# Removal of Solids and Major Plant Nutrients from Swine Manure Using a Screw Press Separator

J. P. Chastain, W. D. Lucas, J. E. Albrecht, J. C. Pardue, J. Adams III, K. P. Moore

**Abstract.** *A screw press separator was temporarily installed on a commercial swine farm in Horry County, South Carolina. The separator had a 0.5 mm screen and was operated with a single 40 kg weight on each pressure plate arm. Prediction equations were developed from the data to describe the removal of total solids (TS), total volatile solids (VS), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonium nitrogen ($NH_4$–N), organic nitrogen (organic–N), and total phosphorus (TP). Separated solids were analyzed to determine the percent total solids and the concentration of major plant nutrients. The concentration of total potassium (TK) in the separator influent and effluent was the same within measurement error. The removal of TS, VS, N, and P was found to vary significantly with the TS concentration of the influent manure. Therefore, building management and the methods used to implement the machine in the manure handling system would have a significant impact on separator performance. The prediction equations were used to calculate separator performance for a typical pit–recharge swine building based on observed characteristics on the cooperator's farm. The screw press would be capable of removing 14.9% of the TS, 19.6% of the VS, 34.9% of the COD, 9.2% of the TKN, 16.0% of the organic–N, and 14.8% of the TP from the manure added by housed swine.*

**Keywords.** *Manure, Liquid–solid separation, Nutrient management.*

Most swine production facilities in the United States, Canada, and Europe use liquid or slurry manure handling systems to facilitate the mechanization of collection, transfer, storage, and land application tasks. In cold climates, slurry swine manure is often stored until conditions are favorable for land application in lined earthen basins, below or above ground storage tanks, or in pits below slotted floors. In temperate and warm climates, it is common to treat and store swine manure in anaerobic or facultative lagoons. Liquid–solid separation has traditionally been viewed as a method to improve the pumping and irrigation characteristics of liquid manure, to generate solids for composting, and to use separated solids for refeeding (Lindley, 1982; Fedler et al., 1985; McClaskey, 1985).

Liquid–solid separation via gravity settling has been used extensively to reduce the solids content in feedlot runoff and flushed dairy manure. Mechanical separation techniques have been widely used with flush manure handling systems in dairy housing facilities. However, liquid–solid separation techniques have not been widely used in swine manure handling systems.

The odor generation potential from lagoons and storage structures has increased public concern over the use of liquid manure storage systems. Liquid–solid separation is not only being viewed as a method to improve the handling characteristics of manure, but as a method to reduce the volatile solid loading rate on lagoons, and as the first step in a swine manure treatment system.

An article by Zhang and Westerman (1997) reviewed the published data on gravity and mechanical liquid–solid separation techniques and the particle size distributions of animal manure. Their review concluded that the large particles in manure take a relatively long time to degrade and do not contribute greatly to odor production. However, the large particles do contribute to the accumulation of sludge in anaerobic lagoons. Over time, the sludge volume can decrease the treatment volume and cause excessive odors. Swine manure particles with an average diameter of 0.25 mm or less are the fastest to biologically degrade and must be removed with coarse particles to greatly reduce the odor generation potential of liquid swine manure.

Gravity settling of swine manure can remove as much as 60% of the total solids from swine manure (Lorimore et al., 1995). However, the separated solids have a high water content and must be handled as slurry. Zhang and

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Clemson University and Clemson University Extension does not endorse or recommend the FAN screw press over any other type of screw press separator that may be available.

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Westerman's (1997) literature review provided data on many types of mechanical separators including the stationary inclined screen, vibrating screen, rotary screen, belt press, and centrifuge. However, no published data was provided for a screw press. Very few of the mechanical separators reviewed produced swine solids that were dry enough to pile easily (20% TS or more). The vibrating screen operated with a 0.516–mm screen was reported to remove 27% of the total solids and produced solids with 20% dry matter. A centrifuge can be used to remove as much as 61% of the TS with a dry matter content ranging from 16 to 27%.

A screw press separator, loaned from FAN Separator®, USA, was used to process swine manure from feeder–to–finish buildings that had a pit–recharge manure handling system. The objectives of the study were to:

1. observe the variation in the total solids concentration (TS) in the manure as a recharge pit is emptied,
2. determine the amount of TS, VS, COD, N, P, and K removed by the screw press, and
3. measure the dry matter and major plant nutrient content of the separated solids.

# Experimental Methods

## Description of the Screw Press

A screw press separator is a machine that uses a large screw to force manure through a tube and past a cylindrical screen (fig. 1). A plug of manure solids is formed at the end of the tube and the flow of separated solids is controlled by a set of pressure plates. The resulting internal pressure within the tube forces the liquids out through the screen. The amount of force exerted by the pressure plates affects the moisture content of the separated solids and depends on the amount of weight that is suspended on the pressure plate arms. An appropriate amount of weight needs to be used to yield a desirable moisture content for the separated solids.

Swine manure is typically pumped from a reception pit to the intake of the separator as manure flows from the building. Therefore, the concentration of solids and plant nutrients in the separator influent would vary with respect to time. The flow through the screw press can range from 189 to 662 L/min depending on the solids content of the influent manure. The screw press throughput rate is slower for thicker slurries than thin slurries. The flow supplied to the press intake needs to be greater than the throughput rate to insure that the screw is always "biting" into a full pipe. Supply flow rates in the range of 470 to 750 L/min are typical. The excess flow bypasses the screw intake and is returned to the reception pit. A vertical vent pipe is provided at the influent port to facilitate gravity flow of the excess manure back to the reception pit and also limits the pressure at the intake of the screw.

The amount of solids that can be removed by a screw press depends on the particle size distribution in the manure, the screen opening size, screen length, and solids content of the influent manure. The screw press used in this study had the following specifications:

- the stainless steel cylindrical screen was 521 mm long
- the screen was made from wedge wire and had 0.5–mm wide slots that ran the entire length of the screen,
- a 4.0–kW three–phase motor was used to drive the stainless steel screw,
- the stainless steel screw turned at 36 rpm, and
- a single 40–kg counter weight was used on each of the pressure plate arms.

A 0.5–mm screen was used because this is the standard size provided by the manufacturer for swine manure. A 40–kg weight was used on each pressure plate arm because preliminary tests indicated that this amount of weight would yield separated solids with a moisture content that allowed them to stack easily in a conical pile.

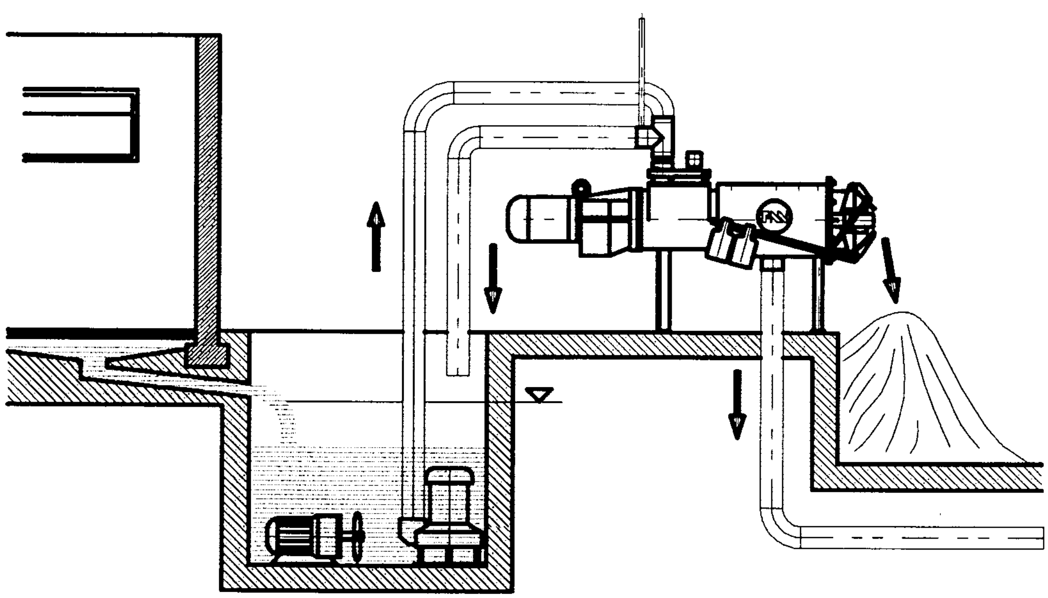

**Figure 1. Schematic of a typical screw press installation (illustration used with permission from FAN Separator®, USA).**

### Description of the Facilities

The buildings and manure management system on the farm used in this study was designed to accommodate 6400 grow–finish swine. Feeder pigs enter at an average mass of 23 kg and are marketed at an average mass of 104 kg. The average animal mass is about 64 kg. Eight buildings are used to house approximately 800 pigs each. Animal numbers varied from 728 to 824 per building during the study. Each building has a totally slotted floor and manure is collected and removed beneath the slotted floor using an adaptation of the gravity drain, pit–recharge system described by Barker and Driggers (1985).

A pit–recharge manure handling system consists of an under–floor pit with an average depth of 61 to 76 cm. The floor of the pit is sloped 1 cm/2.4 m toward a collection gutter that conveys manure to a drain that is located in a sump outside the building. The 203–mm OD drain is plugged using a removable standpipe made of PVC. A slot is cut in the side of the standpipe to control the liquid depth in the building. The level is set so that the highest part of the pit floor is covered by 76 to 152 mm of water. The pit is filled with recycled lagoon supernatant. After filling the pit, manure is allowed to accumulate in the pit for 6 to 12 days. The pit is emptied by pulling the standpipe and allowing the pit contents to drain to an anaerobic lagoon. The recharge pit volume below the floor of the buildings on the cooperator's farm was 162,772 L and is in the typical range.

### Sampling Methods to Observe the Variation in TS Content while Emptying a Pit–Recharge Building

Manure is allowed to collect in a recharge pit for 6 to 12 days prior to emptying. As a result, a large fraction of the manure solids settle to the bottom of the pit. When the pit is emptied the pit supernatant flows out of the building first and the majority of the manure solids are removed during the last half of the flow duration. As a result, the total solids content of the manure from a recharge pit varies significantly as the manure flows from the building. Therefore, the TS content of the manure pumped to the screw press would also vary with time.

The variation of the TS concentration in the effluent was observed for four pit–recharge grow–finish buildings to characterize the variability in the solids content of the manure that would be processed by the screw press. The four buildings that were selected contained swine with average masses of 25, 48, 88, and 95 kg. The manure was allowed to accumulate in the pit for 6 days for the buildings that contained the 88– and 95–kg animals and 12 days for the buildings that housed the 25– to 48–kg animals. The number of animals per building ranged from 728 to 824. The variation in TS was observed by collecting 500–mL manure samples at even time intervals as the manure flowed from the building. The samples were collected from the sump outside of the building and above the gravity drainpipe inlet. The time that each sample was collected and the total time required to empty the building was recorded. The samples were immediately placed on ice and were transported to Clemson University for laboratory analysis.

The TS concentration of each sample was determined using the standard oven drying method (APHA, 1992). The average flow rate for each building was calculated by dividing the recharge pit volume (162,722 L) by the total time required to empty the pit.

### Sampling Methods to Evaluate the Screw Press

The screw press was mounted temporarily on a stack of wooden palates. The discharge point of the screw press was about 1.5 m above the ground. Separated solids were collected in a plastic container that was placed on a trailer. The separator was fed with a gasoline–driven pump that was rated to provide a flow of 1,136 L/min. The manure was pumped from the external sump of the gravity drain to the top of the screw press through a 102–mm flexible hose. The excess flow was returned to the sump through a separate 102–mm flexible hose. The processed wastewater, or effluent, from the screw press was discharged down the PVC standpipe through a third flexible hose and flowed directly to the lagoon.

This simple arrangement presented several sampling difficulties. It was impossible to process all of the manure from the entire building since the low flow rate of the pump would not empty the pit fast enough to flush the thickest manure to the sump. Therefore, the sampling objective was to gather enough pairs of influent and effluent samples to describe the solids and major plant nutrient removal characteristics of the screw press for swine manure as a function of influent TS concentration. Consequently, obtaining a reliable pair of influent and effluent samples at the same time became paramount. The only way to obtain a valid pair of influent and effluent samples was to have one person collect a 500– to 750–mL sample of the influent from the discharge of the overflow hose, and another person collect a 500– to 750–mL sample from the effluent line of the separator.

The sampling procedure was initiated by pulling the standpipe out of the drain and allowing the pit to empty at the maximum flow rate for several minutes to flush solids into the sump. To take a sample, the gravity drain was sealed with the standpipe, and the flow was allowed to stabilize before a sample was taken to minimize the variation in the characteristics of the manure being fed the screw press. After a pair of influent and effluent samples was taken they were poured rapidly and completely into clean, pre–labeled plastic bottles and were stored on ice. The standpipe was removed again to allow additional manure to flow from the building and discharge into the lagoon. When it was time to collect another sample, the drain was closed, the flow was allowed to stabilize, and another set of samples was collected. This procedure was continued until the manure depth in the sump was too shallow for the pump to maintain prime. This sampling procedure required a minimum of three people.

Sampling directly from the drain sump worked well for obtaining samples with TS less than 30 g/L. However, the majority of the manure solids in the building settle to the bottom of the pit. Therefore, the final slurry that contained the majority of the solids was very difficult to pump to the screw press because the depth of the slurry was too shallow at times to maintain prime on the pump.

A 5,670–L tank type manure spreader was used to prepare a large sample of slurry from the settled layer in the recharge pit. The slurry was allowed to settle for 30 min, and the supernatant was pumped off and discharged to the lagoon. This process was repeated until the tank was 75 to 80% full of slurry. The manure wagon was then positioned next to the screw press and the slurry was processed. The overflow hose from the screw press was directed back to the tank and was used as the sampling point for the influent. Effluent was discharged to the lagoon through the standpipe. This sampling technique required a minimum of three people and was typically performed with four or more individuals assisting. Influent samples ranging in solids contents of 30 to 70 g/L were obtained in this manner.

A total of 20 pairs of influent and effluent samples were obtained from two pit–recharge buildings over a period of four days using the defined procedures for five pit emptyings. The influent TS concentration varied from 8.6 to 70.6 g/L (0.86 to 7.06% TS).

### Quantities Measured

The following variables were measured for each pair of influent and effluent samples: total solids (TS), total volatile solids (VS), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonium nitrogen ($NH_4$–N), total phosphorus (TP), and total potassium (TK). Organic nitrogen (organic–N) is the difference between TKN and $NH_4$–N. Plant nutrient analyses were provided by the Agricultural Service Laboratory at Clemson University.

The samples were analyzed for TS, VS, and COD in the Agricultural, Chemical, and Biological Research Laboratory in the Department of Agricultural and Biological Engineering at Clemson University. The total and volatile solids were determined for each influent and effluent pair as the average of two subsamples using standard oven drying and furnace incineration techniques (APHA, 1992). The chemical oxygen demand was measured using the closed reflux colorimetric method (APHA, 1992). Two well–mixed subsamples were sealed in glass ampoules and oxygen was consumed and was compared to standards at 600 nm generated with a spectrophotometer.

Nine bags of separated solids were collected as they fell from the screw press. The plastic bags were sealed and stored on ice immediately. The samples were analyzed to determine TS, TKN, $NH_4$–N, organic–N, TP, and TK.

## Results and Discussion

### Variation in Solids Content of Manure as a Pit–Recharge Building is Emptied

After filling the pit, manure is generally allowed to accumulate for 7 to 10 days. When the pigs are small, 25 kg, it is not uncommon for manure to be allowed to collect for 8 to 12 days. The amount of time required for the pit to drain depends on the size of the drainpipe, length of the pipe to the lagoon, number of elbows in the plumbing, and the number of drains. A single drain was used for all buildings on the cooperator's farm.

The total time required to empty the pit below four different buildings ranged from 40 to 80 min and was normalized as indicated in figure 2. Variations in the drain design and differences in total friction loss due to variable pipe lengths and numbers of elbows were believed to be the reason for this variation.

The average total solids concentration (TS) ranged from 15.4 to 23.3 g/L. The variation in average TS was due to

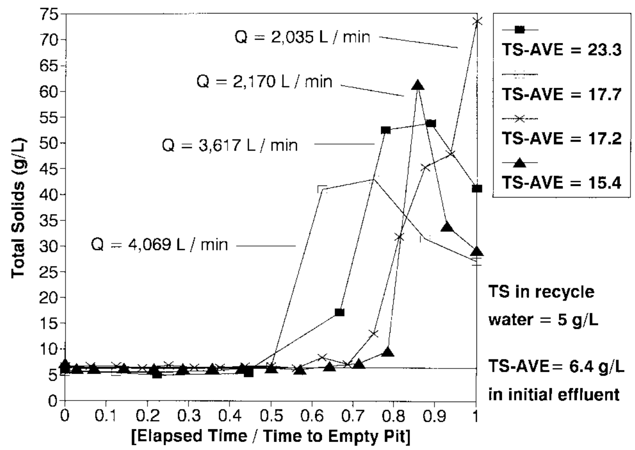


**Figure 2. Variation in total solids concentration in manure as four recharge pits was emptied (TS–AVE = average total solids concentration in the pit).**

variations in pig weight from 25 to 95 kg and manure accumulation periods of 6 to 12 days. The average flow (Q) was estimated based on the pit volume and the time required to empty the pit and ranged from 2037 to 4069 L/min.

The most important observations from the data shown in figure 2 are listed below.

- The average flow rate (Q) determined the point at which a significant discharge of solids began. At the highest value of Q (4069 L/min) a significant increase in solids, as indicated by a sharp increase in TS, occurred after 50% of the total time needed to empty the pit had elapsed. At the lowest flow rates, the majority of the solids were removed after 70 to 75% of the time required to empty the pit had elapsed. Most of the solids flowed out of the building in a wave that lasted a short period of time. Except for the slowest flow (Q = 2035 L/min), the TS concentration decreased after the wave of solids flowed out of the building. These data indicate that the majority of the solids in the pit occupied 20 to 25% of the total volume. It should be noted that the flow of manure is not constant, but depends on the height of the liquid in the pit. The initial flow is higher than Q and the final value is lower than Q.
- As the majority of the solids flow from the pit the TS concentration ranged from 13 to 73 g/L. The largest peak TS concentrations were associated with the lowest flows.
- The recharge pit served as a gravity–settling basin, and provided a means to determine the amount of solids settled in the pit. The initial flow of wastewater was the supernatant and had an average TS concentration of 6.4 g/L with a standard deviation of 0.838 g/L (n = 35) for all four cases. The fraction of solids settled in the recharge pit was calculated from the average TS concentration in the pit and the TS of the supernatant as $(TS_{AVE} - 6.4)/TS_{AVE}$. The fraction of the TS that settled in the pit ranged from 0.58 at a $TS_{AVE}$ of 15.4 g/L to 0.72 at a $TS_{AVE}$ of 23.3 g/L.
- The TS concentration of the recycled lagoon water that was used to fill the recharge pit was measured and was found to be 5.0 g/L. Therefore, 78% of the TS in the super-

natant of the recharge pits was from the recycled lagoon supernatant.

### Removal of Total and Volatile Solids

The amount of total solids removed by the screw press varied greatly with the influent TS concentration as shown in figure 3. A high level of correlation existed between the reduction in total solids (influent – effluent) and the influent TS concentrations. The following equation provided the best fit of the data ($r^2$ = 0.9549, $s_{y \cdot x}$ = 1.5520):

$$TSR = 0.113 - 0.05708\ TS_{IN} + 0.00423\ TS_{IN}^2 \quad (1)$$

where
TSR = total solids removed (g/L)
$TS_{IN}$ = influent total solids (g/L)

Using equation 1 it was determined that the screw press did not remove a significant amount of solids at influent concentrations less than 11.1 g/L (1.11% TS). Therefore, for all future calculations TSR was taken to be zero at $TS_{IN}$ = 11.1 g/L. As the influent concentration of solids increased above 11.1 the removal of TS increased in a parabolic manner. Obviously, the larger influent solid concentrations had a larger number of particles that were greater than the screen slot size of 0.5 mm. In addition, as the screw press was loaded with manure containing a large TS concentration, a fraction of the solids smaller than 0.5 mm were trapped in the plug as it was conveyed past the screen.

The volatile solids concentration in the influent and effluent correlated well with the total solids concentration as indicated in figure 4. The slope of the regression equations for the influent and effluent samples were not significantly different based on confidence intervals computed from the ANOVA about the regression lines (Younger, 1979). Therefore, the influent and effluent data were pooled. Linear regression of the pooled data with a computed intercept provided a coefficient of determination ($r^2$) of 0.9950. However, it is physically impossible for VS to have a value at TS = 0. Therefore, the line was forced through the origin. The value of $r^2$ was reduced to 0.9881 with a standard error of the y–estimate ($s_{y \cdot x}$) of 1.5707. The regression equation that is to be used for prediction is:

$$VS = 0.687\ TS \quad (2)$$

The slope of equation 2 indicates that on the average the volatile solids constitute 68.7% of the total solids. Based on ASAE D384.1 (1998), 77.3% of the total solids in fresh swine manure are volatile. On the average, the amount of volatile solids removed from the pit–recharge buildings was 11% lower than the value recommended for fresh manure. This difference is greater than one standard deviation as provided by the ASAE data. It is believed that this magnitude of VS reduction can be explained by anaerobic decomposition in the recharge pit over a period of 6 to 12 days and differences in feed formulations.

The reduction in VS concentration (VSR) was found to correlate well with the influent total solids concentration and followed a similar parabolic pattern as observed for the total solids. The prediction equation for VSR is ($r^2$ = 0.9732, $s_{y \cdot x}$ = 1.0667):

$$VSR = 0.227 - 0.0564\ TS_{IN} + 0.00387\ TS_{IN}^2 \quad (3)$$

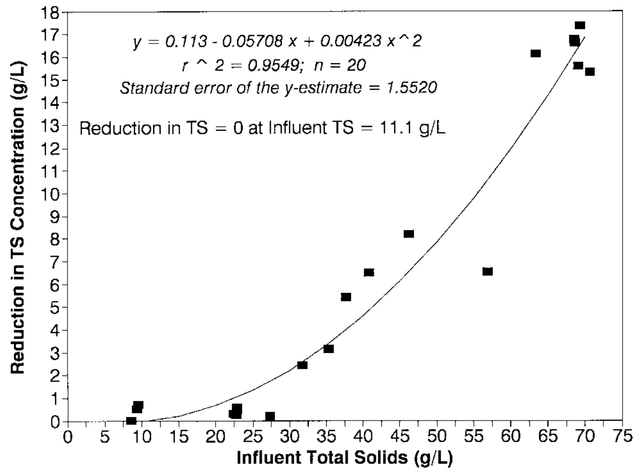


**Figure 3. Total solids removed from swine manure by the screw press.**

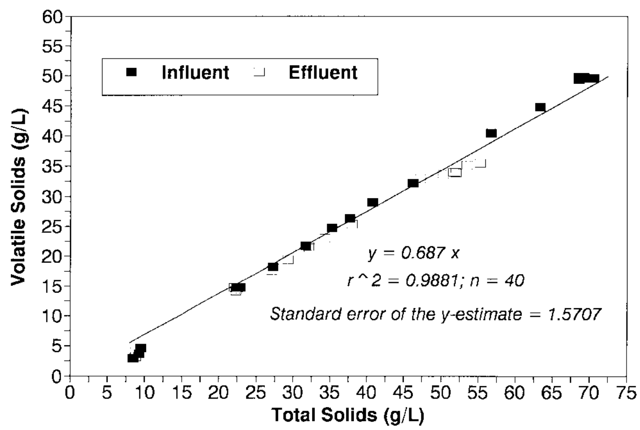


**Figure 4. Variation in volatile solids concentration in the separator influent and effluent.**

where VSR = volatile solids removed (g/L).

Equations 1 through 3 were used to calculate the percentage of total and volatile solids removed by the screw press (using $TS_{IN}$ and $VS_{IN}$ in the appropriate denominator) and the results are shown in figure 5. The removal of TS varied from 0% at $TS_{IN}$ = 11.1 g/L to 24% at 70 g/L. The percentage of VS removed varied from 1 to 31.7%. These results clearly indicate that the best TS and VS removal was obtained for thicker slurries. Furthermore, the screw press was more effective at removing volatile solids than total solids.

### COD Removal

The COD concentrations in the influent and effluent were also described by a common regression equation as shown in figure 6. However, the scatter in the data was greater since COD is more difficult to measure. The prediction equation COD is ($r^2$ = 0.765, $s_{y \cdot x}$ = 9.012):

$$COD = 0.811\ TS \quad (4)$$

The other useful relationship that can be developed from the data is the correlation between the effluent and influent

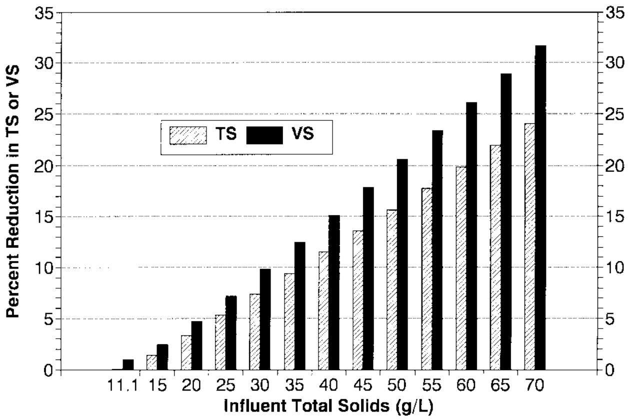


**Figure 5. Percentage of total (TS) and volatile (VS) solids removed by the screw press.**

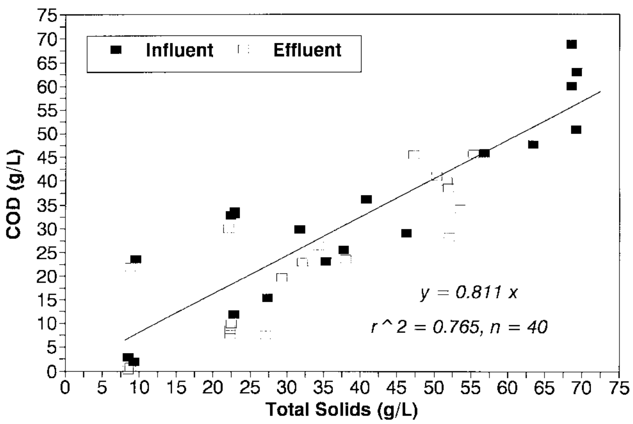


**Figure 6. Variation in chemical oxygen demand (COD) in the separator influent and effluent.**

values of COD. The prediction equation for $COD_{OUT}$ is ($r^2$= 0.714, $s_{y \cdot x}$ = 7.714):

$$COD_{OUT} = 0.651\ COD_{IN}. \qquad (5)$$

Equation 5 can be used to show that, on the average, the screw press removed 34.9% of the COD regardless of the influent concentration of COD ([1 – .651] × 100 = 34.9%).

### Removal of Major Plant Nutrients

The concentration of nitrogen and phosphorous was expected to correlate significantly with respect to the total solids content as demonstrated by Chescheir et al. (1985). Significant linear correlations were found for TKN, $NH_4$ – N, organic–N, and TP with respect to TS for both the influent and effluent samples. Confidence intervals were calculated for the coefficient and y–intercept for each equation using the techniques given by Steel and Torrie (1980) and Younger (1979). The coefficients and y–intercepts for the regression equations were not significantly different for the influent and effluent samples as demonstrated for organic–N in figure 7.

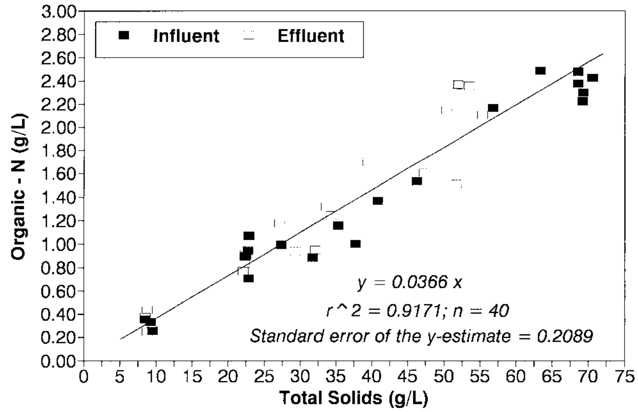


**Figure 7. Variation in organic nitrogen in the separator influent and effluent with respect to TS.**

This result indicates that the change in plant nutrient concentration across the separator was a function of the solids removal alone. Therefore, all 40 observations were pooled and the resulting regression equations and relevant statistics are shown in table 1. The best correlation was for organic nitrogen, which is contained in the solids, and the worst correlation was for ammonium nitrogen that is readily lost by volatilization.

Potassium (TK) did not correlate significantly ($r^2$ = 0.068) with respect to TS. In fact, the TK concentration for the influent and effluent was the same within measurement error (only 1.7% different). The overall average concentration of potassium in all 40 samples was 1.731 g/L with a standard deviation of 0.2879 (CV = ±16.6%).

Significant correlations were found for each form of N and TP with respect to the concentration of total solids. However, the coefficient of variation about the regression lines (table 1) ranged from ±14.1 to ±22.4% and would induce a significant variation if removal efficiencies were computed on a point–by–point basis. Using the regression equations given in table 1 allowed the plant nutrient concentrations of the influent and effluent to be estimated based on 40 measurements instead of only two measurements.

The nitrogen and phosphorous removed by the screw press was calculated by computing the effluent concentration of the separator from equation 1 ($TS_{OUT} = TS_{IN} – TSR$) and using the equations given in table 1 to calculate the influent and effluent concentrations of N and P. The percent reduction in N and P is shown in figure 8. The removal of plant nutrients varied from 0 at $TS_{IN}$ = 11.1 g/L to a maximum removal at

**Table 1. Regression equations for the nitrogen and phosphorous concentrations in the influent and effluent swine manure (pooled data, n = 40).**

| Regression Equation | $r^2$ | $s_{y \cdot x}$ | CV[a] (%) |
|---|---|---|---|
| TKN = 0.0695 TS + 0.996 | 0.8595 | 0.553 | ±14.6 |
| $NH_4$ – N = 0.0337 TS + 0.961 | 0.6220 | 0.517 | ±22.4 |
| Organic – N = 0.0366 TS | 0.9171 | 0.209 | ±14.3 |
| TP = 0.0389 TS | 0.8306 | 0.349 | ±22.4 |

[a] CV = coefficient of variation = ($s_{y \cdot x}$ / mean) × 100.

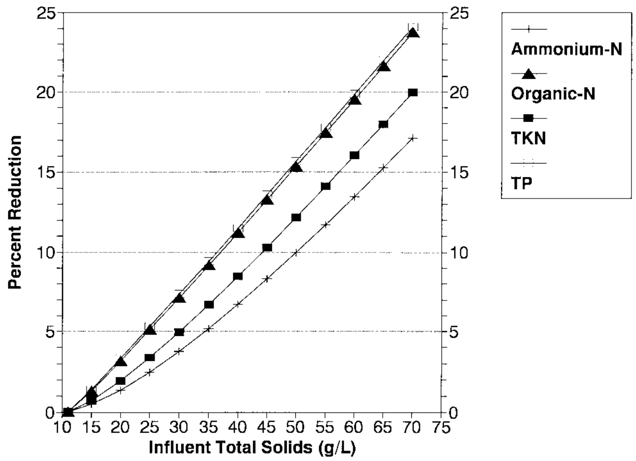


**Figure 8. Removal of nitrogen and phosphorous by the screw press.**

$TS_{IN}$ = 70 g/L. The maximum removal of plant nutrients was 20.0% for TKN, 17.0% for $NH_4$–N, 23.8% for organic–N, and 24.0% for TP.

### Characteristics of Separated Solids

Nine samples of separated solids were collected as they fell from the screw press. The solids content varied from 22.6 to 34.4%. The average solids content was 27.5%. The only nutrient that was found to correlate well with the solids content was organic nitrogen. The nutrient content of the separated solids is described in table 2.

The analysis of the plant nutrients indicated that, on the average, 72% of the total nitrogen (TKN) in the separated solids was in the organic, or slow release, form. The solids would be a valuable nitrogen source for any crop that needs nitrogen throughout the growing season. The solids should work well in a compost mix as long as the moisture and carbon content are properly adjusted.

The screw press produced solids that piled easily and gave off very little odor. A solids storage area should be used to provide rain protection to prevent the generation of strong odors.

## Discussion

Analysis of the data clearly indicates that the amount of solids, volatile solids, and major plant nutrients that can be removed from swine manure using a screw press varies greatly with the total solids content of the manure that is fed to the machine. Furthermore, most mechanical separators are installed in such a way that the manure is processed as it flows from the building. The average total solids concentration in the pit can range from 15 to 30 g/L depending on the animal age and the number of days that manure is allowed to accumulate. The observed variation of the TS concentration in swine manure as it flows from a building (fig. 2) indicated that the majority of the manure accumulates in a layer of settled solids on the bottom of the recharge pit. The supernatant layer of the recharge pit has a very low TS concentration (6.4 g TS/L) and contains suspended and soluble solids and plant nutrients that cannot be removed by the screw press (TS < 11.1 g/L, fig. 3). Therefore, the manure that comprises the settled layer is the only fraction of the pit contents that can be effectively processed by a screw press. The use of a large amount of recycled lagoon supernatant (162,772 L) can add a significant amount of suspended and dissolved solids and plant nutrients to the recharge pit that can not be removed by screening. Analysis of the recycled lagoon water used on the cooperator's farm indicated that the recharge water added 5.0 g TS/L, 3.44 g VS/L, 0.76 g TKN/L, 0.24 g organic–N/L, and 0.19 g TP/L to the pit. Calculation of the amount of solids and plant nutrients added to the recharge pit by the housed swine must take into account the mass of solids and plant nutrients added to the pit by the recycled lagoon supernatant.

**Table 2. Nitrogen, phosphorous, and potassium concentrations in separated swine solids (wet basis).**

| Concentration | Relevant Statistic |
|---|---|
| % TS = 27.5% | Range = 22.6 – 34.4% |
| Ammonium – N = 2,144 mg/kg | CV[a] = ±17.0% |
| Organic–N = 207.27(%TS)–109.8(mg/kg) | $r^2$ = 0.937 |
| TKN = $NH_4$ – N + Organic – N (mg/kg) | Range = 6719 –7020 mg/kg |
| TP = 2,492 mg/kg | CV = ±21.2% |
| TK = 2,004 mg/kg | CV = ±4.6% |

[a] CV = coefficient of variation = (standard deviation/mean) × 100.

The prediction equations that were developed from the screw press data (eqs. 1, 2, 3, and table 1) were used to calculate the removal of solids and nutrients from a pit–recharge building based on the recycle water characteristics and in–pit settling observed for the cooperator's buildings and an average pit TS of 20 g/L. Prediction of separator performance requires information concerning the amount of solids settled in the pit and the concentration of the settled solids. The data from emptying recharge pits, given in figure 2, indicated that the TS concentration of the pit supernatant was 6.4 g/L for average pit TS concentrations ranging from 15.4 to 23.3 g/L. Therefore, the fraction of fraction of TS settled (SFTS) can be calculated as:

$$SFTS = (TS_{AVE} - 6.4\ g/L) / TS_{AVE} \quad (6)$$

The data shown in figure 2 and experience gained by pre–settling swine manure in a manure tank indicated that the settled solids layer had an average TS concentration of 50 to 60 g/L. The settled solids layer was assumed to contain 55 g TS/L. The amount of solids and plant nutrients removed from the entire contents of a recharge pit and the removal efficiencies based on the manure added by the housed swine are given in table 3. The results shown in the table indicate that the screw press would remove 12.1% of the TS, 15.9% of the VS, 7.0% of the TKN, and 12.1% of the organic–N and TP contained in the recharge pit in this case. However, 18.8% of the TS, 23.8% of the TKN, 24.7% of the organic–N, and 18.4% of the TP in the pit was added by the recycled lagoon supernatant. Subtracting the mass of solids and plant nutrients added by the recycled lagoon supernatant from the average pit contents indicates that the screw press would remove 14.9% of the TS, 19.6% of the VS, 9.2% of the TKN, 16.0% of the organic–N, and 14.8% of the TP added to the pit by the housed swine.

**Table 3. Calculated removal of solids and plant nutrients for a screw press treating manure from a pit–recharge swine building with an average TS concentration in the pit of 20 g/L.**

| | Average Solids and Nutrients in the Recharge Pit | | Solids and Nutrients Added from Recycled Supernatant | | Average Solids and Nutrients in the Settled Layer | | Fraction Removed by the Screw Press[d] | Removal Based on Average Pit Contents (%) | Removal Based on Swine Manure Added[e] (%) |
|---|---|---|---|---|---|---|---|---|---|
| | (g/L) | (kg)[a] | (g/L)[b] | (kg) | (g/L) | (kg)[c] | | | |
| TS | 20.00 | 3,255.4 | 5.00 | 612.6 | 55.00 | 2,213.7 | 0.178 | 12.1 | 14.9 |
| VS | 13.74 | 2,236.5 | 3.44 | 420.9 | 37.79 | 1,520.8 | 0.234 | 15.9 | 19.6 |
| TKN | 2.39 | 388.4 | 0.76 | 92.7 | 4.82 | 193.9 | 0.141 | 7.0 | 9.2 |
| Organic–N | 0.73 | 119.1 | 0.24 | 29.4 | 2.01 | 81.0 | 0.178 | 12.1 | 16.0 |
| TP | 0.78 | 126.6 | 0.19 | 23.3 | 2.14 | 86.1 | 0.178 | 12.1 | 14.8 |

[a] Pit volume = 162,772 L.
[b] Concentrations measured in the lagoon supernatant on the cooperator's farm. Mass computed based on pit supernatant volume.
[c] Volume of settled layer computed from equation 6 and average TS concentration of settled layer.
[d] Based on concentrations in the settled layer. The screw press will not remove any solids or nutrients from the pit supernatant (TS < 11.1 g/L).
[e] The solids or plant nutrients added by the swine is the total mass in the pit minus the mass added from the recycled lagoon supernatant.

The removal efficiencies shown in table 3 were based on the assumption that the average TS concentration of the settled layer is 55 g/L. Draining the manure from a building into a reception pit and allowing the solids to settle and thicken for a hour or more to a TS of 60 to 70 g/L prior to separation could result in higher removal efficiencies. A submersible pump located in a sump at the bottom of the pit would allow the settled layer to be pumped to the screw press prior to the supernatant layer. Using a tank sized to hold the entire contents of the recharge pit, to receive the manure as it drains from the building would also allow the building to empty at the maximum flow rate possible, not at the flow rate of the pump, which would aide in removing solids from the building as is evident in figure 2.

Most comprehensive lagoon sizing methods (Barth, 1985; ASAE, 1998b) include a treatment volume sized based on the VS loading rate. A 19.6 % reduction in VS loading rate could either reduce the loading rate on an existing lagoon or reduce the treatment volume by 19.6%. If the reduction in VS achieved by the screw press is used to reduce the organic loading rate on a lagoon then odors may be reduced on the farm. Reduction in the organic loading rate generally decreases the TS and VS concentration of the recycle water that is used to remove manure from the building. Reduction in the strength of the recycle water combined with complete cleaning of the pit could help to reduce the amount of odor expelled from swine buildings by ventilation fans.

The separated liquid or effluent was dark in color and had a significant odor. Dilution and treatment in an anaerobic lagoon or an additional treatment process is needed to reduce the odor generation potential of the separated liquid.

## Summary and Conclusions

A screw press separator was temporarily installed on a commercial swine farm in Horry County, South Carolina. The separator had a 0.5–mm screen and was operated with a single 40–kg weight on each pressure plate arm. Samples were collected and analyzed to determine the variation in the removal of solids, chemical oxygen demand, and major plant nutrients. Prediction equations were developed from the data to describe the removal of TS, VS, COD, TKN, $NH_4$–N, organic–N, and TP. Separated solids were analyzed to determine the percent TS and the concentration of major plant nutrients. The prediction equations were used to calculate separator performance for a recharge pit with an average TS concentration of 20 g/L.

The following conclusions were developed based on the data and analyses.

- The amount of TS and VS removed by the separator increased in a parabolic manner with respect to total solids concentration of the separator influent ($TS_{IN}$).
- The percent TS removed varied from zero at $TS_{IN}$ = 11.1 g/L to 24% at $TS_{IN}$ = 70 g/L.
- The percentage of VS removed by the separator ranged from 1 to 31.7%.
- The screw press removed 34.9% of the COD from swine manure regardless of $TS_{IN}$.
- The concentrations of VS, TKN, $NH_4$–N, organic–N, and TP in the influent and effluent were found to correlate well with the total solids content. In addition, the regression equations for the VS, and major plant nutrients were not significantly different for the separator influent and effluent. Therefore, the reduction in volatile solids, nitrogen, and phosphorous due to liquid–solid separation was explained by the decrease in TS.
- The concentration of total potassium (TK) did not correlate with TS and was the same in the influent and effluent.
- The percentage of TKN, $NH_4$–N, organic–N, and TP removed by the separator increased with influent TS concentration in a similar manner as the removal of total solids. The amount of TKN removed ranged from 0 to 20.0%, removal of organic–N ranged from 0 to 23.8%, and the removal of TP ranged from 0 to 24.0%.
- The total solids content of the separated solids ranged from 22.6 to 34.4%. The separated solids piled easily and did not emit a strong odor. The only plant nutrient concentrations that varied with the solids content were the organic–N, and TKN. On the average, 72% of the TKN was organic.
- The separated liquid was dark in color and would require additional treatment to reduce the odor generation potential.
- The actual removal of solids and plant nutrients from swine manure by a screw press will vary with the manage-

ment of the building and how the separator is implemented in the manure handling system. For a typical pit–recharge swine building ($TS_{AVE}$ = 20 g/L, settled layer TS = 55 g/L) a screw press would be expected to remove 14.9% of the TS, 19.6% of the VS, 9.2% of the TKN, 16.0% of the organic–N, and 14.8% of the TP added to the pit by the housed swine

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