Performance of a continuous belt microscreening unit for solid liquid separation of swine waste

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Fernandes, L., McKyes, E. and Obidniak, L. 1988. **Performance of a continuous belt microscreening unit for solid liquid separation of swine waste.** Can. Agric. Eng. **30**: 151–155. Pretreatment of animal waste by solid/liquid separation has many advantages. A new mechanical device was developed to separate swine waste into solid and liquid fractions using an endless belt made of filter material and continuously cleaned by air flow. The performance of the microscreening unit was evaluated over a period of 3 mo. The efficiency of this unit in terms of solids removal increased with the content of solids in the influent slurry. For swine waste with dry matter in the range of 3–8%, the efficiency was between 47 and 59%. The dry matter in the screened solids varied between 14 and 18%, and presented reasonable stacking properties. It was found that as much as 39% of organic carbon; 32–35% of TKN and 17.8–20.9% of total P were removed from the influent slurry in the microscreening process.

INTRODUCTION

Traditionally, animal wastes have been applied to arable land near animal production centers. However, with the increase in intense raising of swine, in particular, there are often more animals contained in certain operations than can be accommodated by the land area immediately at hand. According to Barrington (1985), in some areas of Quebec, for example, the quantities of manure produced often exceed the mass of active chemicals which can safely be spread on the available tillable land by over 200%. Severe watercourse pollution problems have eventually resulted when excess manure enters the waterways by runoff or percolation.

Liquid manure is a slurry which contains a relatively high concentration of suspended solids, dissolved organic matter and salts. It generally requires costly treatment for purification. Many problems in managing livestock slurries are due to difficulties in handling and storing materials with poor flow properties (Pain and Hepherd 1980). Thus, many operations have converted to liquid manure systems, because of ease of mechanization and low labor costs (Hegg et al. 1981). The separation and concentration of the solid fraction from the liquid bulk is frequently advantageous and it may precede or follow another operation for the treatment and potential recycling of animal manure constituents.

The separation of solids from liquid manure has the following advantages (Overcash et al. 1983; Rorick et al. 1980):

1. Recovery of organic solids for reuse in such processes as refeeding, methane generation, pyrolysis or composting.
2. Reduction of the organic waste load on subsequent liquid manure treatment processes, thus reducing overall costs.
3. Reduction of solids in the liquid bulk, thereby facilitating pumping and handling.
4. Removal of organic solids in the reduction of potential surface and ground water pollution.

The separation of settleable solids by means of mechanical devices has been studied in recent years (Hegg et al. 1981; Rorick et al. 1980; Pain et al. 1978). At present there are several basic types of commercially available liquid-solid screen separators which include stationary sloping screens, vibrating screens, rotating screens, flat belt separators and roller-press separators. The efficiency of these units in terms of solid removal from swine waste has been reported to be in the order of 2–50%. The best results were obtained with screening devices that had small mesh sizes in the order of 0.35 mm (Pain et al. 1978). A problem commonly encountered with the operation of these screens has been the clogging of the openings with solids and biological slime build-up.

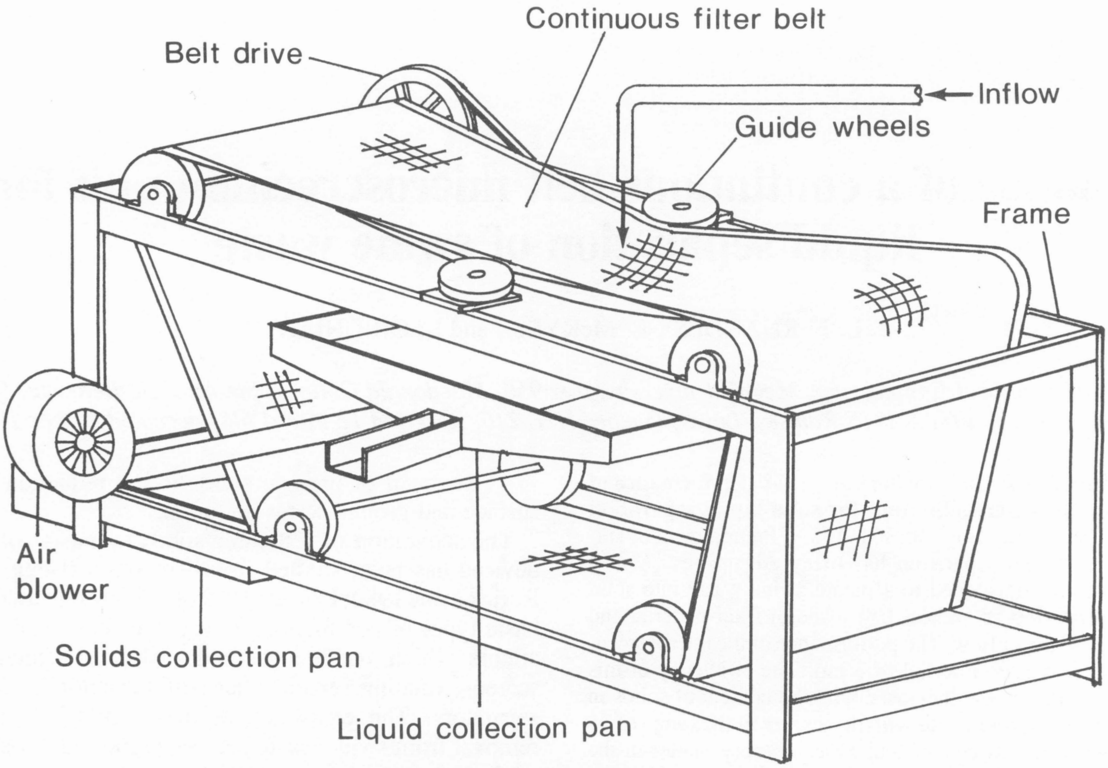
By providing a screen with smaller perforations which could be cleaned continuously, it would be possible to attain higher efficiencies in solids removal, and to maintain a steady hydraulic loading rate.

The objectives of this project were to develop an efficient and economical continuous microscreening unit to separate animal waste slurries into solid and liquid fractions, to evaluate the performance of this unit in terms of separation efficiency and to determine the physical and chemical properties of the effluent liquid fraction.

EQUIPMENT DEVELOPMENT

The concept of a continuous belt separator evolved from the observation of the fact that substantial amounts of free water can be extracted from pig liquid waste as a result of gravity forces on a screen. In preliminary laboratory tests, by increasing the liquid head, and hence the pressure on the filtering material, it was found that moisture removal from solids can be increased. However, the rate of filtration by a screen is limited because the mesh is being continually blocked by solids build-up and the subsequent sealing of the screen. In the laboratory, experiments using a filter with a 100-μm openings showed that the maximum volume of filtrate was obtained during the first 30 s of exposure, but after that the flow of liquid practically stopped due to the clogging of the screen and the formation of a compact cake of retained solids.

These observations led to the development of an experimental microscreening unit as shown in Fig. 1. It consists of a continuous conveyor belt of woven filter of swiss polyester monofilament fabric with 100-μm opening size that is moved horizontally at an adjustable linear speed by an electric motor.



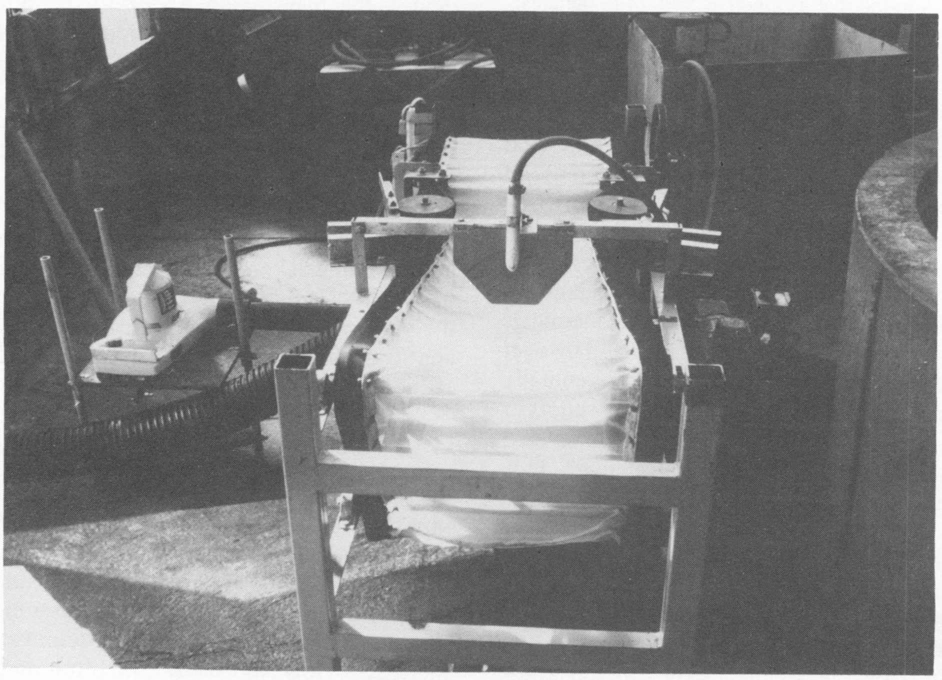


Figure 1. Continuous belt microfiltration unit.

The frame provides support and guides the belt in such a manner that the flat belt with a width of 40 cm is formed into a bag shape at the top, with a width of 20 cm and a maximum depth of about 15 cm.

Liquid waste is continuously discharged onto the belt at the place where the bag starts to form, and the filtrate is collected in a pan under the belt. The solids retained on the screen are removed by two means. Large particles and aggregates fall into a lower pan by themselves as the screen is advanced downwards and the finer particles are blown off by an air knife directed through the bottom of the belt above the solids pan. The air knife consisted of a 0.3 × 30-cm slot and air was supplied by an 840-W electric blower. In this way the filter belt is continuously cleaned and a high rate of manure separation is expected. The evaluation of the performance of this device, and the limits of solids particle size and permissible loading rate were the desired goals of this experimental project.

EXPERIMENTAL PROCEDURE

Liquid swine manure from a growing-finishing herd was used for this study. Fresh manure was collected from the barn drain, mixed with water to give final feed materials with various concentrations of total solids and tested the same day. The filtration unit was operated for a period of 3 mo and between 4 and 6 h per day. The operating variables tested were influent solids concentration (2–8%), flow rate (10–35 L/min) and linear velocity of the filter belt (1.2–5.2 m/min). The combination of the latter two variables resulted in different rates of hydraulic loading of the filter belt, between 0.01 and 0.145 $m^3 \cdot min^{-1} \cdot m^2 \cdot min^{-1}$ flow rate per belt speed times width.

The filter fabric belt size opening used was 100 μm. The temperature during the experimental work ranged between 20 and 25°C.

A minimum of two runs was carried out to test the effects of each of the various levels of the variables considered. Each run involved 300–400 L of raw slurry without preliminary separation on a once-through basis. During the operation, a complete mixing pattern was obtained for the influent slurry by the action of a high-speed impeller-type mixer and a bypass return flow from the main hydraulic line.

Samples to be analyzed were collected from the influent slurry, effluent liquid and separated solids during the middle and towards the end of the run. Analyses of raw waste and liquid separate for particle size distribution was performed according to the wet method of sieve analysis adopted from Kemper (1965).

The analyses for total solids (TS), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN) and total phosphorus (P) were determined using procedures specified in APHA Standard Methods (1980). Wherever it was applicable, analyses were done in duplicates and triplicates.

RESULTS AND DISCUSSION

Generally, in solid/liquid separation processes, the efficiency is expressed in terms of percentage of solids separated from the influent slurry. For the continuous belt microfiltration unit equipped with a 100-μm screen opening, the solid removal efficiency based on the particle size distribution as a percentage of total solids ranged between 47 and 59%, for influent slurry with dry matter contents between 3 and 8%, as indicated in Table I. These results compare favorably with those of existing filtration units as mentioned earlier (Rorick et al. 1980; Pain and Hepherd 1980).

Table I. Particle size distribution as a percentage of total solids

Particle size (μm)	Fresh raw manure (% of mass)	Influent slurry (DM %) 3.0	6.0	8.0
		Solids remaining in separated liquid as % of original raw solids mass		
< 53	52.8	51.7	44.0	40.7
53–75	2.7	0.9	0.5	0.2
75–105	2.5	0.4	0.0	0.0
105–150	1.8	0.0		
150–250	1.3			
250–500	3.1			
500–1180	8.4			
> 1180	27.4			
Total	100.0	53.0	44.5	40.9
Efficiency of solid removal (%)		47.0	55.5	59.1

In Fig. 2 the results were obtained on the basis of the concentration of solids removed by the screen from the influent raw waste. It also reconfirms that efficiency of solids removed increased with the content of dry matter in the raw waste. The results were virtually independent of length of the test or the time at which samples were collected.

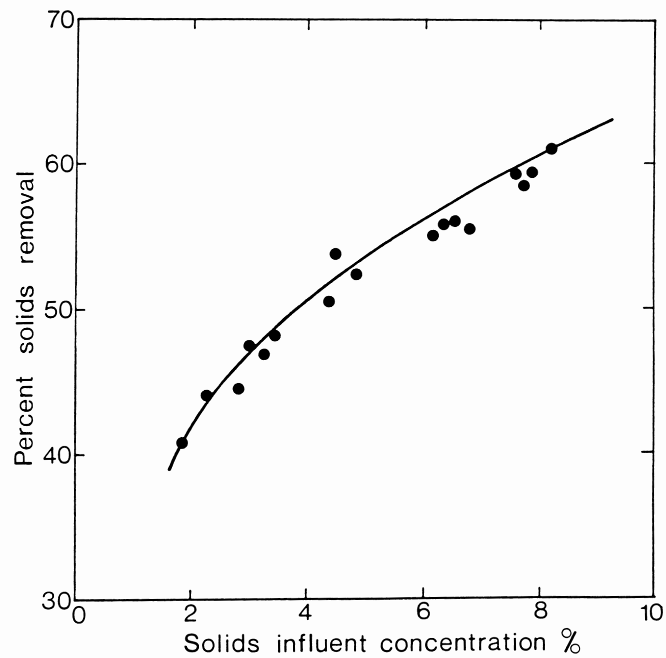


Figure 2. Effect of solids concentration of influent on solids removal.

A curvilinear relationship exists between slurry dry matter concentration and proportion of solids removed. It also appears that the solid removal efficiency should reach a plateau, where increasing dry matter in the slurry would not significantly improve the process. Furthermore, higher solids contents would form a pseudo-plastic fluid, which would require a different manner of handling. For the experiments in this study, swine waste containing dry matter concentrations in the range of 2–8% by weight was tested.

As shown in Table I, the particle size analysis of the separated liquid fraction revealed that some particles smaller than 100 μm have also been removed. Should the separation process be based only on the physical size of the filter openings, then as much as 42% of solids would be retained. For pig waste containing 8% dry matter the solid removal efficiency was 59%. Thus, the relative efficiency of the process, measured in terms of final solids removal improved by 1.42 times the theoretical minimum. The reason for these high results is probably the fact that as solids from the influent slurry are being discharged onto the belt screen, a thin cake of solids forms almost immediately on the filter belt, and smaller particles are trapped thereon. The thickness of this cake can be varied by changing the belt speed, and it is also a function of input slurry application rate and initial solids content.

The dry matter in the screened solids was found to be between 14 and 18%. As can be observed in Fig. 3, there is a direct relationship between solids concentration in the slurry and that in the separated solids. Since there is no pressing stage included

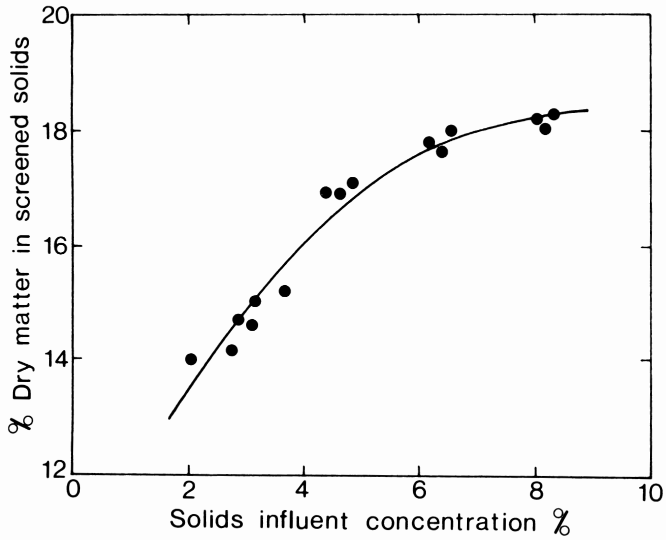


Figure 3. Effect of slurry dry matter content on solids retained on the screen.

in this unit, the only other explanation for the improved dryness of the solids cake is the self-pressing effect brought about by increased height and weight of the slurry solids on the belt.

It was observed visually that the solid fraction deposited in the collection pan possessed reasonable solid stacking properties, although some seepage occurred from the solids at higher moisture contents. This effect is likely due to the presence of more fine particles in these separated solids and consequently an increase in the surface-to-volume ratio, and better water absorption properties.

For the tested slurries, it was found that the maximum hydraulic loading within safety limits was 0.145 $m^3 \cdot min^{-1} \cdot m^2 \cdot min^{-1}$ of slurry flow rate divided by belt speed times width. Above this volume rate, the belt sagged excessively due to overloading. The hydraulic capacity could be increased by implementing minor modifications to the mechanical design of the unit. From Fig. 4, it is apparent that hydraulic loading did not significantly affect the performance of solid removal, and the device appears to be capable of effectively

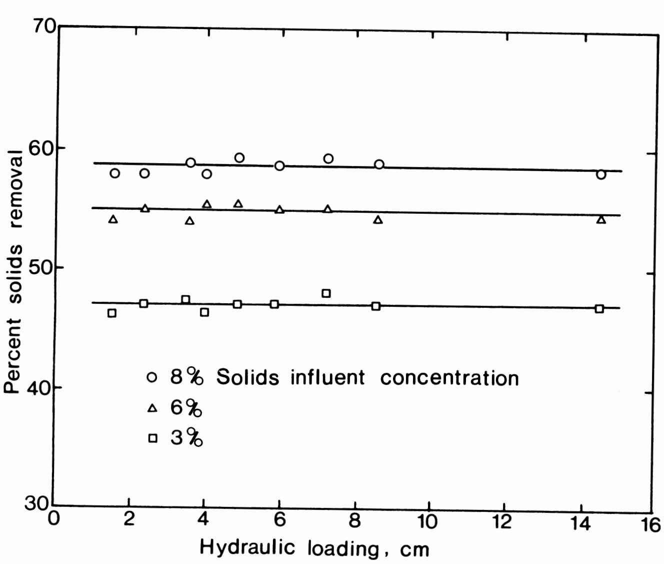


Figure 4. Effect of hydraulic loading on percent solids removal.

handling considerably higher specific inflow rates than were used in the study. This relatively small machine, having a screen loading area of less than 400 cm^2, can efficiently handle a total hydraulic laoding of 35 L/min.

The dewatering effectiveness of the equipment was tested by providing different velocities for screen exposure and maintaining the influent slurry properties and flow rate constant. Pertinent results are tabulated in Table II. In the separated solids, the moisture level did not change a great deal, although there was a small increase in solids moisture content as the belt speed was increased from 1.2 to 5.2 m/min, and the drainage allowed was decreased accordingly.

Table III summarizes the measured physical and chemical characteristics of the raw slurry and the effluent. These results were obtained with a constant specific hydraulic loading of 0.145 $m^3 \cdot min^{-1} \cdot m^2 \cdot min^{-1}$. The data obtained indicate that the unit has a high performance efficiency in the removal of settleable solids, organic matter and nutrients. These would have beneficial effects for a secondary aerobic treatment of wastes, for example.

Table II. Dewatering effectiveness of the continuous-belt microfiltration unit

Linear screen velocity (m/min)	Influent slurry (DM %)	
	6.0	8.0
	% moisture content of screened solids	
1.2	83.9	81.8
2.3	83.5	82.0
3.5	84.2	82.8
4.7	84.5	82.1
5.2	84.4	83.0

Table III. Physical–chemical characteristics of influence slurry and effluent

Parameters	Influent slurry	Effluent	% removal
% Dry solids	4.7	2.20	53.2
	8.00	3.20	60.0
COD (mg/L)	52 300	31 500	39.8
	85 490	52 303	38.8
TKN (mg/L)	3 500	2 380	32.0
	4 170	2 700	35.3
Total P (mg/L)	929	735	20.9
	1 910	1 570	17.8

CONCLUSIONS

Mechanical separations are designed to ease problems related to animal waste management. A continuous-belt microfiltration unit was developed to separate solid particles from bulk liquid manure. The overall performance of the equipment was good. The unit operated for about 300 h, during which the screen did not plug, nor were any other major mechanical problems encountered.

The efficiency of the microfiltration unit, in terms of solids removal, was in the range of 40–60%. In the separated solids the dry matter content was between 14 and 18%. An increased concentration of total solids in the influent slurry improved the efficiency of the separator.

These studies revealed that hydraulic loading had no significant effect on solids removal nor on the dewatering of the slurry. Analyses of the influent swine slurry and effluent showed that as much as 40% COD, 35% TKN and 21% total P were removed by the separation.

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