MANURE COLLECTION AND TRANSFER SYSTEMS IN LIVESTOCK OPERATIONS WITH DIGESTERS

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INTRODUCTION

Manure collection systems are influenced by many factors on livestock operations. Management style, bedding type, topography and manure application methods dictate the design and ultimate success of a manure collection system. Traditional collection systems have evolved based primarily on animal comfort and increased labor efficiency, with long term storage and land application being the only ultimate use of collected manure.

Adaptation of advanced manure processing requires integration of the manure collection systems to provide a consistent, reliable product. Flush, scrape and cross gutter systems all collect and transfer manure, but provide significantly different end products to a manure treatment system. Each system has their advantages and challenges and costs from an operational and processing standpoint.

SYSTEM DESCRIPTIONS

Flush Systems

A flush system will substantially dilute the solids content of the material available for processing, dilution rates can vary from 10:1 to 2:1 parts of water to manure. The final solids concentration will typically be below 2%. The costs to operate and maintain a flush system are dominated by the cost to transfer liquid for flushing. Depending on topography, several high horsepower pumps are often required.

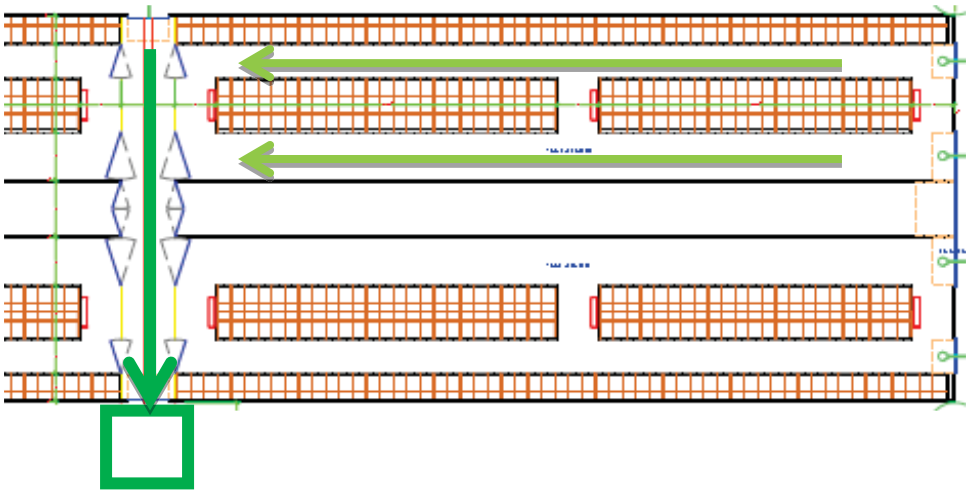
Scrape Systems

Scraping does not use any additional liquid for manure collection. Manure is collected as close to as excreted solids concentrations as possible, typically above 10 % total solids, depending on the amount of bedding and the amount of water used in cow cooling. Collection is accomplished by mechanical means using an automatic alley scraper, skid loader bucket scraper or a vacuum scrape and haul combination.

Cross Gutter Collection Systems

Most collection system will require an additional transfer system to move manure from each alley across the barn to a central reception pit outside of the animal housing system. Manure is scraped along the alleys, parallel to the feed lane and dropped into a cross gutter channel which carries manure to a reception pit. Cross gutter systems use a square channel or round tube underneath the barn floor.

Figure 1. Typical dairy barn layout with a conventional scrape system into a cross gutter collection system to transfer manure to a reception pit.



A flush flume system utilizes fast flowing liquid to transfer manure across the width of a barn or across several barns in a round tube. A high volume pumps creates an adequate flow rate to prevent settling of manure solids and bedding material. Water addition, and separation or dewatering is needed before evacuating to further processing to have enough liquid to keep the flush flume operating. Solids content of a flush flume will typically vary between 4 to 9% total solids.

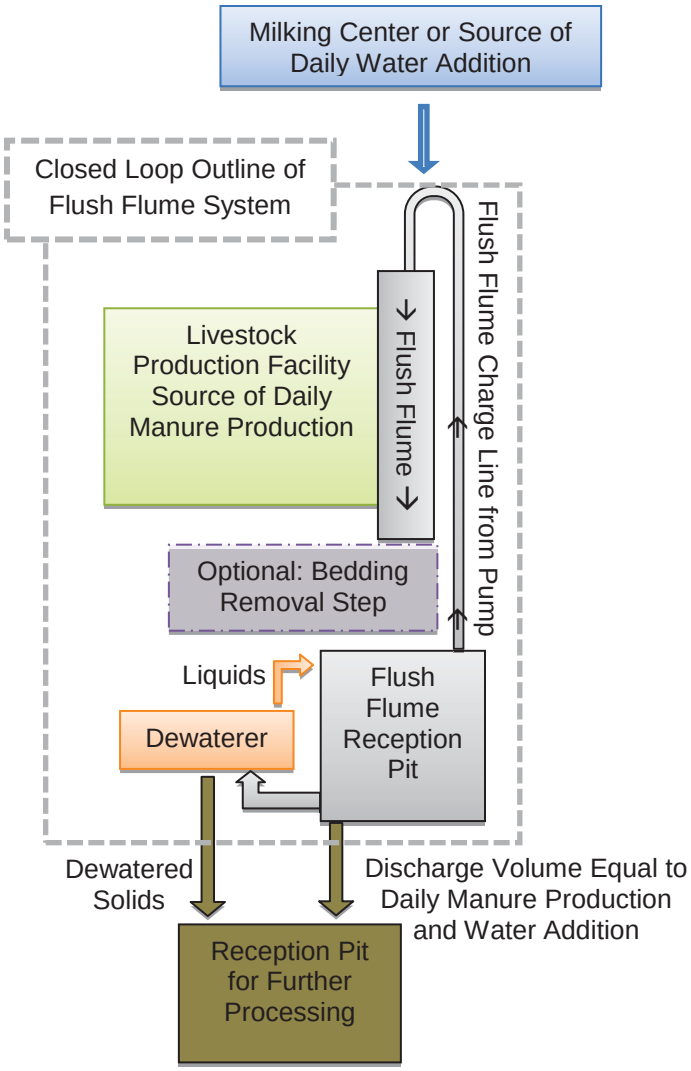
A mechanical cross gutter uses a cable or chain pulled scraper or a horizontal auger in a square concrete channel to mechanically convey manure. Flush and some vacuum scrape and haul systems will not require a cross gutter scraper to bring manure to a central reception pit. Complete scraped systems with a mechanical cross gutter or a vacuum system can have collected material contents between 8 and 18% total solids. This number will change throughout the year based on weather conditions, cow cooling methods such as sprinklers and parlor water addition.

Table 1. Expected total solids content of common manure collection systems on US dairies

	Volume Per Cow Per Day (US gallons)	Expected % Total Solids in Reception Pit
Flush System	60 -200	1-3
Scrape w/Flush Flume	30-50	4-9
Scrape w/Mechanical Cross Gutter	20	8-18 "As excreted"
Vacuum Scrape or Scrape to Reception Pit	20	8-18 "As excreted"

Vacuum scrape and scrape systems with a mechanical cross gutter offer the lowest volumes per cow per day, but can also have the highest variability throughout the year. Additionally, milking center water and the small portion of manure excreted in the milking center will have to be handled separately.

Figure 2. Closed loop system: Scrape with flush flume system on a dairy facility.



Dairy manure scrape systems with flush flumes offer an extremely attractive balance between volume per cow per day and consistency of the product available for processing throughout the year. The closed loop concept of a flush flume with separation or dewaterering offers control by the dairyman with minimal fresh water addition over and above normal liquid for the milking center. An additional bedding removal or recovery process can be added to provide the farm with bedding independent of the type of further processing.

Flush flumes systems require liquid to be pumped at high rates to create velocity for manure conveyance through a round tube or circular channel. Constant manure addition without adequate dewatering or water addition will lead to reduced pumping volumes, lower fluid velocities and increased solids settling in the flume line.

System Management: Unwanted Material

Inevitably there will be bedding and other unwanted material in the manure system. Wooden hoof blocks, breeding gloves, plastic pieces, rocks and neck straps will clog pumps and create problems in different points in the systems. Easily accessible bar racks or removable catch baskets should be incorporated into a manure system to limit system downtime.

Other unwanted material may include the bedding used for the animal in the production system. Sand bedding in particular is wonderful for dairy cows, useless in most further processing systems and very hard on manure handling equipment. Additionally, even when sand is not used for bedding, cows will excrete several pounds per day of grit passed through from the feed they receive. A properly managed sand separation system, settling pit or grit chamber will remove heavy sediment from the system before further processing.

COST TO COLLECT MANURE

All manure systems have costs associated with initial construction, operation, maintenance and labor expenses. In order to estimate operational expenses, a theoretical 1,200 cow dairy was used to evaluate different systems. The dairy consists of two 600 ft long barns with center manure drops. Each building holds 4 pens of 150 cows each. Assumptions based on equipment sizing, energy usage and maintenance expenses were calculated based upon manufacturer’s specifications for each situation. The site was assumed to be feasible within reason for topography and climate for each collection system, initial construction costs are not included. Fuel consumption data was calculated from ASABE standards for Machinery Data based on horsepower required for the desired task. Calculated numbers were compared against actual producer responses with similar collection systems.

For manure collection systems, flush, vacuum scrape and skid loader scrape systems tend to have higher energy usage based upon the higher horsepower required to move large volumes of water or large pieces of machinery. Additionally, the labor cost on vacuum scrape and skid loader scrape are higher since an operator is required to be in the machine at all times. Flush systems and automatic alley scraper systems are generally timed or push button operation. Automatic alley scraper systems require less energy but require more maintenance time and expense per day. For a cross gutter system, scraping is dominated by the daily maintenance costs, whereas auger and flush flumes are energy dominated.

Table 2. Daily energy, labor and maintenance costs for different manure collection and cross gutter systems on a calculated 1,200 cow dairy

	Manure Collection Systems				Cross Gutter Systems		
	Alley Scrapers	Flush System	Vacuum Scrape	Skid-Loader	Scraper	Auger	Flush Flume
Daily energy usage	6.48	18.51	144.27	34.19	0.69	9.26	6.17
Labor cost per day	17.14	4.29	80.57	52.29	1.07	1.07	1.07
Daily maintenance Cost	16.44	8.22	15.07	15.07	4.11	5.48	2.74
Cost per day to operate	40.06	31.02	239.91	101.54	5.88	15.81	9.98
Cost per cow per day	0.03	0.03	0.20	0.08	0.00	0.01	0.01

As with any system, there are other factors that will contribute to long term success. Vacuum scrapers and skid-loaders can be driven to a shop for maintenance in an area with readily accessible tools and lifts. Flush systems are limited in certain regions due to freezing and the need to handle and store large volumes of liquid. Alley scraper systems require daily maintenance in the barn, as well as some forward thinking when spreading fresh bedding and using stall grooming equipment.

LONG DISTANCE MANURE TRANSFER

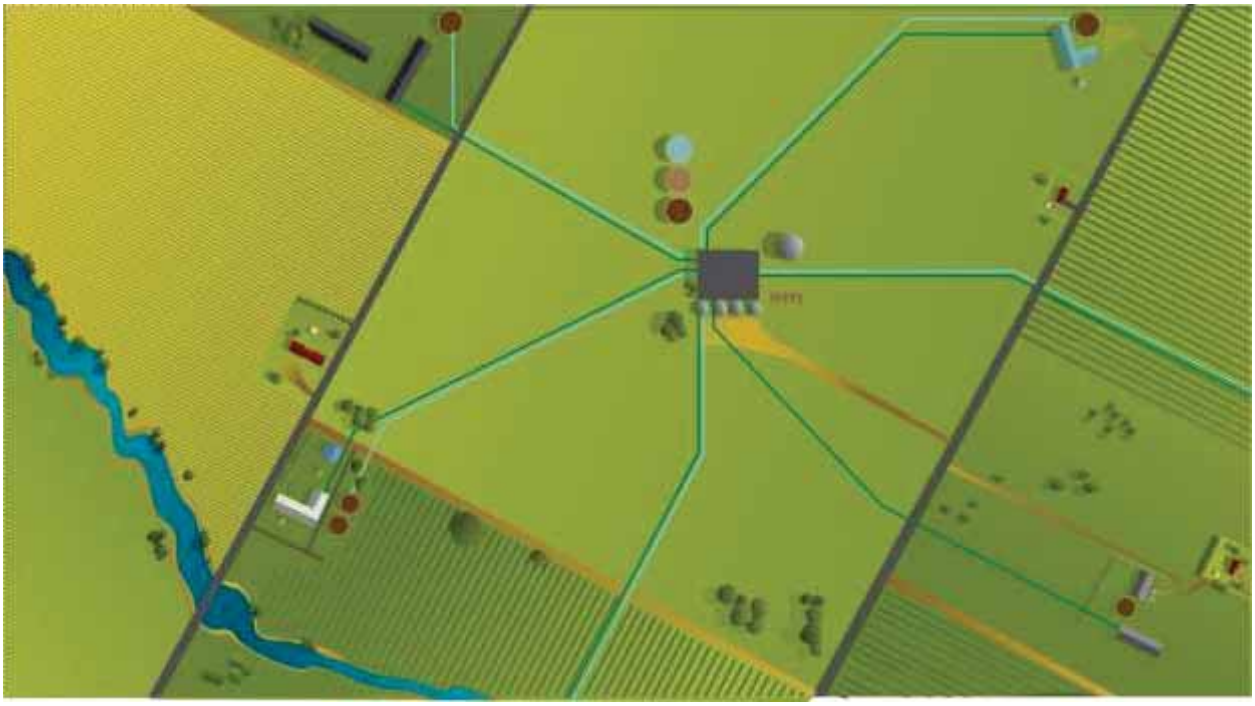
As further manure processing gains acceptance on livestock facilities, a centralized processing location often appears as the most attractive solution for multiple site locations. Advantages are numerous for both the producer of manure as well as the operator of the manure processing location. A major cost obstruction to a centralized plant is the expense of transferring manure or feed stock from individual locations, and returning effluent to utilize existing waste storage facilities.

There are three common methods to transfer manure long distances;

- Trucks and tanks over the road
- High volume, intermediate pipeline transfer
- Low volume, continuous pipeline transfer

Using semi trucks or tractors and manure tanks is the most common way today to transfer manure from one location to another. Tanks are readily available, may already part of a farms equipment package, and would not require any additional infrastructure.

Figure 3. Transferring material from individual farms to a central processing facility



Pumping manure has often been limited by distance and energy usage. High volume, high horsepower pumps are commonly used during times of manure application. Temporary pipelines are laid across the ground and manure is pumped directly to the field where it is applied. A similar, permanent system can be installed using a high horsepower pump to transfer manure in short bursts throughout the day. An alternative pumping method is to use a low horsepower, low flow rate, positive displacement pump to transfer manure slowly throughout the day. A permanent pipeline is still required.

With either high or low volume pumping, sedimentation of material in the pipeline is a concern during idle and pumping times.

Energy Usage to Transfer Manure

In order to compare different manure transfer systems a representative example was selected. Equipment packages and motor sizes were selected on manufacturer's recommendations to transfer 72,000 gallons of manure over a distance of 5,000 ft. The manure tank transfer assumed time for loading/unloading and road transport. The two pumping schemes assumed level ground with a permanent PVC pipeline and electric motors with a 78% efficiency.

Table 3. Comparison of different manure transfer systems

	Manure Tank Transfer	High Volume, High Horsepower	Low Volume, Low Horsepower
Transport Size	7,300 gal. manure tank	6" PVC	4" PVC
Engine/Motor HP	200 hp (149 kW)	150 hp (112 kW)	7.5 hp (5.6 kW)
Transfer Rate (US Gal. per hour)	28,800 (4, 7,200 gal. loads per hr)	48,000 (800 gal. per min)	6,000 (100 gal. per min
Total Time for Transfer	2.5 hrs	1.5 hrs	12 hrs
Energy Usage per Day	40.7 gal. diesel	215 kWh	86 kWh
Cost @ $3.50 per gallon diesel and $0.08 per kWh	$142.45	$17.20	$6.88

Overall, a low volume, low horsepower pumping system uses the least amount of energy to transfer the required volume, even though the total operating time is significantly longer. The energy savings are achieved by the enormous reduction in friction due to the low flow rates along the length of the pipeline. Other factors need to be considered such as: back-up plans for line plugging, time commitments for employees and maintenance costs.

CONCLUSIONS

Manure collection systems are unique to each type of livestock production system. Each system will deliver a different available product to a reception pit available for further processing. Manure collection systems designs should be dominated by animal performance and management style prior to considering further processing. A system's success is determined by the ability to maintain animal comfort in the production system while delivering a consistent product for the further processing. Minimizing labor inputs, allowing for redundancies and establishing emergency plans must be established in the design phase of a project.

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