7.6	7.5	7.9	7.7	7.9	7.8	7.8
EC[e], mmho cm^{-1}	5.5	10.5	10.1	9.9	12.4	9.0	9.5

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}.

Table 6. Effects of Season on Mean Nutrient Concentration of Kansas Finishing Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	10	10	10	10	9	7	56
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	1,850	1,543	1,770	1,342	816	1,495	1,469
Organic N[b]	353	384	437	363	209	362	351
Total N	2,202	1,927	2,206	1,706	1,023	1,859	1,820
Major Nutrients, ppm							
Phosphorus, P	185	284	403	247	122	238	246
Phosphate, P_2O_5[c]	420	644	914	560	278	538	559
Potassium, K	1,790	1,700	1,753	1,651	1,949	1,877	1,786
Potash, K_2O[d]	2,156	2,048	2,103	1,987	2,348	2,259	2,150
Calcium, Ca	441	512	615	548	382	500	500
Sodium, Na	513	366	413	399	490	452	439
Chloride, Cl	1,053	909	1,038	954	1,094	1,033	1,013
Magnesium, Mg	48	106	168	125	57	77	97
Sulfur, S	70	103	130	108	61	95	94
Copper, Cu	1.8	3.5	7.0	4.8	2.0	3.0	3.7
Zinc, Zn	8.6	15.4	38.1	15.2	7.6	12.5	16.2
Iron, Fe	22.6	36.7	60.0	41.2	26.2	25.9	35.4
Manganese, Mn	2.6	5.0	7.2	5.0	3.0	3.7	4.4
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	9,597	9,148	10,862	9,514	6,810	9,265	9,199
Solids, %	1.2	1.4	1.7	1.3	1.0	1.3	1.3
pH	7.7	7.6	7.8	7.8	7.9	7.9	7.8
EC[e], mmho cm^{-1}	5.3	9.2	9.9	10.2	11.1	9.4	9.1

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P / .44). [d]Calculated (K_2O = K / .83). [e]Electrical Conductivity, mmho cm^{-1}.

Table 7. Effects of Season on Mean Nutrient Concentration of Kansas Farrow-to-Finish Lagoons[a]

Item	February	April	June	August	October	December	Mean
Number of samples	8	8	8	8	8	5	45
Nitrogen, ppm							
Nitrate, NO_3^--N	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Ammonium, NH_4^+-N	764	779	731	505	488	594	643
Organic N[b]	127	208	240	125	138	157	166
Total N	891	987	970	630	630	753	810
Major Nutrients, ppm							
Phosphorus, P	86	87	165	123	106	72	106
Phosphate, P_2O_5[c]	194	197	375	279	241	162	241
Potassium, K	1,024	957	1,023	1,238	1,422	1,086	1,125
Potash, K_2O[d]	1,234	1,153	1,228	1,490	1,713	1,308	1,354
Calcium, Ca	216	193	280	172	182	150	198
Sodium, Na	311	246	246	287	345	256	281
Chloride, Cl	726	499	639	721	850	590	671
Magnesium, Mg	30	37	58	61	40	30	43
Sulfur, S	18	49	53	39	41	20	36
Copper, Cu	0.5	1.8	4.8	1.2	0.5	0.2	1.5
Zinc, Zn	2.5	4.1	9.8	3.8	2.7	0.8	4.0
Iron, Fe	6.0	7.0	23.9	14.2	10.7	2.8	10.7
Manganese, Mn	0.6	1.1	3.3	1.1	1.0	0.4	1.2
Other Constituents							
Carbonate, CO_3	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Bicarbonate, HCO_3	4,813	4,402	5,085	4,421	4,648	4,504	4,645
Solids, %	0.5	0.6	0.8	0.7	0.7	0.6	0.6
pH	7.7	7.7	7.7	7.7	7.9	7.8	7.7
EC[e], mmho cm^{-1}	3.9	5.8	7.2	7.2	8.1	6.4	6.4

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}.

Table 8. Effects of Season on Mean Nutrient Concentration of Kansas Hoop Barn Manure[a]

Item	February	April	June	August	October	December	SEM	Mean
Number of samples	6	6	6	6	6	5		35
Nitrogen, ppm								
Nitrate, NO_3^--N	238	159	191	N/A	678	81	173	225
Ammonium, NH_4^+-N	1,695	2,067	1,706	1,634	2,315	2,601	518	2,003
Organic N[b]	6,078	6,075	8,155	7,131	4,910	6,238	896	6,431
Total N	7,850	8,377	10,128	8,841	7,904	8,966	1,177	8,678
Major Nutrients, ppm								
Phosphorus, P	4,194	3,677	3,786	4,963	4,710	4,851	645	4,364
Phosphate, P_2O_5[c]	9,532	8,357	8,595	11,265	10,703	11,003	1,467	9,908
Potassium, K	7,835	8,426	8,662	8,131	9,534	10,616	1,184	8,867
Potash, K_2O[d]	9,439	10,152	10,392	9,789	11,486	12,778	1,425	10,673
Calcium, Ca	46,279	29,764	36,569	36,625	52,254	60,564	10,554	43,676
Sodium, Na[fg]	2,117	1,248	1,225	1,096	1,347	1,361	235	1,398
Chloride, Cl[f]	2,123	2,134	1,208	2,798	3,096	3,215	376	2,429
Magnesium, Mg	3,315	2,669	2,886	3,323	3,428	3,639	325	3,210
Sulfur, S	1,491	1,674	1,854	1,268	1,607	1,490	230	1,564
Copper, Cu[g]	81	75	575	38	29	40	54	140
Zinc, Zn	157	177	157	215	159	220	31	181
Iron, Fe	4,128	5,635	2,873	5,129	5,087	6,544	1,243	4,899
Manganese, Mn[f]	196	219	216	232	265	289	39	236
Other Constituents								
Solids, %	51	55	60	47	57	69	6	57
pH	7.1	7.0	7.1	N/A	6.7	7.0	.3	7.0
EC[e], mmho cm^{-1}	5.4	7.2	7.1	N/A	9.5	6.1	.6	7.1

[a]Lagoons sampled from February to December. [b]Calculated (Organic N = Total N - NH_4^+-N - NO_3^--N). [c]Calculated (P_2O_5 = P/0.44). [d]Calculated (K_2O = K/0.83). [e]Electrical Conductivity, mmho cm^{-1}. [f]Linear effect, $P<0.05$. [g]Quadratic effect, $P<0.05$.

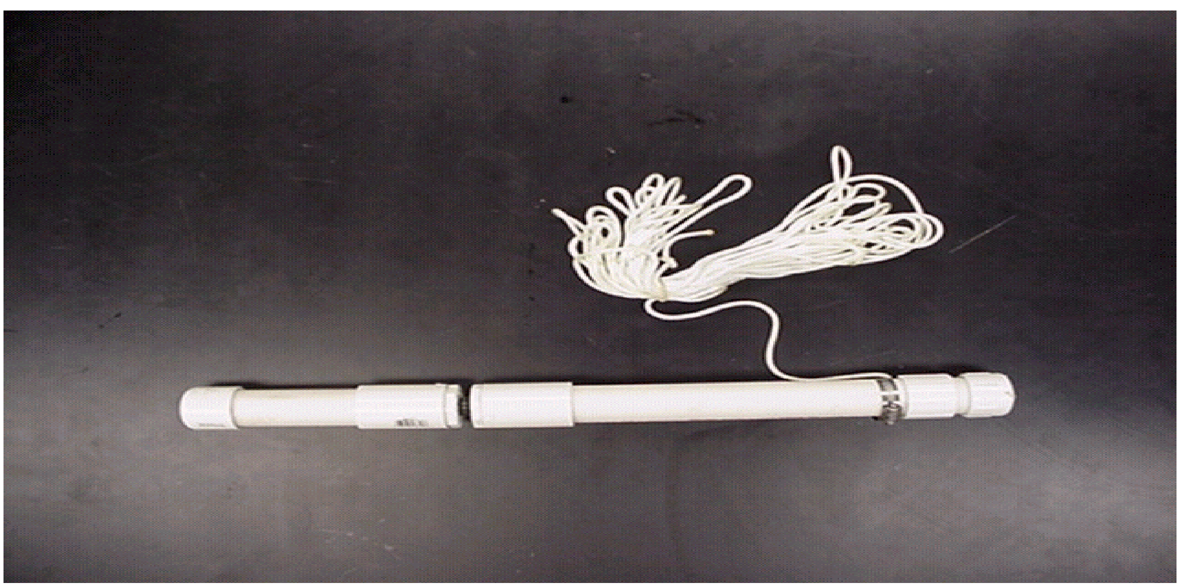

Figure 1. Lagoon Sampler.