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# Survey of Arkansas Swine Liquid Waste Systems

*Authors:*

Van Eps, M.A.; Formica, S.J.*; Kresse, T; Czarnomski, A.; VanSchaik, E.; Giese, J.

*Summary:*

The Arkansas Department of Pollution Control & Ecology (ADPC&E) recognized the potential for improperly managed swine liquid waste systems to become significant point and nonpoint sources of pollution. In an effort to evaluate the management of Arkansas swine liquid waste systems, the Environmental Preservation Division of the ADPC&E began sampling liquid waste storage structures. In the fall of 1997, with cooperation from the Arkansas Pork Producers Association (APPA), the ADPC&E surveyed 10% of the state swine facilities to characterize the liquid swine waste and to determine the extent of solids accumulation in the storage structures. Results from this project are being used to develop waste management strategies to minimize nonpoint source pollution and improve the fertilizer value associated with swine production activities in Arkansas. The project included two phases: (1) discrete sampling of waste storage structures at two swine facilities; one with a "maintained" liquid waste system and one with a "non-maintained" liquid waste system and (2) collecting composite samples of waste storage structures and assessing the waste management practices at 10% of the permitted swine facilities in Arkansas.

# Survey of Arkansas Swine Liquid Waste Systems

***M. Van Eps, S. Formica, T. Kresse, A. Czarnomski, E. Van Schaik, J. Giese, T. Morris***
Arkansas Department of Pollution Control & Ecology. Environmental Preservation Division.
8001 National Drive, Post Office Box 8913, Little Rock, AR 72219-8913

**Introduction**
The U.S. Environmental Protection Agency (EPA) reports that agricultural activity is the leading source of pollutants which threaten the water quality of rivers, streams, and lakes in the United States. Over time, nonpoint agricultural sources of nutrients, sediment, pesticides, and biochemical oxygen demand can render a body of water unable to support aquatic life, threatening entire ecosystems (EPA 1998). Storm water run-off from confined animal production activities have the potential to contribute significantly to nonpoint nutrient loading in the absence of adequate waste management practices.

The State of Arkansas ranks number 12 in the United States in pork production, yielding 2.1 million swine, annually. There are approximately 400 swine production facilities in the state with a 60/40 split between sow-pig and finishing operations, respectively. These facilities utilize liquid waste management systems, which are permitted by the Arkansas Department of Pollution Control & Ecology (ADPC&E) under Regulation No. 5, to handle their manure production. Regulation No. 5 provides management, operation, and maintenance procedures necessary to prevent point source pollution and minimize nonpoint source pollution to the waters of the state (ADPC&E 1992). Animal waste generated at swine facilities is handled in a similar manner at virtually all of the swine production facilities in Arkansas. Manure is flushed from the swine barns and stored in earthen ponds until it is applied as a fertilizer to pasture or crops. Generally, liquid waste systems in Arkansas are designed for waste storage and not for biological treatment, and require specific management practices in order to avoid becoming an environmental liability. Information is limited concerning the concentrations of nutrients and solids in liquid waste storage structures and the effects that waste management practices have on these concentrations. In order for the liquid swine waste to be properly utilized as a fertilizer, it is important to adequately characterize the waste generated at these facilities.

The ADPC&E recognized the potential for improperly managed swine liquid waste systems to become significant point and nonpoint sources of pollution. In an effort to evaluate the management of Arkansas swine liquid waste systems, the Environmental Preservation Division of the ADPC&E began sampling liquid waste storage structures. In the fall of 1997, with cooperation from the Arkansas Pork Producers Association (APPA), the ADPC&E surveyed 10% of the state swine facilities to characterize the liquid swine waste and to determine the extent of solids accumulation in the storage structures. Results from this project are being used to develop waste management strategies to minimize nonpoint source pollution and improve the fertilizer value associated with swine production activities in Arkansas. The project included two phases: (1) discrete sampling of waste storage structures at two swine facilities; one with a “maintained” liquid waste system and one with a “non-maintained” liquid waste system and (2) collecting composite samples from waste storage structures and assessing the waste management practices at 10% of the permitted swine facilities in Arkansas.

## Project Overview and Methodology

### Phase I

Phase I of the project involved discrete sampling of the liquid waste storage structures at two swine facilities to determine the relationships between the pond nutrient profile and waste management. Both swine facilities, Farm #5 and Farm #7, are 300 sow-pig farrowing operations, housing approximately 300 sows, each weighing 147 kg. Every two weeks, 250 weaner pigs each weighing 4.5 kg, are removed from the farms. Liquid waste management systems are used to handle the waste generated from these operations. Waste material is flushed from the barns to a two-pond waste storage unit which includes a settling basin and holding pond. Stratification naturally occurs in holding ponds creating a sludge layer on the pond bottom, which will be referred to as the "solids," and a dilute supernate layer on top, which will be referred to as the "grey water." Grey water from the holding ponds is pumped to flush tanks and then is used to flush waste from the barns by gravity flow. The stored liquid waste is periodically land applied to fescue and bermuda pastures. Historically, waste management practices at Farm #5 and Farm #7 were similar in that both systems were improperly maintained. Periodically, liquid waste was removed and land applied, but the liquid waste removed was mostly grey water. This practice resulted in excessive amounts of solids accumulating in the holding pond. After receiving assistance, Farm #5 began to completely remove solids from the settling basin and holding pond, annually, utilizing an agitator and pump. Farm #5 will be referred to as a "maintained" system. In contrast, Farm #7 continued to pump mostly grey water, never completely emptying the pond contents. Farm #7 will be referred to as a "non-maintained" system. Both facilities were in excess of 10 years old.

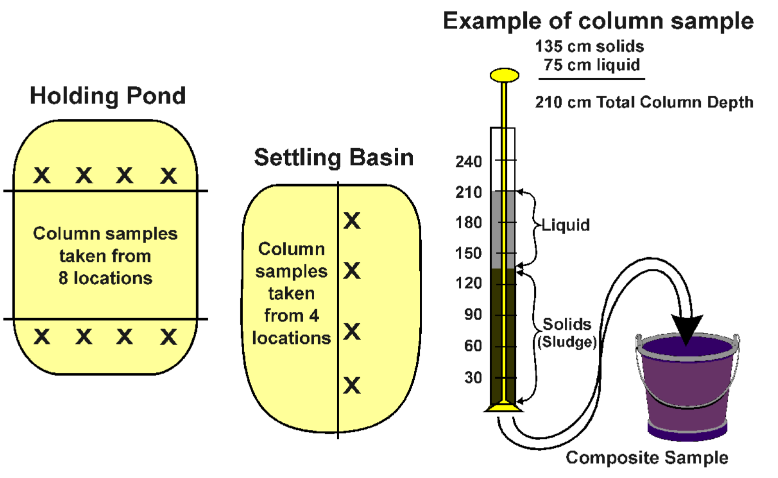
Discrete and composite samples were collected from the holding ponds, using a boat, at the maintained and non-maintained systems on June 24, 1997. Samples were analyzed for TKN, $NH_3$-N, $NO_3$-N, TP, Ortho-P, total solids, Cl, $SO_4$, and TOC using EPA-approved methods. A clear-column sampling device designed by a University of Arkansas Agricultural Engineering senior design team (Clift, et., al. 1997) was used to collect both discrete and column samples. Discrete samples were taken at 30 cm intervals throughout the water column in the center of the holding ponds. A composite sample was also taken from each holding pond by thoroughly mixing 4 column samples collected across the width of the pond. The sampling device was effective in the collection of all waste samples in the maintained system. Problems were encountered in the collection of both discrete samples and column samples when the compacted solids layer was encountered in the non-maintained system. A discrete sample could not be collected below a depth of 120 cm because the sampler could not penetrate the compacted solids at this point. Additionally, collection of the composite samples was increasingly hindered by the degree of compaction in the lower solids layer.

### Phase II

Phase II of the project included a comprehensive evaluation of 10% of the swine facilities with permitted liquid waste systems in the state of Arkansas to determine: (1) mass and concentration of nutrients and (2) the extent of solids accumulation in the liquid waste storage structures. Farms were visited from late October 1997 through early December 1997 and were selected in a random manner. Participating farms represented a cross section of swine production facilities in Arkansas with respect to liquid waste system designs, type of production facility, facility size, and geographic location. A total of 40 farms were evaluated of which 25 were sow-pig operations and 15 were finishing operations. The liquid waste systems were designed with either single holding pond or settling basin/holding pond storage structures. The average facility age was nine years. Site visits were made to each facility to conduct composite sampling of the holding pond and settling basin (when present), field measurements of the pond dimensions, and a waste management inquiry.

Phase II composite sampling procedures were developed based on previous swine waste pond sampling experience and the results of the phase I sampling event. Composite samples of the waste holding ponds and settling basins (when present) were collected, using a boat. The samples were analyzed for TKN, $NH_3$-N, $NO_3$-N, TP, Ortho-P, TDS, TSS, Cl, $SO_4$, and TOC using EPA-approved methods. Column samples of pond waste water were collected using a Coliwasa sampler, from a total of eight locations in the holding pond, and then emptied into a bucket (Figure 1). The column samples were taken along two passes across the width of the holding pond. The column samples were mixed thoroughly in a bucket, and then the composite sample mixture was placed in a sample bottle for analyses. The method for collecting a composite sample from a settling basin was the same as the holding pond, except only one pass across the length of the pond was made. The sampling device was constructed of clear plastic graduated with 2.5 cm increments and a plunger and rod to open and close the sampler. A modular design of the device allowed for adding the appropriate length of tubing depending on pond depth. The sampler could obtain column samples in ponds up to a maximum depth of 366 cm. The thickness of stratified solid and liquid layers along with waste water depth were recorded for each of the eight column samples. The Coliwasa sampler was much more effective than the University of Arkansas sampler utilized in phase I. The Coliwasa sampler penetrated the compacted solids layer more effectively, but it was still difficult to obtain the bottom 15 to 30 cm of solids in holding ponds with excessive solids accumulation. Other site information obtained and recorded during the farm visit was the waste system dimensions and the results from a waste management inquiry, which included information on waste system equipment, waste pond clean-out frequency, waste system operating cost, and facility age.

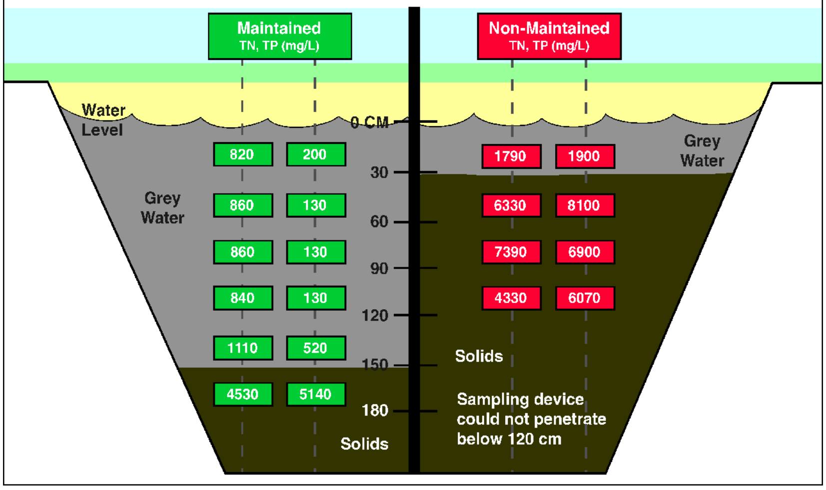
**Figure 1. Phase II Pond Sampling Method**




## Results and Discussion

The results from the phase I discrete sampling of two liquid waste holding ponds indicate a distinct difference in total nitrogen (TN) and total phosphorus (TP) concentrations associated with maintained and non-maintained systems (Figure 2). The TN was calculated by summing TKN and $NO_3$-N values. These waste systems contain less than 0.3% $NO_3$-N; therefore, TKN values are approximately equal to the TN. From 30 to 150 cm of the maintained holding pond profile (Farm #5), the average TN concentration was 898 mg/L and the average TP concentration was 221 mg/L. At 180 cm, these concentrations increased to 4530 mg/L for TN and 5140 mg/L for TP. This increase correlated with the appearance of solids observed in column samples taken in the field. Solids material was not observed in the discrete samples until 150 cm, where it was observed to be 95% grey water and 5% solids material. The discrete sample collected at 180 cm was observed to be 100% solids material. The total solids concentration at 180 cm was 50 times greater than the average concentration in the grey water and was 17 times greater than the sample collected at 150 cm. Based on the discrete sampling results and the field observations, it was estimated that accumulated solids occupied less than 20% of the pond design volume in the maintained holding pond.

**Figure 2. TN & TP Concentration Profiles in Maintained and Non-Maintained Holding Ponds**




The TN and TP concentrations of the non-maintained holding pond (Farm #7) were 1790 and 1900 mg/L, respectively, 30 cm from the pond surface. From 60 to 120 cm, these concentrations increased nearly 4 times for both TN and TP, with an average concentration of 6020 and 7030 mg/L, respectively. These results also correlated with the appearance of solids observed in column samples taken in the field. The discrete sample taken at 30 cm was observed to be 66% grey water and 34% solids material. Samples collected from 60 to 120 cm were observed to be 100% solids material. In the non-maintained pond, the decrease in concentrations of TN and TP at and below 90 cm is most likely inaccurate. Due to the difficulty encountered in penetrating the phase I column sampler into the increasingly compacted solids layer, it was difficult to obtain a representative discrete sample at or below these depths. Based on the discrete sampling results and the field observations, it was estimated that accumulated solids occupied over 75% of the pond design volume in the non-maintained holding pond. These results indicate that a lack of proper solids management in liquid waste systems results in excessive amounts of compacted solids in the holding pond and an accumulation of nutrients. Also, accumulated solids occupy the design storage volume reserved for the liquid waste generated at the facility, increasing the potential for discharges and improper application of liquid waste.

A comparison of the concentrations of nutrients and minerals in the discrete samples collected at 30 cm of the maintained and non-maintained holding pond are shown in Figure 3. The liquid waste at this level is representative of the recycle flush water used to flush swine waste from the barns. Ideally, the cleaner the flush water, the more effective it is in removing swine waste from the barns. The total solids concentration for the non-maintained holding pond was more than 7 times higher when compared to the maintained holding pond. Total solids concentrations were 4500 and 31,900 mg/L for the maintained and non-maintained holding ponds, respectively. The most significant difference in nutrient concentration is observed to occur with TP. Concentrations of TP were 197 mg/L and 1900 mg/L for the maintained and non-maintained holding ponds, respectively. The TN concentrations were 819 and 1790 mg/L in the maintained and non-maintained holding ponds, respectively. As such, the TP concentrations were approximately 10 times higher in the non-maintained holding pond when compared to the maintained pond, and TN concentrations were approximately 2 times higher. These results indicate that the accumulation of solids in the non-maintained system had decreased the quality of flush water needed for removing waste from the barns.

**Figure 3. Waste Strength of Discrete Samples Collected 30cm From the Surface of a Maintained and Non-Maintained Holding Pond**

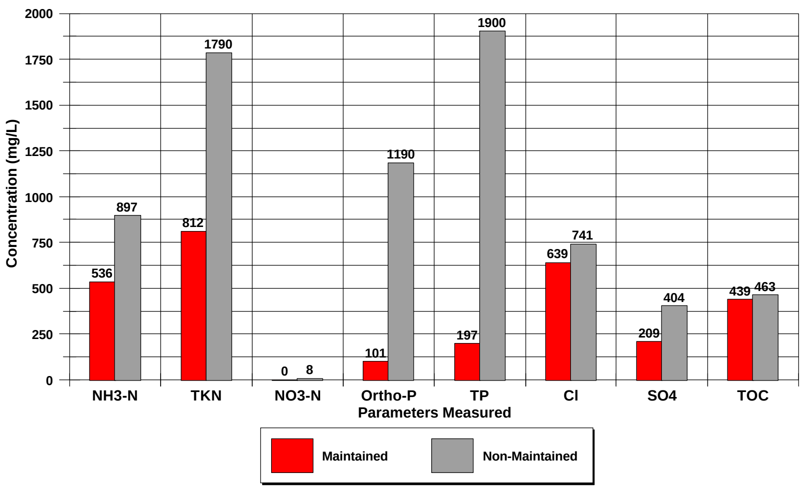
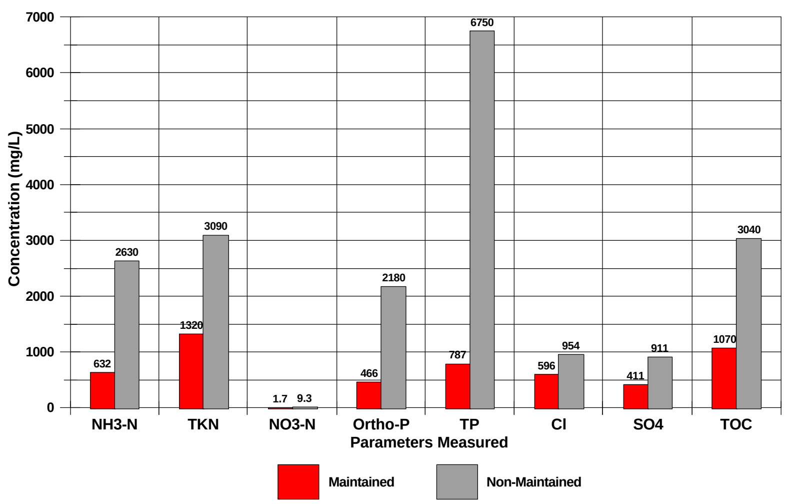


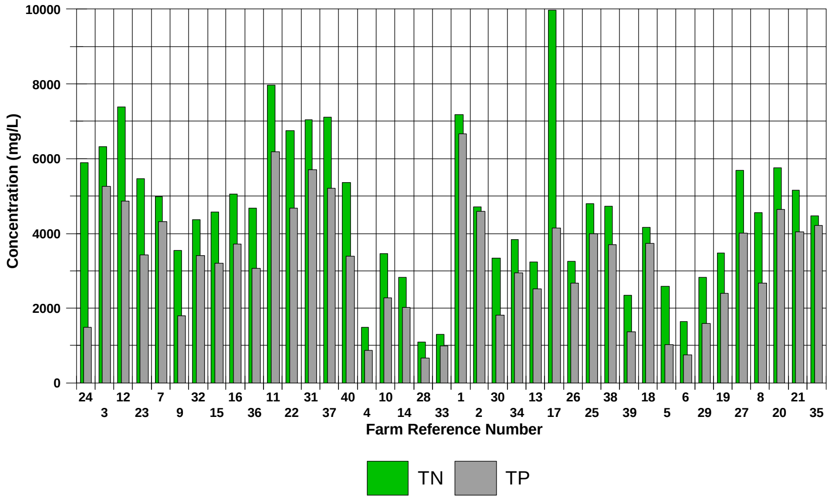

Figure 4 displays the results of the phase I composite samples collected from the maintained and non-maintained holding ponds, and reveals additional problems associated with improper liquid waste management. The concentrations of each parameter measured in the non-maintained holding pond are over 2 times greater than the maintained holding pond. The TKN and TP concentrations in the non-maintained holding pond are 2.4 and 8.6 times greater than the concentrations in the maintained holding pond, respectively. This suggests that as solids accumulate in these systems, nutrients also accumulate. It is interesting to note that the phosphorus accumulation is approximately 4 times greater than the nitrogen accumulation. This creates a greater imbalance between these two nutrients when utilizing liquid swine waste as a fertilizer. For many pasture forage crops grown in Arkansas, the USDA Natural Resources Conservation Service reports a nitrogen to phosphorus plant uptake rate of 10 to 1 (NRCS 1993). The ratio of nitrogen to phosphorus for the maintained holding pond was approximately 1.7 to 1, and for the non-maintained holding pond it was 0.5 to 1. The change in nutrient ratio increases the potential for transport of phosphorus to receiving bodies of water during storm events.

**Figure 4. Difference in Overall Waste Strength in Maintained and Non-Maintained Holding Ponds**



Concentrations of TN and TP which were determined from the analyses of composite samples collected from 40 holding ponds during phase II are shown in Figure 5. The TN concentrations of waste in holding ponds averaged 4630 mg/L with a range of 1100 to 9980 mg/L. The TP concentrations of waste in the holding ponds averaged 3280 mg/L with a range of 660 to 6670 mg/L. The Ortho-P concentrations were approximately 50 percent of the TP concentrations. The average nitrogen to phosphorus ratio for liquid swine waste in the holding ponds was 1 to 1 with a minimum ratio of 0.8 to 1 and a maximum ratio of 3 to 1.

**Figure 5. Concentrations of TN and TP Occurring in Phase II Composite Samples of Holding Ponds**

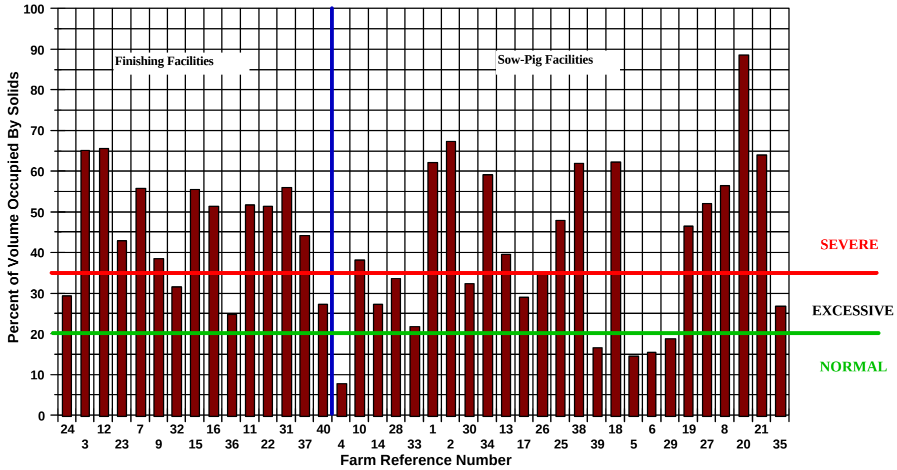



Of the 40 farms surveyed, 57% had liquid waste system designs in which liquid waste from the houses was piped to a settling basin prior to the holding pond. Settling basins should help to minimize solids accumulation in the holding ponds if solids are routinely removed from these basins. The TN concentrations in the settling basins averaged 5070 mg/L with a range of 2360 to 9980 mg/L. The TP concentrations in the settling basins averaged 3240 mg/L with a range of 775 to 6210 mg/L.

The average total mass of nitrogen present in the 40 liquid waste systems (holding pond only or holding pond/settling basin combination) was 2310 kg with a range of 504 to 6460 kg. The average total mass of phosphorus present in the liquid waste systems was 2790 kg with a range of 425 to 12,900 kg. Information on permitted land available for the application of liquid swine waste was only available for 37 of the 40 farms. Currently, in Arkansas land application rates for animal waste are based on the nitrogen plant uptake rate. Implementing a nitrogen based application rate, 47% of the facilities evaluated would have to find additional land for a complete waste system clean-out. The average projected nitrogen fertilizer value for these facilities was $6700 (U.S. dollars).

Samples collected from holding ponds and settling basins during the phase II survey of the 40 swine facilities in Arkansas indicated that the liquid waste systems were not being managed in a way to prevent the accumulation of solids. Figure 6 shows the degree of solids accumulation in the waste holding ponds. The “Farm Reference Number” on the horizontal axis is a random number assigned to each farm for identification purposes only. The “% solids accumulation” in the holding ponds is defined as the percent of the design pond volume occupied by the solids, which was estimated using the depth of solids observed in the column samples and the design holding pond volume. Holding pond volume occupied with solids averaged 43% with a range of 8 to 89%. Using the phase I results, solids accumulation ratings were developed and are shown in Figure 6. Between 0% and 20% solids accumulation in the holding pond was considered to be a liquid waste system with a “normal” level of solids; 12% of the holding

Figure 6. "% Solids Accumulation" in Sampled Holding Ponds of Phase II




ponds sampled were in this range. Between 20% and 40% solids accumulation in the holding pond was considered to be a liquid waste system with "excessive" solids accumulation; 36% of the holding ponds sampled were within this range. Between 40% and 100% solids accumulation in the holding pond was considered to be a liquid waste system with "severe" solids accumulation; 52% of the holding ponds sampled were within this range.

As shown in Table 1, average nutrient concentrations increased with a corresponding increase in the "% solids accumulation". Facilities with "excessive" ratings had approximately 2 times the total solids, TN, and TP concentrations as facilities with a "normal" rating. However, average TN concentrations for facilities with "severe" ratings only increased by 2.5 times the concentrations for facilities with a "normal" rating, while the TP increased by 3.7 times. Similar to the phase I sampling results, phosphorus accumulated at a higher rate in holding ponds than did nitrogen.

**Table 1.** Comparison of "% Solids Accumulation" with TN, TP, and Total Solids Concentrations

| "% Solids Accumulation" in Holding Ponds | Total Solids (mg/L) | Total Nitrogen (mg/L) | Total Phosphorus (mg/L) |
|---|---|---|---|
| 0% to 20% (normal) | 8250 | 2180 | 1120 |
| 20% to 40% (excessive) | 15,700 | 4190 | 2440 |
| 40% to 100% (severe) | 25,100 | 5390 | 4200 |

The following is a summary of the phase II waste management inquiry for the 40 farms surveyed:
1) 88% of the operators were not able to effectively remove solids from their liquid waste systems;
2) 50% of the operators utilized some form of agitation to enhance solids removal;
3) 48% of the operators with a two-pond liquid waste system completely removed solids from the settling basin on a routine basis;
4) none of the facilities had ever completely removed the contents of the holding pond;
5) the most common equipment used for waste removal from holding ponds was stationary irrigation sprinklers fed by diesel pumps through above ground interlocking piping; and
6) generally, operators were aware that solids were accumulating in their liquid waste system and were interested in incorporating waste management practices that would improve the storage capacity and minimize the effect their facility was having on the environment.

## Conclusions

Stratification of liquid swine waste naturally occurs in storage structures creating liquid and solid layers with distinctly different characteristics. The solids layer is more difficult to sample and has significantly higher nutrient concentrations when compared to the liquid layer. To obtain representative samples of liquid swine waste in storage structures, it is important to incorporate sampling methods that account for these two layers.

The lack of specific waste management practices for removal of solids from liquid swine waste storage structures can result in the following: (a) an accumulation of solid material, nitrogen, and phosphorus with the rate of phosphorus accumulation greater than nitrogen; and (b) a decrease in the quality of waste water available for recycle flush systems. Long term accumulation of solids in holding ponds designed for liquid waste storage results in a significant loss of the design storage volume. This situation becomes critical in winter months as land application of liquid animal waste is prohibited in the State of Arkansas during periods of freeze or times of ground saturation. Also, the loss of storage volume increases the potential for waste discharges.

Of the 40 swine facilities surveyed in this study, 52% were estimated to have a solids accumulation problem. Most facility operators had not incorporated effective management practices for the removal of solids, and were aware that solids were accumulating in their liquid waste systems. Facility operators expressed an interest in incorporating an effective solids management program and any practices that would reduce the impact their operation had on the environment.

Economical and practical solids management practices that are protective of the environment and optimize the fertilizer value of liquid swine waste need to be developed and incorporated into swine waste management. The results of this study were presented to swine farmers throughout Arkansas at the 1998 Regulation No. 5 liquid swine waste training sessions. Currently, the ADPC&E has obtained grant money to work with individual swine farmers, local conservation districts, and the APPA in addressing solids accumulation problems.

## References

Arkansas Department of Pollution Control & Ecology "Regulation No. 5: *Liquid Animal Waste Systems*," Little Rock, AR, 1992, 1 pp.

Clift, L.; Carver, S.; Neison, D.; Roper, J.; Wright, L.; and Cusher, A., "Lagoon Sampler," Design Project for course number 4813 "*Equipment Design for Biological Systems*," University of Arkansas, Department of Biological and Agricultural Engineering, Fayetteville, AR, 1997.

National Resources Conservation Service, "Agricultural Waste Management Filed Handbook," Washington, D.C., 1992, 6-20 pp.

U.S. Environmental Protection Agency, "1996 National Water Quality Inventory Report to Congress," Washington, D.C., 1998