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Joseph P. Harner

John F. Smith

Michael J. Brouk

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IMPACT OF SEPARATOR EFFICIENCY AND REMOVED SOLIDS MOISTURE CONTENT ON MAKE-UP WATER REQUIREMENTS FOR SAND RECOVERY

J. P. Harner, J. F. Smith, and M. J. Brouk

Summary

Separator efficiency and moisture content of separated solids influence the make-up water requirements on a dairy seeking to utilize recycled water for sand reclamation. Additional water requirements range from 0 to 79 gallons/cow per day depending on the efficiency of the solid to liquid separation process. Make-up water includes any water stored in a containment structure, excluding urine. Final moisture content of the separated solids had marginal impact on the additional water requirements.

(Key Words: sand recovery, recycled water, separator efficiency.)

Introduction

Cow comfort is often improved by bedding freestalls with sand. Many popular press articles, as well as scientific peer reviewed articles, have discussed the benefits of sand. Sand is not as readily available in all parts of North America, and cost varies from \$5 to \$25 per ton. Some producers are concerned about the agronomic impact of the sand-laden manure applied to fields. Other see an increase in maintenance cost of equipment when handling sand-laden manure because of sand abrasiveness. Another disadvantage is that sand tends to settle in undesirable areas, such as lagoons or digesters. These concerns highlight the importance of removing sand from the waste stream quickly and economically. Removing sand from the waste stream is accomplished

by diluting the sand-laden manure stream with water.

Both mechanical and passive (gravity) systems require addition of water. Fresh water is preferred; but generally, recycled water from a storage pond or lagoon is used. Use of recycled water reduces the total volume of liquid that must be applied to land. It should not reduce, however, the land base requirements for nutrient management plans. Excreted nutrients that must be applied to land are a function of excreted manure (number of cows), not extra water. To the best of the authors' knowledge, no peer reviewed publications exist that quantify the required volume or the minimum quality of the recycled water.

A dairy flushing will use 3 to 5 gallons of water per square foot of floor space per day. A typical dairy layout has approximately 48 square feet of alley space per cow. Actual square footage may be larger, depending on cross alleys, or smaller if 3-row pens are used. This suggests that between 150 and 250 gallons or 1,200 to 2,000 lb of water are required for flushing alleys each day per cow. If 50 lb of sand are used per stall, then 24 to 40 lb of water is required per lb of sand removed. The ratio of flush water to excreted manure ranges from 8:1 to 14:1.

Recycled water contains nutrients and solids that tend to increase over time if no dilution or make-up water is added to the system. Total solids content in the water influences quality of recovered sand. As total solids in recycled water increase, sand will separate but

may contain excess organic matter that is not suitable for reuse. The authors recommend that the recycled water have a maximum of 2 to 4% total solids, with less being better. No intensive field studies have been published, however, that quantify the impact of water quality versus reclaimed sand quality. Manure as excreted contains 12 to 13% total solids. Including the parlor wash, water reduces total solids content to < 10% in most cases. Total solids of the final stream may be reduced if solid separators are used between the sand separation phase and the liquid storage. The objective of this study is to develop a procedure to estimate the total supplemental or make-up water necessary to reach a desired solid content in the recycled water.

Procedures

A spreadsheet model was developed to determine the additional water requirements. The weight of the dry matter weight was determined by:

Eq. 1

$$TS_{dm} = M_{excreted} \times (100 - MC_{initial}) / 100,$$

where:
 TS_{dm} = total solids (dry matter basis, lb),
 $M_{excreted}$ = total manure excreted (lb), and
 $MC_{initial}$ = initial moisture content of the solids (% wb).

Quantity of material removed by the separator was calculated by:

Eq. 2

$$Wgt_{separator} = (TS_{dm} \times S_{eff} / 100) \times 100 / (100 - MC_{solids}),$$

where:
 $Wgt_{separator}$ = total weight of the material removed (lbs),

S_{eff} = the separator removal efficiency (%), and
 MC_{solids} = final moisture content of the removed solids (% wb).

Final weight of the material is calculated based on the desired solid content of the waste stream entering a containment structure.

Eq. 3

$$Wgt = Wgt_{separator} \times (100 - MC_{solids}) / (D_{solids})$$

where:
 Wgt = final weight of the material entering the structure (lb), and
 D_{solids} = desired solid content of the material in the structure (%).

Additional water requirements may then be determined by using:

Eq. 4

$$Wgt_{water} = Wgt - Wgt_{separator}$$

where:
 Wgt_{water} = weight of the extra water required (lbs).

The Excel spreadsheet model assumed a fixed manure production of 140 lb of manure/day per cow at a moisture content of 87.5%. Separator efficiencies evaluated ranged from 10 to 80%. Final moisture content of the separated material was varied from 50 to 80%. Separator efficiency is defined as the percentage of total solids removed as determined by total input solids and output solids. Total solid removal is based on a dry matter basis and includes both dissolved and non dissolved solids. Separated material represents the portion of the input waste stream separated by the separator and is partitioned or stored somewhere other than the liquid containment structure.

Results

Figure 1 shows total weight reduction as a function of solid separator efficiency and moisture content of the separated solids. The graph shows that if separator efficiency is 20% or less, that regardless of moisture content, the final weight reduction will be < 20 lb. Figure 2 illustrates the percentage weight reduction as a function of separator efficiency and separated solids moisture content. Using the 20% removal efficiency, total weight reduction of the manure stream entering the liquid containment structure is < 15%. These graphs illustrate that even though material is being removed by a separator, there is still a large percentage of the solids and liquids fraction entering the liquid containment structures.

Tables 1, 2, 3 and 4 show the supplemental, or make-up, water required to reach a desired solids content level of 2, 3, 4, and 6%, respectively, in the containment structure. Make-up water necessary to maintain the total solids in the recycled flush water at 2% is shown in Table 1. Solid separator efficiency affects extra water requirements more than final moisture content of separated solids. Because the dry matter mass of the removed solids is fairly low (Figure 1), less moisture is necessary to reach the final weight. Additional water requirements range from 79 to 13 gallons, depending on the separator efficiency. An increase in supplemental water is required as separator efficiency decreases or moisture content increases. If a two- or three-stage lagoon system is used for solid separation rather than a solid to liquid separation process, then the water requirements are 89, 53, 36, and 18 gallons/cow per day to reach a total solids content of 2, 3, 4, and 6%, respectively.

Impact of desired total solids in the recycled water may be seen by comparing Tables 1 and 4. This is illustrated by comparing the additional water requirements assuming 50% total solids removed and a moisture content of 70%. Table 1 indicates that 39 gallons/cow

per day is required, and Table 4 shows only 4 gallons/cow per day are required. Table 4 is representative of the situation on many dairies in which the only supplemental or make up water added to the system is through rain water on to the surface of the containment structure and parlor wash water. Additional water requirements are 15 gallons or less, but the recycled water will contain 6% total solids, and high quality sand may be not be recovered.

Many separators have a reported efficiency of 20 to 50%. Twenty to 40 gallons of supplemental, or make-up, water/cow per day is required if 3% total solids in the recycled water is desired (Table 3). Sources of this supplemental water may come from rainwater onto the containment structure surface, milk parlor wash water or clean up water, extraneous drainage, or make-up water from a freshwater pond or groundwater.

Conclusions

Successful reclamation of sand requires supplemental water to adequately separate the organic and inorganic matter. Separator efficiency and moisture content of the separated solids influence the make-up water requirements on dairies seeking to use recycled water for sand reclamation. Additional water requirements range from 0 to 79 gallons/cow per day depending on the solid to liquid separation process before a containment structure. If supplemental water is required, then the design engineer must determine if there is adequate water available for recycling. Daily disposal cost of this extra water may increase variable costs up to \$0.79/cow per day if the separation process is inefficient, assuming an application cost of \$0.01 per gallon. Operating costs may be reduced by purchasing sand for bedding rather than handling extra water requirements for recycling sand if the solid to liquid separation process is inefficient or if irrigation is not available to handle the additional water. Supplemental water requirements

are influenced by the efficiency of the solid to liquid separation process and the acceptable percentage of total solids content in the con-

tainment structure. Final moisture content of the separated solids has only marginal impact on the daily disposal cost.

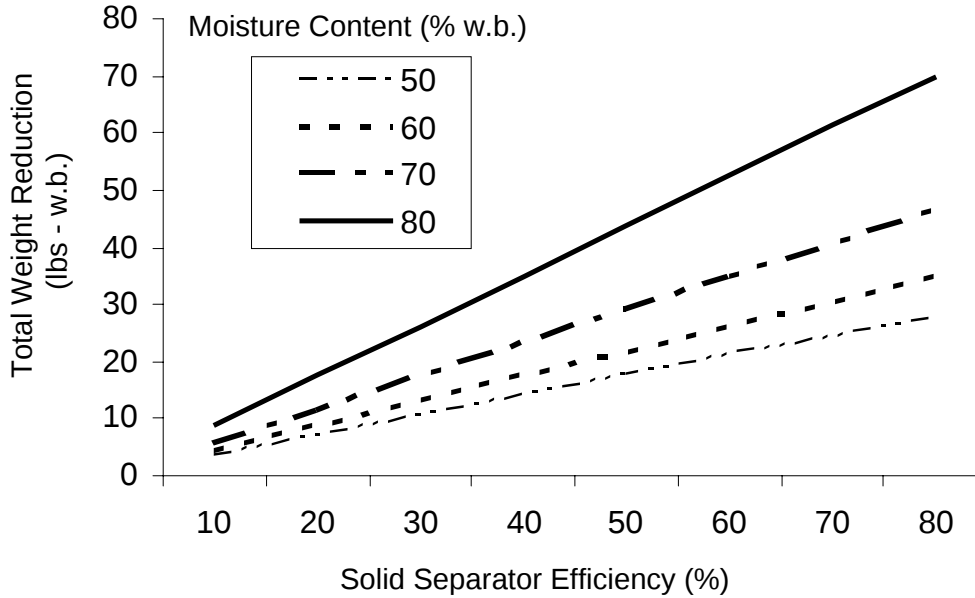


Figure 1. Impact of Solid Separator Efficiency and Final Moisture Content of the Separated Material on the Weight of Material Removed Assuming a Cow Excretes 140 lb of Manure per Day.

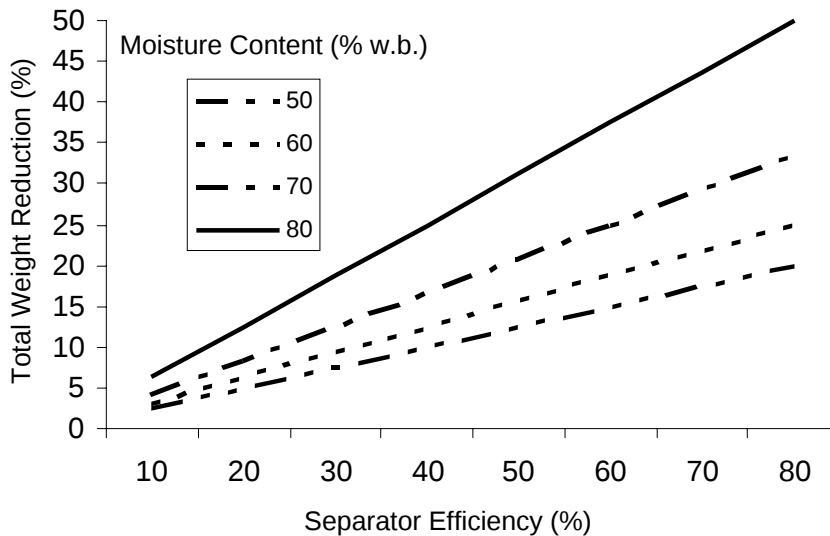


Figure 2. Impact of Solid Separator Efficiency and Final Moisture Content of the Separated Material on the Volume Reduction Assuming a Cow Excretes 140 lb of Manure per Day.

Table 1. Supplemental Water (gallons) Required per Cow per Day to Maintain Total Solids in a Containment Structure at 2% Based on Total Solids Removed and Final Moisture Content of the Separated Material Assuming the Cow Excretes 140 lb of Manure per Day

Total solids removed, %	Final moisture content of solids, % wet bulb			
	50	60	70	80
10	78	79	79	79
20	68	69	69	70
30	58	59	59	60
40	48	48	49	52
50	38	38	39	41
60	28	28	30	32
70	18	18	20	22
80	8	8	10	13

Table 2. Supplemental Water (gallons) Required per Cow per Day to Maintain Total Solids in a Containment Structure at 3% Based on Total Solids Removed and Final Moisture Content of the Separated Material Assuming the Cow Excretes 140 lb of Manure per Day

Total solids removed, %	Final moisture content of solids, % wet bulb			
	50	60	70	80
10	47	47	47	47
20	40	40	41	41
30	34	34	34	35
40	27	27	28	30
50	20	21	22	24
60	14	14	15	18
70	7	8	9	12
80	1	1	3	6

Table 3. Supplemental Water (gallons) Required per Cow per Day to Maintain Total Solids in a Containment Structure at 4% Based on Total Solids Removed and Final Moisture Content of the Separated Material Assuming the Cow Excretes 140 lb of Manure per Day

Total solids removed, %	Final moisture content of solids, % wet bulb			
	50	60	70	80
10	31	31	31	32
20	26	26	27	27
30	21	22	22	23
40	16	17	18	19
50	12	12	13	15
60	7	7	8	11
70	2	3	4	6
80	0	0	0	2

Table 4. Supplemental Water (gallons) Required per Cow per Day to Maintain Total Solids in a Containment Structure at 6% Based on Total Solids Removed and Final Moisture Content of the Separated Material Assuming the Cow Excretes 140 lb of Manure per Day

Total solids removed, %	Final moisture content of solids, % wet bulb			
	50	60	70	80
10	15	15	15	16
20	12	12	13	13
30	9	9	10	11
40	6	6	7	8
50	3	3	4	6
60	0	0	0	0
70	0	0	0	0
80	0	0	0	0