Separating Manure Solids with a Biomass Filter

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ASL-R1694

Summary and Implications

Several biomaterials were tested as filter materials to remove solids from liquid swine manure. Oat straw, soybean residue, and corn stover performed as well as, or better than, many mechanical systems. Using these readily available materials may be an economical alternative to purchasing and managing commercial solids separation systems.

Introduction

Environmental problems facing the livestock industry have increased the pressure on livestock operators for better treatment of swine manure. Solid-liquid separation is one potential treatment process that may be of benefit. Solid separation produces a solid fraction and a liquid fraction that can be handled separately for different purposes. The solid fraction can be recycled as livestock feed, or applied to the field as fertilizer and soil conditioner. If composted, it can provide excellent mulch for nursery and landscape use or serve as bedding. The solid fraction may require the addition of carbon to adjust the C:N ratio, and to reduce the moisture content to compost properly. The liquid fraction may be irrigated, and is easier to handle with standard pumping and piping system. The reduced organic loading on the swine manure lagoons by the separated liquid fraction may result in lower odors and increased service life. Satisfactory separation of swine manure solids is difficult to achieve.

Most separation methods are based on particle size and particle density differences. The two most common methods used are settling basins and mechanical separators. Separation efficiencies typically range from 12 to 25% for simple screen separators and settling systems. More sophisticated devices such as centrifuges, and chemical enhanced settling can achieve higher efficiencies, but involve additional equipment and/or management requirements. This study was designed to investigate the use of cheap, plentiful biomaterials as filter media for separating solids from liquid swine manure.

Materials and Methods

Biomaterials tested in this laboratory study were oat straw, soybean residue, and corncobs. A 10-in. diameter by 22-in. PVC cylinder was used in a laboratory study to hold the biofilter materials. A bottom drain, allowed collection of filtered liquid manure. Two expanded metal screens, one on the bottom and one on the surface of the filtration materials established the filter volume (the position of the top screen was adjustable). The bottom screen prevented loss of filtration material through the bottom opening. Before filtration, the selected filtration biomaterial was packed in the separation cylinder with different orientations, depths, and densities.

The swine manure used in this study was freshly collected, with a total solids (TS) content of 10 to 12% and diluted to approximately 4% before use. For filtration, 1 gal. of swine manure was poured manually on the top of the filter material. The liquid fraction was collected in a 1-gal. pail below the outlet of the cylinder. The duration for the filtration process was recorded with a stopwatch. After measuring the volume, the collected liquid was completely mixed, and four subsamples were taken immediately for TS analysis. This process was repeated on a volume basis (1 gal. per time) until the filter was eventually plugged. Removal efficiency (percentage of solids removed) was calculated based on the difference between %TS of applied manure and %TS of collected manure.

Oat straw was tested oriented both horizontally and vertically at different filter depths, and densities. For soybean straw, density was the only factor examined because the straw did not lend itself to different orientations. Three densities tested for soybean straw were 1, 1.25, and 1.5 lb/ft^3. Each biomaterial was tested for removal efficiency, filtration duration, and total volume of liquid manure that could be handled before plugging.

Oat straw was tested first. It was tested with both a horizontal and vertical orientation at depths of 1 ft. in the separation cylinder. The TS concentration of applied manure was 4.34%. The horizontal filter was more likely to plug with little improvement in separation efficiency compared with vertical. Tests with the 1-ft. deep, vertical orientation were performed at four different densities of oat straw. Most of the solids were trapped in the top portion of the filter with very little being captured in the bottom. A 4-in. filter depth was then tried at the three different densities, and found to achieve nearly the same performance with less material. To test the effect of initial TS on removal efficiency, the filtration tests were performed on the 4 in. oat straw filter with 1.75 lb/ft^3 density, for manure at various initial solid concentrations (1.42, 2.57, 3.89, 4.78, and 5.99%, respectively).

Results and Discussion

Overall removal efficiencies for the biomaterials tested ranged from a high of 52.3% down to -5.0% as shown in Table 1. A limitation with the corncobs was simply the testing apparatus. The cylinder used was not large enough to adequately test unground randomly placed corncobs.

Oat straw. Oat straw was generally effective at removing solids from liquid swine manure. Based on initial results a vertical orientation was selected for further study.

The average removal efficiency for the vertical orientation of 1-ft. oat straw at various densities ranged from 35 to 42%. In general, both removal efficiency and filtration duration increased with increasing volumes of applied manure. As solids accumulated on the inner surface of the filter, a layer of solid cake was formed in the top portion of the filter. The cake became deeper until it eventually plugged the filter. The porosity of filter decreased with the increasing volume of the applied manure. As a result, the removal efficiency generally increased with time so the maximum value appeared at the very end of process. Figure 1 shows removal efficiencies for oat straw at three different densities.

Table 1. Solids removal efficiencies of various biomaterials.

Biomaterial Type	Filter Density (g/cm^3)	Ratio of manure filtered to biomass (l/kg)	Average Removal Efficiency (%)
Oat straw (30-cm)	0.014	151.2	37.8
	0.017	105.8	42.2
	0.020	88.2	38.7
	0.024	86.4	40.7
Oat straw (10-cm)	0.024	181.4	30.6
	0.028	151.2	37.6
	0.033	86.4	39.4
Soybean stubble	0.024	108.0	29.9
	0.031	50.4	24.5
	0.037	41.2	25.2
Corn stover	0.028	66.7	28.9
	0.037	50.4	37.2
	0.043	36.0	40.9
Corncobs (4-cm) (vertical orientation)	0.330	11.7	14.3
Corncobs (4-cm) (random orientation)	0.168	91.5	2.6
Corncobs (8-cm) (random orientation)	0.198	24.3	6.2
Ground corncobs (1-cm)	0.305	50.5	22.7
Ground corncobs (1.5-cm)	0.236	43.3	22.7
Ground corncobs (3-cm)	0.352	21.9	22.7

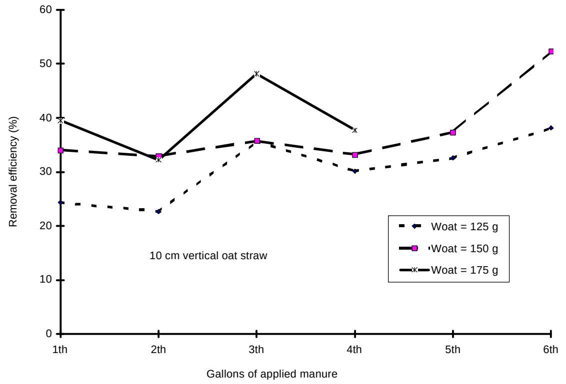
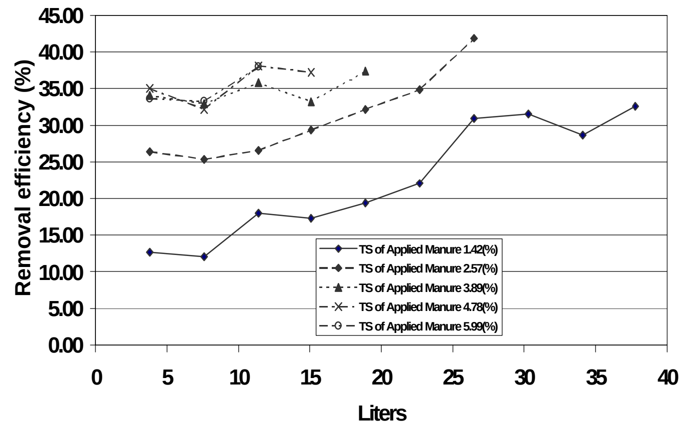


Figure 1. Solids removal efficiency using 10-cm depth of vertically oriented oat straw show that efficiencies increase slightly with increasing material filtered.



.Figure 2. Solids removal efficiency of 4 in. oat straw depth with varying initial manure solids concentrations

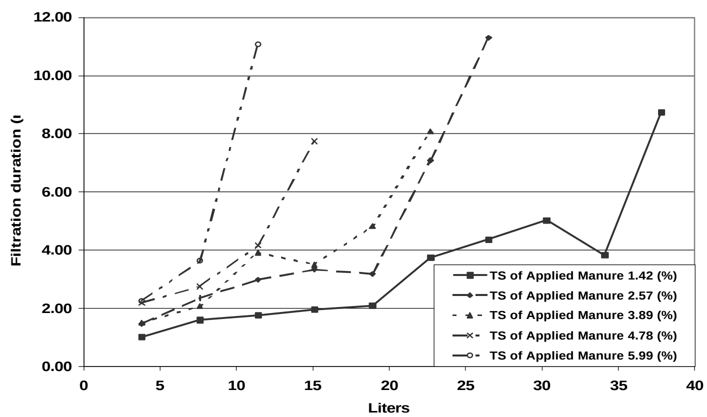


Figure 3. Filtration duration of manure with varying initial solids concentrations through 4 in. oat straw filter.

Because most of the solids were trapped within the top 4 inches of the filter (based on the observations during the experiments with 1-ft. of oat straw), the filtration test was then repeated on the 4-in. straw filter with different densities. The average removal efficiency ranged from 31 to 39%, close to what was obtained from the 1 ft. straw filter, which implied that the similar separation efficiency can be achieved by using much less filtration biomaterial. Figure 1 shows separation efficiency for the 4-in. straw depth.

To determine whether the biofilter would work for varying solids concentrations of manure five different initial solids concentrations were tested (1.42, 2.57, 3.89, 4.78, and 5.99%). Results are shown in Figures 2 and 3. Generally, the removal efficiency and filtration duration increased with the increasing concentration of the applied manure. Earlier plugging indicated by longer filtration duration and less volume, also was observed for the higher concentrations.

Soybean residue. The average removal efficiency for three different soybean residue densities is 29.9, 24.5, and 25.2% for filter densities of 1.5, 1.9, and 2.3 lb/ft^3, respectively. In general, both filtration duration and removal efficiency increased as additional manure was applied. The higher density filter plugged significantly earlier than that of lower density, and the filtration duration of each gallon was generally longer for the filter with the higher density compared with the lower density.

Corncobs and ground corncobs. Corncobs were selected as testing materials primarily due to their surface roughness. It was thought the surface roughness might help to increase the solid removal. For the random positioning of corncobs (the cobs were piled in the separation cylinder randomly), the solid separation test was performed with two different depths (3.2 in. and 1.6 in.) of filter. The average solid removal efficiency of a total volume of eight gallons of applied liquid manure was only 2.6% for the 1.6-in. filter. The corresponding value for the 3.2-in. filter was 6.2% averaged from a total of 5 gal. of applied volume. Corncobs were basically ineffective for swine manure solids separation as shown in Table 1.

The removal efficiency was improved significantly by placing the corncobs vertically. As shown in Table 1, the efficiency was 14.3% for the 1.6-in. filter, much greater than the corresponding value obtained from random setting with the same depth. However, the total volume before plugging was only 2.0 gal. (the corresponding value was 8 gal. for the random setting). Early plugging was a problem with ground corncobs. Although the removal efficiency was 14.3, 21.4, and 22.8% from the filters filled with ground corncobs of 0.5 in., 0.6 in. and 1.2 in., respectively, plugging was observed after only 0.5 gal. of liquid manure were applied. The depth of 0.5 in. was approximately equal to the average size of the ground cobs, which means only a single layer of this material was used as the filter in this case. It still plugged quickly.

Conclusions and Summary

Several conclusions have been drawn from this solids separation study:

1. Oat straw, soybean residue, and corn residue were effective for solids removal from swine manure.
2. Generally, decreased filter porosity brings about higher removal efficiency, but results in eventual plugging of filtration materials.
3. Solids were trapped mainly within (not on top of) the top portion of the filter.
4. Solids removal was more efficient, and plugging occurred sooner from thicker manures.
5. Biomaterials have potential to be used as filter materials for liquid swine manure.