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Solids-liquid separation

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Farmers are facing considerable problems with liquid manure. This method of handling offers some advantages in animal houses but causes problems outdoors in the further use of the manure. The concentration of nutrients has a large variation depending on the type of manure and water added, but is very low compared with solid manure and fertilizer. This means that, relative to its fertilizing value, a considerable volume has to be stored and later handled in the field.

Due to the increased use of liquid and slurry manure handling systems in confinement operations and accompanying concerns with odors and nutrients associated with these systems, removal of solids from the manure is becoming more attractive to animal producers. Solids-liquid separation provides a feasible approach to concentrate organic solids and nutrient elements present in the manure into a small fraction for utilization. After separation, it is possible to apply the concentrated dry matter and nutrient-rich fraction during the growing season and thus obtain the best utilization of the manure by crops. The amount to be spread is reduced, compared with the usual practice, but provides the same amount of nutrients. This means less damage caused by heavy transport in the field, and less work for the farmer when he or she has to bring out manure at a busy time at the beginning of a growing season. In this way, farmers will secure more efficient use of manure in their fields. Solids-removed liquid will have lower organic contents and thus a lower potential for odor generation during storage and land application. With proper treatment, it can be recycled for flushing purposes.

Solids-liquid separation has been widely used for treating municipal and industrial wastewaters. Because of the associated costs, it has not become widely accepted by farmers for animal manure management. However, continuing trends toward animal industry consolidation and expansion and increasing public concerns with odors and the excess nutrients that are being generated by large animal operations demand a close examination of solids-liquid separation as a method to help reduce manure odors and facilitate nutrient management. In fact, effective solids-liquid separation—that is, a system capable of removing a substantial amount of organic solids from fresh liquid or slurry manure—will potentially offer the benefits of production of nutrient-rich organic solids, odor reduction in subsequent liquid manure storage systems, and improvement in the economics of subsequent liquid manure treatment processes due to the reduced organic strength in manure. In summary, solids-liquid separation can be beneficial to farmers in managing livestock manures.

Equipment for solids-liquid separation

Among the challenges confronting the livestock producer is identifying the most appropriate solids-liquid separation device for his or her particular location. There are several factors which can aid in making that selection. The first is to identify the purpose of solids-liquid separation. Some common purposes include:

- to reduce the loss of storage volume due to the transport of inorganic soil particles from a feedlot,
- to market separated solids from a manure flushing system, or
- to practice solids composting.

Determining the purpose for solid-liquid separation will provide selection criteria for selecting the most appropriate separation system from the numerous devices available on the commercial market for separating the solids in a liquid manure stream from the transporting water[1]. Solids-liquid separation processes include sedimentation, screening, centrifugation, and filtration[2]. The common methods used in separating solids from liquid in manure are listed in **Table 1**.

Table 1. Common technology for solids-liquid separation

Separators	Capital investment ($)	Annual operation cost ($)
Screens	5,000–35,000	Depends
Belt press	170,000	38,000
Centrifuge	200,000	75,000
Gravity decant	10,000	97,500
Drum/roller press	35,000	—

Sedimentation

The simplest of solids-liquid separations is the result of settling by particles of a specific gravity greater than 1. Unroofed feedlots are typically served by a simple settling tank located downstream of the manure covered surface but ahead of any storage, treatment or collection function. Typical design parameters are based on residence time at some defined flow rates. A designer might define the basin as needing to be designed to provide one hour of detention time at the maximum rainfall rate that could be expected to occur during a one hour period once every two years. Climatic data are available that allow designers to determine the appropriate design rainfall rate in inches per hour. By multiplying the rainfall rate by the area contributing runoff, a rainfall volume can be calculated. This leads to a retention pond volume. Clearly, a settling basin designed on this basis will provide more than one hour of detention when the rainfall rate is less than the design rate and less when it is more. The good news is that the highest solids concentrations generally occur during the first part of storm and during a smaller rainfall event.

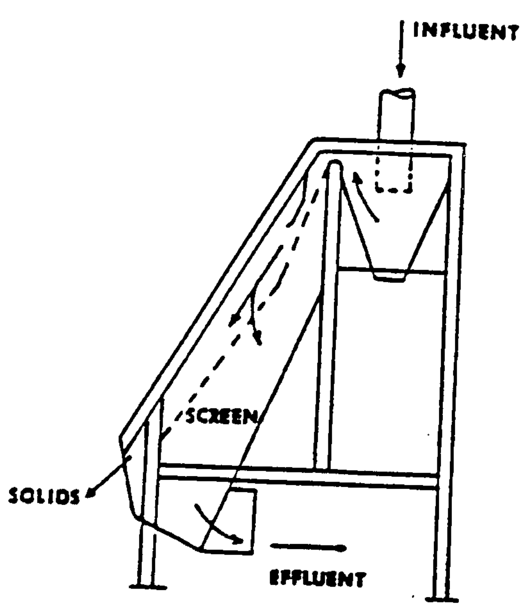
Screen separators

The screen separators that have been used with animal manure include stationary screen, vibrating screen, and rotating screen separators.

Stationary screen separators

Stationary screen separators use slow relative motion between the manure and the screen as caused by the gravity of the manure to facilitate the separation. A stationary inclined screen separator has screen mounted on an incline with the liquid of slurry manure pumped to the top edge of the screen, having the liquids to pass through the screen and drain away while having the solids to move down the face of the screen and drop to a collection area (**Figure 1**)[3]. Stationary screen separators are widely used on dairy farms in the United States for removing fibrous coarse particles from dairy manure to ease the manure handling the storage and land application. The most attractive feature of the stationary screen separators is the lack of moving parts and therefore low maintenance and no power requirement.

Figure 1. Stationary inclined screen separator



Vibrating screen separators

A vibrating screen in its simplest form is a fabric supported by a wire grid (**Figure 2**)[3]. Beneath the fabric there are typically a series of washer-shaped items that are mounted so they can move horizontally relative to the fabric. As they move, they cut off any material that made it partially through the fabric. This process of fibrous material passing part way through the filter fabric is often called stapling. The vibrating screen can overcome this problem. In addition, the shaking action of the screen causes the particles retained on the screen to move to one side where they drop onto a chute and from there into the solids handling equipment. Vibrating screens have been used in livestock waste treatment despite their significant initial investment cost and regular maintenance requirements for proper operation.

Rotating screen separators

A rotating screen separator uses a rotating screen (**Figure 3**)[4]. The manure is deposited to the top of the screen at a

Figure 2. Vibrating screen separator

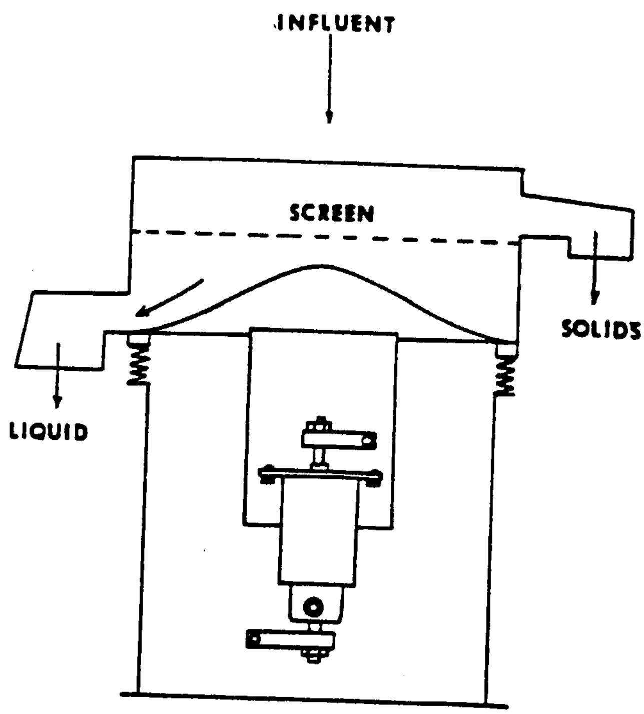


Figure 3. Rotary screen separator

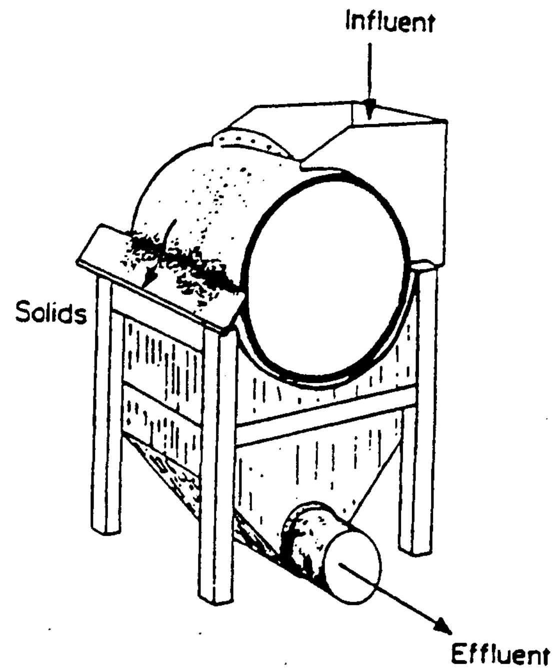
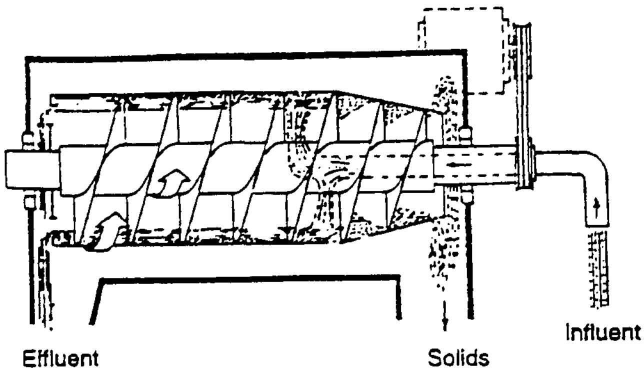


Figure 4. Horizontal decanter centrifuge



controlled rate. The solids retained on the screen are scraped into a collection area and the liquids passing through the screen are collected in a tank.

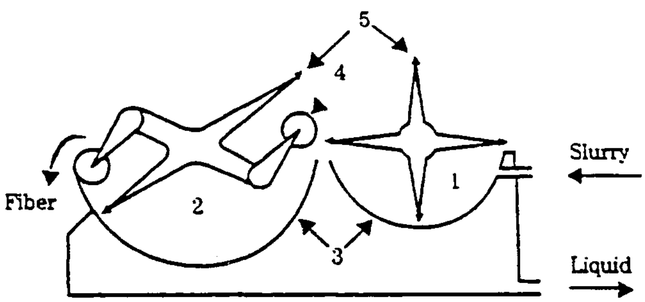
Centrifuges

Mechanical centrifuges (**Figure 4**) are based on the same physical characteristic as the simpler settling basins[5]. The advantage is that centrifuges require less land area and can deliver the solids fraction in a form that is more convenient for further processing. The costs are based on the capacity of the device. Because of the way centrifuges have been built in the past, they typically have a greater capacity than would be needed by most individual swine producers. In some areas, it has been possible to use centrifuges for dewatering lagoons on a contractual basis. Truck-mounted centrifuges can serve several individual livestock producers. The solid fraction from a centrifuge may be as dry as 20–25% solids depending on the centrifuge and the use of filtering aids.

Press separators

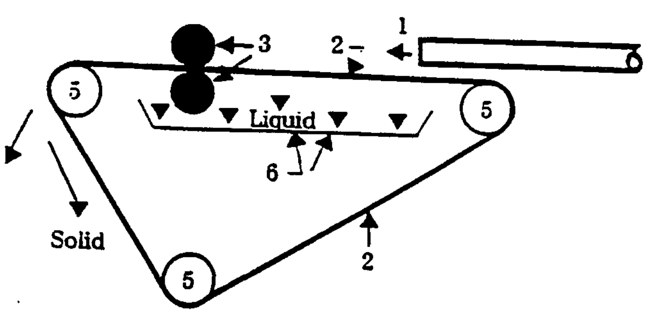
The separated solids generated from these separators contain high moisture contents (85–95%) and need to be dewatered for further uses such as composting. Presses are designed for solids dewatering. The presses pressurize solids with rollers or screws against an opposing screen or a perforated belt, through which the liquid is removed. Typical press systems include roller presses (**Figure 5**)[6], belt presses (**Figure 6**)[6], and screw presses (**Figure 7**)[2]. The roller press uses two concave screens and a series of brushes and rollers[6]. The manure slurry is deposited on the first screen and then moved across both screens with

Figure 5. Roller press separator



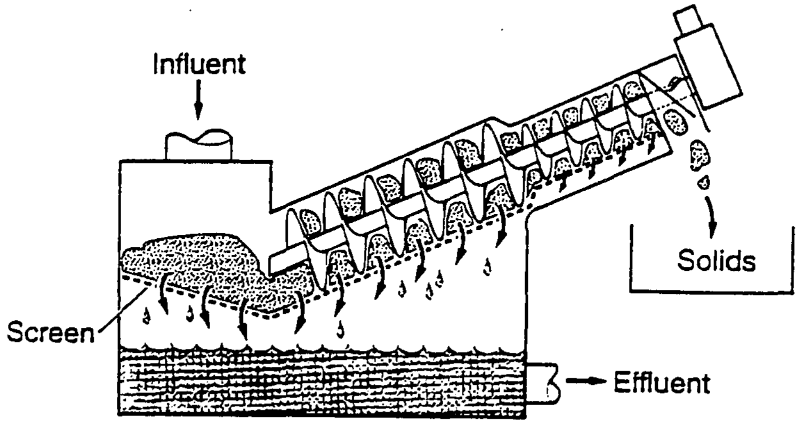
1 **Screening stage**
2 **Roller pressing stage**
3 **Screens**
4 **Spring loaded press roller**
5 **Brushes**

Figure 6. Belt press separator



1 **Slurry input**
2 **Polyester mesh belt**
3 **Press rollers**
4 **Rotary brush**
5 **Belt guide rollers**
6 **Liquid collection trough**

Figure 7. Screw press separator



brushes and squeezed by the rollers. The belt press uses a flat, woven fabric belt that runs horizontally between squeezing rollers[6]. The liquid is pushed through the belt by the rollers and the solids are carried along on the belt and dropped to a solids collection chamber. The screw press uses a central screw conveyor housed in a cylindrical screen. The screen is used to retain the solids in the manure slurry which is pumped into the screen chamber and the screw is used to convey the solids to the discharge chute. During transport, the solids are compacted and dewatered.

Performance of the separators

The performance of sedimentation basins and mechanical separators is evaluated by the amount of total solids removed from the influent manure and moisture content of the solids separated. A high percentage of solids removal and a low moisture content of the solids separated are desirable. Sedimentation basins or tanks are used for removal of settleable solids from dilute wastewater such as flushed manure and feedlot runoff. Settling is usually hindered when the suspended solids in the wastewater exceeds about 1%[7]. Manure flow rate, solids settling rate, and detention time are the primary design parameters for sedimentation basins. Moore et al.[8] examined the solids settling characteristics in liquid manure of 0.1–1.0% initial total solids from several animal species (beef, dairy, swine, poultry, and horses) and suggested a detention time of 10–100 minutes to be used for designing sedimentation basins.

Screens are the most extensively tested separators. The performance of screen separators is mainly determined by

- screen opening size,
- flow rate, and
- the characteristics of manure to be separated, such as the initial solids content and particle size distribution.

Smaller screen openings will generally yield a higher percentage of solids removal but the separated solids may have higher moisture content, because screen openings smaller than a certain size tend to retard the flow of manure through the openings due to adherence interactions between solid particles, water, and screen surfaces, resulting in detainment of more water on the screen together with solids. Screens with openings of 1–3mm are mostly used for removal of large particles, and therefore are used widely for processing dairy manure to produce bedding and compost materials. Screens with smaller openings tend to experience clogging problems.

Belt presses are found to have higher separation efficiencies and produce drier solids than the screen separators, but their structures and operation are more complicated and costs are higher. Performance data for the screw presses and roller presses are lacking in the literature[2]. Centrifuges and hydrocyclones have also been tested with different types of animal manure, but their relatively high prices and complex equipment structures have not made them a popular choice for animal producers.

Table 2 presents some information regarding the performance of different mechanical separators[2]. For swine manure, the efficiency of the screens (stationary, vibrating, and rotating) with 0.86–1.00mm openings is less than 52%, the efficiency of a belt press with a fine pore size (0.1 mm) is 47–59%, and the efficiency of a centrifuge is 45%.

Economics of solids-liquid separation

Solids-liquid separation, like other operations on animal farms, requires:

- initial capital investment for the separator system and its installation,

Table 2. Performance of mechanical separators

Separator	Animals	Screen opening (mm)	TS in raw manure (%)	Separation Efficiency (%)					TS in solids (%)	Liquid flow rate (l/min)
				TS	VS	COD	TKN	TP		
Stationary inclined screen separator	Swine	1.500	0.20–0.70	9	—	24	—	—	6	235
		1.000	0.20–0.70	35	—	69	—	—	9	123
		1.000	1.00–4.50	6–31	5–38	0–32	36	2–12	5	—
	Dairy	1.680	4.60	49	—	—	—	—	13–22	—
	Beef	0.500	0.97–4.10	9–13	—	—	—	—	13–22	—
Vibrating screen separator	Swine	1.700	1.50	3	—	6	—	—	17	37–103
		0.841	1.50–2.90	10	—	1–14	—	—	18–19	15–103
		0.516	1.80	27	—	24	—	—	20	37–57
		0.516	3.60	21–52	25–55	17–49	5–32	17–34	9–17	38–150
		0.390	0.20–0.70	22	28	16	—	—	16	67
		0.440	1.00–4.50	15–25	18–38	13–26	2–5	1–15	13	—
		0.104	3.60	50–67	54–70	48–59	33–51	34–59	2–8	38–150
	Dairy	1.700	0.90–1.90	8–12	—	—	—	—	12–15	35–103
		0.841	1.00–1.80	12–13	—	—	—	—	18–19	15–76
		0.600	1.00–1.70	10–16	—	—	—	—	12	14–54
	Beef	1.700	1.60	12	—	—	—	—	15	40–114
		0.841	1.60	6	—	7	—	—	16	38–108
		0.600	1.60–3.20	11–16	—	5–7	—	—	15–16	19–63
		0.841	6.80	26	—	—	—	—	24	71
Rotary screen separator	Swine	0.750	2.40–4.12	4–8	—	4	—	—	16–17	80–307
		0.800	1.00–4.50	5–24	9–31	2–19	5–11	3–9	12	—
Belt press separator	Swine	0.100	3.00–8.00	47–59	—	39–40	32–35	18–21	14–18	—
Centrifuge	Swine	—	1.00–7.50	15–61	18–65	8–44	3–32	58–68	16–27	—
	Beef	—	3.60–6.20	51–61	60–65	52–60	23–28	43–48	19–26	—

- labor for the system's operation,
- maintenance, and
- repair[2].

The retail price of a mechanical separator varies from $10,000 to $200,000, depending on the separator type and its thoughput capacity (amount of wastewater processed per unit time in m^3/min or gal/min). **Table 3** lists the approximate capital and operating cost for different separators[9]. The throughput capacity of a typical mechanical separator varies from 0.38 to 2.27 m^3/min (100 to 600 gal/min). With the same capacity, screens are usually less expensive than presses and centrifuges. The characteristics of the manure to be treated also affects the type of separators to be used. Screens, especially stationary and rotating screens generally work better with the manure of a low total solids level (<5.0%), while presses and centrifuges work better with the manure of a high total solids level. Generally speaking, the cost of using solids-liquid separation on animal farms is determined by

- the amount of manure to be processed,
- the extent of solids removal from the manure, and
- the potential for solids reuse and value recovery.

Impact of solids-liquid separation on manure odor reduction

Solids-liquid separation divides raw manure into two fractions: solids and liquids. The newly separated solids are still quite wet, with moisture content of above 70%. If left alone in the field, the solids will naturally undergo anaerobic decomposition and become odorous. Therefore, special care must be provided to preclude the odor generation if the solids are to be stored for an extended period of time. Composting or drying immediately after separation will help keep the odors of manure solids at a minimum level. As far as the liquid portion of manure is concerned, odor generation potential depends largely on the amount of odor-producing organic substances remaining in the liquid and management of the liquid in the subsequent storage and/or treatment units. Theoretically, it is expected that the odor generation rate will be reduced in liquid because of the reduction in biochemical oxygen demand as compared with the raw manure if the same storage and/or treatment practices are applied to both. Unfortunately, quantitative information about this reduction is not available. More research is required to develop a better understanding of the impact of solids-liquid separation (at different separation levels) on odor reduction in subsequent liquid manure storage and/or treatment units, and and to determine the economics of different separations methods.

Table 3. Capital and operating cost for different separators

Separators	Capital investment ($)	Annual operation cost ($)
Screens	5,000–35,000	Depends
Belt press	170,000	38,000
Centrifuge	200,000	75,000
Gravity decant	10,000	97,500
Drum/roller press	35,000	—

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