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SOLIDS-SEPARATION SYSTEMS FOR LIVESTOCK MANURE AND WASTEWATER[1]

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ABSTRACT

Six difference solids separators were demonstrated side-by-side at the Southwest Dairy Field Day sponsored by the Texas Agricultural Extension Service. Inflow, outflow, and separated solids samples were taken from each separator and analyzed at approved laboratories for solids, COD, and nutrient content. The mechanical separators reduced suspended fixed solids and suspended volatile solids by an average of 20 and 25 percent, respectively. The limited sampling and the inherently high variability of wastewater sampling and analysis prohibit reliable comparisons among separators.

INTRODUCTION

The concept of separating suspended solids from wastewater streams is gaining acceptance as an important element of effective dairy waste management systems. Preservation of stormwater capacity in runoff holding ponds, reduction in volatile-solids loading on treatment lagoons, and ease of solids recovery and recycling are three of the principal benefits of including a solids separator in the waste management system for a new or expanding livestock operation. In some cases, retrofitting lagoon/holding pond systems can improve treatment efficiencies and mitigate existing management problems.

Texas' so-called "no-discharge" policy requires that waste management systems be designed and operated so that there is no threat of illegal discharge of waste-contaminated water across property lines or into the waters of the State of Texas, except in the event of the 25-year, 24-hour rainfall event. Consequently, lagoons and runoff holding ponds must be designed so that all direct rainfall and open-lot runoff from storms of size up to and including that event must be collected and detained until it can be land-applied in a safe and controlled manner. The "detention storage" portion of the pond design, which accounts for that runoff volume, must be preserved in order that the no-discharge requirement can be met. Solids that settle in the bottom of the ponds will encroach upon that design volume, and while lagoon/holding pond designs typically include an allowance for a certain duration of sludge accumulation, eventually that allowance will be used up. Further accumulation then reduces the effective detention capacity below the legal requirement.

Mechanical solids separators can play a key role in preserving lagoon capacity, reducing the threat of illegal discharge, easing lagoon maintenance, and providing convenient access to manure solids for composting, incinerating, and/or land application.

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[1]Demonstration was featured at the Southwest Dairy Field Day, George DeVries Dairy, Stephenville, Texas 5/14/92.

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TYPES OF SOLIDS SEPARATORS

The three major types of solids separators available today are (1) settling basins or tanks, (2) screen separators, and (3) liquid cyclones. The settling basin, as the name implies, detains liquid manure and/or corral runoff so that the heavier and larger solids settle out and accumulate at the basin bottom. The screen separators come in a variety of configurations, but all use essentially the same principle: wastewater is drained (or forced) through a fine mesh of non-corrosive steel, and those particles larger than the mesh openings are collected from the screen. Hydrocyclones operate on the same principle as cyclones used for air quality control in cotton gins and sawmills; wastewater is introduced at high velocity into a conical chamber where the heavier suspended solids are forced to the outside of the chamber and allowed to fall into a collection device.

SEPARATORS DEMONSTRATED AT THE SOUTHWEST DAIRY FIELD DAY

The separators described below are the units demonstrated at the Field Day. Each company listed provides other separator systems in addition to those described here.

1. Dairyland Automation
   Box 283
   Sulphur Springs, Texas 75482
   Attn: Mr. John Willis
   (903) 885-6428

Dairyland Automation demonstrated an "auger-screen" separator. Liquid manure is introduced at the bottom of an inclined, trough-shaped steel screen; an auger laid into the screen cavity conveys the solids along the screen while the free liquids drain by gravity into a discharge pipe. The auger blades are fitted with abrasion-resistant brushes along with the entire length of the separator, keeping the screen clean and providing some additional dewatering pressure to the separated solids.

2. Innovative Resources, Inc.
   115B South Dallas St.
   Ennis, Texas 75119
   Attn: Mr. Ollie Harwell

Innovative Resources demonstrated a static screen separator, in which liquid waste is pumped into a reservoir at the top of an inclined flat steel screen. The liquid spills over the reservoir edge onto the screen, and as the liquids drain through the screen, separated solids collect at the bottom. The Innovative Resources unit has a roller press at the bottom of the screen to further dewater the separated solids, but the screen may be operated with or without the press. A series of high-pressure impact sprinklers remove debris from the screen after use.

3. Agpro, Inc.
   Route 7 Box 100
   Paris, Texas 75460
   ATTN: Mr. Harvey Blackshear or Neal Dismukes
   (903) 785-5531

The Agpro separator consists of an inclined screen which may be mounted directly into an open wastewater channel. A series of horizontal bars are continuously dragged up the screen surface by a chain, carrying the solids over the top of the inclined screen while the liquids drain into the channel on the downstream side of the separator. Since the separator may be installed directly in an open channel, no pump is required.

4. Agkone, Inc.
586 E. Washington
Stephenville, Texas 76401
ATTN: Sabino Cortez
(817) 965-4590

Agkone provided two sizes (3" and 10" diameters) of their hydrocyclones. Wastewater is pumped into the cyclone inlet, which is offset so that a high-velocity vortex develops in the cyclone chamber. The separated solids which collect on the inside surface of the cone discharge at the base of the cone, while the clarified effluent exits at the top of the cone. In a typical Agkone system, the separated slurry is collected behind a porous dam so that remaining liquid may continue to decant.

5. American Environmental Systems
3566 North J Street
P.O. Box 1258
Tulare, CA 93275
Attn: Mr. John St. George
(209) 686-3373

The static screen currently in use at the George DeVries Dairy is a product of American Environmental Systems of Tulare, CA. Agitated wastewater from a collection sump is pumped into a small reservoir at the top of an inclined flat screen (similar to the Innovative Resources screen) and flows by gravity down the face of the screen. The liquid drains through the screen into a discharge pipe which conveys the clarified effluent to the primary lagoon; the separated solids fall from the face of the screen and are carried horizontally from the screen by an auger and allowed to fall to the concrete slab below.

6. Environmental Protection Technologies International
1800 Willow Forge Drive
Columbus, OH 43220
Attn: Dr. E. Paul Taiganides
(614) 451-4112

EPT's separator is known as a screw-press auger. An auger is mounted inside a cylindrical screen within the housing (different screen meshes may be selected and are easily installed). Liquid manure is introduced at one end of the auger cylinder and is pressed against an adjustable mechanical resistance at the other end. The compression squeezes the liquid from the suspended solids and through the screen, while the comparatively dry separated solids exit at the end.

SAMPLING AND ANALYSIS RESULTS

Three samples each of the inflow and outflow liquids were collected from each of the separators listed above (except the EPT screw-press auger) on May 6, 1992. In addition, one sample of the separated solids was collected from each. An additional sample of the separated solids was collected from the Innovative Resources static screen to demonstrate the effectiveness of the roller press.

The liquid samples were each analyzed for COD, BOD_5, total solids, fixed solids, volatile solids, total nitrogen, total and soluble phosphorus, and total potassium. The solids samples were analyzed for total nitrogen, total phosphorus, total potassium, moisture content, and ash. The results are summarized in the tables below.

Table 1. DAIRYLAND AUTOMATION (auger screen)

	Inflow, mg/L	Outflow, mg/L	% Reduction
Total Solids	10,900 ± 1,422	10,723 ± 1,834	1.6
Fixed Solids	3,313 ± 166	3,327 ± 186	(-) 0.4
Volatile Solids	7,587 ± 1,272	7,397 ± 1,649	2.5
Total Suspended Solids	7,593 ± 1,403	7,363 ± 1,765	3.0
• Susp. Fixed Solids	1,250 ± 151	1,250 ± 165	0.0
• Susp. Volatile Solids	6,343 ± 1,267	6,113 ± 1,602	3.6
Total Nitrogen	621 ± 15	652 ± 16	(-) 4.9
Total Phosphorus	85 ± 4	95 ± 2	(-) 11.3
Soluble Phosphorus	5.3 ± 1.2	5.3 ± 0.2	- 0 -
Total Potassium	501 ± 13	495 ± 26	1.3
COD	11,517 ± 1,285	11,413 ± 1,523	0.9
BOD_5	1,041 ± 175	1,146 ± 211	(-) 10.1

Table 2. INNOVATIVE RESOURCES (static screen with roller press)

	Inflow, mg/L	Outflow, mg/L	% Reduction
Total Solids	10,797 ± 612	9,353 ± 197	13.4
Fixed Solids	3,610 ± 252	3,683 ± 57	(-) 2.0
Volatile Solids	7,187 ± 368	5,670 ± 167	21.1
Total Suspended Solids	6,627 ± 603	5,017 ± 570	24.3
• Susp. Fixed Solids	1,110 ± 210	973 ± 159	12.3
• Susp. Volatile Solids	5,517 ± 403	4,043 ± 477	26.7
Total Nitrogen	803 ± 26	778 ± 9	3.1
Total Phosphorus	115 ± 4	106 ± 1	7.3
Soluble Phosphorus	1.7 ± 1.0	3.0 ± 1.6	(-) 78.3
Total Potassium	652 ± 13	647 ± 24	0.8
COD	10,606 ± 510	9,135 ± 39	13.9
BOD_5	1,100 ± 135	1,020 ± 17	7.3

Table 3. AGPRO (screen)

	Inflow, mg/L	Outflow, mg/L	% Reduction
Total Solids	15,053 ± 630	12,137 ± 355	19.4
Fixed Solids	4,480 ± 72	4,137 ± 80	7.7
Volatile Solids	10,573 ± 619	8,000 ± 285	24.3
Total Suspended Solids	10,063 ± 685	7,670 ± 265	23.0
• Susp. Fixed Solids	1,550 ± 113	1,130 ± 511	27.1
• Susp. Volatile Solids	8,513 ± 621	6,540 ± 756	23.2
Total Nitrogen	1,025 ± 49	889 ± 17	13.3
Total Phosphorus	143 ± 11	117 ± 4	18.4
Soluble Phosphorus	8.0 ± 1.7	1.9 ± 0.6	76.3
Total Potassium	811 ± 8	749 ± 10	7.6
COD	15,508 ± 2,582	11,322 ± 362	27.0
BOD_5	1587 ± 332	1244 ± 317	21.6

Table 4. AGKONE (3" hydrocyclone)

	Inflow, mg/L	Outflow, mg/L	% Reduction
Total Solids	11,743 ± 642	9,833 ± 451	16.3
Fixed Solids	3,607 ± 98	3,413 ± 131	5.4
Volatile Solids	8,137 ± 545	6,420 ± 347	21.1
Total Suspended Solids	7,507 ± 569	5,597 ± 424	25.4
• Susp. Fixed Solids	1,122 ± 83	867 ± 83	22.8
• Susp. Volatile Solids	6,387 ± 536	4,730 ± 364	25.9
Total Nitrogen	823 ± 38	823 ± 9	- 0 -
Total Phosphorus	106 ± 4	106 ± 7	- 0 -
Soluble Phosphorus	3.1 ± 0.2	3.6 ± 0.8	(-) 17.4
Total Potassium	670 ± 13	689 ± 26	(-) 2.8
COD	10,033 ± 745	9,148 ± 316	8.8
BOD_5	1137 ± 234	1147 ± 230	(-) 0.9

Table 5. AGKONE (10" hydrocyclone)

	Inflow, mg/L	Outflow, mg/L	% Reduction
Total Solids	14,497 ± 425	13,350 ± 252	7.9
Fixed Solids	4,610 ± 92	4,453 ± 60	3.4
Volatile Solids	9,887 ± 384	8,897 ± 301	10.0
Total Suspended Solids	9,503 ± 384	8,367 ± 244	12.0
• Susp. Fixed Solids	1,137 ± 629	1,267 ± 118	(-) 11.4
• Susp. Volatile Solids	8,367 ± 421	7,100 ± 287	15.1
Total Nitrogen	960 ± 23	934 ± 9	2.7
Total Phosphorus	142 ± 9	134 ± 4	5.4
Soluble Phosphorus	2.5 ± 3.0	1.7 ± 0.1	33.3
Total Potassium	784 ± 27	761 ± 9	2.8
COD	14,809 ± 747	13,989 ± 23	5.5
BOD_5	1,813 ± 64	1,630 ± 121	10.1

Table 6. AMERICAN ENVIRONMENTAL SYSTEMS (static screen)

	Inflow, mg/L	Outflow, mg/L	% Reduction
Total Solids	6,187 ± 1,372	6,930 ± 742	(-) 12.0
Fixed Solids	1,930 ± 111	2,187 ± 55	(-) 13.3
Volatile Solids	4,257 ± 1,267	4,743 ± 690	(-) 11.4
Total Suspended Solids	3,677 ± 1,415	4,530 ± 767	(-) 23.2
• Susp. Fixed Solids	560 ± 140	843 ± 84	(-) 50.5
• Susp. Volatile Solids	3,117 ± 1,276	3,687 ± 686	(-) 18.3
Total Nitrogen	439 ± 15	439 ± 26	- 0 -
Total Phosphorus	55 ± 2	52 ± 5	6.0
Soluble Phosphorus	6.8 ± 0.8	6.1 ± 1.0	10.3
Total Potassium	361 ± 9	350 ± 22	3.0
COD	7736 ± 897	6728 ± 1353	13.0
BOD_5	711 ± 163	794 ± 128	(-) 11.6

Table 8. DAIRYLAND AUTOMATION (auger screen),
May 1990, Wood County, Texas

Constituent	Inflow Concentration, ppm	Outflow Concentration, ppm	% Reduction
Total Solids	16,780	6,230	62.9
Total Solids	14,700	2,900	80.3
• Susp. Volatile Solids	14,000	3,000	78.6
Total Nitrogen, TKN	570	680	(-) 19.3
Total Phosphorus	2.86	2.86	- 0 -
COD	5,040	8,300	(-) 64.7
BOD_5	7,100	5,500	22.5

CONCLUSIONS

The effectiveness of mechanical solids separators will vary with water use, management rigor, inflow concentrations, and many other variables. However, we may conclude that mechanical separators will provide average reductions in suspended solids of between 20 and 30 percent when operated properly. Other separation technologies, such as settling basins, may also be suitable for confined livestock operations. Each method has unique advantages and disadvantages with respect to management requirements, power consumption, cost, and retrofit capabilities that must be made before a wise selection can be made. The solids and nutrient content of the separated solids will vary with systems, with some producing a free-draining product and others a slurry. This will make a difference in further requirements for handling, storage, processing (composting) and land application. It is evident, however, that solids separation is a management tool that can facilitate and significantly improve the economical and environmentally-sound management of livestock waste that will help to protect the quality of water resources.

Table 7. ANALYSIS OF SEPARATED SOLIDS (all devices)

Separator	Comments	TN (ppm)	TP (ppm)	TK (ppm)	Moisture (% w.b.)	Dry Matter (% w.b.)	Ash (% d.b.)
A. Corral-Scraped Manure							
1. DeVries Dairy		11,817	3,195	7,631	43.82	56.18	56.17
B. Solids Separation							
1. Dairyland Automation	Inclined auger, hollow sleeve	3,263	580	641	73.60	26.40	10.50
2. Innovative Resources	Without roller press	2,601	357	760	86.22	13.78	7.93
	With roller sleeve	--	--	--	74.61	25.39	5.96
3. AgPro	Extractor	3,426	408	897	81.44	18.56	7.03
4. AgKone 3"	After some drainage	1,397	245	821	87.47	12.53	12.65
5. AgKone 10"	No drainage	967	148	178	97.06	2.94	26.61
6. American Environmental	Static screen present at DeVries Dairy	4,418	383	663	71.93	28.07	6.24
Mean S.D.	n = 6	2,679 ±1,304	354 ±148	660 ±255	82.95 ±9.40	17.04 9.40	11.83 7.62

DISCUSSION

The purpose of this field study and field day event was to demonstrate different types of solids separation equipment, and a methodology that can be used for evaluating alternate systems. Because of the extremely short-term nature of the study under possibly non-optimal conditions, the results are intended for educational rather than comparative purposes.

Concentrations of constituents in dairy waste are highly variable, even over short time intervals. In addition, it is quite difficult to obtain representative samples of inflow and outflow streams. Because of the limited number of samples taken and the variable nature of the contents of the supply sump, the data above must not be used as a basis for comparisons among different separators. (For example, consider the percent reduction in total solids for the American Environmental Systems static screen. The negative value indicates an increase in the concentration of total solids, which cannot be since large piles of separated solids were observed.) Much more extensive, detailed and rigorous sampling and analysis would be required to make such determinations with any reliability.

The sampling of the separated solids was easier and the moisture content analysis more reliable. Limited comparisons based on moisture content/dry matter would be justified, but comparisons of nutrient content are not advisable.

Because of the improbable results obtained from the 5/6/92 sampling of the Dairyland Automation auger-screen separator, results from a previous sampling of the unit in 1990 at a dairy in Wood County are shown below. Again, reductions in individual constituents should not be viewed as a basis for scientific comparison with other separators.