Storing & Handling Sand-laden Dairy Manure
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A Description of Manageable Practices on Midwest Farms

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INTRODUCTION

The use of sand as a bedding material coincides with improvements in and increased use of free stalls for dairy housing. Sand provides greater cushion and surface drainage than other materials to enhance stall use and cow cleanliness.

Many veterinarians recommend sand bedding to reduce mastitis risk and maintain foot and leg health. These benefits must be weighed against difficulties experienced when handling sand-laden manure.

This bulletin examines the characteristics and challenges of sand bedding from a manure storage and handling perspective. It describes systems that have been employed successfully on Midwest dairy farms, beginning with the most straightforward and reliable, and extending to systems that may include greater efficiencies, but demand more planning, management and expertise. Preferred handling methods, construction components, and equipment selections and features are offered, as available.

COMMON BEDDING SANDS

Both coarse and fine textured sands are being used for bedding. The suitability of the material for bedding and the performance of the manure handling system can be affected by the texture and quality of sand used.

Coarse sands are usually graded and are often washed. Fresh 2NS sand, a common grade, is free of stones, contains negligible clay or organic matter and has a loose, porous structure. These are very desirable features for establishing a clean, dry and comfortable stall bed.

But 2NS sand can be difficult and expensive to obtain and its large particle size makes it settle out quickly and difficult to scour back into suspension from the bottom of manure storage pits. Coarse sands are also the most abrasive to manure handling equipment.

A variety of fine-textured bedding sands are in use. Many manufactured sands — mason, sandblast or reject sand — are fine textured. They are usually similar to a graded sand referred to as Regular 8. Most pit-run or bank-run sands are also fine textured. Examine these sands for stone, root and clay content because excessive amounts of foreign matter will make the sand unsuitable as bedding material for dairy cattle.

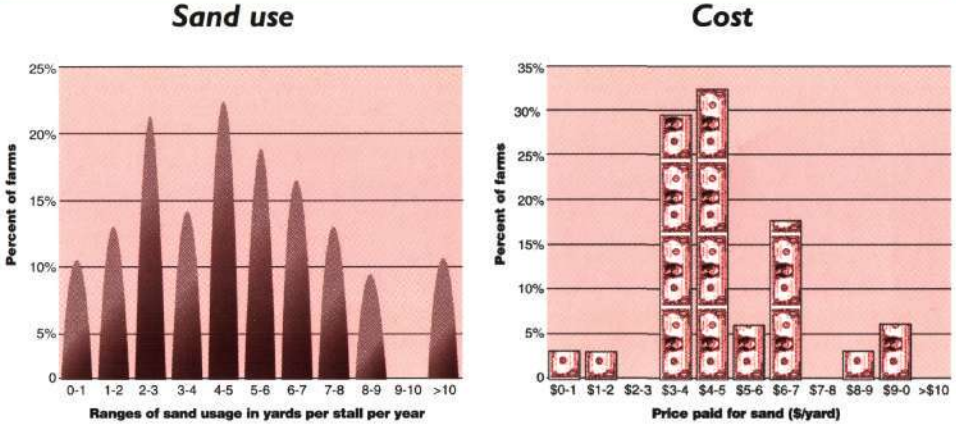
In the stall, fine sand is more susceptible to compaction but reportedly stays in place longer than coarse-textured sand. Fine-textured sand also stays suspended in manure longer, is easier to get back into suspension with agitation, and appears to be less abrasive to equipment. However, the small particles are tracked by the cows into the milking parlor and can enter sealed components in equipment.

Reliable information is limited on sand use and characteristics of sand-laden dairy manure. Figure 1 shows the amount of sand used and the cost of purchased sand based on a sampling of 57 Midwest dairy farms.[1] The amount used ranged from 0.3 to 11.8 yards per stall per year with an average of 4.6 yards per stall per year (about 53 lb per stall per day) assuming year-long use. The rate of use reflects differences in stall maintenance and efforts to reduce sand use. Lower rates of use generally result in reduced cow comfort and cleanliness.

[1] Preliminary data on sand use and handling methods were collected by Andrew Wedel, Michigan State University.

Figure 1.

Bedding sand usage and cost reported on 57 dairy farms in Michigan, Wisconsin and Illinois.



Characteristics of Sand-laden Manure

CHARACTERISTICS OF RAW, UNDILUTED SAND-LADEN DAIRY MANURE

Composition

A 1,400 lb cow typically produces[2] 115 lb/day of 87.3% moisture content manure yielding a solids content of 14.6 lb/day. Raw dairy manure is a semi-solid with a bulk density of 62 lb/cubic ft.

[2]Data obtained from the Dairy Housing and Equipment Handbook, MWPS-7, 1985. Midwest Plan Service, Ames, IA.

Traditional organic bedding materials readily absorb moisture but add little to the weight of manure handled. This creates a more solid and stackable manure. Yet, dilution of such manure in storage can produce a pumpable slurry or liquid.

Because sand has a density of 150 lb/cu ft or more, it adds considerable weight to the manure mixture. But sand does not absorb moisture. Based on published manure production figures and the average sand usage found in the farm survey, a mature dairy cow produces 165 lb of sand-laden manure daily. This manure has a density of about 75 lb/cu ft and a moisture content near 62%.

While a gallon of raw manure or manure with organic bedding weighs about 8 lb, sand-laden manure can easily weigh 10 lb, or more, per gallon. Consider heavy-duty tires and frame capacity on all spreaders.

Compared to raw dairy manure, a sand-laden manure system must handle, on average, 43 percent more material by weight and 18 percent greater total volume. Of greater importance, sand-laden manure is 21 percent more dense, and has 425 percent more total solids.

Handling characteristics

The increased density can have especially serious implications for equipment used to haul sand-laden manure. While a gallon of raw manure or manure with organic bedding weighs about 8 lb, sand-laden manure can easily weigh 10 lb, or more, per gallon. Consider heavy-duty tires and frame capacity on all spreaders. Even though it has a high solids content, containment is necessary when storing sand-laden manure because the manure will slump and seep water. Sand-laden manure is best handled with a tire scraper or bucket loader (see Figure 2).

In an undiluted state, sand-laden manure is quite viscous and sand settling during storage occurs very slowly. Solids, including sand, typically remain throughout the expanse of manure. Pumping, therefore, is only possible with a positive displacement pump.

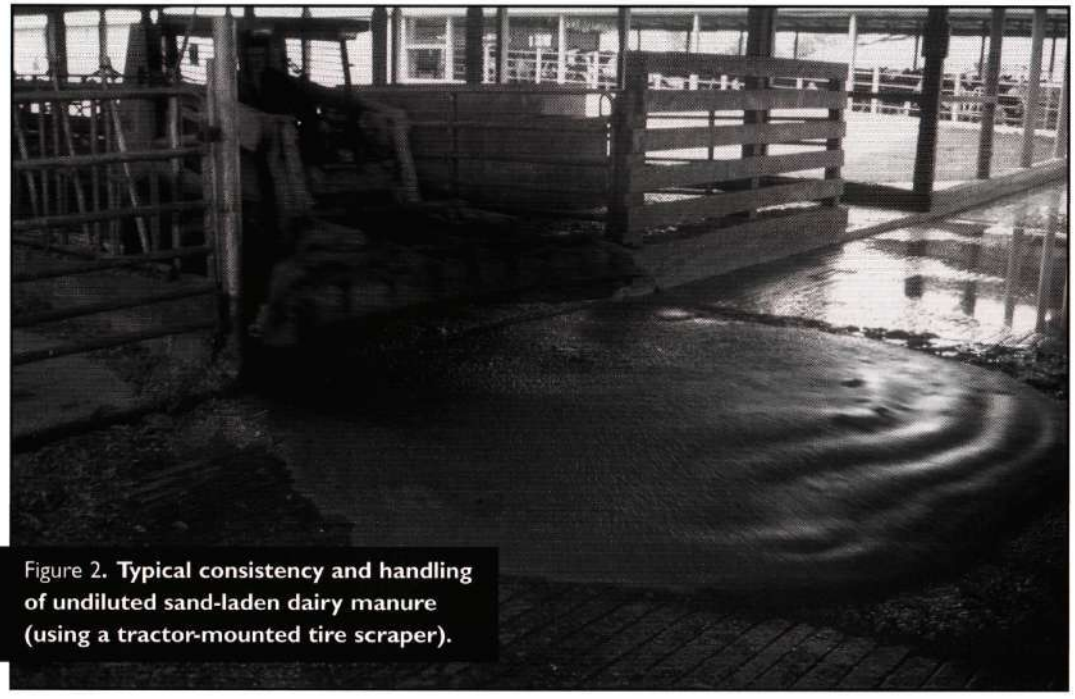


Figure 2. **Typical consistency and handling of undiluted sand-laden dairy manure (using a tractor-mounted tire scraper).**

DILUTED SAND-LADEN DAIRY MANURE

The handling characteristics of sand-laden manure and the performance of selected handling systems are greatly affected by dilution. Precipitation, milking parlor wastewater, flush water and surface water run-off are common sources of dilution water.

Settling of solids

Dilution expedites the settling of solids, especially larger sand particles.

In the Midwest, attempts to settle out sand prior to storage are limited by potential freezing conditions and

narrow windows of time for manure application. Land availability and construction costs for dilution water storage also require consideration. More commonly, precipitation causes settling within the manure storage.

Excess water can quickly settle out sand from freshly loaded manure. Sand can build up and develop a large mass of solids (as in Figure 3) similar to that seen when top-loading frozen or dry manure. This makes it difficult to load more manure into the storage.

Settling is inevitable during extended storage of diluted sand-laden manure. The amount of settling varies with the amount of sand used, dilution rate and storage duration. It is not uncommon to have settled sand and manure solids build to two feet, or more, on the bottom of long-term storages.

Sand settling can also occur in transport equipment and irrigation lines. This can be minimized by maintaining or inducing circulation of fluid and by reducing idle time.

Pumping considerations

While positive displacement pumps provide a means of transferring raw manure to a storage, centrifugal pumps are better suited for emptying manure storages because of their higher capacities; a few hundred gpm to several thousand gpm are available.

However, to use these pumps, the manure must be in liquid or semi-liquid (slurry) form, so dilution water is required. The dilution water promotes settling of solids which may or may not be desired. If the intent is to pump sand and other solids from the storage, an intricate balance of dilution, agitation and pumping is required.

Regardless of the rated or implied pump capacity, actual pumping rates may be considerably lower with sand-laden manure. Generally, the greater the dilution, the higher the pumping rate, etc. However, reduced capacity is not the biggest problem farmers struggle with when trying to pump sand-laden manure.

Machinery wear from pumping sand-laden manure is a major concern for most farmers. Figure 4 illustrates the wear that occurred on pump equipment after extensive use in sand-laden manure. Pump bearings are often replaced on an annual basis by farmers and custom operators, costing several hundred dollars.

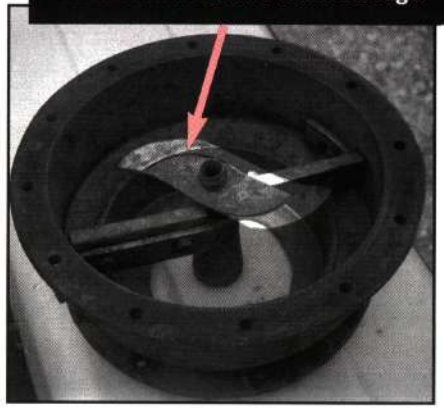


Figure 4. **Extensive wear in a centrifugal pump unit used by a custom operator to transfer sand-laden manure from storage.**

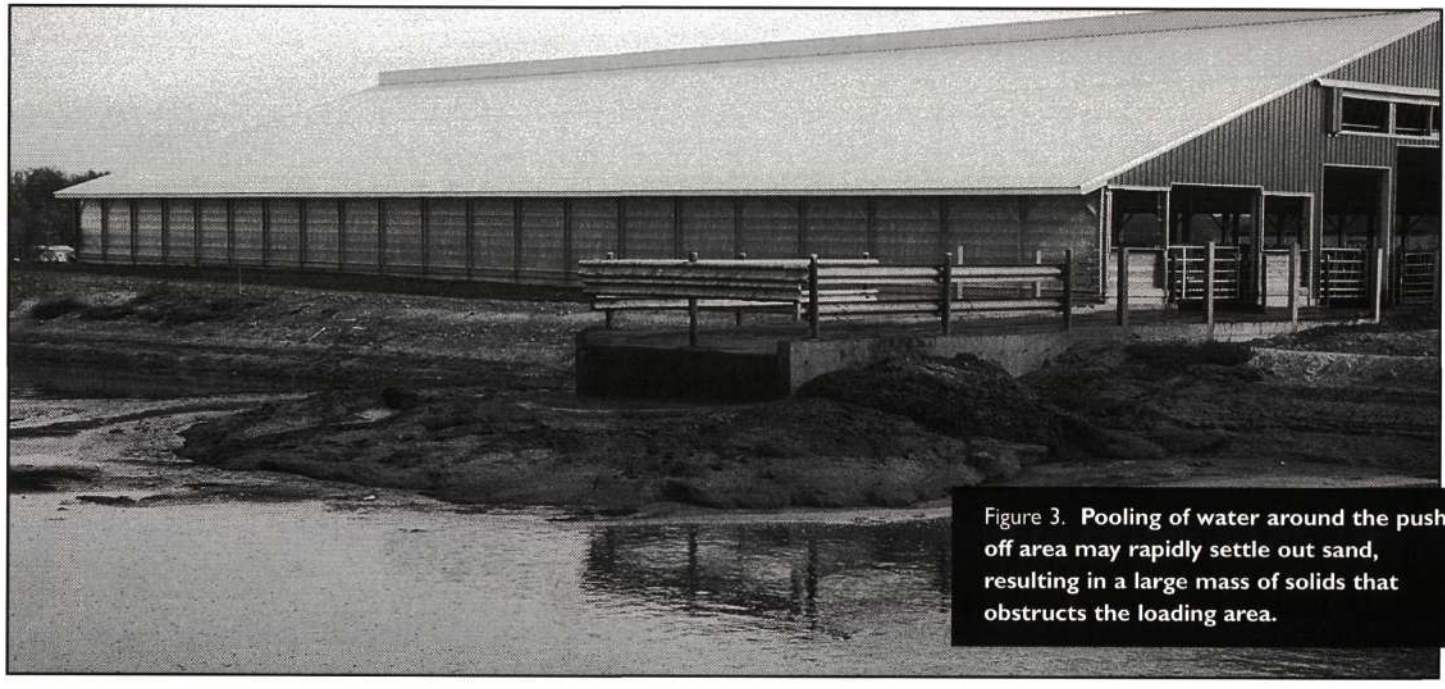


Figure 3. **Pooling of water around the push-off area may rapidly settle out sand, resulting in a large mass of solids that obstructs the loading area.**

The traditional pump and discharge agitation unit will not accomplish good subsurface agitation.

Pump wear increases according to the amount and texture of sand in the manure, the aggressiveness of agitation and the amount of pump time. These factors can vary considerably between handling systems and should be considered when comparing overall costs of each system.

AGITATION

Agitation of sand-laden manure in storage deserves considerable attention. Some farmers are successfully pumping out manure storages full of sand-laden manure. They do so through careful planning, use of appropriate equipment and skillful agitation. Many others have turned to other bedding materials because they were unable to agitate settled sand into suspension to remove it from storage.

Subsurface vs. surface agitation

Traditional agitation of manure with organic bedding involves breaking up the surface crust that forms on storages and mixing this floating material with the liquid and the small layer of organic solids that settles to the bottom.

Manure is usually circulated using a centrifugal pump with a chopper and high volume discharge. The agitation process can be evaluated by observing what is happening at the surface of the storage; good surface activity indicates good agitation.

Agitation of sand-laden manure is much more complex and demanding. If there is a surface crust, it is very thin. Surface activity does not contribute to, nor even indicate, good re-incorporation of sand into the manure; agitation of sand-laden manure in storage must take place below the surface.

Effective subsurface agitation is an intensive process of scouring the settled sand surface and lifting sand particles upward into the moving stream of manure. Farmers have described the important lifting process as a powerful "fluffing" or billowing action.

The traditional pump and discharge agitation unit will not accomplish good subsurface agitation. Actually, such equipment may worsen the situation if, after being discharged during recirculation, sand settles out beyond the effective reach of the pump.

Subsurface agitation and re-incorporation of sand in long-term manure storages requires using rugged prop-type equipment. The propeller agitation device may be a separate piece of equipment, as shown in Figure 5, or it may be included as part of the pump system.

Information is scant regarding technical requirements for effective agitation of sand-laden manure. However, farmers who are successfully agitating sand into solution suggest the following essential criteria:

1 Maintain a reasonably deep liquid layer in the storage at all times. Don't start pumping until fully agitating at several locations around the manure storage pit. A reserve of water must be available so that water can be added in the final phases of emptying the storage.

2 Provide access for setting up an agitation unit nearly anywhere along the perimeter of a long-term storage pit.

3 Agitate almost continuously.

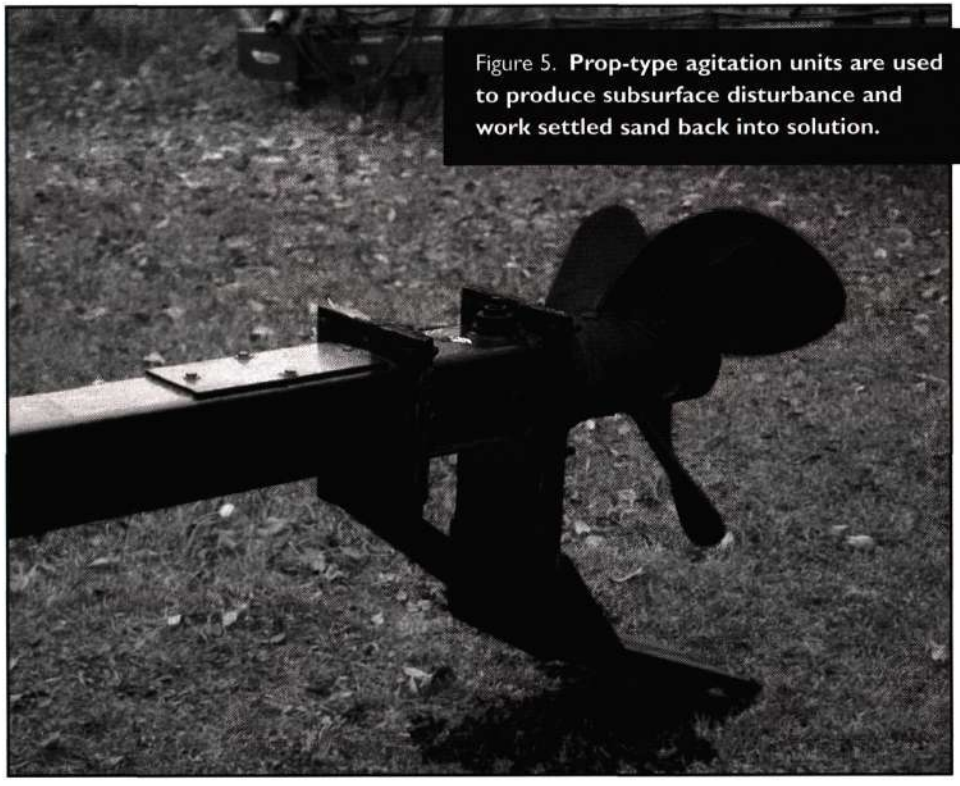


Figure 5. **Prop-type agitation units are used to produce subsurface disturbance and work settled sand back into solution.**

Once agitation begins, one or more prop-type units must operate almost continuously throughout the emptying process.

4 Lift and move sand during agitation. Good sand re-incorporation in the manure depends on the amount of power supplied, propeller design, and operation angle. Flexible agitation units (eg. three-point hitch mounted) provide the operator greater control over this process.

5 Construct a durable storage that will not erode with aggressive agitation and that resists trapping sand. Concrete tanks with rounded corners are ideal.

Fluid motion and sandwall development

Containment of sand during agitation is important. Full agitation of small, contained quantities (less than 300 cu ft) of diluted sand-laden manure can be accomplished fairly easily because all the manure can be kept in motion with commonly available equipment. However, as storages become larger, getting and keeping sand in suspension through fluid motion becomes increasingly difficult.

A common misunderstanding is that a blasting action (whether above or below the surface) is the primary requirement for agitation of sand-laden manure. A high velocity blast of fluid is effective in scouring sand off a storage floor or solids surface, but it may be quite ineffective in moving the sand up into the body of liquid manure. This lifting action is necessary to keep the sand suspended long enough to remove it with a pump.

Frequently, the result of such uncontained agitation is the formation of a bowl or ridge of sand around the agitation site. Liquid in the bowl can be easily removed with a pump. Most of the liquid, however, is retained behind the ridge of sand which acts as a dam. The retained liquid and ensuing seepage hinder solids removal via a front-end loader. Once sandwalls form, they can be quite difficult to remove (see Figure 6).

Sandwalls form when sand is propelled horizontally outward (vs. upward) from the agitation unit. Sand rapidly settles out in the slowly moving fluid, away from the point of agitation. Figure 7 illustrates fluid velocity levels and depths of settled sand in a storage following aggressive, blasting agitation.

If using a single agitation unit, regularly adjust its position and location to avoid creating a sandwall. Multiple units allow the operator to overlap agitation and effectively keep the manure in motion.

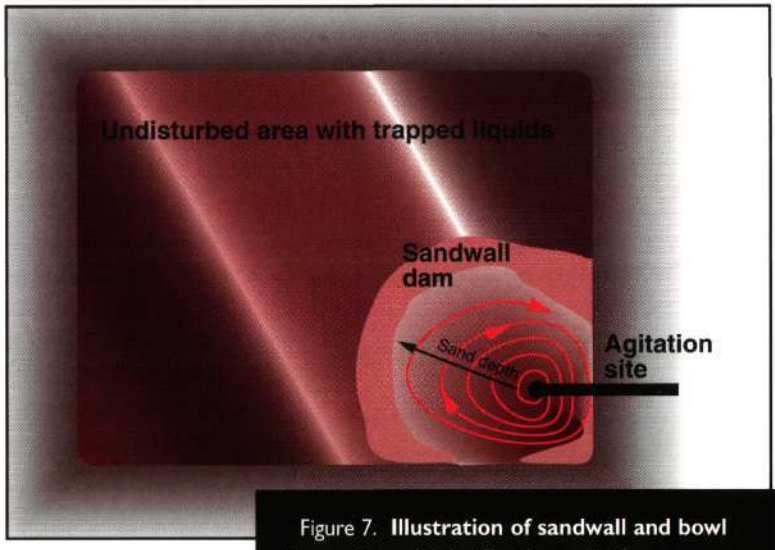


Figure 7. **Illustration of sandwall and bowl formation with ineffective agitation, showing relative fluid velocity and depth of sand in a long-term storage.**

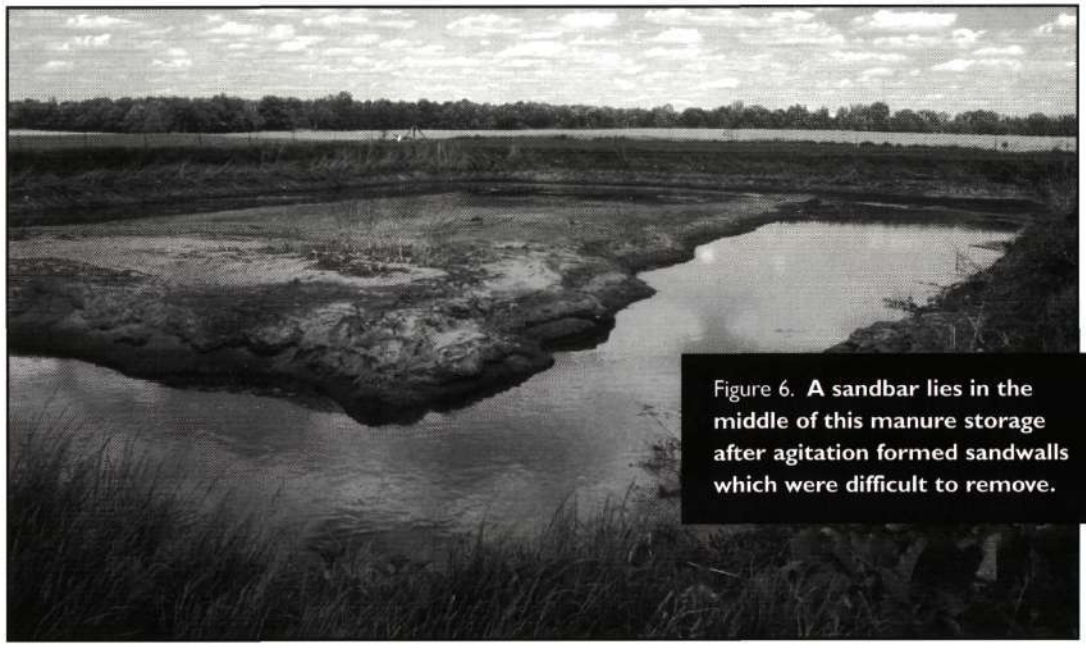


Figure 6. **A sandbar lies in the middle of this manure storage after agitation formed sandwalls which were difficult to remove.**

Storage & Handling

Obviously, subsurface agitation is an involved process requiring considerable expense and skill. Additional technical and practical information is needed to improve farmers' ability to effectively agitate and pump sand-laden manure. Consider other handling options if these basic requirements cannot be met. A contingency plan (described in a later section) is also recommended if sandwalls begin to develop.

SPECIAL CONSTRUCTION CONSIDERATIONS FOR MANURE STORAGES

Sand-laden manure storages have particular needs to accommodate agitation and solids removal. Consider the following construction features[3] when planning a storage for sand-laden manure (Figure 8):

[3]Various portions of this section were compiled using suggestions from Michigan Natural Resources Conservation Service (formerly Soil Conservation Service) staff. Written NRCS guidelines for storing sand-laden manure do not exist at this time.

Ample access for loading the storage

If a push-off is used to load the storage, this area should be wide enough to allow pushing manure into the storage from more than one location. Pour concrete along the entire width of this area leading to the manure storage pit. Push-off walls should drop off sharply to prevent manure from freezing onto the concrete and blocking the loading area. A vertical wall is preferred; if banked, maintain at least a 1:1 slope. *Include a safety rail above this wall to prevent the tractor and driver from accidentally going over the edge.*

A wetted storage bottom helps disperse freshly loaded manure away from the loading area and throughout the storage. However, pooling of water around the loading area increases the likelihood that sand will settle out there.

Alternate loading access is also generally desirable for other storage loading options in the event that sand builds up and blocks the intended path of manure into the storage.

Temporary storage area

A containment area for a 2 to 7 day storage is desirable to accommodate frozen manure or to hold manure while improving the primary storage. Typically, this will be a concrete slab (20 ft x 20 ft or more) in combination with an L-shaped buckwall 4 to 5 ft high. Run-off must be appropriately controlled.

Perimeter access

Most systems that pump from long-term manure storages containing sand require equipment access to the storage at several locations around the perimeter.

Provide at least one access site for agitation and pumping for every

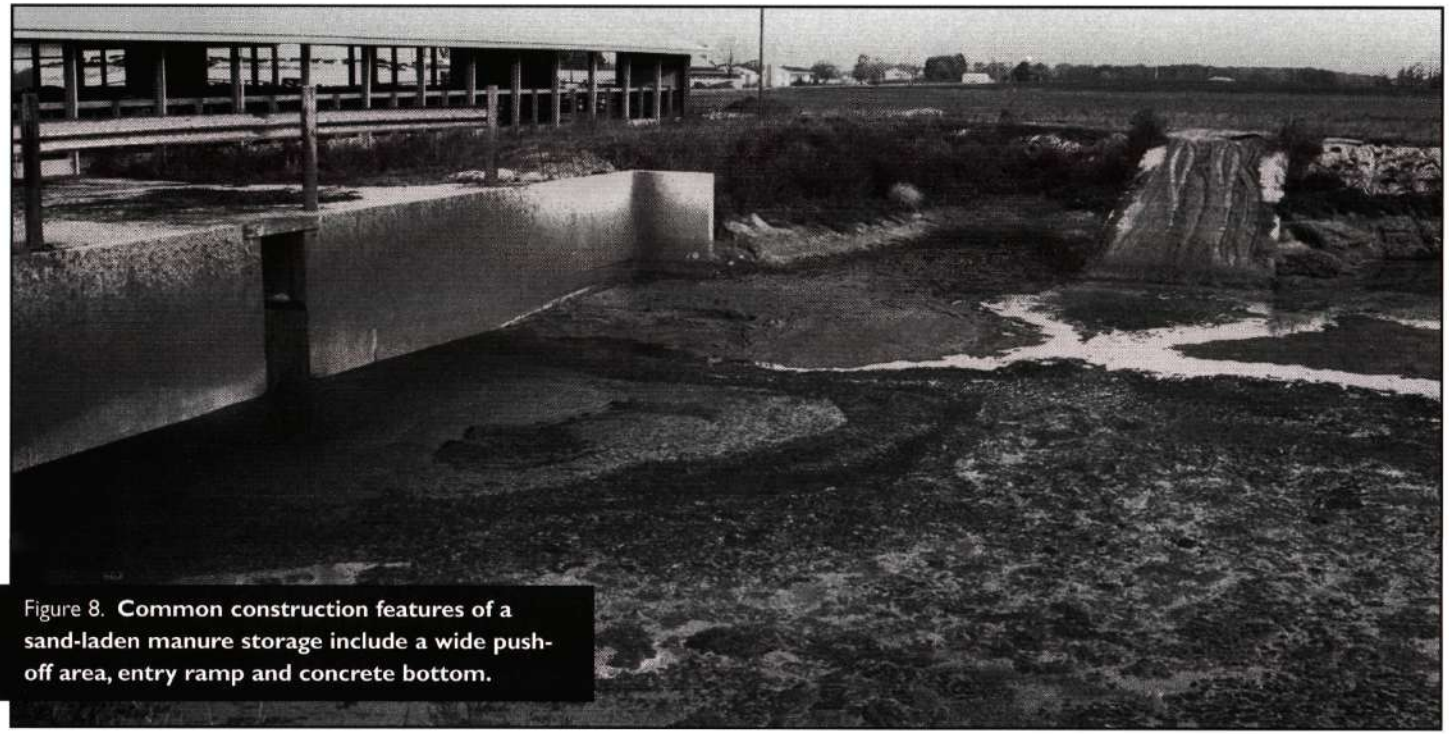


Figure 8. **Common construction features of a sand-laden manure storage include a wide push-off area, entry ramp and concrete bottom.**

2,500 sq ft of storage surface area (e.g. 3 or more sites for a 100 ft x 60 ft storage) for removal of ponded liquids. Systems designed to remove sand in the pumping process usually require greater access to the storage.

Safety concerns need to be addressed with perimeter access. *Use security fencing around the manure storage to keep people and animals away from the area.*

An access site must be firm, fairly even and unobstructed to safely accommodate a tractor. The storage should also have a solid, durable sidewall near an access site. A 1:1 or steeper grade on the interior sidewall and concrete construction are recommended for designated access sites (see Figure 9), especially at locations where prop-type agitation units will operate.

Manure storages constructed with a substantial above-grade berm pose special problems for sand-laden manure since access to the storage is more limited. If used, the top of the berm should be flat and a minimum 8-ft wide for mowing. Even wider crests (20 ft or more) are needed at designated access areas to allow a tractor to make a partial turn.

A concrete floor is highly recommended in any sand-laden manure storage.

The manure pit floor

A concrete floor is highly recommended in any sand-laden manure storage. Most farmers are not satisfied with earthen bottom storages.

The added weight of sand-laden manure and the likelihood of heavy equipment entering the storage pit dictates a base of at least 4 inches of packed sand and a quality concrete floor reinforced with wire mesh, or at least 5-inches thick.

Pour a level floor or gently slope the floor (normally no more than 1 or 2 percent) to direct the flow of liquids toward a sump or pumping area and away from any areas where solids are to collect and drain. A flat surface prevents undesired ponding.

Sump

In systems utilizing a stationary pump or one primary pump location, consider including a sump in the storage floor. A sump is a 1-ft to 2-ft deep hollow or basin that is wide enough to accept the pump intake. Used in conjunction with a sloped bottom, a sump can help maintain more consistent pump operation.

Access ramp and buckwalls

The access ramp, concrete bottom and buckwalls are distinct features of sand-laden manure storages that allow convenient removal of solids that may otherwise build up over time. The ramp provides access for a front-end loader and spreader. Pumping may also be done from the ramp, but don't restrict access to the storage by locating a sump or low spot at the base of the ramp.

Locate the ramp and the sump (if any) away from the buckwall(s) so that solids removal naturally progresses toward a buckwall.

Safety concerns suggest that the ramp slope 1:20 or 1:12. Space limitations may dictate a steeper ramp but slopes greater than 1:8 are discouraged. Consider extending the ramp beyond the natural perimeter of the storage as an alternative to using a steep ramp. Ribbing the ramp surface on a diagonal will improve traction and may improve maneuverability of vehicles using the ramp.

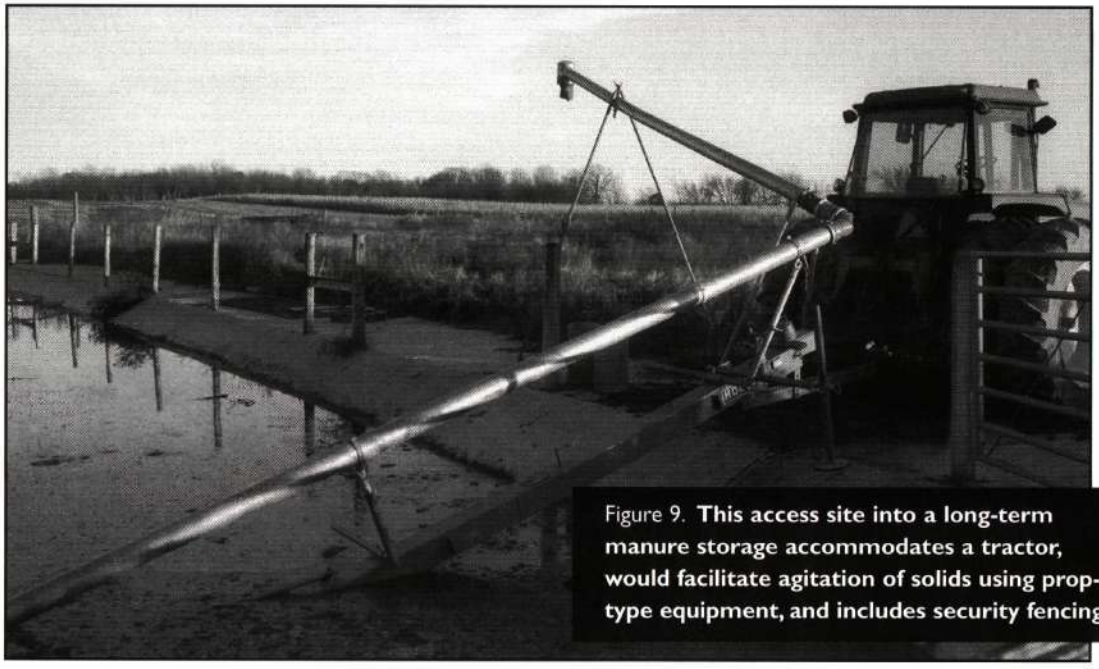


Figure 9. **This access site into a long-term manure storage accommodates a tractor, would facilitate agitation of solids using prop-type equipment, and includes security fencing.**

The concrete wall along the loading area can be used as a buckwall when removing manure with a front-end loader. Generally, concrete walls in an L-shape function best as a manure buckwall.

STORAGE AND HANDLING SYSTEMS

Alternatives for handling sand-laden manure differ primarily in length of storage, level of dilution, and requirements for labor and equipment. Several systems are described here.

Select a system based on the most appropriate fit given farm resources, limitations and management goals. Table 1 provides a convenient reference guide for evaluating the systems.

Daily haul

Daily haul involves comparatively few sand-related handling problems and is the lowest cost system. Heavy spreader loads and added wear on paddles are the primary handling concerns.

A V-spreader or box spreader, suitable for loose manure, is generally used. The manure is loaded into the spreader by scraping directly over a push-off ramp, into a sump that feeds an auger, or to an area with buckwalls where a front-end loader can scoop it up and load the spreader.

Daily surface spreading of manure must satisfy environmental regulations. Soil type, terrain and travel distance may limit the use of daily haul on many farms. On others, crops persistently occupy land during the growing season, leaving only small windows of time available for manure application. Also, application of manure onto frozen soil may be prohibited in some areas necessitating long-term storage.

Daily haul normally requires substantially more labor hours than does a long-term manure storage system. Farmers who supply most of the labor themselves, or who are already stretching their hired labor supply, may opt for long-term storage alternatives to reduce daily labor demand. Or, they may want to free up time for other tasks. Others use manure handling activities to fill up the daily work routine of employees.

Temporary storage provisions (concrete slab and buckwall) are strongly recommended with daily haul. A short-term storage allows manure to be stored for a few days when land, labor or equipment are unavailable, or weather prevents spreading.

Daily haul involves comparatively few sand-related handling problems and is the lowest cost system.

Table 1
Sand-laden Manure Handling System Reference Guide

System name	Material type(s) handled	Perimeter access needed	Need sump?	Prop-type agitation needed?	Compatible with irrigation?	Pump wear
Daily haul	semi-solid	n.a.	no	no	no	n.a.
Covered storage	semi-solid	single location	only w/auger	no	no	n.a.
Skim & haul	liquid, semi-solid	multiple pump sites	recom-mended	no	yes	low
Trench & haul	liquid, semi-solid	single side	no	no	susceptible to plugging	med.
Stir & pump	pumpable slurry	multiple agit. sites	yes	recom-mended	susceptible to plugging	high
Fully agitate & pump	liquid	all sides - agitation	recom-mended	yes	can be	med.
Mine & haul	slurry, semi-solid	multiple pump sites	recom-mended	recom-mended	susceptible to plugging	high

Note that a concrete bottom and access ramp are required or highly recommended in all storages for sand-laden manure.

Covered storage

A covered storage area can be used to store several weeks or months of sand-laden manure in an undiluted state prior to spreading. The physical properties of undiluted sand-laden manure do not change appreciably during storage, so handling equipment is similar to that with daily haul.

Augers or gravity flow discharges become quite useful for emptying the larger volume of manure in such storages.

The storage should have a concrete floor and solid buckwalls on three sides. Provide access to the storage via a ramp or removable wall sections in the other side. This access is necessary to push remaining manure to the sump or discharge site.

Design the storage to exclude rain and snow (see Figure 10). The roof must be high enough to allow a tractor scraper or front-end loader to move about easily inside the stor-

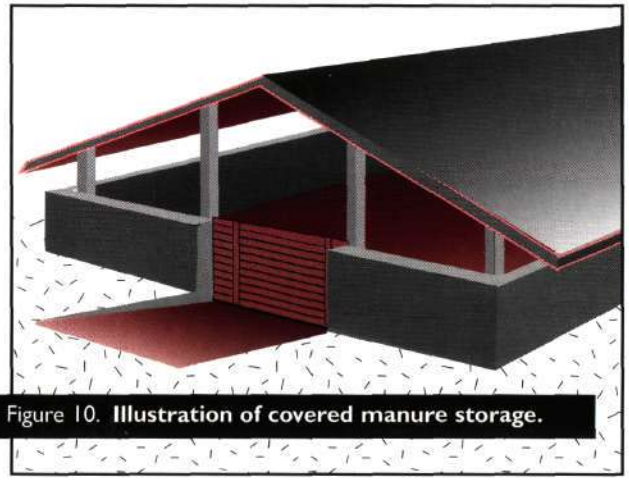


Figure 10. **Illustration of covered manure storage.**

The roof may be a good investment when contrasted to the additional equipment needs and handling difficulties associated with an uncovered storage.

age. Good site drainage keeps clean run-off water away from the storage.

An advantage to hauling from covered storages is more flexibility than daily haul in accommodating labor, land, equipment and weather constraints. Relatively simple processes and construction are involved and less volume is handled compared to options for diluted manure. Smaller storages, requiring fairly frequent hauling, still may lead to times when land is unavailable for hauling or conditions make hauling difficult.

Construction of a roof adds to the cost of manure storage, but its cost is often the only added storage expense involved compared to other storage options for sand-laden manure. The roof may be a good investment when contrasted to the additional equipment needs and handling difficulties associated with an uncovered storage.

Skim off water and haul solids

One widely used approach to dealing with diluted sand-laden manure in storage is to simply skim the liquid off the top of the storage and haul the remainder out as semi-solid material.

In long-term storage, liquids are typically removed two or three times a year while the bulk of the solids are hauled out each fall. This method will be used as the basis for comparison for manure handling systems that follow. The requirements of the manure storage in this system are:

- An earthen storage with a concrete floor, access ramp and buckwall (two concrete sides in an L-shape are preferred).
- Minimal agitation since the intent is to remove surface liquid with minimal incorporation of solids.
- Possibly several access sites along the perimeter for pumping to insure reasonable removal of any ponded liquids.
- A slightly sloped floor to drain liquid away from the settled solids as they are being removed. The more water removed and handled as a liquid, the easier and less time-consuming it will be to haul out remaining solids.

This approach works well with irrigation systems since the intent is to pump mostly water that contains comparatively small quantities of sand. The timeliness provided with irrigation is desirable since liquids are often removed several times during the year. Tank spreaders can also be used effectively.

Considerable flexibility is available for disposal of the liquids since equipment needs, time required for pumping and sand-induced problems are smaller than in other systems. This flexibility is especially advantageous during spring and summer when time is often limited for applying manure.

However, this approach depends heavily on the ability to spread solids when land and labor are available. By fall, solids may occupy half or more of the available storage volume. If you are unable to remove the solids, the risk is that storage capacity will be exceeded in winter, or that disposal must occur during spring planting season. Farmers with limited spreader capacity or labor available for this activity are strongly advised to consider other options.

Other factors to consider are that two lines of manure handling equipment are required — liquid and semi-solid — and that the nutrient content of the manure may vary considerably.

If you are unable to remove the solids, the risk is that storage capacity will be exceeded in winter, or that disposal must occur during spring planting season.

Trench and haul solids

The trench-and-haul approach is an extension of the basic skim-and-haul method. It differs primarily in that the manure storage is actively drained of liquids, requiring some pumping of sand-laden material. Generally, additional removal of liquids reduces the time spent in the

subsequent process of removing sand and manure solids. Solids are usually removed each time liquid is pumped out.

The basis of this system is to agitate and begin pumping from the ramp at one end of the storage. The pump is maneuvered down the center of the storage, removing liquids and local solids that are incorporated into the outflow. Ponds of water can be drained by using the high volume discharge to cut branching channels, but no serious effort is made to incorporate additional solids. When pumping has progressed into the pit far enough to have drained off most of the liquids, a front-end loader and spreader are used to remove the remaining solids.

The manure storage needs to be designed to promote proper drainage. Figure 11 illustrates the drainage pattern as seen from above the storage and shows the suggested section view down the center of the storage. A concrete bottom, access ramp and wall(s) are needed.

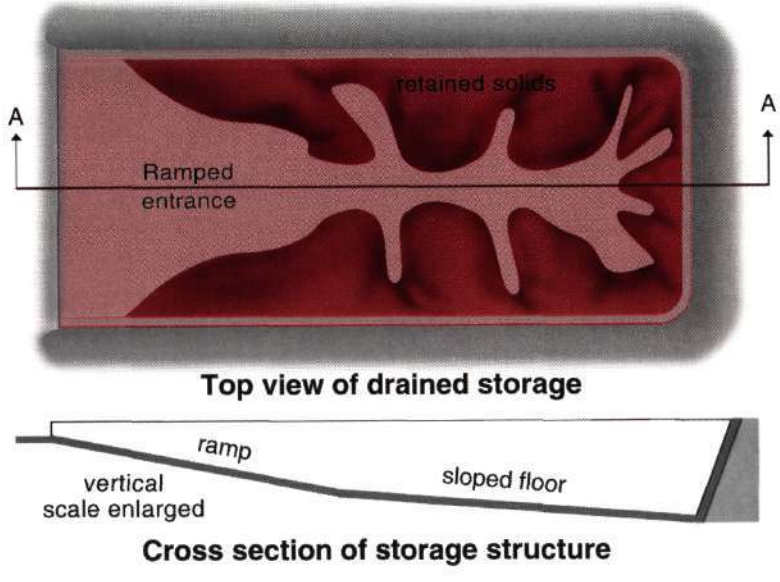


Figure 11. **Top view of branch formation and construction cross section in the trench-and-haul system.**

Since only one perimeter access point — the ramp — is needed for each drainage branch, it may be possible to empty wide, less accessible manure storages with this approach.

The storage floor slopes away from the base of the ramp so that liquids always flow toward the pump as it is advanced into the storage. This ready supply of liquid is needed for agitating sand in the immediate area into suspension for removal. No sump is used. Fresh manure should be loaded into the deeper half of the storage.

Spans of 25 to 50 ft can be drained, depending on the agitation and pumping system used and the amount of sand in the storage. The wider spans are obtained by using the high volume discharge present on many agitation units to cut branching channels in the manure.

Form several trenches in wide storages that cannot be drained with a single trench. Since only one perimeter access point — the ramp — is needed for each drainage branch, it may be possible to empty wide, less accessible manure storages with this approach.

This system is not as accommodating with irrigation since more sand is present in the flow and the flow may not be consistent. Tank wagons are preferred for handling liquids. Self-loading wagons may be ideally suited for such designs.

More time is spent removing liquids, but the total annual hours required should be similar to, or less than, the basic skim-and-haul system. This system is typically less demanding in the fall but not as timely for spring or summer applications. Separate lines of manure handling equipment are still required.

Stir-up a slurry and pump

The stir-and-pump approach uses a single line of equipment. Agitation is used to mix solids into the liquid and the resulting manure slurry is pumped into tank wagons for application. When the manure becomes too thick to agitate and pump, water is added and the process continues. Finally, the remaining sand-laden material is stirred by driving a tractor-loader or payloader around in the storage. By adding water and funneling manure to the pump, the storage is emptied via the pump and tank wagons.

A concrete floor and ramp are required. The floor may slope to a

This is the only current practice that completely empties long-term, diluted sand-laden manure storages using a single means of manure application.

pumping area and include a sump. Circular or nearly square storages may better facilitate the stirring process. Concrete buckwalls are recommended to prevent erosion while scraping along the edges of the storage.

A stationary, mobile or self-loader pump may be used. Maintain an accessible dilution water supply for at least 10 percent of the original storage volume. Holding ponds for parlor waste water or retained yard run-off can be good sources of water.

The stir-and-pump system operates best when an additional person performs agitation, dilution and stirring activities. However, total labor hours should be less than with previous methods since solids are not handled separately. Equipment needs are also reduced. Wear on the pump and other components may be substantial, however.

The concept of physically stirring the manure, as shown in Figure 12, may not appeal to everyone. However, this is the only current practice that completely empties long-term, diluted sand-laden manure storages using a single means of manure application.

Fully agitate and pump out slurry

Most dairy operators who use sand bedding and a manure storage, would like to empty the storage with a single line of manure handling equipment without having to enter it. Such systems consist entirely of agitation, pumping and intermediate dilution. For most operators, however, this process is a vision that is never realized due to an inability to properly agitate solids off the bottom of the storage.

For most operators, this process is a vision that is never realized due to an inability to properly agitate solids off the bottom of the storage.

The currently known requirements for thorough agitation of sand-laden manure have already been described. In systems that were unsuccessful in using this approach, the primary shortcomings observed were insufficient agitation capacity, poor access to the storage for thorough agitation, or not enough time spent agitating. Prematurely removing liquids or not having a supply of dilution water available are also common deficiencies in existing systems. The authors question whether operations using substantial quantities of coarse sand can expect success using this system regardless of their capacity and skill in agitation.

Construction needs for this system depend on the size of the storage and agitation capacity available. A concrete structure or tank is suggested for small manure storages (up to about 50 ft x 100 ft x 8 ft) using farmer-owned equipment. Larger storages require greater agitation capacity which usually requires rented equipment or custom services. Concrete walls are unnecessary when experienced custom applicators, using multiple agitation units, are employed. A ramp and concrete floor are recommended in all sand-laden manure storages.

Divide large storages with an access strip and a water control section as shown in Figure 13 (page 12). The access strip should be wide enough to easily maneuver a tractor and agitation unit. Use the water control section to retain and control liquids and as an emergency over-

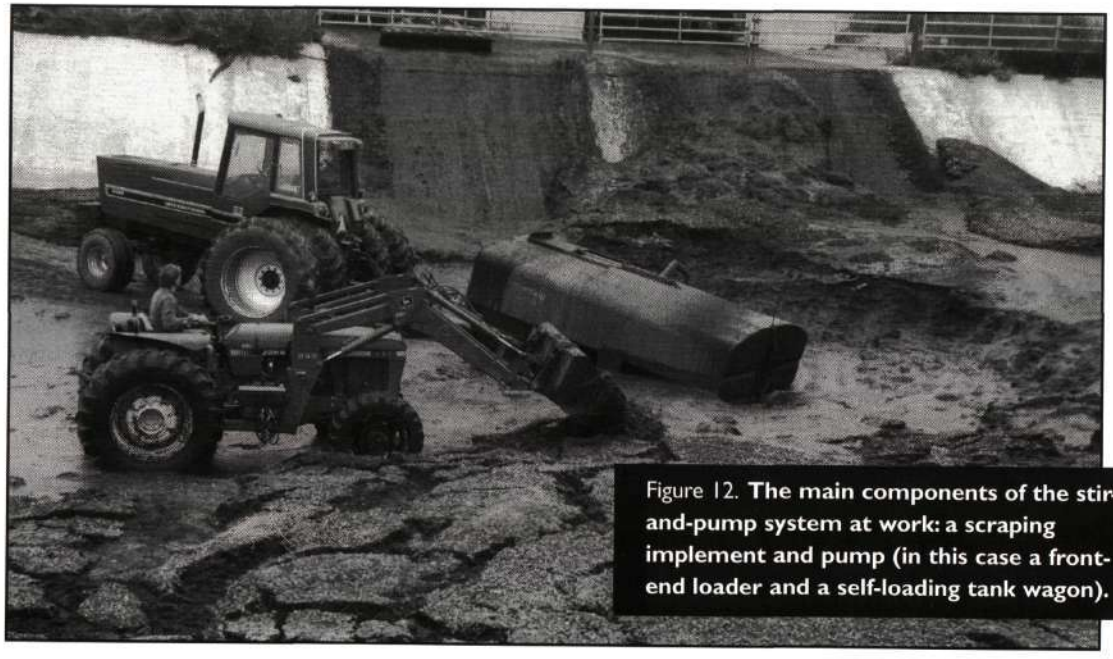


Figure 12. **The main components of the stir-and-pump system at work: a scraping implement and pump (in this case a front-end loader and a self-loading tank wagon).**

flow device. Additional perimeter access and water supply can greatly enhance agitation capabilities.

A few farmers pump out most of the stored manure for application and don't have to enter the storage to remove solids each year. However, the need to eventually remove sand should be expected and provided in the system's design.

Mine out manure with pump and haul remaining solids

The mine-and-haul method is generally used in situations where the fully agitate-and-pump approach has failed. This method incorporates parts of each previously described system for handling diluted sand-laden manure. It is probably the least efficient system discussed here, involving substantial amounts of equipment, labor and wear. But it may satisfy the needs of certain situations, such as a contingency plan for other systems.

Typically, agitation is used to incorporate sand into solution in a section of the storage. The resulting slurry is pumped to a tank wagon or possibly to a nearby irrigation system. If no sandwall is created, the method functions similarly to the skim-and-haul approach, drawing water off the top of the storage to the pump. If a sandwall forms, dilution water can be added to the bowl. Using another round of agitation and pumping, more sand is removed and the bowl is enlarged.

The pump is then relocated and this process is repeated at other locations until the remaining material is solid enough to haul with a loader and spreader. Solids can be cleaned out each time after the liquid fraction is removed or left in storage to be hauled out later (usually once in the fall).

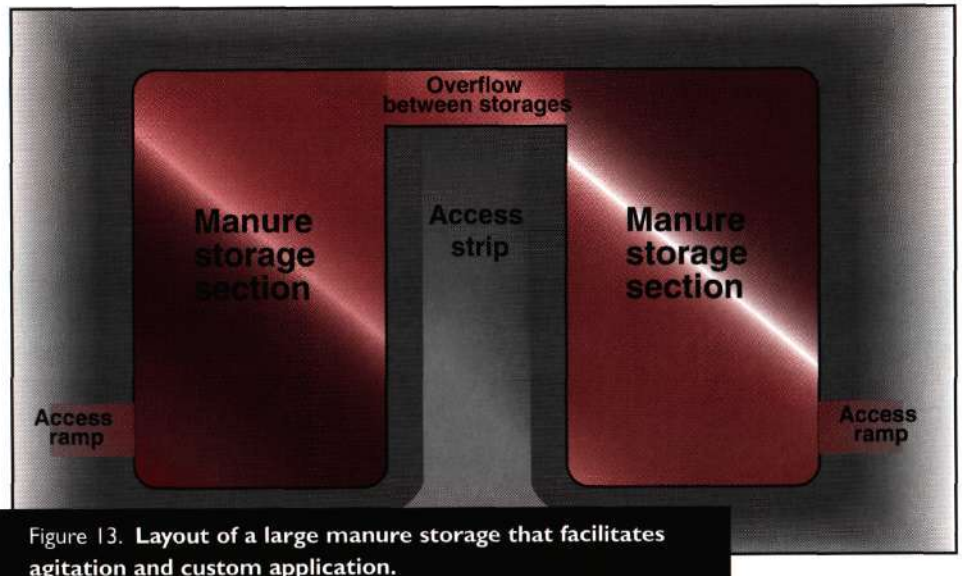


Figure 13. **Layout of a large manure storage that facilitates agitation and custom application.**

MULTI-STAGE SYSTEMS

Two- and three-stage manure storage systems may be justified as a means of reducing the construction cost and increasing the management efficiency of storing liquids in long-term manure storages. In a properly designed and managed system, the secondary storage, used primarily for liquid overflow from the primary storage, may be of typical earthen construction, not requiring a concrete bottom or ramp.

On the other hand, multi-stage storages do not provide manure separation, nor do they necessarily make it any easier to handle sand-laden manure in the primary storage.

Multi-stage designs for handling sand-laden manure should include a well developed plan for handling manure out of the primary storage. The requirements for the primary storage are the same as, or more demanding, than those of a single stage system.

The method selected for emptying the primary storage may greatly affect the management of liquids in the secondary storage(s). Methods that include agitation of solids will require access to some or all of the liquid overflow.

Therefore, it is important that the primary storage be designed around the method chosen for emptying it. In addition, construct a concrete overflow weir opposite the manure loading area to help ensure that sand and heavy solids are detained long enough to settle from the liquid. Do not use a picket dam because sand-laden material will flow through it. Make ample provision for access to, and around, the primary storage.

Consult with a qualified engineer when designing multi-stage systems. The storages are more likely to function as intended if they are properly sized and manure handling operations occur on schedule. With some additional planning, the layout shown in Figure 13 could be converted into a two-stage manure storage.

METHODS OF TRANSFERRING SAND-LADEN MANURE TO STORAGE

Tractor scrape

Scraping manure directly into the storage using a tractor-mounted scraper is the most straight-forward and reliable method available. Tire scrapers perform best with sand-laden manure. The option of tractor-scraping frozen manure is highly recommended in any Mid-west free stall operation. Frozen manure may require use of a blade or bucket.

Few sand-related problems arise with tractor scraping. Wear to floor and scraper surfaces can be minimized by reducing downward pressure on the loader surfaces.

A possible drawback to tractor scraping is the need to construct paved lanes from each barn to the manure storage. Also, some farmers feel this method is labor intensive.

Mechanical conveyors

Mechanical alley scrapers and barn cleaners can be used to move sand-laden manure. Wear on moving parts exposed to sand is extensive, however, and grooves quickly evolve in concrete that is in frequent contact with chain-driven blades (paddles) or cables. Considerable attention may be required to keep the system in working order, especially during cold weather.

Positive displacement pumps

Piston or pneumatic pumps effectively transfer collected sand-laden manure although wear on components is accelerated because of the abrasive nature of the sand. Clogging problems can be avoided by periodically putting a wad of straw or other matted material through the system. The wad acts as a wiper, cleaning sand from the bottom of the discharge pipe.

Gravity flow cross channel

Sand-laden manure that has been scraped and collected will flow by gravity to storage if more elevation difference is provided than is required for raw manure. Special considerations are needed to avoid problems with plugging. The main collection channel across the barn should be at least four feet by four feet. Provide access to the channel for cleaning equipment or other operations to remove any sand obstructions that may develop.

Use a large pipe having smooth inner lining (e.g. PVC pipe) to transfer manure from the channel to storage. Locate the pipe discharge a few feet off the bottom of the storage. Otherwise, sand that settles out in storage will quickly block the discharge and plug the pipe.

Centrifugal pumps can be used to transfer sand-laden manure from reception pits following dilution and agitation but there are several limitations with these systems.

There may be some advantage to building up a head of manure within the cross channel and then releasing a surge of manure, possibly including added water, through the discharge. But, remember that excessive dilution of stationary sand-laden manure greatly hastens settling of sand.

Reception pit and transfer pump

Centrifugal pumps can be used to transfer sand-laden manure from reception pits following dilution and agitation but there are several limitations with these systems.

Reasonable performance can be expected when using a small reception pit and a single pump to collect and transfer manure on a nearly daily basis. An upright-cylindrical storage is preferred. Larger or quite rectangular pits resemble a long-term storage where sand settles out and builds up on the bottom. Additional measures must then be taken to remove the sand.

If the desired storage capacity is more than can be handled by a single agitation unit, install additional units with overlapping agitation. Otherwise, sandwalls will form between the units.

In some areas, barns are built with a manure pit under the main cross alley. Sand build-up is a persistent problem for many of these operations. Consider the implications of settling and alternatives for removing sand before selecting such a design.

EQUIPMENT OPTIONS FOR HANDLING SEMI-SOLIDS

Front-end loader

The front-end loader is the conventional tool for handling undiluted, sand-laden manure. However, the front-end loader has a limited capacity and labor demands are high, especially when handling thin, sloppy manure.

Auger

A limited number of manufacturers produce augers that are designed

to handle sand-laden manure. Most of these augers are effective with undiluted manure. A typical model is rated at about 100 cu ft per minute when PTO-driven and installed no more than 30 degrees from horizontal. Electric powered augers typically handle less than 50 cu ft per minute.

Augers installed at steeper angles or operated in diluted slurries usually run at reduced capacities.

Select an auger that is top-driven and has easy-to-replace bearings. Bearings in bottom-driven models will fail quickly when operated in sand-laden manure. Augers are usually priced by length, e.g., $110 per foot of flight; $350 for the power unit.

V-spreader

The V-spreader is an appropriate implement for hauling sand-laden, semi-solid manure. Desirable features include an auger system to move and clean out sand, heavy duty tires and axles for carrying dense sand-laden manure and durable, replaceable hammers that ease maintenance. Truck-mounted units and a cover are desirable if material is hauled any distance on public roadways. Spreader capacities commonly range from about 200 to 400 cu ft. Figure 14 shows a V-spreader being loaded with a front-end loader.

Box spreader

The common box spreader can be used to haul sand-laden material if the rear discharge can be sealed to contain liquids during transport. Capacity and purchase cost are usually lower than with V-spreaders. Recall that sand-laden manure is quite dense and it can be easy to overload the spreader. Box spreaders are dual purpose in that they can also be used to handle solid pen manure.

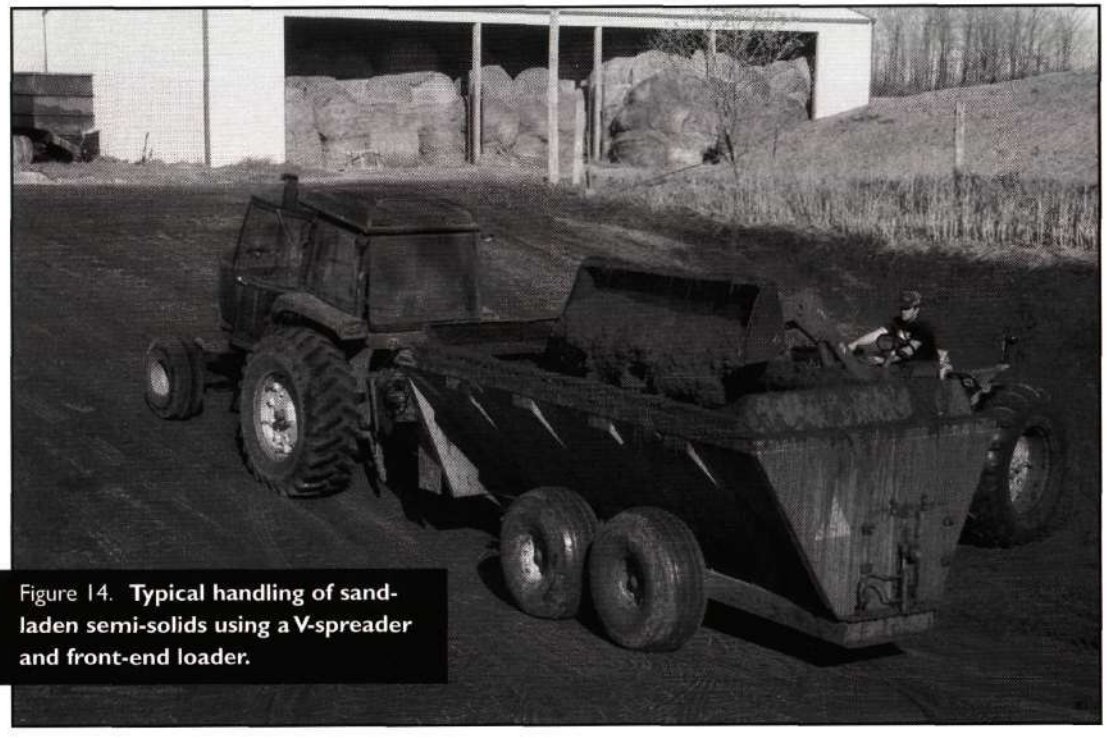


Figure 14. **Typical handling of sand-laden semi-solids using a V-spreader and front-end loader.**

EQUIPMENT OPTIONS FOR HANDLING LIQUIDS AND SLURRIES

Tank wagon

A tank wagon is a mobile storage tank having a pump discharge. Common variations include truck mounting, self-loading units, and injection equipment. Capacities range from a few hundred to several thousand gallons.

In a recent price check, a 9,500-gallon unit with injection and a 225 PTO horsepower tractor requirement cost about $60,000. A 3,600-gallon broadcast unit (which can be operated by a 100 or greater PTO horsepower tractor) cost about $15,000.

Figure 15 shows a truck-mounted tank wagon equipped for fluid circulation. Most newer models contain a front-mounted pump and an over-the-top circulation pipe and discharge which improves in-tank agitation and sand removal. Pump life can be extended if agitation is done just prior to field application.

Older models may function with less sand buildup if the existing baffles are removed or are replaced with a simpler structure. Truck tires

and a heavy-duty suspension are recommended for hauling sand-laden manure.

Irrigation equipment

Center pivot and portable set irrigation units are generally incompatible with sand-laden manure due to rapid wear and nozzle plugging. Travelling gun units are better suited for field application although there is risk of sand settling in the transfer pipe. Trouble-free field application of sand-laden manure requires that the system deliver a steady flow of uniformly liquid material.

Toolbar injection

Injection equipment that mounts behind a tractor utilizes a flexible hose that is pulled behind the unit, similar to a traveling gun irrigation system. The flow requirements are the same as with irrigation since manure is usually pumped directly to the field.

V-spreader

A V-spreader with a cover may be used for handling smaller quantities of liquid manure.

RENTAL EQUIPMENT AND CUSTOM SERVICES

The use of rented equipment or custom application services may be worthwhile when manure application equipment costs are unmanageable or time available for manure application is limited. However, carefully consider availability and long-term cost.

Rentals

Cooperative agreements to share equipment with neighbors can be an effective way to reduce costs. Renting or leasing equipment may be another option. A variety of equipment rentals and pricing arrangements may be available, especially in intensive dairy areas.

Custom services

Custom manure handling services may greatly ease farm labor demands, reduce equipment costs and improve application timeliness. Custom operators generally use irrigation or toolbar injection equipment, although some custom operators use tank wagons. Many do not handle semi-solids and some will not handle (or will charge more to handle) sand-laden manure, concerned that it is prone to plug and prematurely wear out equipment. Typically, rates vary according to the volume and consistency of manure and the distance to the field. A guideline cost is ½-cent per gallon.

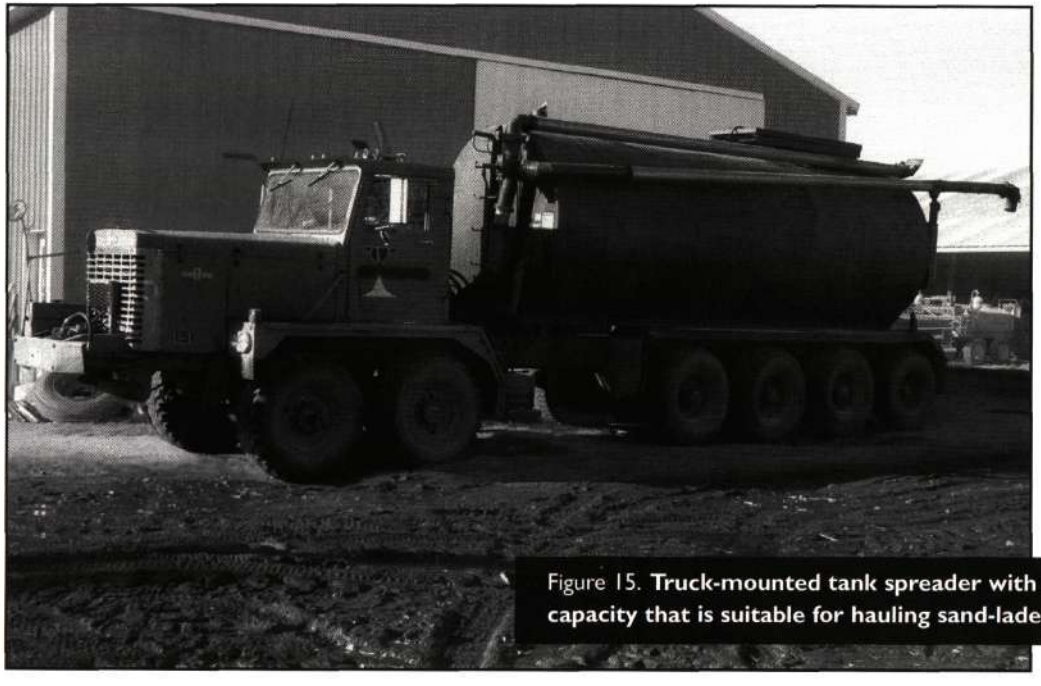


Figure 15. **Truck-mounted tank spreader with over-the-top circulation capacity that is suitable for hauling sand-laden manure slurry.**

SUMMARY

Sand bedding has many advantages for cow comfort and health but it may greatly complicate the farm manure handling system. Good planning — including selection of a handling system, storage needs and equipment — is essential.

In general, either some manure must be handled out of storage as a semi-solid or the facilities and equipment must be available to accomplish effective sub-surface agitation. Practical separation systems have not been developed yet for on-farm use in the Midwest.

Overall, the benefits of using sand in stalls must be weighed against the costs of handling sand-laden manure on a farm-by-farm basis.

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