Evaluation of Mechanical Liquid/Solid Manure Separators

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Executive Summary

A study was conducted during the summer and fall of 2002 to develop a standard test for mechanical liquid manure separators. Part of the study involved using the test to investigate the effectiveness of six mechanical manure separators. All separators were tested using three manure types, a low dry matter liquid hog manure, a medium dry matter liquid hog manure and liquid dairy manure. The liquid manures had similar characteristic for each type tested. Of the separators tested, three were presently being used commercially on farms. The other three systems, although used for other commercial applications, had not been designed for manure separation and could thus be called prototypes. Standard reporting forms were developed to summarize the performance of the separators. Highlights of the study:

- The results for the six units gave quite a range of results. Also, there was a considerable difference in performance depending on which of the three manures was being tested.

- The Maximizer had the highest capacity of the models tested, with a range of 306 to 590 L/min.

- There was a considerable range of values in the volume of manure separated per kW-h of electricity, from 94 L for the VSEP to 10,535 L for the Maximizer. The Surface to Surface was diesel powered, with an efficiency of 1226 L of manure per L of fuel.

- The particle size distribution in the manure and the separated liquids can give valuable information needed to properly design a system. The use of four screens should give the information needed - examples of sizes: 10 mesh, 50 mesh, 100 mesh and 325 mesh (i.e. 2.0, 0.30, 0.15 and 0.045 mm hole sizes).

- More than one sample should be tested to establish the particle size distribution, to reduce the variability of results.

- Most separators were effective at removing coarse manure particles i.e. those trapped by a 50 mesh, or larger, screen.

- There was a wide range of values for the quantity: Percent initial solids removed into the separated solids - ranging from < 0.1% to 100%. The high value was for the VSEP, where the separated solids are still in a slurry form. The Maximizer and Surface to Surface achieved highs of 38% and 34%, respectively.

- Removal of solids was very poor for Manure 1 (DM in range 0.34 to 0.84%) for four of the six separators.

- The removal of N into the separated solids followed the same pattern as removal of solids.

- The removal of P into the solids portion was similar, although there was less confidence in the values, since most concentrations were reported by the lab at only one significant digit.

- The VSEP unit removed all total coliform and *E. coli* bacteria. Other systems did not have a significant impact on bacteria numbers.

- Labour needs to operate the six systems varied, but most systems have the ability to be fully automated for on-farm use.

- Odours from the separated liquids were similar to liquid manure in most separators tested. The only exceptions were the separated liquids from the VSEP separator, which were essentially odour free.

- Odours from the separated solids appeared to be dependant on the moisture level of the solids after separation. The separators most effective in drying the solids were also the most effective in reducing or removing odours. This included the Surface to Surface, the SEI and the Maximizer systems.

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Evaluation of Mechanical Liquid/Solid Manure Separators

Background

For several years, farmers have been interested in the idea of separating solids from liquids in a liquid manure system. In the past, the perceived benefits included:

- an improvement in the handling, processing and storage properties of the manure - the liquid effluent is much easier to agitate, there is much less risk of plugging transfer pipes, less power is needed to pump the liquid; and
- the creation of a value-added product, such as bedding or feed.

The industry has evolved, and the needs of the farmers have changed. The benefits listed above still apply, but farmers need equipment to address the following additional challenges:

- Farmers face greater manure transportation costs as facility sizes continue to increase and manure must be transported greater distances. Reducing the N and P concentration in the liquid effluent would be an advantage.
- There is much greater attention placed on pathogens in manure and the potential risks of water contamination during spreading. Separation, either by itself or with other processes, may help reduce these risks.
- There is even greater pressure to reduce odours, and separation may help - again, either by itself or as part of a larger treatment system.
- The solids may be composted, or otherwise treated, to produce value-added products that may be sold off the farm.

The main methods of separation have included settling (gravity), chemical separation, and mechanical separation. Each method has its place. The mechanical systems are viewed by many to be relatively expensive but the most compact and the quickest. There are performance differences between the different methods and between mechanical separators. New equipment is on the market now, and technologies that have been very effective in the wastewater industry (e.g. membrane systems) are now being considered as part of manure treatment systems.

For the variety of mechanical separators being marketed today, it is not always possible to get accurate and complete performance data. Even when this information is available, it is not in a standard format, thus making comparisons between types of equipment difficult. Depending on the role of the separator in a farmer's manure system, the desired performance characteristics may be quite different. For example, one farmer may want a system that removes as much N and P as possible into the solids portion, while another may want an effluent that can be used in a flushing system and may want a less expensive unit.

Objectives

A study was begun in 2002 to address the lack of information on test procedures and standardized test results for mechanical separators. The objectives were:

1. Measure the effectiveness of several mechanical manure separators at removing solids from

liquid swine manure.

2. Compare the characteristics of the liquid and solid phases of separated manure using several mechanical separators.
3. Develop a test procedure that can be used to perform standard tests of mechanical manure separators to rate their effectiveness.

The study was designed to be completed in three stages: a) a detailed literature review of mechanical manure separation; b) development of a standard test protocol; c) testing of several separators using the new test and fine-tuning of the test procedure.

Literature Review

Highlights of the literature review (Ford and Fleming, 2002) are as follows:

- Mechanical solid-liquid manure separators generally fall into three categories: screens, centrifuges, and presses and may include combinations of these.
- The most commonly used measures to evaluate a separator's performance in the past have been the separator throughput and the physical and chemical constituents of the separated fractions in relation to the influent manure.
- The shortfall of many studies has been their limited focus on certain constituents. Some parameters which should be considered more often by researchers evaluating a particular separator's performance include: particle size distribution, maintenance requirements, odour observations, energy consumption, and cost.
- The greatest single improvement to most separator test protocols would be the analysis of the particle size distribution of the influent manure and the separated liquid effluent. The profile of solids in the influent manure would allow for the selection of the most appropriate screen size. Comparison of the separated liquid and the unseparated manure would reveal the efficiency of a particular separator at removing solid particles within a specific range.
- Various calculations have been used to determine a separator's efficiency. It is important that researchers clearly state or derive how they calculated the separation efficiency.
- The measure of separation efficiency referred to as the "percent removal efficiency", is a commonly used indicator of separator performance and is simple to calculate. It provides useful information to a researcher testing a separator or to an individual determining the feasibility of a certain unit in their manure handling system. The second measure of separation efficiency, which considers the concentrations of parameters in the separated solids fraction, should also be used, regardless of the goal of the testing.
- Many studies have not reported or measured enough parameters to conduct a mass balance. The flow rate of the influent and liquid effluent streams should be reported, to make mass balance calculations possible.
- Chemical and physical analysis of constituents in the different separated streams and the influent manure have been highly variable. The top three reported parameters for the percent removal efficiency were Total Solids (TS), chemical oxygen demand (COD), and phosphorus (P), respectively. The concentrations of these three constituents were measured both in the

separated liquid and the influent manure. The top four reported concentrations of parameters in the separated solids fraction included TS, P, K, and VS, respectively.

- Great variability in the test conditions existed in the manure type and dilution, influent flow rate, operational parameters, and the length of testing. Because of this variability, it is very difficult to draw general conclusions about the performance of generic separator types.
- Sand bedding in free stall barns presents a challenge to the dairy industry since sand is very abrasive to mechanical manure system components, including separation units. Manure from free stall barns with sand bedding has been used in the testing of a stationary inclined screen. Other separator types, however, have not been tested with manure containing sand bedding.
- There is a misconception that phosphorus can be easily concentrated in the separated solids portion. In all but one of the studies reviewed, less than 30 % of the P was removed into the solids fraction for swine and dairy manure of varying dilutions and influent flow rates.

Development of Test Procedure

Based on the results of the literature review and the perceived information needs of farmers and system designers, a test procedure was developed. Most of the measurements seem like common sense but some were nevertheless omitted from several of the tests reviewed in the literature. Some of the tests that have been carried out in the past involved on-farm installations and monitoring for long periods of time. While this has advantages, it is often difficult to achieve. A compromise was proposed where smaller volumes of manure would be evaluated but more than one manure type would be examined. This has the advantage that it gives information about a range of manure types, acknowledging that a separator may work very well with one type of manure or specific range of dry matter contents, but may not perform equally well with all manures.

For reporting the test results, a standard reporting format was developed. The test reports for all six of the units in the study are attached in the appendix of this report. A summary of the test procedure used in this study follows:

a) General

- Test at least three different manures - representing a range of dry matter contents and livestock types (reflecting the target livestock groups)
- Test at least 20,000 L of each manure. For smaller separators (e.g. prototypes), test the machine based on a time limit - aim for at least four hours of operation for each manure type.

b) Prior to separation

- Characterise the influent manure:
    - consider the length of time the manure was stored before separation
    - consider how fine the grain in the feed has been ground
- List the energy requirements of the separator and the energy requirements of any additional implements necessary for the operation of the separator (e.g. lift pumps, etc.)

- Record the model, manufacturer and selling price for the separator
- Record dimensions of components of the separator (e.g. overall screen size (length, width), size of screen pore openings, screen angle of incline, centrifuge upper and lower diameters)
- Provide operational parameters of the separator (e.g. frequency of vibration of screen)
- Conduct a particle size distribution analysis of the influent manure to determine the profile of solid particles in the unscreened manure - using the following screen openings: 2.0, 0.30, 0.15 and 0.045 mm (i.e. 10, 50, 100 and 325 mesh)
- Measure the rate of energy consumption
    - for systems powered by electricity, use a power meter and record the initial and final reading of this meter to determine the kWh of energy consumption
    - for diesel powered systems, calculate the volume of diesel fuel used during testing
- Agitate (stir) the tank containing the influent manure to re-suspend any settled solids
- A sample is needed of influent manure - it may be easier to collect this prior to starting the separator, although it is preferable to collect this during the test. Take a composite sample (consisting of 3 representative samples) of the influent manure to measure the following:
    - the solids content (DM), pH, and concentrations of N, P, K, NH_4-N and volatile solids (optional)

  a second single sample will be taken for the following:
    - bacteria analysis: *E. coli* and total coliform

c) During separation

- Record the time at the start of testing. Record the time and volume separated at several times during the test (as a check on the more detailed flow rate monitoring).
- In addition, measure and record the flow rate of influent manure in one of two ways:
    - with a Doppler flow sensor for the duration of the test period **-** flow rates will be recorded as frequently as every minute and the total flow can be measured as often as every five minutes
    - measure the volume of influent manure over a one minute time period - flow rates measured in this way should be taken three to five times during the testing period (note: this method of flow rate measurement will only be used when it is not possible to set up the Doppler flow sensor)
- Measure the flow rate of the separated solids three to five times, once the separator has been operating for a sufficient time period (ideally, disregard the initial and final 20% of the manure volume). Use a graduated container and record the volume accumulated in one minute. Also record the time at which these flow rates were taken. Note: Theoretically, these values could be calculated, but this step provides a very good check on the earlier measurements.
- Take samples of the separated solids. The time at which these samples were taken should be recorded. No sampling will be taken during the initial and final 20% of manure volume.
    - three samples of the separated solids will be taken for analysis of N, P, K, NH_4-N, DM, and pH
    - two samples will be taken for bacteria analysis: total coliform and *E.coli*
- Take samples of the separated liquid. Record the time at which these samples were taken. No

sampling will be taken during the initial and final 20% of manure volume.

- three samples will be taken for analysis of N, P, K, NH_4-N, DM, and pH
- two samples will be taken for bacteria analysis including, total coliform and *E. coli*
- do a particle size distribution on this liquid, similar to that done for the influent

- The following should be monitored throughout the testing period:
  - labour/maintenance requirements - this should be considered in both a qualitative and quantitative sense - e.g. what type of maintenance management is required and the approximate length of time required to adequately complete these maintenance tasks (the amount of labour required by one person per unit volume of manure can then be determined)
- Record the time the testing was completed and the total volume of influent manure processed

d) Varying parameters during separation

If parameters on the separator can be varied (such as flow rate and screen opening), more than one test will be needed (e.g. a vibrating screen may be run in the first test with a 40 mesh screen and in the second test this screen will be replaced by 60 mesh screen).

e) Additional Analysis of the Liquid and Solid Streams

- make qualitative odour observations of the odour levels of effluent and separated solids (relative to the influent manure)
- determine the volume and mass of the separated solids

Equipment Testing

Six liquid manure separators were selected to evaluate their relative performance. Not all separators were designed to perform in the same fashion. However, every attempt was made to keep as many factors as possible constant and to monitor the same parameters. Some separators were lab-scale machines and others were farm-scale machines with large capacities. Some were prototypes while others had a proven history of use on farms. The standard test was deemed to be a useful tool in the development and testing of new separators, so including some prototype machines was deemed appropriate. A few extra pre-test steps were needed for the prototypes, however. With some prototypes, not enough experience was available to allow setup in order to achieve the optimum performance (i.e. this standard had not been determined). In these cases, setup and adjustments were based on the advise of the equipment suppliers.

a) Manure Characteristics

Testing was based on how the six separators performed with three manure types. They were: i) a liquid hog manure with about 1% dry matter, ii) a liquid hog manure with a dry matter in the range of 2% to 4%, and iii) a liquid dairy manure with less than 5% dry matter. Each separator was tested using approximately 19,000 litres of liquid manure per manure tested. For the laboratory scale systems, a test was run for up to 4.75 hours .

The sources of the “low dry matter” liquid hog manure were a local farmer and from the Ridgetown College swine finishing herd. Manure characteristic were similar from both sources. There was no bedding used in either barn and feed was ground to 4.7 mm (3/16"). The manure was taken from long term storages (outside storage tanks). The tanks had been pumped out about six months earlier and fresh manure had been added periodically. Only limited agitation could be used in these tanks during the study.

The second DM level of liquid hog manure came from two local hog farms, both using wet/dry feeders. Manure characteristics and dry matters were similar from both of these farms. There was no bedding used in the barns. Feed was ground to 4.7 mm (3/16"). The manure was taken from long term storages that would have fresh manure flushed into them from smaller storages under the barns. The tanks were pumped out up to six months earlier, and some fresh manure was added periodically. This manure was agitated prior to testing to suspend the solids.

The dairy manure was taken from a large liquid manure storage tank at Ridgetown College. This manure was from a long term storage (the tank was pumped out up to six months earlier) with the daily addition of about 5,000 to 10,000 L of fresh manure. The manure contained bedding from the cattle as well as water added to help with agitation of the tank. Milk-house wastewater was added to the tank. The tank had limited agitation during the tests, but an effort was made to agitate the area of the tank serving as the manure source.

One of the separators (the Maximizer) was tested using fresh manure from a 300 milking cow dairy farm. The manure storage contained liquid dairy manure and milk-house wastewater produced on the farm. In this case, the separated manure was still relatively fresh (i.e. separated before any solids started to break down in storage), thus potentially improving the measured efficiency of the separator.

Tables 1 and 2 give examples of influent manure nutrient and bacteria data for one of the tests.

Table 1 - Nutrient levels in influent manure for Surface to Surface equipment test

	DM (%)	N (%)	P (%)	K (%)	NH_4-N (mg/L)	VS (%, DM basis)	C (%)	pH
M1	0.6	0.08	0.01	0.06	3272	67.6	0.41	7.7
M2	3.79	0.4	0.05	0.26	912	69.7	2.64	7.5
M3	1.32	0.18	0.01	0.14	811	64.5	0.85	7.4

where M1 and M2 are liquid swine manure, M3 is liquid dairy manure

Table 2 - Bacteria levels in influent manure for Surface to Surface equipment test

	total coliform (cfu/100 mL)	**E. coli (cfu/100 mL)**
M1	240,000	93,000
M2	230	230
M3	240,000	93,000

b) Data Collection

This section contains information on sampling and measurement procedures. Some of this information is already reported in the section earlier on Development of the Test Procedure. Additional detail is included here.

- Flow rates were monitored constantly and recorded at regular intervals.
- Observations on separator operation, labour requirements, changes in capacity over time, odour evaluations of the influent manure, separated liquids and solids and the solids densities were taken throughout the testing.
- The power use of the separator was monitored. For the separators that used electrical power a meter was used to measure total Kilowatt-hours used for the test. For electrical equipment that could not be wired into the meter, specifications were taken and the power use was estimated based on the manufacturer's specifications. For equipment that used diesel power, total fuel consumption was measured for each test.
- Samples of the influent manure, separated liquids and separated solids were taken throughout the test. They were tested for Total Nitrogen, Total Phosphorous, Total Potassium, Ammonium-N, dry matter, Loss of Ignition at 475 degrees Celsius (VS-Volatile Solids), and pH. There were three samples taken from each of the separated liquids and the separated solids. They were taken at about 5,000 litres, 10,000 litres and 15,000 litres of manure separated. One sample of influent manure was tested but was a composite sample of at least three sub-samples taken from the inflow at a similar time that the separated samples were taken.
- Samples were taken for bacteria testing from the influent manure, separated liquids and separated solids. Two samples were taken, at about 5,000 litres and 10,000 litres of manure separated for the separated liquids and separated solids. One sample of influent manure was tested but was a composite sample of at least 3 sub-samples taken from the inflow at a similar time that the separated samples were taken. The samples were tested for *E. coli* and total coliform.
- Particle size distribution was measured using 11 precision weighed soil screens with a mesh sizes ranging from 4.0 mm openings to 0.045 mm openings (U.S.A. standard #5 to #325 screens) - listed in Table 3. The screens were stacked with the most coarse mesh size on top and the finest on the bottom. A 500 mL composite sample of liquid manure was then poured onto the top screen of the stack and then lightly washed through by spraying tap water using a

hose and spray nozzle. The washing moved the fine material still laying on the screen down to the appropriate screen size. The top screen was removed and the next screen was sprayed to ensure that the fine solids were washed down into the finer screens. This was repeated until all the screens had been washed. They then were dried for 24 hours at 105 ^{o}C and again weighed using a precision electronic scale. The weight difference between the tare weight of the screen and the dried screen was the dry matter that was greater in size than the mesh. This process was used for all influent manure and separated liquids for each manure type and separator tested.

Table 3 - Screen mesh size used in the order stacked from top to bottom

mesh size	metric equivalent
5	4.00 mm
10	2.00 mm
18	1.00 mm
40	425 µm
50	297 µm
60	250 µm
80	177 µm
100	150 µm
120	125 µm
230	63 µm
325	45 µm

- Flow rates for the influent manure were measured constantly using a Greyline Instruments Inc. Doppler Flow Meter, Model DFM-III, series D, giving total flow as well as the real time flow rate. Flow rates were recorded at regular intervals to monitor flow rate variability. The manure tank volume was also measured and recorded in some cases as a check of flow rate and volume. Low flow rates such as those from laboratory scale separators were measured using graduated containers and a stop watch.
- Separated solids flow rate and volume were measured at regular intervals from the solids stream using graduated containers and a stop watch. The total volume of solids separated was also measured.
- Separated solids were collected in a graduated container and weighed to determine their density. Using the density and total volume of separated solids, a total mass was calculated.
- The testing start and finish times of each separator were recorded. Flow rates and sampling

times were recorded. Comments on the operation of the separators throughout the test were also recorded.

- Odour assessments were taken throughout the time of the testing. Odour ratings were subjective and related the relative odour of the separated liquids and solids to the influent manure being tested. Ratings were based on presence or absence of odour and odour character.

c) Description of Mechanical Separators Tested

The systems tested were separators from the region that were either developed to separate livestock manure or had the potential to handle liquid livestock manure. They included a screw press, a combination inclined screen and screw press, a round vibrating screen, a two stage rectangular vibrating screen and hydrocylones, a drum type screen and a membrane filter system (reverse osmosis). Following is a short description of each system:

i) Key Dollar Cab - model 100 (supplied by Verellen Optimized Energy) **-** This is a rotating drum separator. The machine evaluated was a prototype, originally developed for use in the food processing industry. It was deemed to have potential to remove solids from liquid livestock manures. It consists of a drum screen that rotates partly submerged in a tank of liquid manure. All metal parts are stainless steel. Liquids migrate into the drum screen as it rotates and the solids that accumulate on the outside of the screen are flushed out using a high pressure spray from inside the drum. A portion of the manure effluent (or clean water) is pressurized using a 0.38 kW jet pump producing 275 kilopascals pressure (40 psi). This is sprayed from the inside of the drum to keep the screen clean. Fine solids are collected in a trough and drained to a holding tank. Some coarse solids settle in the tank in which the drum rotates, to be removed later, though no system had been designed to remove these solids. A 0.38 kW electric motor driving a reduction gear drive rotates the drum.

ii) Maximizer Separator (supplied by Ballagh Liquid Technologies Inc.) - This is a combination of an inclined screen with a rubber-paddled flighted conveyor plus a screw press to further de-water the solids. The conveyor is 7.3 metres long, elevated at one end above the ground to 4.72 metres with screens the full length of the conveyor. The conveyor screen hole sizes may be changed, depending on the manure (e.g. 0.8, 1.6 or 3.2 mm round holes). The screw press has a 203 mm diameter auger and screen, with the screen 305 mm long having 1.6 mm or 3.2 mm holes. A spring-loaded (adjustable) cantilevered door provides resistance pressure to squeeze out excess liquids. The separator metal parts are all stainless steel construction. This system is currently being used on farms.

iii) Surface to Surface, 280 Centre St., Petrolia, Ontario. This is a prototype manure separator, comprised of a combination of a two-level vibrating screen and four hydrocyclones. Coarse solids are first removed by the lower screen and discharged off the end of the screen. Separated liquids are pumped from a tank below the coarse screen through four hydrocyclones onto a fine screen for further separation. Liquids are then pumped to a storage tank. The system is powered by a diesel engine running a hydraulic pump that operates the hydrostatic drives used on the separator. All metal parts are either stainless steel or painted steel.

iv) SEI Dewatering System (Manufactured by Sleegers Machine and Fabrication Inc.) - This is a screw press system. It has a design capacity of between 90 to 909 L/min. It is constructed of carbon steel, weighing 426 kg. It is powered by a single phase, 5.6 kW, 220 volt, 40 amp electric motor driving a reduction gear drive that turns the 26.0 cm diameter, 108 cm long stainless steel auger with a 59 cm long flighting. The auger had single flighting for dairy manure and double flighting for liquid swine manure. Nylon brushes were mounted on the flighting to keep the screens clean. The auger rotated inside a 52 cm long stainless steel axial wire screen (slot size 1.0 mm for dairy manure and 0.25 mm for swine manure) that was mounted inside the exterior housing. The auger was supported by a bearing on each end, allowing close tolerances with the screen. The opening for the solids discharge had a spring loaded plug with a solids cutter, that mounted on the auger shaft and could be adjusted to give the desired solids dry matter level. This system is currently being used on farms.

v) SWECO - LS18-53 (lab scale tester) - This is a round vibrating screen using two eccentric weights on an electric motor to produce a vibration that spirals coarse solids around the screen from the centre to the outside, where they are discharged. The coarse materials stay on top of the screen and fine solids and liquids fall through to the lower level to exit through a spout. The system is self cleaning. Metal parts are all stainless steel construction. This system was designed to process a large range of products, including dry industrial material, sewage, vegetable processing waste, liquid wastes with coarse solids as well as liquid manure.

vi) VSEP - Series LP (New Logic, Emeryville, California) - This is a membrane filter, set up for this test with reverse osmosis filters. The unit evaluated was a “lab” scale model (a larger unit has been operating on a swine farm in Korea). The Vibrating Shear Enhanced Process (VSEP) uses a vibrating stack of 18 reverse osmosis membranes, high pressure and a timed (open and closed) outlet valve to remove water from liquid manure. The stack of membranes was vibrated using an electric motor with an eccentric weight, vibrating a heavy metal plate (seismic mass) transferring the motion up a tubular tuned torsion spring to the reverse osmosis head. The vibration creates a shear force that prevents fouling of the membranes with solids. It is powered by two electric motors - a 1.1 kW electric motor for the vibration system and a 2.25 kW electric motor for a diaphragm pump to pump the influent manure and pressurize the system to 3100 kilopascals (450 psi). Influent manure flowed from a 40 litre tank via a 38 mm diameter plastic hose through an in-line 0.297 mm (50 mesh) screen to the pressure pump. Pressurized manure was pumped through a 12.7 mm braided steel, high pressure hose to the top of the vibrating filter head. Clean water (permeate) exits the centre top of the filter head, through a clear 12.7 mm vinyl hose into a storage tank. Concentrate exits through the bottom of the filter head via a 12.7 mm metal tube, through pressure and flow control valves into another storage tank. Concentrate passed through an automated valve that is opened and closed depending on the setting of the timer (controlling the permeate recovery percentage - the longer it was closed the higher the recovery rate).

Test Results

a) Performance of Mechanical Separators - General

The test procedure outlined earlier was followed as closely as possible for the testing of each of the six separators. Test reports for each of the units evaluated are attached in the appendix of this report. Two of the separators (VSEP and Key Dollar Cab) required pre-screening of the manure to remove coarse solids.

As expected, the results of testing for the six units gave quite a range of results. Also, there was a considerable difference in performance among the three manures tested. The following sections will examine these differences in detail.

b) Separator Capacity

Three of the manure separators tested were farm scale systems, the Maximizer, the Surface to Surface separator and the SEI Dewatering System. The other three separators, the Key Dollar Cab Drum, the SWECO screen and the VSEP (reverse osmosis) were laboratory scale systems. Separator capacities were quite variable and changed with the manure separated.

The Maximizer had a higher capacity (in terms of manure flow rate) than any of the other systems (see Figure 1). The SEI screw press and the Surface to Surface vibrating screens and hydrocyclones had lower capacities than the Maximizer for all manures tested. The SEI screw press had reduced capacity with hog manure due to problems with the fine screen used. Once the regular screen was installed for the dairy manure, capacity increased and plugging was not a problem.

The laboratory scale systems had a much lower capacity. The lowest capacity was the VSEP (reverse osmosis) unit, which could only process about two litres per minute. Commercial scale units of VSEP have an expected capacity of 150 L/min. The SWECO vibrating screen also had very low flow rates as the dry matter levels increased. SWECO has a commercial scale system that uses a 152 cm diameter screen, increasing the capacity to about 1400 L/min for dilute manure and approximately 225 L/min for manure with a higher solids content.

c) Power Requirements

The energy requirements of the separators were measured. The volume of manure separated per kW-h of electrical use was calculated for those systems using electricity. For the systems using diesel engines, the volume of manure separated per litre of fuel was calculated. A sample of these results is shown in Table 4. It shows a considerable range in energy requirements. There were also cases of considerable variation between manure types for individual separators.

These types of numbers may be used by the potential equipment buyer to estimate the energy costs of running the equipment. At the time of testing, electricity was valued at $0.092 per kilowatt hour and diesel fuel at $0.65 per litre.

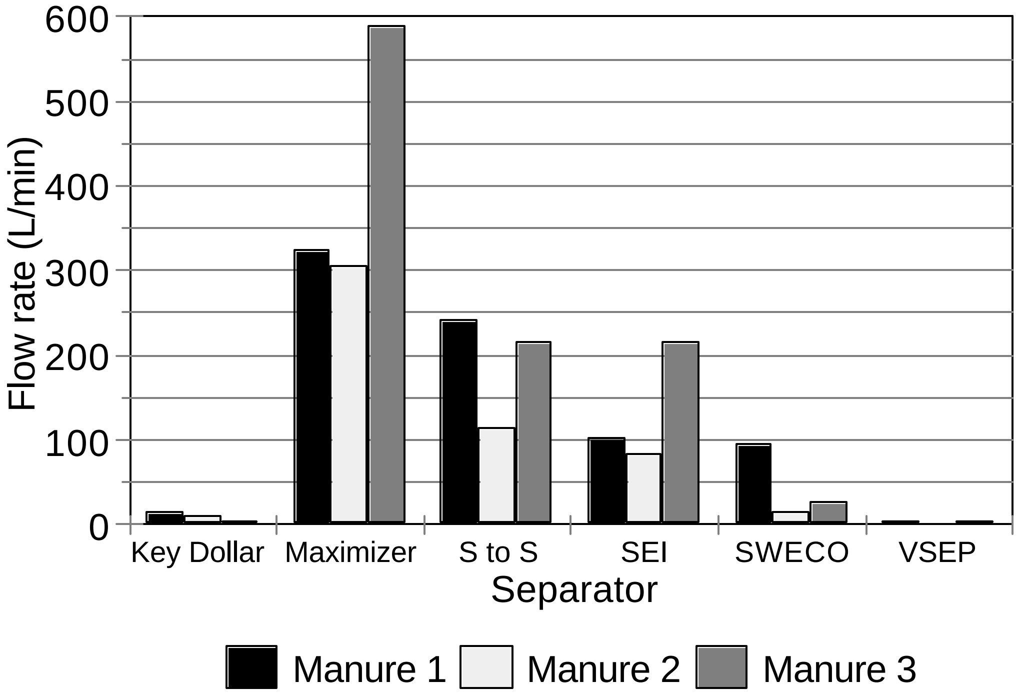


Figure 1 Manure flow rates for the 6 separators and the 3 manure types tested

Table 4 - Energy requirements for each separator for the dairy manure test

Separator	Manure volume separated per kW-h electricity (L)	Manure volume separated per L fuel (L)
Key Dollar	4342	
Maximizer	10535	
S to S		1226
SEI	4800	
SWECO	3030	
VSEP	94	

* The Key Dollar and the VSEP needed pre-screening of manure - the energy associated with this step is not included in the above table

d) Particle Size Distribution

All influent manure and separated liquids were screened to develop a particle size distribution profile. The rationale was that the larger the manure particles, the easier it would be to remove them from the manure. If a manure was comprised mainly of very tiny particles, the separator would not be as effective at removing solids (at least certain types of separators). In fact, most of the separators tested relied on screening as part of the process.

Eleven screens were used to profile the particle size distribution. The process proved to be labour-intensive. Only two samples of each manure were tested - one influent sample and one effluent (separated liquids) sample. Figure 2 shows the kind of comparison that was possible between influent and effluent particle sizes. It demonstrates that the coarse solids (i.e. those trapped by the 5 and 10 mesh screens), were removed by the separator and the remaining solids passed through the machine untouched. Unfortunately, not all graphs showed as clear a trend as this. There was a great deal of variability in the numbers. This suggested that either: there were too many screens used, or there were too few manure samples tested, or the test itself was difficult to carry out in a consistent manner. Of course, there could have been a combination of these factors.

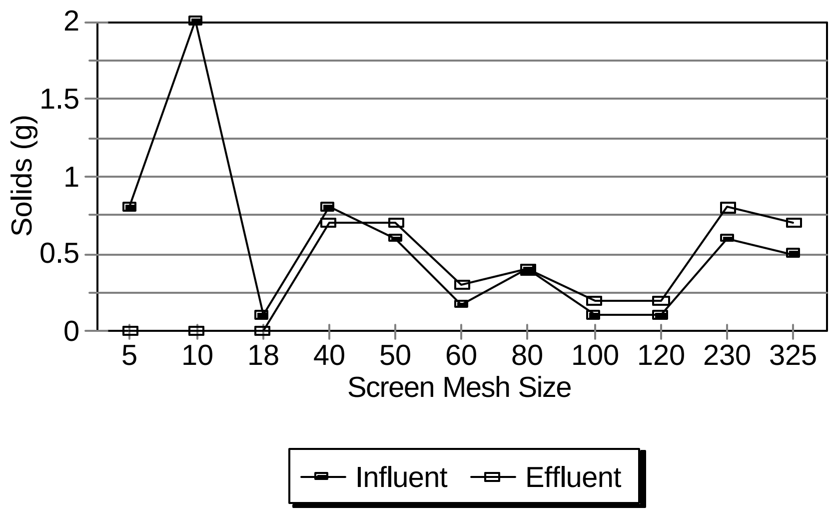


Figure 2 Particle size distribution for SEI (screw press) separator and Manure 2 (swine manure)

The reasonable approach seemed to be to simplify the test by using only four representative screen sizes, and to ensure that in future tests, two or three samples of influent and effluent are measured, instead if one. Figure 3 shows the distribution graph for the Maximizer separator, for the dairy manure test. It summarizes the data so that there are only four screen sizes, making the graph easier to interpret, especially in those cases where the numbers are more variable. Once again, it shows that the removal of solids was in the larger particles (i.e. those trapped by a 50 mesh, or larger, screen).

It appeared that some of the "screen" separators removed particles smaller than their screen size due to a smearing of the manure over the screen holes (thus reducing their size). The Maximizer separator was designed to take advantage of this to improve the effectiveness of the separation. Rubber paddles smear the manure over the holes but also act as a squeegee to force liquids through the holes.

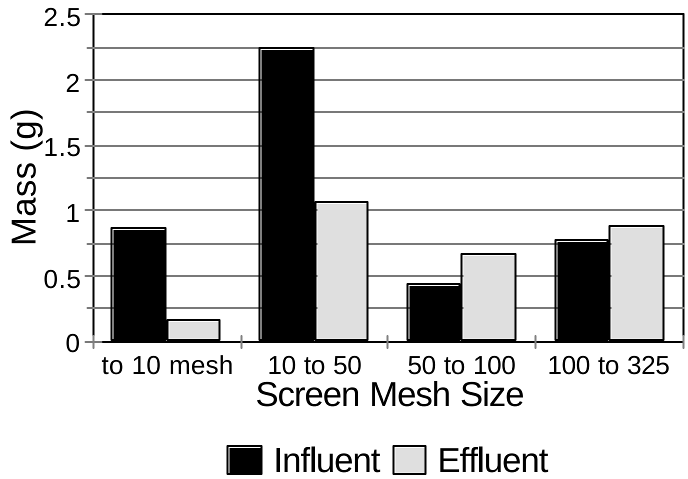


Figure 3 Particle size distribution for the Maximizer separator and dairy manure

e) Removal of Solids

Several methods have been used to express the efficiency of separators in removing solids from the influent manure. The calculation that appears to serve the greatest variety of design needs is as follows:

$$\text{\% of initial solids removed into separated solids} = \frac{\text{flow rate of DM in separated solids}}{\text{flow rate of influent DM}} \times 100$$

The results for the six separators and three manure types are shown in Figure 4. This is plotted with a “log scale” Y axis, in order to show the wide range of efficiencies in performing this task. The VSEP reverse osmosis unit removed virtually all of the solids in the influent. In contrast, the Key Dollar Cab prototype removed very little solids. Other units were closer to the 1 to 10% range, depending on the manure. As expected, the performance was poorest, generally, for Manure 1, which had the lowest solids content.

f) Removal of Nutrients

A similar calculation was used to express the efficiency at removing N and P from the influent manure. These two nutrients were deemed to be the most important. Indeed, many farmers have shown an interest in separation as a means of reducing P levels in liquid effluent, thus offering greater flexibility in nutrient management planning. Figure 5 shows the percentage removal of N that was achieved during the testing, and Figure 6 gives the corresponding P values.

Once again, a wide variation in results is evident, between machines and between manure types. This is most evident in the P removal. One of the problems with the P removal numbers is that the levels of P were low in the influent manure and in most cases were reported by the lab at an accuracy of only one significant digit. Concentrations reported as 0.01 or 0.02 mg/L make

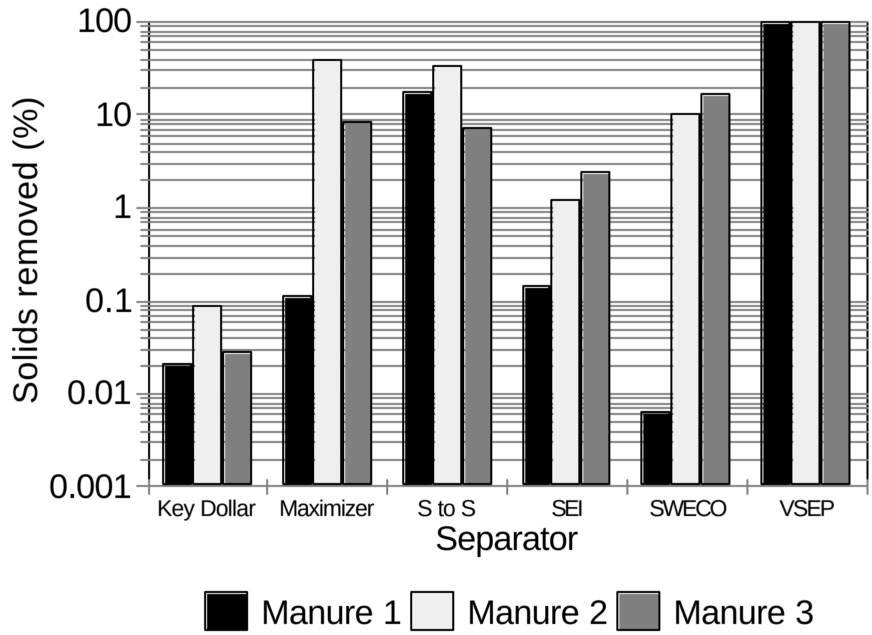


Figure 4 Percent of initial solids removed into the separated solids for all six separators and three manure types

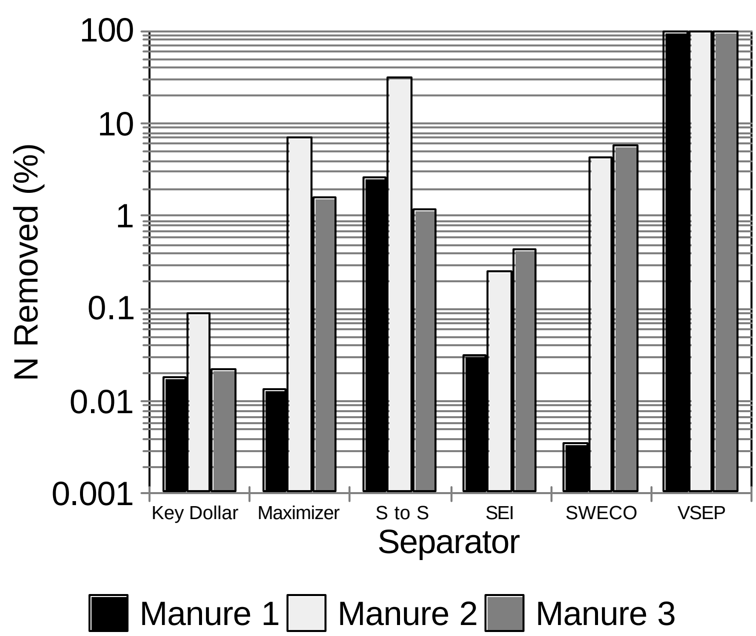


Figure 5 Percent of the initial N removed into the separated solids for all six separators and three manure types

precise removal calculations less reliable than desired, and probably account for a certain amount of the variation shown in the figure. However, it appears to be rather optimistic to expect most mechanical separators to remove more than about 10% of the manure P.

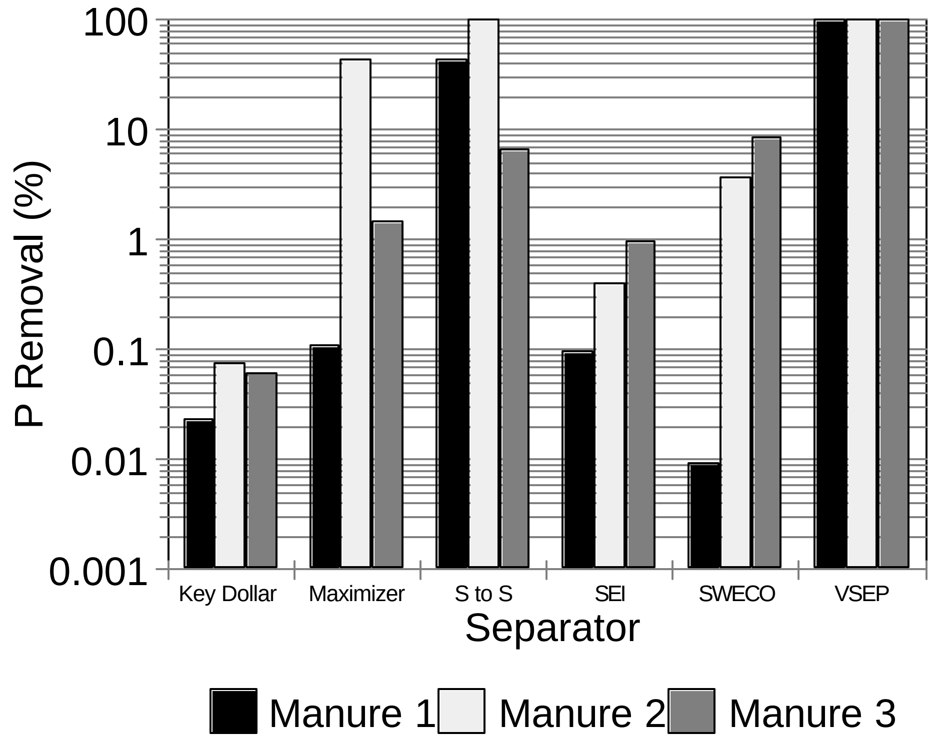


Figure 6 Percent of the initial P removed into the separated solids for all six separators and three manure types

The tables in the test reports (appendix) give an idea of changes in K, NH_4-N, Volatile solids, Carbon and pH. The volatile solids would likely only be of interest if the separator manufacturer were making claims about odour removal - most do not. Measuring C is likely of limited use and has been dropped from the test protocol. The pH is reported and may be needed for certain applications. In general, there were some changes in pH, most often resulting in a higher pH for the separated solids but little change for the liquids.

g) Removal of Bacteria

There is a great deal of attention focussed on pathogenic microorganisms in livestock manure and the fate of these organisms in the environment. It is logical that certain separator manufacturers will make claims about removal of bacteria, if their unit is capable of reducing numbers. The indicator organisms measured during this study were total coliform and *E. coli* bacteria. These are relatively easy and inexpensive tests and these organisms will always be present in typical livestock manure. The VSEP unit was able to remove all of the bacteria tested, which was expected, as the opening size was smaller than the size of organisms. None of the other separators showed any consistent removal of significant amounts of bacteria into the separated solids. In other words, the units were not effective at significantly reducing bacteria levels in the separated liquids. Tables containing bacteria values are included in the appended test reports.

h) Labour Requirements

Part of the test protocol involved recording the labour needed to run the test and projecting the labour needs to operate the unit on a farm. Most of the systems tested required at least one operator to run them properly. All systems tested have the ability to be run fully automated, thus reducing labour needs. The Maximizer, for example, required one operator during the testing. However, with the use of a system of floats and switches and a simple logic board it became fully automatic, requiring only periodic maintenance visits when placed on a farm. The more simple the separator design, the easier it would be to automate. The VSEP was the most complicated unit to set up and operate, requiring regular cleaning of the filter pack and prefilter. It also required more operator monitoring during separation to ensure it was running as desired.

Maintenance for all of the tested separators would be minimal. Examples of the types of maintenance needed:

- The SEI screw press requires periodic greasing of two fittings and occasional servicing to check on the screen, solids plug, auger, electric motor and drive system. .
- The Maximizer has no grease fittings that require regular greasing but the seals between the holding tank at the base of the inclined screen and flighted conveyor system and the separated liquids tank must be checked for leaks, the conveyor paddles and screens for wear, the screw press for proper operation and plugging and check the electric motors.
- The SWECO screen has no parts to lubricate but may require periodic servicing to check on the screen, screen cleaners, bearings, springs and the electric motor that produces the vibration.
- For the Surface to Surface separator, the operator would have to check on the diesel motor for fuel, oil, coolant belts and proper operation, as well as monitor the hydraulic system including oil levels, pumps, hoses and motors. The separator has screens, manure pumps and hydro cyclones to monitor occasionally.
- The Key Dollar Cab Drum separator would require monitoring of the electric drive motor, the drive chain, reduction gear transmission, and the pressure pump and system. A system would also be required to pre-screen the manure and also to remove any solids that precipitate from the influent manure in the tank.
- The VSEP requires the greatest amount of regular maintenance. The manure must be pre-screened to remove coarse solids so there would be another system to monitor, as well as the VSEP. The pre-filtration system must be monitored to detect plugging. The pressure system (pump, high pressure hoses, flow and pressure control valves) must be regularly checked. The vibration system, the motor, seismic mass, tuned torsion spring, and filter pack require regular monitoring. The filter pack bolts and nuts must be torqued regularly. The electronic controls must be adjusted as needed to the required settings and the filter pack must be flushed with fresh water, an acid wash, a fresh water flush, a caustic wash and a fresh water flush after about

48 hours of operation or when flow starts declining. The commercial systems are fully automated, removing the need for most of this maintenance.

For all of these systems the operator would also have to monitor the operation of pumps delivering manure to the separators. The separated liquids would likely flow by gravity to storage. Otherwise, this pumping system would also require monitoring.

i) Odour Levels

Some separators are marketed with claims that they can reduce odours in the liquid effluent (perhaps also the separated solids). During the testing, odour assessment were made for the effluent and separated solids. These were compared to odour levels in the influent manure. The ratings were very subjective, not using any instruments to measure the concentration of odours, but simply using the human nose to evaluate relative levels of odour and how offensive the odours were. A more formal test procedure should be used in cases where odour control is a primary concern.

The separation process appeared to have at least some impact on odours from the separated liquids and solids. In all cases except for the VSEP, odours from the separated liquids were similar to those from the influent manure (i.e. based on odour, this liquid could not be distinguished from influent manure). The VSEP unit removed most of the odours leaving only a slight ammonia and sulphur smell in the effluent. The odours were not detectable after a few hours of exposure to the air.

The odours from the separated solids were reduced in certain cases. The level of odour reduction seemed to be dependant on the amount of moisture still in the separated solids, so the separators most effective in drying the solids had the greatest impact on odours. The concentrations of volatile solids were measured, with the expectation that these numbers would be a predictor of odour suppression. This did not seem to be as good an indicator, however, as the dry matter content of separated solids. The most effective in this regard were the Surface to Surface, the SEI and the Maximizer systems. The other separators did not appreciably reduce odours in the separated solids.

j) Economics of Manure Separation

There are a number of issues to look at when determining the relative economics and costs of manure separation. There is an initial capital investment to purchase and set up each of the separators. There are operating costs which are influenced by the separator’s capacity, energy use, maintenance, reliability, labour and availability of parts and service. Other factors are the economics associated with possible reduced environmental risks, changes in manure volumes, potential for creation of value-added products, relative ease of meeting Nutrient Management targets (mandated in Ontario and elsewhere).

Estimated capital costs of the separators evaluated were:

- SWECO vibrating screen (152 cm diameter) $21,498.00
- SEI Dewatering System screw press $26,900.00
- Key Dollar Cab Inc. rotating drum screen $30,000.00 to $40,000.00
- Maximizer screen + flighted conveyor + screw press $53,037.00
- Surface to Surface vibrating screen + hydro cyclones $100,000.00
- VSEP reverse osmosis (farm scale system) $409,000.00

Most of the separators would need a shelter to protect them from the environment and freezing. All systems except the SEI screw press should be in a heated shelter (assuming winter operation). All separators are prone to corrosion, though some have gone to greater lengths to reduce this. All separators using screens are subject to mineral deposits on the screens over time. Regular cleaning will be needed. Separators that are run seasonally will require a proper shut down between operations and a proper startup to prevent equipment from seizing up, rust from developing on parts and mechanical equipment from failing.

Summary and Conclusions

A study was conducted during the summer and fall of 2002 to develop a standard test for mechanical liquid manure separators. Part of the study involved using the test to investigate the effectiveness of six mechanical manure separators. All separators were tested using three manure types, a low dry matter liquid hog manure, a medium dry matter liquid hog manure and liquid dairy manure. The liquid manures had similar characteristic for each type tested. Of the separators tested, three were presently being used commercially on farms. The other three systems, although used for other commercial applications, had not been designed for manure separation and could thus be called prototypes. Standard reporting forms were developed to summarize the performance of the separators. Highlights of the study:

- The results for the six units gave quite a range of results. Also, there was a considerable difference in performance depending on which of the three manures was being tested.

- The Maximizer had the highest capacity of the models tested, with a range of 306 to 590 L/min.

- There was a considerable range of values in the volume of manure separated per kW-h of electricity, from 94 L for the VSEP to 10,535 L for the Maximizer. The Surface to Surface was diesel powered, with an efficiency of 1226 L of manure per L of fuel.

- The particle size distribution in the manure and the separated liquids can give valuable information needed to properly design a system. The use of four screens should give the information needed - examples of sizes: 10 mesh, 50 mesh, 100 mesh and 325 mesh (i.e. 2.0, 0.30, 0.15 and 0.045 mm hole sizes).

- More than one sample should be tested to establish the particle size distribution, to reduce the variability of results.

- Most separators were effective at removing coarse manure particles i.e. those trapped by a 50 mesh, or larger, screen.

- There was a wide range of values for the quantity: Percent initial solids removed into the separated solids - ranging from < 0.1% to 100%. The high value was for the VSEP, where the separated solids are still in a slurry form. The Maximizer and Surface to Surface achieved highs of 38% and 34%, respectively.

- Removal of solids was very poor for Manure 1 (DM in range 0.34 to 0.84%) for four of the six separators.

- The removal of N into the separated solids followed the same pattern as removal of solids.

- The removal of P into the solids portion was similar, although there was less confidence in the values, since most concentrations were reported by the lab at only one significant digit.

- The VSEP unit removed all total coliform and *E. coli* bacteria. Other systems did not have a significant impact on bacteria numbers.

- Labour needs to operate the six systems varied, but most systems have the ability to be fully automated for on-farm use.

- Odours from the separated liquids were similar to liquid manure in most separators tested. The only exceptions were the separated liquids from the VSEP separator, which were essentially odour free.

- Odours from the separated solids appeared to be dependant on the moisture level of the solids after separation. The separators most effective in drying the solids were also the most effective in reducing or removing odours. This included the Surface to Surface, the SEI and the Maximizer systems.

Acknowledgements

The authors would like to acknowledge the support for this project from Ontario Pork. The project also relied on the generous donation of the separators tested by the suppliers noted .

1. SEI Dewatering System screw press manufactured and supplied by Sleegers Machine and Fabrication Inc., London, Ontario
2. The Maximizer, a combination inclined screen with a flighted conveyor and a screw press, supplied by Ballagh Liquid Technologies, Wingham, Ontario
3. SWECO vibrating screen supplied by Canada Process Equipment, Mississauga Ontario
4. Surface to Surface combination vibrating screen and hydro cyclone system, manufactured and supplied by Surface to Surface Inc., Watford, Ontario
5. Key Dollar Cab Inc. rotating drum screen, supplied by Verellen Optimized Energy Inc., Shedden, Ontario

6. VSEP reverse osmosis system manufactured by New Logic and supplied by Rondeau Anaerobics, Ridgetown, Ontario

References

Ford, M. and Fleming, R. 2002. Mechanical Solid-Liquid Separation of Livestock Manure - Literature Review. Report to Ontario Pork. Ridgetown College, University of Guelph. 49 pages + appendix

Appendix

Attachments include:

a) Mechanical Solid-Liquid Separation of Livestock Manure - Test Procedure - October 2002

b) Test Report - Key Dollar Cab

c) Test Report - Maximizer

d) Test Report - Surface to Surface

e) Test Report - SEI

f) Test Report - SWECO

g) Test Report - VSEP

Mechanical Solid-Liquid Separation of Livestock Manure
- Test Procedure -

October 2002

General:

- Test at least three different manures - representing a range of dry matter contents and livestock types (reflecting the target livestock groups)
- Test at least 20,000 L of each manure

Prior to separation:

- Characterise the influent manure:
  - consider the length of time the manure was stored before separation
  - consider how fine the grain in the feed has been ground
- List the energy requirements of the separator and the energy requirements of any additional implements necessary for the operation of the separator (e.g. lift pumps, etc.)
- Record the model, manufacturer and selling price for the separator
- Record dimensions of components of the separator (e.g. overall screen size (length, width), size of screen pore openings, screen angle of incline, centrifuge upper and lower diameters)
- Provide operational parameters of the separator (e.g. frequency of vibration of screen)
- Conduct a particle size distribution analysis of the influent manure to determine the profile of solid particles in the unscreened manure - using the following screen openings: 2.0, 0.30, 0.15 and 0.045 mm (i.e. 10, 50, 100 and 325 mesh)
- Measure the rate of energy consumption
  - for systems powered by electricity, use a power meter and record the initial and final reading of this meter to determine the kWh of energy consumption
  - for diesel powered systems, calculate the volume of diesel fuel used during testing
- Agitate (stir) the tank containing the influent manure to re-suspend any settled solids
- A sample is needed of influent manure - it may be easier to collect this prior to starting the separator, although it is preferable to collect this during the test. Take a composite sample (consisting of 3 representative samples) of the influent manure to measure the following:
  - the solids content (DM), pH, and concentrations of N, P, K, NH_4-N and volatile solids (optional - measure if there are claims about odour control)

  a second single sample will be taken for the following:
  - bacteria analysis: *E. coli* and total coliform

During separation:

- Record the time at the start of testing. Record the time and volume separated at several times during the test (as a check on the more detailed flow rate monitoring).
- In addition, measure and record the flow rate of influent manure in one of two ways:
  - with a doppler flow sensor for the duration of the test period - flow rates will be recorded as frequently as every minute and the total flow can be measured as often as every five minutes
  - measure the volume of influent manure over a one minute time period - flow rates

measured in this way should be taken from three to five times during the testing period (note: this method of flow rate measurement will only be used when it is not possible to set up the doppler flow sensor)

- Measure the flow rate of the separated solids three to five times, once the separator has been operating for a sufficient time period (disregard the initial and final 20% of the manure volume). Use a graduated bucket and record the volume accumulated in one minute. Also record the time at which these flow rates were taken. Note: Theoretically, these values could be calculated, but this step provides a very good check on the earlier measurements.
- Take samples of the separated solids. The time at which these samples were taken should be recorded. No sampling will be taken during the initial and final 20% of manure volume.
  - three samples of the separated solids will be taken for analysis of N, P, K, NH_4-N, DM, and pH
  - two samples will be taken for bacteria analysis: total coliform and *E.coli*
- Take samples of the separated liquid. Record the time at which these samples were taken. No sampling will be taken during the initial and final 20% of manure volume.
  - three samples will be taken for analysis of N, P, K, NH_4-N, DM, and pH
  - two samples will be taken for bacteria analysis including, total coliform and *E. coli*
  - do a particle size distribution on this liquid, similar to that done for the influent
- The following should be monitored throughout the testing period:
  - labour/maintenance requirements - this should be considered in both a qualitative and quantitative sense - e.g., what type of maintenance management is required and the approximate length of time required to adequately complete these maintenance tasks (the amount of labour required by one person per unit volume of manure can then be determined)
- Record the time the testing was completed and the total volume of influent manure processed

Varying parameters during separation:

If parameters on the separator can be varied (such as flow rate and screen opening), more than one test will be needed (e.g. a vibrating screen may be run in the first test with a 40 mesh screen and in the second test this screen will be replaced by 60 mesh screen).

Additional Analysis of the Liquid and Solid Streams

- make qualitative odour observations of the odour levels of effluent and separated solids (relative to the influent manure)
- determine the volume and mass of the separated solids

Mechanical Manure Separator Test Report

Manufacturer:	Key Dollar Cab - supplied by Verellen Optimized Energy
Model:	model 100 - prototype
Separator type:	rotating drum
Description:	- the machine evaluated was a prototype originally developed for use in the food processing industry - and deemed to have potential to remove solids from liquid livestock manures - consists of a drum screen that rotates partly submerged in a tank of liquid manure - metal parts are all stainless steel - liquids migrate into the drum screen as it rotates and the solids that accumulate on the outside of the screen are flushed out using a high pressure spray from inside the drum - a portion of the manure effluent (or clean water) is pressurized using a 0.38 kW jet pump producing 275 kilopascals pressure (40 psi) - sprayed from the inside of the drum to keep the screen clean - fine solids are collected in a trough and drained to a holding tank - some coarse solids settle in the tank in which the drum rotates, to be removed later - screen rotates using a 0.38 kW electric motor driving a reduction gear drive
Test Configuration:	- tested with few alterations from its original application - drum screen hole size: 0.060 mm (250 mesh)
Test date(s):	November 13 and 14, 2002
Test Location:	Ridgetown College, Ridgetown, Ontario
Test Setup:	1. Manure was pre-screened using a 0.150 mm (100 mesh) vibrating screen. 2. Manure was pumped into the unit using a 51 mm flexible plastic hose by a 0.75 kW electric sludge pump. 3. Manure flow was monitored using a flow meter, giving total flow as well as the real time flow rate. 4. The separated liquids flowed into a tank adjacent to the separator and were pumped into a manure storage using a 0.38 kW sludge pump and 51 mm hose. 5. Samples were collected from the flushed solids, separated liquids and influent manure throughout the test for nutrient and bacteria testing as well as particle size distribution.

Manure(s) tested:	1 - liquid swine manure 2 - liquid swine manure 3 - liquid dairy manure
Test duration:	Based on **Time** Manure 1 4.0 h (8,450 L) Manure 2 2.0 h (1,340 L) Manure 3 2.0 h (1,650 L) Note: Since the manure had to be pre-screened, only a limited amount of manure was available to test.

Test Data

Flow rates through separator:	Average flow rates once initial adjustments were made: Manure 1 16 L/min (i.e. m^3/hr) Manure 2 10 L/min (i.e. m^3/hr) Manure 3 3.8 L/min (i.e. m^3/hr)
Volume of separated solids:	Volume / % of total manure / Density Manure 1 < 2 L <0.15 NA Manure 2 < 2 L <0.15 NA Manure 3 < 2 L <0.15 NA Note: The solids reported here are those removed from the drum - settled solids were not measured.
Power consumption:	Manure volume separated per kW-h of power: Manure 1 5,526 L Manure 2 3,526 L Manure 3 4,342 L

Nutrient levels in influent manure, separated solids and liquids

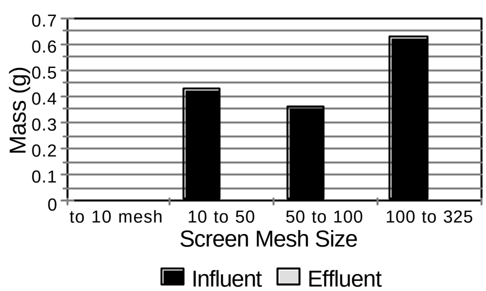
	DM (%)	N (%)	P (%)	K (%)	NH_4-N (mg/L)	VS (%, DM basis)	C (%)	pH
Influent Manure								
M1	0.34	0.09	0.01	0.06	940	50.2	0.17	7.8
M2	1.2	0.2	0.04	0.11	1981	54.5	0.64	7.9
M3	1.27	0.11	0.02	0.09	743	67.1	0.85	8
Separated Solids								
S1	0.3	0.07	0.01	0.05	766	50.5	0.15	7.9
S2	0.7	0.12	0.02	0.06	1076	61.3	0.42	8
S3	0.29	0.02	0.01	0.02	128	64.6	0.19	8
Separated Liquids								
L1	0.36	0.09	0.01	0.06	963	46.3	0.17	7.8
L2	1.2	0.17	0.05	0.09	1511	55	0.65	7.9
L3	0.9	0.08	0.02	0.06	556	65.5	0.59	7.8

Bacteria levels in influent manure, separated solids and liquids

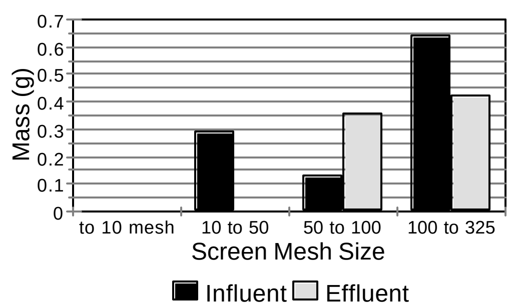
	total coliform (cfu/100 mL)	E. coli (cfu/100 mL)
Influent Manure		
M1	120	70
M2	1400	820
M2	22000	4500
Separated Solids		
S1	450	80
S2	1900	465
S3	4000	31000
Separated Liquids		
L1	310	80
L2	11000	600
L3	4400	3300

Particle Size Distribution

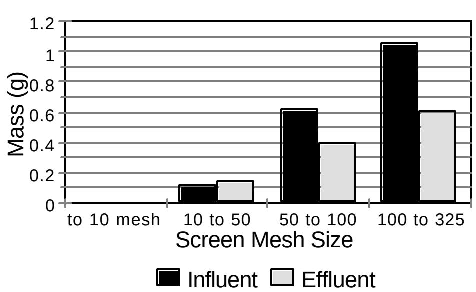
Manure 1



Manure 2



Manure 3



Conversion Table

mesh size	opening size (mm)
10	2.0
50	0.30
100	0.15
325	0.045

Performance Calculations

Feed flow rate	Manure 1 16 L/min Manure 2 10 L/min Manure 3 3.8 L/min
Solids (concentrate) flow rate	Manure 1 3.8 g/min Manure 2 14.9 g/min Manure 3 4.6 g/min based on estimates of solids removed listed above and density of 1000 g/L
% of initial solids removed into separated solids[a]	Manure 1 0.02 Manure 2 0.09 Manure 3 0.03 based on estimates of solids removed listed above and density of 1000 g/L
% of initial N removed into separated solids[b]	Manure 1 0.02 Manure 2 0.09 Manure 3 0.02 based on estimates of solids removed listed above and density of 1000 g/L
% of initial P removed into separated solids[c]	Manure 1 0.02 Manure 2 0.07 Manure 3 0.06 based on estimates of solids removed listed above and density of 1000 g/L
Dry Matter content of separated solids	in range 0.29 to 0.7 %

a $\frac{\text{separated solids DM (kg/min)}}{\text{influent DM (kg/min)}} \times 100$

b $\frac{\text{separated solids N (kg/min)}}{\text{influent N (kg/min)}} \times 100$

c $\frac{\text{separated solids P (kg/min)}}{\text{influent P (kg/min)}} \times 100$

Observations During Test

- Separated solids data were collected from the solids removed by the back-spray, even though a significant portion of the manure solids simply settled in the tank.
- For Manure 1, separated liquids could be used to flush the solids off of the scren. However, for Manure 2 and Manure 3, fresh water was used to flush the screen. Flushing with separated liquids caused a plugging of the screen on the inside. Flushing either with water or separated liquids added a significant portion of liquid to the separated solids, making the solids more dilute.
- Odours from the flushed solids and separated liquids were similar to those of the influent manure.

Economic Considerations

Approximate purchase price ($Cdn)	- estimated $30,000 to $40,000 for farm-scale unit
Approximate additional setup costs	- should be operated inside a shelter (heated in winter)
Labour needs	- can be run with limited labour once it is set up - could also be automated to operate unattended - would require monitoring of the electric drive motor, the drive chain, and reduction gear transmission - must monitor the pressure pump and system to be sure it is running at the correct pressure and there are no plugged spray nozzles
Operating costs	maintenance - machine appears to be reliable, has a relatively simple design supplies - none needed power - electrical - mentioned earlier
Other	-

General Comments

- This system was designed so that it required limited labour and maintenance to operate and could be automated thus requiring only occasional monitoring. The equipment appears to be robust enough and built to resist corrosion, so that only limited maintenance should be required. It does require a system to handle the solids that are rejected by the screen. It also requires pre-screening of the manure - which can be done using an inclined screen with a flighted conveyor that is available with this unit (but was not included with the test unit).

- The screen removed most coarse particles from the manure
- It appears that separation of manure similar to those tested is not practical using this separator. Flow rates were very low, largely due to the very fine screen. The screen was not fine enough to remove enough of the solids to make a significant difference but fine enough to severely restrict the manure flow.
- A system is needed to remove any solids that settle out in the influent manure tank.
- Comments on test procedure:
    - calculations of P removal efficiencies are variable, partly due to the fact that the concentrations of P tend to be close to the lower detection limit of the analysis procedure
    - the length of the test (volume of manure separated) is a compromise - it does not allow for an evaluation of long-term performance (e.g. slime problems, mechanical breakdowns, deterioration of the equipment, gradual plugging, etc.) but it does allow for testing more than one manure type, which is essential
    - there was an attempt to get manure samples in a wider range of DM contents
    - more samples should have been taken for the particle size distribution analysis - there is too much variability in the test results to rely on only one sample of influent and effluent

Report created by: Ron Fleming and Malcolm MacAlpine - June 30, 2003
Ridgetown College - University of Guelph

Tested by: Malcolm MacAlpine
Ridgetown College - University of Guelph

In consultation with Mike Verellen, Verellen Optimized Energy

Mechanical Manure Separator Test Report

Manufacturer:	Maximizer Separator distributed by: Ballagh Liquid Technologies Inc.
Model:	Maximizer
Separator type:	inclined screen with screw press
Description:	- a combination of an inclined screen with a rubber-paddled flighted conveyor plus a screw press to further de-water the solids - the conveyor is 7.3 metres long, elevated at one end above the ground to 4.72 metres with screens the full length of the conveyor - conveyor screen hole sizes may be changed, depending on manure: e.g. 0.8, 1.6 mm or 3.2 mm round holes - screw press has a 203 mm diameter auger and screen, with the screen 305 mm long having 1.6 mm or 3.2 mm holes - a spring-loaded (adjustable) cantilevered door provides resistance pressure to squeeze out excess liquids - separator metal parts are all stainless steel construction to reduce corrosion
Test Configuration:	- two electric motors: a 1.5 kW motor drove the conveyor chain and a 2.25 kW motor operated the screw press <u>Manures 1 and 2:</u> - separator was set up to handle a low dry matter liquid hog manure, with the first 2.4 metres of screen having a hole size of 0.8 mm and the top 4.8 metres with a hole size of 1.6 mm. - screw press had a screen with a 1.6 mm hole size - the spring loaded door on the screw press was set to adequately dry the manure solids <u>Manure 3 (dairy):</u> - the screen hole size was 3.2 mm for the full 7.3 metres - screw press had a screen with a 3.2 mm hole size - located on a 300 milking cow dairy farm treating all liquid dairy manure and milk-house waste water produced on the farm - manure was separated when fresh (i.e. before any possible biological breakdown of solids in storage) - separator was enclosed in a heated building to protect it from the weather and prevent freezing

	- manure flowed from a pull plug system in the manure and milk-house waste storages into a holding tank that held the flushed manure - a float mechanism initiated a cycle that started a sludge pump in the holding tank, pumping manure into the Maximizer - a float in the Maximizer tank started the separator and also shut off the flow of fresh manure into the tank once filled - the pump was cycled on and off as needed to keep the manure at the required levels
Test date(s):	December 4, 5 and 21, 2002 (1 manure type each day)
Test Location:	- Ridgetown College, Ridgetown, Ontario - Manures 1 and 2 - On-site at a dairy farm - Manure 3
Test Setup:	Manures 1 and 2: 1. The manure was pumped into the unit using a 51 mm flexible plastic hose using a 0.75 kW cutter pump. Manure flow was monitored using a flow meter, giving total flow as well as flow rate. This manure was agitated during the test. 2. The influent manure was pumped into a tank at the bottom of the inclined screens. 3. The separated liquids drained through the screen into a separated liquids tank. 4. The separated liquids were pumped off the surface of the tank into a liquid manure spreader using a 0.38 kW sludge pump and a 51 mm hose. 5. The solids were pushed out the end of the screw press separator into a front end loader bucket or a truck box. The solids flow rate was monitored by measuring the solids volume and mass extruded. 6. Samples from the separated solids were collected at the completion of the test. 7. Separated liquid and influent manure samples were collected throughout the test for nutrient and bacteria testing as well as particle size distribution. Manure 3: 1. Similar to above, but using the on-farm system of pumping into the separator. The separated liquids flowed off the top of the separated liquids tank on the Maximizer into a series of three settling tanks (gravity settling).

Manure(s) tested:	1 - liquid swine manure 2 - liquid swine manure 3 - liquid dairy manure
Test duration:	Based on **volume of manure separated** Manure 1 24,600 L Manure 2 25,600 L Manure 3 29,500 L

Test Data

Flow rates through separator:	Average flow rates once initial adjustments were made: Manure 1 324 L/min (i.e. 19.4 m^3/hr) Manure 2 306 L/min (i.e. 18.4 m^3/hr) Manure 3 590 L/min (i.e. 35.4 m^3/hr)
Volume of separated solids:	<u>Volume</u> / <u>% of total manure</u> / <u>Density</u> Manure 1: 1.0 L, 0.004, 830 g/L Manure 2: 700 L, 2.73, 834 g/L Manure 3: 800 L, 2.71, 270 g/L
Power consumption:	Manure volume separated per kW-h of power: Manure 1 8,200 L Manure 2 7,738 L Manure 3 10,535 L

Nutrient levels in influent manure, separated solids and liquids

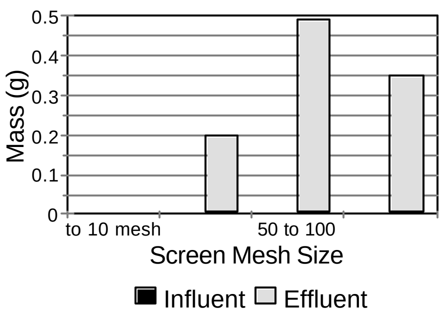
	DM (%)	N (%)	P (%)	K (%)	NH_4-N (mg/L)	VS (%, DM basis)	C (%)	pH
Influent Manure								
M1	0.39	0.11	0.01	0.06	1132	51.5	0.2	7.4
M2	1.4	0.22	0.05	0.1	1993	55	0.76	7.7
M3	1.88	0.11	0.02	0.11	668	77.2	1.45	7.7
Separated Solids								
S1	13.3	0.44	0.33	0.1	1725	84.8	11.3	8.3
S2	23.5	0.69	0.94	0.13	2499	77.1	18.4	8.3
S3	21.6	0.24	0.04	0.12	341	95	20.5	8.3
Separated Liquids								
L1	0.4	0.13	0.01	0.07	954	47.5	0.19	7.9
L2	1.5	0.22	0.06	0.1	1985	55.2	0.83	7.7
L3	1.7	0.12	0.02	0.12	657	74.6	1.27	7.4

Bacteria levels in influent manure, separated solids and liquids

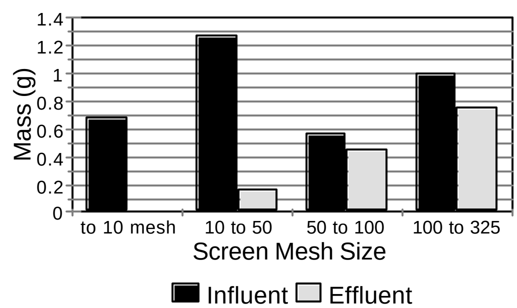
	total coliform (cfu/100 mL)	E. coli (cfu/100 mL)
Influent Manure		
M1	8200	9300
M2	1400	950
M3	320000	290000
Separated Solids		
S1	13000	6900
S2	80000	38000
S3	210000	180000
Separated Liquids		
L1	4300	3800
L2	1200	690
L3	270000	240000

Particle Size Distribution

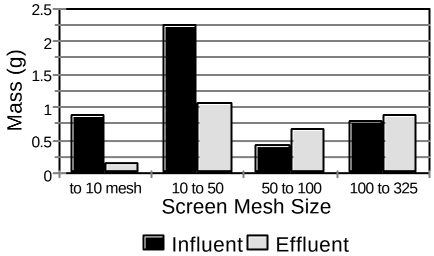
Manure 1



Manure 2



Manure 3



Conversion Table

mesh size	opening size (mm)
10	2.0
50	0.30
100	0.15
325	0.045

Performance Calculations

Feed flow rate	Manure 1 Manure 2 Manure 3	324 L/min 306 L/min 590 L/min
Solids (concentrate) flow rate	Manure 1 Manure 2 Manure 3	0.011 kg/min 6.98 kg/min 4.32 kg/min
% of initial solids removed into separated solids[a]	Manure 1 Manure 2 Manure 3	0.12 38.3 8.41
% of initial N removed into separated solids[b]	Manure 1 Manure 2 Manure 3	0.013 7.15 1.60
% of initial P removed into separated solids[c]	Manure 1 Manure 2 Manure 3	0.11 42.9 1.46
Dry Matter content of separated solids	in range 13.3 to 23.5%	

a $\frac{\text{separated solids DM (kg/min)}}{\text{influent DM (kg/min)}} \times 100$

b $\frac{\text{separated solids N (kg/min)}}{\text{influent N (kg/min)}} \times 100$

c $\frac{\text{separated solids P (kg/min)}}{\text{influent P (kg/min)}} \times 100$

Observations During Test

- As the manure was elevated up the screens, the solids tended to smear over the holes, thus reducing the hole size and limiting the amount of solids that passed through the screens.
- The separator worked well for the liquid dairy manure. The system was fully automatic.
- Odours from the separated liquids were similar to those of the influent manure. Odours from the separated solids were similar or less than the influent manure and odour levels reduced further over time.

Economic Considerations

Approximate purchase price ($Cdn)	- $53,000
Approximate additional setup costs	- should operate inside a shelter - protect from freezing and weather
Labour needs	- The Maximizer Separator can be run with limited labour once it is set up. It may be automated to operate unattended. - The unit has no grease fittings that require regular greasing. - Regular inspections should be made of: a) the seals between the holding tank at the base of the inclined screen and flighted conveyor system and the separated liquids tank - check for leaks, b) the conveyor paddles and screens - check for wear, c) the screw press - check to ensure proper operation and no plugging, and d) the electric motors.
Operating costs	**maintenance -** mentioned above **supplies -** none needed **power -** electrical - mentioned earlier
Other	- separated solids are suitable for composting

General Comments

- The Maximizer was designed to process liquid dairy manure, liquid hog manure, vegetable processing waste, and other liquid wastes with coarse solids. It is presently operating in a number of applications worldwide.
- It appears that separation of a low dry matter liquid hog manure (similar to Manure 1 in this test) is not likely practical using this separator. There were not enough coarse solids for separation to remove much of the dry matter. The test was much more successful with the second liquid hog manure, which had a Dry Matter content of 1.9%
- Comments on test procedure:
    - the handling process for influent manure should be modified - a system is needed to ensure constant agitation of the influent manure (was not always possible) or else more samples of influent manure must be collected (instead of one composite sample) - these individual samples should be matched with corresponding samples of separated solids and liquids

- calculations of P removal efficiencies are variable, partly due to the fact that the concentrations of P tend to be close to the lower detection limit of the analysis procedure
- the length of the test (volume of manure separated) is a compromise - it does not allow for an evaluation of long-term performance (e.g. slime problems, mechanical breakdowns, deterioration of the equipment, gradual plugging, etc.) but it does allow for testing more than one manure type, which is essential
- there was an attempt to get manure samples in a wider range of DM contents - most separators would have higher efficiencies with higher DM manure
- more samples should have been taken for the particle size distribution analysis - there is too much variability in the test results to rely on only one sample of influent and effluent

Report created by: Ron Fleming and Malcolm MacAlpine - June 5, 2003
Ridgetown College - University of Guelph

Tested by: Malcolm MacAlpine
Ridgetown College - University of Guelph

In consultation with Byron Ballagh, Ballagh Liquid Technologies

Mechanical Manure Separator Test Report

Manufacturer:	Surface to Surface, 280 Centre St., Petrolia, ON
Model:	prototype manure separator
Separator type:	vibrating screen with hydrocyclones
Description:	- a combination of a two-level vibrating screen and four hydrocyclones - coarse solids are first removed by the lower screen and discharged off the end of the screen - separated liquids are pumped from a tank below the coarse screen through four hydrocyclones onto a fine screen for further separation - liquids are then pumped to a storage tank - powered by a diesel engine running a hydraulic pump that operates the hydrostatic drives used on the separator - metal parts are either stainless steel or painted steel
Test Configuration:	- The lower coarse screen was an 0.18 mm screen (80 mesh) and was 0.74 metres wide and 1.88 metres long. - The top screen was an 0.075 mm screen (200 mesh) and was 0.74 metres wide and 1.88 metres long. - This separator was trailer mounted.
Test date(s):	August 13 and 14, 2003
Test Location:	Ridgetown College, Ridgetown, Ontario
Test Setup:	1. The manure was pumped into the unit through a 102 mm flexible plastic hose using a hydrostatically driven sludge pump. 2. Manure flow was monitored using a flow meter, giving total flow as well as the real time flow rate. 3. The separated liquids flowed into a tank adjacent to the separator and were pumped into a liquid manure spreader using a 0.38 kW sludge pump and 51 mm hose. 4. The influent manure was pumped into a tank at the top of the separator and flowed onto the lower coarse screen. 5. The screened liquid manure drained into an agitated tank below and was then pumped through the hydro cyclones and onto the top screen. 6. The liquids that flow through the top screen were caught in a pan and directed to the liquid discharge. 7. The solids were discharged off the end of the screens into a

	front-end loader or a dry manure spreader. 8. The solids flow rate was monitored by measuring the solids volume and mass discharged. 9. The equipment required two operators for this test but in a commercial setting one person could operate it. This separator had not been used to treat liquid manure previously thus there was more time taken in adjusting settings to improve its operation. Some settings used in this testing may not be used on the farm. Maintenance requirements were limited since this machine had been developed for rigorous commercial use. 10. Samples were collected from the separated solids, liquids and influent manure throughout the test for nutrient and bacteria testing as well as particle size distribution. Separated Solids were collected to determine their density and flow rate and the total volume was also measured.
Manure(s) tested:	1 - liquid swine manure 2 - liquid swine manure 3 - liquid dairy manure
Test duration:	Based on **volume of manure separated** Manure 1 16,600 L Manure 2 15,250 L Manure 3 19,000 L

Test Data

Flow rates through separator:	Average flow rates once initial adjustments were made: Manure 1 242 L/min (i.e. 14.5 m^3/hr) Manure 2 115 L/min (i.e. 6.90 m^3/hr) Manure 3 216 L/min (i.e. 13.0 m^3/hr)
Volume of separated solids:	<table><tr><td></td><td><u>Volume</u></td><td><u>% of total manure</u></td><td><u>Density</u></td></tr><tr><td>Manure 1</td><td>147.0 L</td><td>0.886</td><td>541 g/L</td></tr><tr><td>Manure 2</td><td>1524 L</td><td>9.99</td><td>1043 g/L</td></tr><tr><td>Manure 3</td><td>167 L</td><td>0.879</td><td>1075 g/L</td></tr></table>
Power consumption:	Manure volume separated per L of diesel fuel consumed: Manure 1 1383 L Manure 2 824 L Manure 3 1226 L

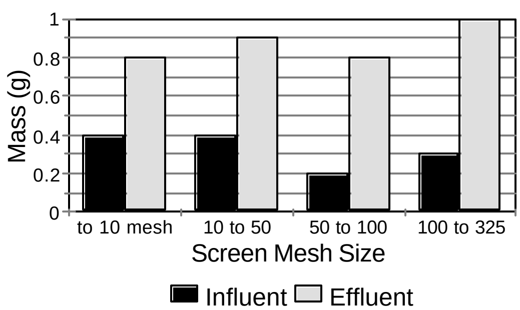
Nutrient levels in influent manure, separated solids and liquids

	DM (%)	N (%)	P (%)	K (%)	NH_4-N (mg/L)	VS (%, DM basis)	C (%)	pH
Influent Manure								
M1	0.6	0.08	0.01	0.06	3272	67.6	0.41	7.7
M2	3.79	0.4	0.05	0.26	912	69.7	2.64	7.5
M3	1.32	0.18	0.01	0.14	811	64.5	0.85	7.4
Separated Solids								
S1	21.8	0.44	0.89	0.07	2377	35.2	7.5	8.4
S2	12.43	1.21	0.6	0.58	3984	45.6	5.97	8.1
S3	10.24	0.22	0.07	0.13	1185	46	4.75	8.4
Separated Liquids								
L1	0.6	0.12	0.02	0.06	1185	61.4	0.37	7.6
L2	3.74	0.42	0.17	0.26	2902	64.7	2.42	7.8
L3	1.11	0.1	0.01	0.13	850	64.1	0.71	7.7

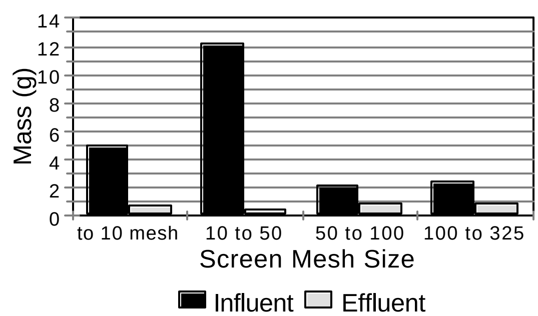
Bacteria levels in influent manure, separated solids and liquids

	total coliform (cfu/100 mL)	E. coli (cfu/100 mL)
Influent Manure		
M1	240000	93000
M2	230	230
M3	240000	93000
Separated Solids		
S1	240000	93000
S2	820	610
S3	5700000	1300000
Separated Liquids		
L1	190000	170000
L2	220	120
L3	590000	68000

Manure 1

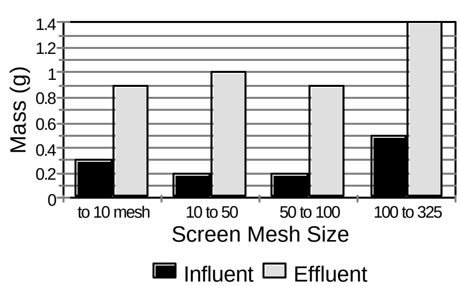


Manure 2



Particle Size Distribution

Manure 3



Conversion Table

mesh size	opening size (mm)
10	2.0
50	0.30
100	0.15
325	0.045

Performance Calculations

Feed flow rate	Manure 1 242 L/min Manure 2 115 L/min Manure 3 216 L/min
Solids (concentrate) flow rate	Manure 1 1.16 kg/min Manure 2 12.0 kg/min Manure 3 2.04 kg/min
% of initial solids removed into separated solids[a]	Manure 1 17.4 Manure 2 34.2 Manure 3 7.33
% of initial N removed into separated solids[b]	Manure 1 2.63 Manure 2 31.5 Manure 3 1.15
% of initial P removed into separated solids[c]	Manure 1 42.6 Manure 2 125 (believed to be a "lower detection limit" issue) Manure 3 6.61
Dry Matter content of separated solids	in range 10.24 to 21.8%

a $\frac{\text{separated solids DM (kg/min)}}{\text{influent DM (kg/min)}} \times 100$

b $\frac{\text{separated solids N (kg/min)}}{\text{influent N (kg/min)}} \times 100$

c $\frac{\text{separated solids P (kg/min)}}{\text{influent P (kg/min)}} \times 100$

Observations During Test

- Odours from the separated liquids were similar to those from influent manure. Odours from the separated solids were less offensive than influent manure after separation and over time were barely detectable.
- For Manures 2 and 3, the manure foamed during separation due to the agitation. A small amount of liquid vegetable oil was added to the separator to eliminate the foam.

Economic Considerations

Approximate purchase price ($Cdn)	- $100,000
Approximate additional setup costs	- can be operated without a shelter
Labour needs	- fairly routine: regular checks of the diesel motor for fuel, oil, coolant belts and proper operation; monitor the hydraulic system including oil levels, pumps, hoses and motors; monitor the separator's two screens, manure pumps and hydrocyclones - should be possible to automate the systems and reduce labour inputs
Operating costs	**maintenance** - machine appears to be robust - it has been well-tested, though it has more moving parts than some other systems **supplies -** none needed **power -** diesel engine
Other	- separated solids are suitable for composting

General Comments

- The Surface to Surface Separator was a prototype originally developed to recover Bentonite Clay from the cutting solution used for horizontal drilling.
- It appears that separation of a low dry matter liquid hog manure (i.e. < 1% DM) is not practical using this separator. Even though the separator removed a significant amount of the coarse solids, it had very little impact on the manure dry matter level.
- There was a considerable variation in performance (e.g. ability to remove Dry Matter and nutrients into the separated solids) from one manure to the next.
- The system of performing particle size distributions needs some refinement to avoid situations seen in the graphs for Manures 1 and 3 (above) - this has nothing to do with the machine being tested.
- The unit is relatively easy to mount on a trailer, so moving from one farm to another would be fairly simple.
- Comments on test procedure:
    - calculations of P removal efficiencies are variable, partly due to the fact

that the concentrations of P tend to be close to the lower detection limit of the analysis procedure

- the length of the test (volume of manure separated) is a compromise - it does not allow for an evaluation of long-term performance (e.g. slime problems, mechanical breakdowns, deterioration of the equipment, gradual plugging, etc.) but it does allow for testing more than one manure type, which is essential
- there was an attempt to get manure samples in a wider range of DM contents - most separators would have higher efficiencies with higher DM manure
- more samples should have been taken for the particle size distribution analysis - there is too much variability in the test results to rely on only one sample of influent and effluent

Report created by: Ron Fleming and Malcolm MacAlpine - June 4, 2003
Ridgetown College - University of Guelph

Tested by: Malcolm MacAlpine and Marcy Ford
Ridgetown College - University of Guelph

Machine operation during testing: Doug Pullman, Surface to Surface

Mechanical Manure Separator Test Report

Manufacturer:	Sleegers Machine and Fabrication Inc.
Model:	SEI Dewatering System
Separator type:	Screw Press
Description:	- design capacity: 90 to 909 L/min. - made of carbon steel, weighing 426 kg - powered by a single phase, 5.6 kW, 220 volt, 40 amp electric motor driving a reduction gear drive that turns the 26.0 cm diameter, 108 cm long stainless steel auger with a 59 cm long flighting - auger had single flighting for dairy manure and double flighting for liquid swine manure - nylon brushes mounted on the flighting to keep the screens clean - auger rotated inside a 52 cm long stainless steel axial wire screen (slot size 1.0 mm for dairy manure and 0.25 mm for swine manure) that was mounted inside the exterior housing - auger supported by a bearing on each end, allowing close tolerances with the screen - opening for the solids discharge had a spring loaded plug with a solids cutter, that mounted on the auger shaft and could be adjusted to give the desired solids dry matter level
Test Configuration:	Manures 1 & 2: - double flighted auger, with brushes attached to the auger flighting - 0.25 mm stainless steel axial wire screen - a coarse fibre plug made of partially cured compost was inserted into the solids discharge prior to starting - the metal solids discharge plug was then pushed into place and the discharge resistance pressure set Manure 3: similar to above, except - single flighted auger, with brushes attached to the auger flighting - 1.0 mm slot size bar screen
Test date(s):	October 2, October 16 and November 5, 2002 (1 manure type each day)

Test Location:	Ridgetown College, Ridgetown, Ontario
Test Setup:	1. Manure was pumped into the separator using a 0.75 kW sludge pump via a 51 mm flexible plastic milkhouse hose. 2. Manure flow was monitored using a flow meter, giving total flow as well as the real time flow rate. 3. The intake head was fitted with an overflow hose with a quarter turn ball valve, allowing excess liquid manure to flow back to the tank, or restrict the return flow. 4. Manure flow was also monitored by measuring the manure tank depth over time to give a comparison flow. 5. The separated liquids drained through a discharge at the bottom of the separator into a tank and was pumped into a liquid manure spreader using a 0.38 kW sludge pump and 51 mm hose. 6. The solids were pushed out the discharge and were collected in large pails. 7. The solids flow rate was also monitored by measuring the solids volume and mass extruded. 8. The separator was set up with a double flighted auger with nylon brushes attached to the auger flighting and a 0.25 mm stainless steel axial wire screen. 9. A coarse fibre plug made of partially cured compost was inserted into the solids discharge, then the discharge resistance pressure was set, manure was pumped into the separator and the press started.
Manure(s) tested:	1 - liquid swine manure 2 - liquid swine manure 3 - liquid dairy manure
Test duration:	Based on **volume of manure separated** Manure 1 13,454 L Manure 2 10,000 L Manure 3 19,200 L

Test Data

Flow rates through separator:	Average flow rates once initial adjustments were made: Manure 1 102 L/min (i.e. 6.12 m^3/hr) Manure 2 83 L/min (i.e. 4.98 m^3/hr) Manure 3 215 L/min (i.e. 12.9 m^3/hr) Note: For Manures 1 and 2, one of the pumps in the test setup limited the flow of manure through the separator - i.e. the separator could have handled higher flow rates.

Volume of separated solids:	 Manure 1 — Volume: 4.86 L; % of total manure: 0.036; Density: 533 g/L Manure 2 — Volume: 18.3 L; % of total manure: 0.183; Density: 417 g/L Manure 3 — Volume: 150 L; % of total manure: 0.781; Density: 206 g/L
Power consumption:	Manure volume separated per kW-h of power: Manure 1 4,168 L Manure 2 1,600 L Manure 3 4,800 L

Nutrient levels in influent manure, separated solids and liquids

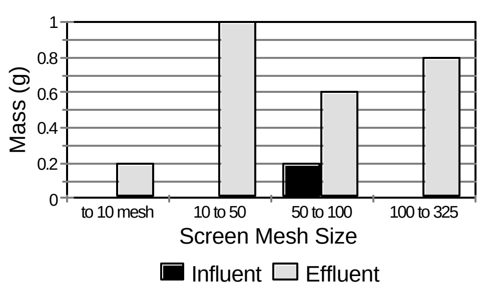
	DM (%)	N (%)	P (%)	K (%)	NH_4-N (mg/L)	VS (%, DM basis)	C (%)	pH
Influent Manure								
M1	0.84	0.18	0.02	0.11	1847	54.6	0.46	7.9
M2	2.2	0.29	0.13	0.13	2287	62.7	1.38	7.5
M3	1.85	0.16	0.02	0.12	1093	68.3	1.26	7.6
Separated Solids								
S1	6.41	0.29	0.1	0.36	1717	69.2	4.4	8.1
S2	34.8	0.94	0.69	0.16	3062	86.8	30.2	8.3
S3	27.71	0.44	0.12	0.12	1205	88.5	24.64	8.7
Separated Liquids								
L1	0.92	0.18	0.03	0.12	1847	55.1	0.51	8
L2	2.43	0.27	0.11	0.12	2205	60.3	1.47	7.5
L3	2.38	0.17	0.03	0.12	1261	73.3	1.75	7.6

Bacteria levels in influent manure, separated solids and liquids

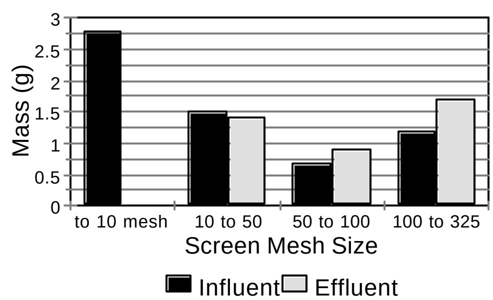
	total coliform (cfu/100 mL)	E. coli (cfu/100 mL)
Influent Manure		
M1	14000	<10
M2	9300	4300
M3	50000	33000
Separated Solids		
S1	2500000	10
S2	460	240
S3	62000	21000
Separated Liquids		
L1	32000	15
L2	7000	3300
L3	63000	40000

Particle Size Distribution

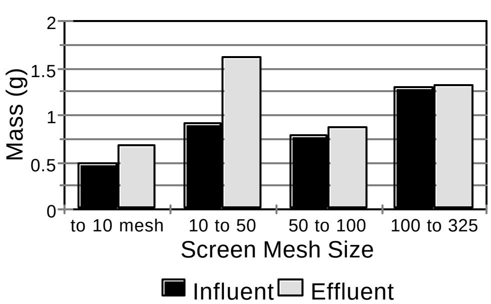
Manure 1



Manure 2



Manure 3



Conversion Table

mesh size	opening size (mm)
10	2.0
50	0.30
100	0.15
325	0.045

Performance Calculations

Feed flow rate	Manure 1 Manure 2 Manure 3	102 L/min 83 L/min 215 L/min
Solids (concentrate) flow rate	Manure 1 Manure 2 Manure 3	19.6 g/min 63.3 g/min 346 g/min
% of initial solids removed into separated solids[a]	Manure 1 Manure 2 Manure 3	0.15 1.21 2.41
% of initial N removed into separated solids[b]	Manure 1 Manure 2 Manure 3	0.03 0.25 0.44
% of initial P removed into separated solids[c]	Manure 1 Manure 2 Manure 3	0.10 0.41 0.97
Dry Matter content of separated solids	in range 6.41 to 34.8%	

a $\frac{\text{separated solids DM (kg/min)}}{\text{influent DM (kg/min)}} \times 100$

b $\frac{\text{separated solids N (kg/min)}}{\text{influent N (kg/min)}} \times 100$

c $\frac{\text{separated solids P (kg/min)}}{\text{influent P (kg/min)}} \times 100$

Observations During Test

- Due to the low solids content for Manures 1 & 2, it was difficult to develop a good liquid seal in the solids discharge. For Manure #1, it took 2.5 hours and 4,000 litres of liquid manure for a seal to develop. For Manure 2, it took 2 hours and 4000 L of manure. For manure 3, it took 2.75 hours and 3,500 litres of liquid manure. Once the plug was set, it was not necessary to reset it if the separator was used regularly.
- For Manure 1 - The influent manure flow rate started to decline at about 18,600 litres of manure pumped. By 22,454 litres, the flow was virtually stopped and the pressure was building in the separator. The solids end plug then failed and liquids flowed out of the solids discharge. The test was stopped at this point and

the separator dismantled to identify the problem. The screen had become almost completely plugged with hair and solids. It appeared that the screen could not be adequately cleaned with the brushes. The same thing happened with Manure 2. The flow rate started to decline at about 9,700 litres of manure pumped and by 17,000 litres the flow was virtually stopped.

- For Manures 2 and 3 - Odours from the separated solids were significantly reduced after the process and as the solids dried over time, odours were further reduced.
- For Manure 3 - The influent manure flow rate did not decline but continued at a steady state until the test ended. The screen did not plug and the solids plug did not fail. The separator worked well for this manure.

Economic Considerations

Approximate purchase price ($Cdn)	- $27,000
Approximate additional setup costs	- can be operated without a shelter
Labour needs	- can be run with limited labour once it is set up, the plug is set and the press started - could also be automated to operate unattended - operator needs to grease two fittings periodically and remove the stack of solids - during the testing one person was required to ensure proper operation
Operating costs	maintenance - machine appears to be reliable, has a relatively simple design supplies - none needed power - electrical - mentioned earlier
Other	- separated solids are suitable for composting

General Comments

- This screw press was designed to process liquid dairy manure and is presently operating on several dairy farms. It has been tested on swine manure as well. It appears that separation of a low dry matter liquid hog manure is not practical using this separator. There were not enough coarse solids for separation to remove much of the dry matter. It was difficult to set the fibre plug due to the low manure dry matter.

- In a typical farm setup the manure is separated when fresh before the coarse solids start to break down in storage, thus potentially improving the performance of the separator.
- Comments on test procedure:
  - the handling process for influent manure should be modified - a system is needed to ensure constant agitation of the influent manure (was not always possible) or else more samples of influent manure must be collected (instead of one composite sample) - these individual samples should be matched with corresponding samples of separated solids and liquids
  - calculations of P removal efficiencies are variable, partly due to the fact that the concentrations of P tend to be close to the lower detection limit of the analysis procedure
  - the length of the test (volume of manure separated) is a compromise - it does not allow for an evaluation of long-term performance (e.g. slime problems, mechanical breakdowns, deterioration of the equipment, gradual plugging, etc.) but it does allow for testing more than one manure type, which is essential
  - there was an attempt to get manure samples in a wider range of DM contents - most separators would have higher efficiencies with higher DM manure
  - more samples should have been taken for the particle size distribution analysis - there is too much variability in the test results to rely on only one sample of influent and effluent

Report created by: Ron Fleming and Malcolm MacAlpine - June 3, 2003
Ridgetown College - University of Guelph

Tested by: Malcolm MacAlpine & Marcy Ford
Ridgetown College - University of Guelph

Mechanical Manure Separator Test Report

Manufacturer:	SWECO
Model:	LS18-53 (lab scale tester)
Separator type:	Vibrating Screen
Description:	- a round vibrating screen using two eccentric weights on an electric motor to produce a vibration that spirals coarse solids around the screen from the centre to the outside, where they are discharged - coarse materials stay on top of the screen and fine solids and liquids fall through to the lower level to exit through a spout - has a self cleaning system that keeps the screen clean during separation - metal parts are all stainless steel construction (to reduce corrosion) - this system was designed to process a large range of products, including dry industrial material, sewage, vegetable processing waste, liquid wastes with coarse solids as well as liquid manure - presently operating in a number of applications worldwide
Test Configuration:	- screen diameter 458 mm (18") - powered by a 1.13 kW, 120 volt electric motor driving eccentric weights to produce a vibration - screen unit was supported on a series of springs to translate the vibration from the motor to the appropriate screen vibration - screen was a tensile bolting cloth with a hole size of 0.212 mm (70 mesh) - mounted above the liquid collection ring and liquid discharge - there were a number of plastic screen cleaners between a perforated stainless steel plate and the screen - cleaners vibrated below the screen, keeping it open during separation - opening for the solids discharge was above the screen
Test date(s):	October 21, October 22 and November 5, 2002 (1 manure type each day)
Test Location:	Ridgetown College, Ridgetown, Ontario

Test Setup:	1. There was agitation of the tank before and partial agitation during the test. 2. For Manure 1 and 2, the influent manure was pumped onto the centre of the vibrating screen using a 0.75 kW sludge pump and a 51 mm plastic milkhouse hose with a ball valve to control flow rates. Manure flow was monitored using a flow meter, giving total flow as well as the real time flow rate. For Manure 3, the manure was pumped from the manure tank into a smaller holding tank, then was added by hand (using a pail) to the SWECO separator. There was a limited amount of manure available (i.e.Manure 3) thus testing was not as extensive as with the other manures. 3. The liquids were discharged into a tank and then pumped to a manure spreader or another tank. The solids were discharged into plastic pails. 4. The solids flow rate was monitored by measuring the solids volume and mass separated. Separated Solids were collected to determine their density, flow rate and total volume. 5. Samples were collected from the separated solids, liquids and influent manure throughout the test for nutrient and bacteria testing as well as particle size distribution.
Manure(s) tested:	1 - liquid swine manure 2 - liquid swine manure 3 - liquid dairy manure
Test duration:	Based on **volume of manure separated** Manure 1 16,250 L Manure 2 2,940 L Manure 3 2,000 L

Test Data

Flow rates through separator:	Average flow rates once initial adjustments were made: Manure 1 94 L/min (i.e. 5.64 m^3/hr) Manure 2 15.5 L/min (i.e. 0.93 m^3/hr) Manure 3 26 L/min (i.e. 1.56 m^3/hr)
Volume of separated solids:	Volume / % of total manure / Density Manure 1 0.5 L 0.003 1000 g/L Manure 2 66 L 2.24 1109 g/L Manure 3 80 L 4.0 1054 g/L
Power consumption:	Manure volume separated per kW-h of power: Manure 1 7,738 L Manure 2 1,420 L Manure 3 3,030 L

Nutrient levels in influent manure, separated solids and liquids

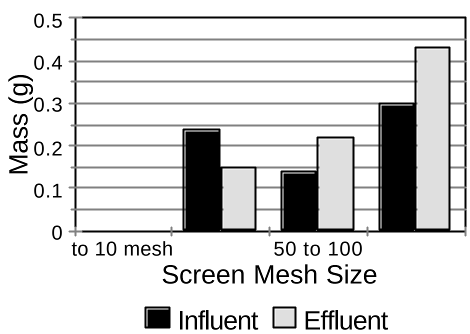
	DM (%)	N (%)	P (%)	K (%)	NH_4-N (mg/L)	VS (%, DM basis)	C (%)	pH
Influent Manure								
M1	0.34	0.11	0.01	0.05	1061	48.3	0.16	7.6
M2	2.2	0.26	0.08	0.13	2050	59.8	1.3	7.5
M3	1.85	0.16	0.02	0.12	1093	68.3	1.26	7.6
Separated Solids								
S1	0.7	0.13	0.03	0.06	1056	65.6	0.5	8
S2	9	0.44	0.12	0.13	1955	88.3	8	8
S3	7.27	0.22	0.04	0.12	1076	88.1	6.41	8.1
Separated Liquids								
L1	0.34	0.1	0.01	0.06	1079	47.3	0.16	7.7
L2	2.1	0.28	0.09	0.12	2039	56.9	1.2	7.5
L3	1.63	0.17	0.03	0.12	1166	57.5	1.01	7.7

Bacteria levels in influent manure, separated solids and liquids

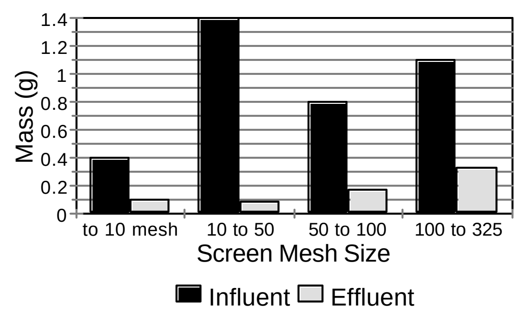
	total coliform (cfu/100 mL)	E. coli (cfu/100 mL)
Influent Manure		
M1	1000	600
M2	3000	3000
M2	50000	33000
Separated Solids		
S1	1800	1400
S2	6000	5500
S3	74000	47000
Separated Liquids		
L1	950	550
L2	6100	5000
L3	64000	42000

Particle Size Distribution

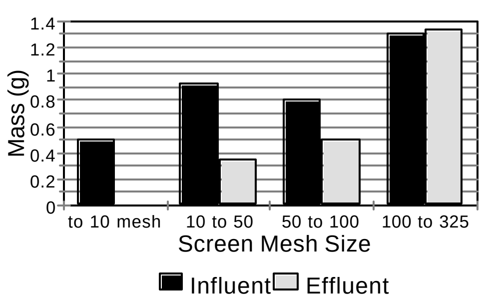
Manure 1



Manure 2



Manure 3



Conversion Table

mesh size	opening size (mm)
10	2.0
50	0.30
100	0.15
325	0.045

Performance Calculations

Feed flow rate	Manure 1 Manure 2 Manure 3	94 L/min 15.5 L/min 26 L/min
Solids (concentrate) flow rate	Manure 1 Manure 2 Manure 3	0.003 kg/min 0.386 kg/min 1.10 kg/min
% of initial solids removed into separated solids[a]	Manure 1 Manure 2 Manure 3	0.006 10.2 16.6
% of initial N removed into separated solids[b]	Manure 1 Manure 2 Manure 3	0.004 4.21 5.80
% of initial P removed into separated solids[c]	Manure 1 Manure 2 Manure 3	0.009 3.73 8.43
Dry Matter content of separated solids	in range 0.7 to 9.0 %	

a $\frac{\text{separated solids DM (kg/min)}}{\text{influent DM (kg/min)}} \times 100$

b $\frac{\text{separated solids N (kg/min)}}{\text{influent N (kg/min)}} \times 100$

c $\frac{\text{separated solids P (kg/min)}}{\text{influent P (kg/min)}} \times 100$

Observations During Test

- For Manure 3, the separator was easily overloaded with the high volume of coarse solids in the manure. Flow rates had to be reduced over time as solids levels rose (due to settling in the holding tank). With the flow levels adjusted the separator worked well for this manure with no plugging..
- Odours from the separated liquids were similar to those from the influent manure. Odours from the separated solids were similar to those from influent manure for Manure 1. For Manure 2 and 3, odours from the separated solids were less offensive but similar to those from influent manure.
- In spite of the fact that this was a laboratory scale system, it handled Manure 1 (with a low solids content) very well and at relatively high flow rates. However, with

the relatively high coarse solids content of Manure 2 and 3, the screen became overloaded quickly and very low flow rates were attained.
- When operated at low flow rates, the system worked well during the test.

Economic Considerations

Approximate purchase price ($Cdn)	- $21,500
Approximate additional setup costs	- should be located inside a shelter
Labour needs	- can be run with limited labour and can be automated to operate unattended - - during the testing one person was required to ensure proper operation
Operating costs	maintenance - machine appears to be reliable, has a relatively simple design supplies - none needed power - electrical - mentioned earlier
Other	-

General Comments

- The SWECO vibrating screen separator can operate with limited labour. The system could be set up to operate unattended and only checked for periodic maintenance. There is little that can go wrong with this system if the flow rate is matched to the ability of the separator to screen the manure. This unit would likely perform best under some cover to protect it from the environment. For the testing it required one operator.
- It appears that separation of a “low dry matter” liquid swine manure (e.g. Manure 1) is not practical using this separator. There were not enough coarse solids for separation to remove significant amounts of dry matter.
- It appears that separation of liquid manure with a dry matter content of at least 1.5% can be practical using this separator. This separator did not dry the solids significantly, so the solids would have to be handled as a semi solid manure.
-

Report created by: Ron Fleming and Malcolm MacAlpine - June 26, 2003
Ridgetown College - University of Guelph

Tested by: Malcolm MacAlpine
Ridgetown College - University of Guelph

Mechanical Manure Separator Test Report

Manufacturer:	New Logic, Emeryville, California
Model:	VSEP Series LP
Separator type:	Membrane filter - reverse osmosis
Description:	- Vibrating Shear Enhanced Process (VSEP) used a vibrating stack of 18 reverse osmosis membranes, high pressure and a timed (open and closed) outlet valve to remove water from liquid manure - the stack of membranes was vibrated using an electric motor with an eccentric weight, vibrating a heavy metal plate (seismic mass) transferring the motion up a tubular tuned torsion spring to the reverse osmosis head - vibration creates a shear force that prevents fouling of the membranes with solids - powered by two electric motors - a 1.1 kW electric motor for the vibration system and a 2.25 kW electric motor for a diaphragm pump to pump the Influent manure and pressurize the system to 3100 kilopascals (450 psi) - Influent manure flowed from a 40 litre tank via a 38 mm diameter plastic hose through an in-line 0.297 mm (50 mesh) screen to the pressure pump - pressurized manure was pumped through a 12.7 mm braided steel, high pressure hose to the top of the vibrating filter head - clean water (permeate) exits the centre top of the filter head, through a clear 12.7 mm vinyl hose into a storage tank - concentrate exits through the bottom of the filter head via a 12.7 mm metal tube, through pressure and flow control valves into another storage tank - concentrate passed through an automated valve that is opened and closed depending on the setting of the timer (controlling the permeate recovery percentage - the longer it was closed the higher the recovery rate)

Test Configuration:	- The model used in this test is normally used for demonstration purposes. A larger unit would be installed on a typical farm. - Operated in "P" mode - Total filter area: 1.55 m^2 (16.7 sq ft) - The unit was set up for a 50% recovery rate using a one minute cycle, with the valve closed for 0.9 minutes and open for 0.1 minutes. - Pressure settings: 2070 kPa (300 psi) for the open setting and 3275 kPa (475 psi) for the closed setting - Manure flow rate setting: 2.33 litres per minute.
Test date(s):	October 22 and November 20, 2002
Test Location:	Ridgetown College, Ridgetown, Ontario
Test Setup:	1. The raw manure was pre-screened through a 0.15 mm (100 mesh) screen (e.g SWECO vibrating screen) and was stored in a large open tank until processing. 2. The manure was then added to a 40 L plastic tank connected to the VSEP. 3. The manure passed through an in-line filter (the initial filter configuration was too small and was changed early in the testing to create more filtering capacity). 4. Startup: All pressure control valves were open, the pump was started and the pressure ramped up to 200 to 350 kPa (30 to 50 psi). At this point the filter head vibration was started. The unit was operated in this warm-up state until the vibration amplitude of 19 mm was stabilized. Once the unit was warmed up (after about 10 minutes), the pressure control valve on the concentrate line was adjusted to 2070 kPa (300 psi). The unit was run for a few minutes to allow the system to stabilize. Next, a manual pressure and flow control valve on the concentrate line was turned off and the pressure regulator was set to 3,100 kPa (450 psi) to bypass excess flow back into the 40 litre tank. 5. Once the pressure settings were completed the automatic timer was set and the unit then operated in an automatic mode with the valve closed for 0.9 minutes, at 3,100 kPa (450 psi) and open 0.1 minutes at 2070 kPa (300 psi). This setting was used for all of the testing. It was chosen to give a permeate (water) recovery rate of approximately 50%. Pressures were slightly different for Manures 2 and 3. 6. There was no agitation of the influent manure for this test. 7. Samples were collected from the concentrate, permeate and influent manure throughout the test.

Manure(s) tested:	1 - liquid swine manure 2 - liquid swine manure 3 - liquid dairy manure
Test duration:	Based on **Time** Manure 1 3.5 h (460 L) Manure 2 4.0 h (465 L) Manure 3 4.75 h (600 L)

Test Data

Flow rates through separator:	Average flow rates once initial adjustments were made: Manure 1 2.3 L/min (i.e. 0.14 m^3/hr) Manure 2 1.9 L/min (i.e. 0.11 m^3/hr) Manure 3 2.1 L/min (i.e. 0.13 m^3/hr)
Volume of separated solids:	<u>Volume</u> / <u>% of total manure</u> / <u>Density</u> Manure 1 250 L 54.3% 1000 g/L Manure 2 269 L 57.8% 1000 g/L Manure 3 342 L 57.0% 1000 g/L
Power consumption:	Manure volume separated per kW-h of power: Manure 1 82 L Manure 2 86 L Manure 3 94 L

Nutrient levels in influent manure, separated solids and liquids

	DM (%)	N (%)	P (%)	K (%)	NH_4-N (mg/L)	VS (%)	C (%)	pH
Influent Manure (measured) *								
M1	0.34	0.1	0.01	0.06	1079	47.3	0.16	7.7
M2	2.09	0.28	0.09	0.12	2039	56.9	1.19	7.5
M3	1.63	0.17	0.03	0.12	1166	57.5	1.01	7.7
Influent Manure (calculated) **								
M1	0.3	0.09	0	0.05	971	NA	NA	7.5
M2	0.53	0.13	0.01	0.06	1347	NA	NA	7.8
M3	0.67	0.07	0.01	0.06	492	NA	NA	7.5
Separated Solids (concentrate)								
S1	0.55	0.17	0.01	0.09	1755	45.5	0.25	7.8
S2	0.91	0.22	0.02	0.11	2303	40.4	0.37	7.9
S3	1.18	0.12	0.02	0.11	863	65.8	0.77	7.7
Separated Liquids								
L1	0	0	0	0	38.3	NA	NA	7.2
L2	0	0.1	0	0	34.7	NA	NA	7.6
L3	0	0	0	0	0	0	0	7.3

* a well-mixed manure sample was submitted for testing

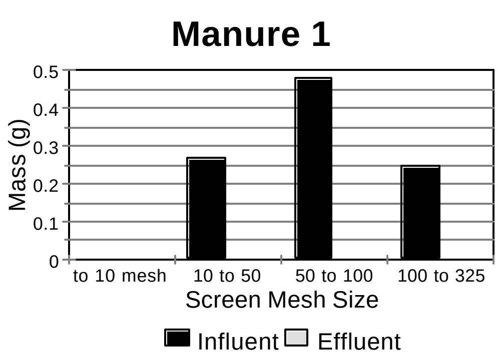
** due to settling in the manure storage prior to passing through the machine, the membrane filter did not receive well-mixed manure - the calculated value, based on conservation of mass, more accurately describes the Influent manure that the unit received

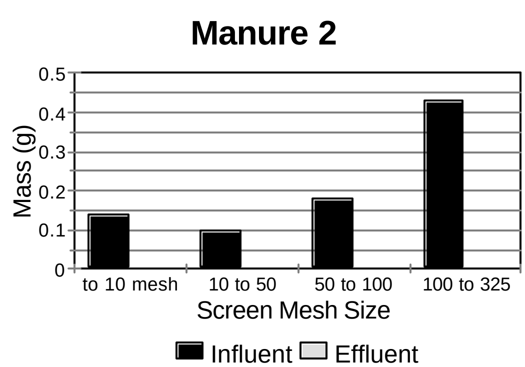
Note: The nutrients, dry matter and bacteria levels were often below the detectable limit for the separated liquids (i.e. permeate) and were reported as 0 by the lab.

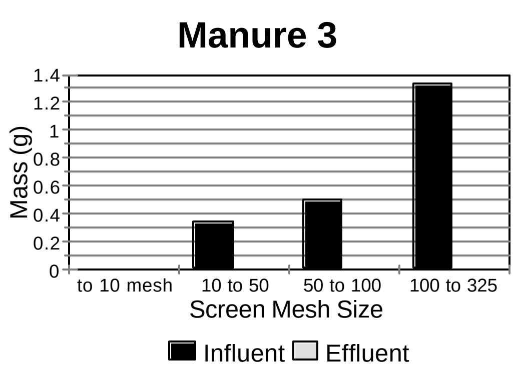
Bacteria levels in influent manure, separated solids and liquids

	total coliform (cfu/100 mL)	E. coli (cfu/100 mL)
Influent Manure (measured)		
M1	970	570
M2	6100	5000
M3	64000	42000
Separated Solids		
S1	1300	650
S2	770	520
S3	8700	7500
Separated Liquids		
L1	0	0
L2	0	0
L3	0	0

Particle Size Distribution







Conversion Table

mesh size	opening size (mm)
10	2.0
50	0.30
100	0.15
325	0.045

Performance Calculations

Feed flow rate	Manure 1 2.3 L/min Manure 2 1.9 L/min Manure 3 2.1 L/min
Solids (concentrate) flow rate	Manure 1 1.25 L/min Manure 2 1.10 L/min Manure 3 1.20 L/min
% of initial solids removed into separated solids[a]	Manure 1 100% Manure 2 100% Manure 3 100% Note - "Calculated" values for Influent Manure were used - see above
% of initial N removed into separated solids[b]	Manure 1 100% Manure 2 97.9% Manure 3 100% Note - "Calculated" values for Influent Manure were used - see above
% of initial P removed into separated solids[c]	Manure 1 100% Manure 2 100% Manure 3 100% Note - "Calculated" values for Influent Manure were used - see above
Dry Matter content of separated solids	in range 0.55 to 1.2%

a $\frac{\text{separated solids DM (kg/min)}}{\text{influent DM (kg/min)}} \times 100$

b $\frac{\text{separated solids N (kg/min)}}{\text{influent N (kg/min)}} \times 100$

c $\frac{\text{separated solids P (kg/min)}}{\text{influent P (kg/min)}} \times 100$

Observations During Test

- After the first hour of testing using Manure 1, the inline filter screen had to be cleaned but did not plug again during the test. The filter gave more problems during the testing of Manure 2, however. Shortly after the testing started, the inlet filter had plugged with hair and slime. The filter was cleaned and the test restarted. The filter again plugged within 10 minutes. This was repeated several more times with the same results. The tank was then drained and refilled with screened liquid manure from the same storage tank. It was apparent that the vibrating screen used to pre-filter the manure was allowing hairs to pass through. This newly-screened manure was then tried in the separator but the filter again plugged within 10 minutes. This time slime had smeared over the filter holes. The filter was cleaned again and the test restarted. The filter again plugged with slime within 10 minutes of operation. The test was then shut down so that New Logic could find a solution. Two larger filters were installed so they could operate independent of each other (i.e. if one filter plugged, it could be removed from the system without shutting down the unit). For Manure 3, the inline filter needed cleaning after about 30 minutes of testing but did not plug again until the end of the test. At this point some manure with a higher solids content entered the system and plugged the in-line filters.

- Manure was pumped from the holding tank into the VSEP tank with no agitation. Due to the delays working with Manure 2, a portion of the solids was allowed to settle out in the holding tank. Some settling also occurred with Manure 3.
- The electrical conductivity of the permeate ranged from 109 to 128 microsiemens/cm^2 for Manure 1, from 100 to 110 microsiemens/cm^2 for Manure 2 and from 39 to 50 microsiemens/cm^2 for Manure 3.
- The temperature of the manure tested was 19 ^{o}C for Manure 1, 8 to 10 ^{o}C for Manure 2, and 4 to 9 ^{o}C for Manure 3.
- The vibrating frequency was in the range 50.6 to 50.8 hertz and motor load was in the range 27% to 34% for the three manures tested.
- Odours from the concentrated solids were similar to the influent manure. The permeate (water) had a slight ammonia odour as well as a slight sulfur odour. After the permeate stood for a few hours odours were no longer detected.

Economic Considerations

Approximate purchase price ($Cdn)	approximately $90,000 Cdn
Approximate additional setup costs	- a pre-filter will be needed in most cases and this could take the form of a more traditional manure separator (such as a vibrating screen)
Labour needs	- During the testing one person was required to ensure proper operation

Operating costs	**maintenance -** The manure must be pre-screened to remove coarse solids so there would be a separate system to monitor as well as the VSEP. The pre-filtration system must be monitored so it does not plug. The pressure system with it's pump, high pressure hoses, flow and pressure control valves must be regularly checked. The vibration system, the motor, seismic mass, tuned torsion spring, and filter pack require regular monitoring. The filter pack bolts and nuts must be torqued regularly. The electronic controls must be adjusted as needed to the required settings and the filter pack must be flushed with fresh water, an acid wash, a fresh water flush, a caustic wash and a fresh water flush after about 48 hours of operation or when flow starts declining. The commercial systems are fully automated, removing the need for most of this maintenance such as tightening the filter head, monitoring the electronics and flushing the filter pack. **supplies -** chemicals for regular cleaning of the filter pack **power -** electrical power to operate the VSEP unit plus any pre-filter and transfer pumps
Other	- the filtered water could be used in the barn, and thus may have a value to the farmer in offsetting the need for other fresh water - manure must still be spread on the fields (likely scenario) but since it is reduced in volume (and nutrients are more concentrated) labour and equipment costs associated with spreading are reduced

General Comments

- The VSEP shows potential as a way to treat dilute livestock manure. It removed pathogens, most of the nutrients and dissolved salts. This potentially makes the permeate useful as drinking water for livestock or wash water in barns. The concentrate contains virtually all of the nutrients from the influent manure. With the VSEP operating at a 50% recovery rate, as in the test setup, half of the influent manure goes to a clean water stream and half is a concentrated liquid manure. Other recovery rates are possible - however, higher water recovery rates would decrease the throughput rate.
- In part of the test, manure solids settled out in the temporary holding tank. There was no effective way to agitate this manure before it passed through the VSEP unit. On the other hand, the influent manure sample submitted for lab analysis was agitated, and contained some of the dense solids that had settled out. The

manure filtered through the VSEP was drawn from the top 3/4 of the tank. It appeared that this settling was an advantage for the machine configuration in this test - “pre-screening” plus “settling” seem to represent the desirable manure preparation steps for this unit.

- Reverse osmosis membranes were used in this test - other membranes are available and they would affect throughput rate and effluent quality.
- Comments on test procedure:
  - the handling process for influent manure should be modified - a system is needed to ensure constant agitation of the influent manure (was not always possible) or else more samples of influent manure must be collected (instead of one composite sample) - these individual samples should be matched with corresponding samples of separated solids and liquids
  - the length of the test (volume of manure separated) is a compromise - it does not allow for an evaluation of long-term performance (e.g. slime problems, mechanical breakdowns, deterioration of the equipment, gradual plugging, etc.) but it does allow for testing more than one manure type, which is essential
  - there was an attempt to get manure samples in a wider range of DM contents - most separators would have higher efficiencies with higher DM manure
  - more samples should have been taken for the particle size distribution analysis - there is too much variability in the test results to rely on only one sample of influent and effluent

Report created by: Ron Fleming and Malcolm MacAlpine - June 3, 2003
Ridgetown College - University of Guelph

Tested by: Malcolm MacAlpine

- in consultation with: Roger Torres (New Logic) and Jim Morris (Rondeau Anaerobics)