Zeolite: An ammonia-absorbing material.

Aerobic: An oxygenated environment or requiring an oxygenated environment to survive.

Protozoa: A one-celled animal that is larger and more complex than bacteria.

2.4.2 Polystyrene Foam Board

Like straw covers, floating foam board is relatively inexpensive. It is a common material used for modular covers. The cover is constructed from five centimeter (two inch) polyethylene foam made from recycled polyethylene chips. **Figure 2.10** is a photograph of foam used to make storage covers. Foam boards may be used alone or paired with **zeolite** or a geotextile. See Section 2.4.3 for more information on geotextile materials. Foam board is UV resistant and can have a lifespan of ten to 20 years under favorable conditions.

Figure 2.10: Foam used in storage covers (C. Henry, 2004).

In lab and field testing, an 80 percent reduction in ammonia emissions was achieved using foam board covers with zeolite (Miner et al., 2000). **Table 2.2** lists the ammonia reductions over a four-week study period of four different foam board cover configurations.

Foam boards are not without problems. The foam material is an ideal habitat for microorganisms. **Aerobic** bacteria and other microorganisms may take up residence in the board over time, degrading the foam material. Filamentous large green algae, blue-green algae, diatoms, motile bacteria, nematodes, ciliated **protozoa**, and sulfur and methane oxidizing bacteria may also live in the foam. The foam boards accumulate odors and biofilm, making them difficult to handle during pumpdown of the storage facility.

2.4.3 Geotextile

Geotextile material is made from a non-woven permeable material like polypropylene. Geotextile is light-weight, porous, and feels like tough felt. Geotextile material may be used for bank-to-bank, modular, or balloon cover designs. **Figure 2.11** is a photograph of a geotextile cover. They are more expensive than straw or foam, but less than plastic, concrete, wood, and steel covers. Geotextile covers require special landfill disposal at the end of their life, adding to their cost. Since geotextile covers are permeable, they are not appropriate for creating anaerobic conditions. However, they are able to capture some gases. In a six farm study, geotextile covers reduced odor emissions by 45 percent (Vansickle, 2002). The largest reduction of hydrogen sulfide was in the first year of use; the performance dropped in the second year. Reductions may be increased by pairing the geotextile cover with a layer of straw.

Table 2.2: Percent reduction in ammonia concentration in headspace in laboratory testing (Miner et al., 2003).

Cover Type	Week				Average
	1	2	3	4	
Cover alone	51	71	79	79	70
Cover plus geotextile	59	78	83	89	77
Cover plus zeolite	72	81	89	88	82
Half-cover	44	59	60	58	55

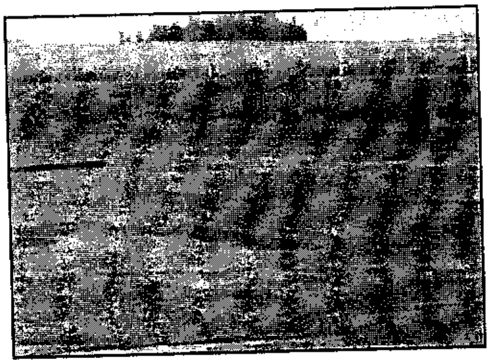

Figure 2.11: Geotextile cover (R. Koelsch, 2004).

2.4.4 Plastic

Plastic covers are impermeable, flexible, and easy to remove for facility maintenance. They can be used for bank-to-bank, balloon, or modular covers; however, if used as a modular cover, they need floatation devices. The plastic used in the covers may be estane polyurethane or XR-5 (marketed as ShelterRite). Plastics, such as Hypalon, PVC, chlorinated polyethylene, and neoprene do not work as well as estane polyurethane. **Figure 2.12** is a photograph of a plastic cover and **table 2.3** lists several plastic cover options and some characteristics.

Plastic covers must be tough and withstand damage from sunlight, ozone, cold weather, wind, sulfuric acid, and microbial attack. The strength of a plastic cover comes from **scrim** molded within the plastic material. Polyester scrim is resistant to acid, sunlight, water solutions, and microbial attack. Nylon scrims are stronger than polyester, resistant to water and soil organisms, but more susceptible to damage by acid and sunlight. Fiberglass may also be used, but is sensitive to water and subject to microbial degradation.

Since plastic covers are impermeable, they are ideal for creating an anaerobic environment. The plastic should have quality, non-leaking seams to prevent air intrusion. Air intrusion can contaminate and lower the quality of the biogas produced and cause failure of the gas combustion equipment.

2.4.5 Concrete, Wood, and Steel

Concrete, wood, and steel may be used as cover materials, typically for bank-to-bank or modular covers. All three of these materials tend to be long-lasting, yet expensive. With these materials, the cover may be continuous with the storage facility exterior.

Concrete is a common and economically accepted building material. Good quality concrete is essential for durability and must be reinforced with rebar. Wood is readily available, even from trees harvested on the farm. However, wood deteriorates over time. While steel is more costly than concrete or wood, it is more resistant to corrosion if coated with a polymer. Unprotected steel will corrode rapidly in the presence of biogas; galvanization does not protect against this kind of corrosion.

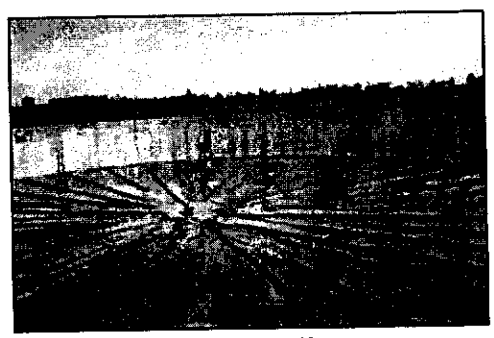

Figure 2.12: Plastic cover (Summergreen Ltd., 2004).

Scrim: Woven fabric.

Table 2.3: Plastic cover material characteristics (Koelsch et al., 1990).

Material	Advantages	Disadvantages
Hypalon 45	Moderately priced; easily repaired in the field; excellent wearing	Not readily available in small orders; failed at least one time
Polyvinyl chloride (PVC)	Relatively inexpensive; excellent chemical resistance; life expectancy of five years when protected from sun	Poor flexibility in cold weather; deteriorates in sunlight within one year
PVC coated with acrylic or hypalon	Moderately priced; good weathering characteristics; life expectancy of five years	Same as PVC
Estane polyurethane	Moderately priced; easily repaired in field; excellent cold weather performance	Subject to deterioration
Butyl (polyisobutylene)	Good performance over wide temperature range	High cost; low ozone resistance
Polyethylene	Low cost; life expectancy of three to five years when sheltered	Poor resistance to abrasion and sunlight; poor adhesion prevents adequate sealing
Chlorinated polyethylene (CPE)	Moderately priced; easily repaired; good resistance to high temperatures	Low strength
Ethylene propylene diene monomer (EPDM)	Good low cost ground liner	Poor resistance to heat and aging
Neoprene (polychlorinated polymer)	Medium to high cost; performs well at high temperatures	Poor aging quality; deteriorates in sun; difficult to repair; must repaint every three years

2.5 Summary

Storage covers can be used to isolate manure and biogas from the environment—reducing air and water quality hazards. Covers can be either impermeable and prevent all gas and liquid transfer with the external environment or be permeable and allow some controllable transfer. Storage covers may be bank-to-bank, balloon, or modular in design and can be constructed from straw, foam, geotextile, plastic, concrete, wood, or metal. **Table 2.4** summarizes the cover materials that may be paired with the different design types. Cover costs depend on the material as well as the design.

Table 2.4: Summary of storage cover materials and designs.

	Cover Material						
Design	Straw	Foam	Geotextile	Plastic	Concrete	Wood	Metal
Bank-to-bank			x	x	x	x	x
Balloon			x	x			
Modular	x	x	x	x	x	x	x

REFERENCED MATERIALS

Call of the Land. 2003. Alberta Agriculture's AgTech Centre Researches the Merits of Straw Versus Synthetic Lagoon Covers. Transcript from 11 December 2003 Radio Show. www1.agric.gov.ab.ca/$department/newslett.nsf/all/cotl4306?OpenDocument. Last visited 14 January 2004.

Chadwick, D., T. Misselbrook, B. Pain. 2000. Is Europe reducing its ammonia emissions at the expense of the global environment? Air Pollution from Agricultural Operations: Proceedings from the 2nd International Conference. P. 1-9. American Society of Agricultural Engineers. St. Joseph, Michigan.

Henry, C. 2004. Photograph of foam used in storage covers. University of Nebraska. Lincoln, Nebraska.

Highline Manufacturing Incorporated. 2004. Photograph of straw storage cover. Vonda, Saskatchewan, Canada.

Koelsch, R. 2004. Photograph of geotextile cover. University of Nebraska. Lincoln, Nebraska.

Koelsch, R.K., J.K. Campbell, E.E. Fabian, R.W. Guest. 1990. Anaerobic Digesters for Dairy Farms. Agricultural and Biological Engineering Extension Bulletin 458. New York State College of Agriculture and Life Sciences. Cornell University, Ithaca, New York.

Lemna Technologies. 2004. Photograph of modular cover. Minneapolis, Minnesota.

Miner, J.R., F.J. Humenik, J.M. Rice, D.M.C. Rashash, C.M. Williams, W. Robarge, D.B. Harris, R. Sheffield. 2003. Evaluation of a permeable, 5 cm thick, polyethylene foam lagoon cover. Transactions of the ASAE. Vol. 46(5). P. 1421-1429. American Society of Agricultural Engineers. St. Joseph, Michigan.

Ohio State University. Ohio Livestock Manure and Wastewater Management Guide. Bulletin 604. Columbus, Ohio. http://ohioline.osu.edu/b604/b604_12.htm. Last visited 19 July 2004.

RCM Digesters. 2004. Photograph of bank-to-bank cover. Berkeley, Californina.

Roos, K.F., A.G. Martin, M.A. Moser. 1999. AgStar Charter Farm Program: Experience with Five Floating Lagoon Covers. Presented at Fourth Biomass Conference of the Americas. August 29-September 2, 1999. Oakland, California. www.epa.gov/agstar/library/cov_costs.htm. Last visited 14 January 2004.

Summergreen Systems, Ltd. 2004. Seaforth, Ontario, Canada.

United States Department of Energy. 1997. Emissions of Greenhouse Gases in the United States. Department of Energy, Energy Information Administration. Pub. No. DOE/EIA 0537(96). Washington, D.C.

United States Department of Energy. 2004. Information Resources - Bioenergy: An Overview. Energy Efficiency and Renewable Energy Website. www.eere.energy.gov/consumerinfo/factsheets/nb2.html. Last visited 16 July 2004.

Vansickle, J. 2002. Lagoon cover research. National Hog Farmer. July 15, 2002. http://nationalhogfarmer.com/ar/farming_lagoon_cover_research/. Last visited 14 January 2004.

White, C. 2004. Diagram of bank-to-bank cover. Waterkeeper Alliance. Tarrytown, New York.

White, C. 2004. Diagram of balloon cover. Waterkeeper Alliance. Tarrytown, New York.

White, C. 2004. Diagram of modular cover. Waterkeeper Alliance. Tarrytown, New York.

Zhang, Y. and W. Gakeer. 1996. A Low Cost Balloon-Type Lagoon Cover to Reduce Odor Emission. www.aginfonet.com/aglibrary/content/prairie_swine_centre/96swine8.html. Last visited 14 January 2004.

Zhang, Y. and W. Gakeer. 1996. Diagram of blower equipment for balloon cover. From A Low Cost Balloon-Type Lagoon Cover to Reduce Odor Emission. www.aginfonet.com/aglibrary/content/prairie_swine_centre/96swine8.html. Last visited 14 January 2004.

Zhang, Y., G.L. Riskowski, T.L. Funk. 1999. Develop and Evaluate a Low Cost Inflatable Cover for Earthen Manure Lagoon to Reduce Odor Emissions. www.age.uiuc.edu/bee/RESEARCH/cover/coverpaper1.html. Last visited 1 September 2004.

Zhang, Y., G.L. Riskowski, T.L. Funk. 1999. Photograph of rope matrix for balloon cover. From Develop and Evaluate a Low Cost Inflatable Cover for Earthen Manure Lagoon to Reduce Odor Emissions. www.age.uiuc.edu/bee/RESEARCH/cover/coverpaper1.html. Last visited 1 September 2004.

Chapter 3
Solids Separation

3.1 Introduction

Just as the name implies, solids separation is the separation of solids from liquid. Solids separation is not a manure treatment technology *per se*—it does not advance biodegradation or change the nutrient content of the manure as a whole. However, solids separation makes manure handling and storage easier, and prepares the manure for future treatment. **Table 3.1** summarizes the potential benefits of solids separation. Fresh manure – a mixture of undigested feed, digestion byproducts, and bacteria – forms a brew of particles, solutions, and **emulsions** that bind with water. This biologically active brew holds water, forming a hard-to-handle and often pungent slurry. Manure flushed out of barns also contains large volumes of water,

Emulsion: A mixture of two liquids that do not form a true solution, but are instead held together by a surfactant, keeping droplets of one liquid dispersed throughout the other.

Table 3.1: Potential solids separation benefits.

Chapter Number	Chapter Name	Treatment Process	Reduce Nitrogen	Reduce Phosphorus	Reduce Biochemical Oxygen Demand	Stabilize Manure	Reduce Manure Volume	Reduce Pathogens	Reduce Manure Gases	Reduce Odor	Reduce Ammonia Volatilization	Operate at Low Temperatures	Minimal Footprint	Low Energy Requirement	Create Biogas	Create Value-Added Products
3	Solids Separation	Source separation								√	√	√	√			
		Gravity separation								√		√		√		
		Mechanical separation								√		√	√			
		Chemical separation								√		√	√	√		

Anaerobic: An oxygen-free environment or requiring an oxygen-free environment to survive.

Nitrification: The conversion of ammonia to nitrite and then to nitrate by the autotrophic aerobic bacteria *Nitrosomonas* and *Nitrobacter*, respectively.

Denitrification: The conversion of nitrate to dinitrogen gas by heterotrophic facultative bacteria.

Inert: A material or compound that does not chemically react with other elements.

Lagoon: A shallow pond where sunlight, oxygen, and bacteria degrade and transform compounds in manure.

bedding, wasted feed, and hair. Fresh and flushed manure, usually stored as a slurry or liquid, can cause odors, attract flies and pests, and pose air and water quality risks. Additionally, wet slurry is unsuitable for some types of biological manure treatments.

This chapter discusses the advantages and disadvantages of implementing solids separation and the different types of solids separation systems. Solids separation may utilize gravity, mechanical systems, or chemicals.

Solids separation is a widely applicable unit process. It is especially appropriate for dilute manures that will be treated by **anaerobic** digestion, **nitrification-denitrification,** composting, constructed wetlands, or other biological treatments. Solids separation is generally not climate dependent, so it can be used in almost any region. The many different configurations make this process adaptable to most size, land, and cost restrictions. **Table 3.2** gives examples of some specific instances where solids separation may be a good addition to a manure management strategy.

Table 3.2: Examples of animal waste handling situations that suggest inclusion of some form of solid-liquid separation (Miner et al., 2000).

Source of Material	Nature of Solids	Problem Caused by Solids Accumulation
Runoff due to rainfall on an unsurfaced feedlot	Soil and manure particles containing undigested feed and hair are carried by the runoff	Soil particles are generally **inert** and if allowed to enter the runoff retention basin, remain at the bottom, occupying space that would otherwise be recoverable for storage
Runoff due to snow melting on a feedlot surface	Snow melt runoff tends to be relatively low in volume but may contain up to ten percent solids, the solids are similar in content to those in rainfall runoff	Large volumes of solids and soil particles consume the storage capacity of the runoff retention basin and can more inexpensively be moved to other facilities
Flushed wastes from a dairy barn	Depending on the nature of the feed ration, solid material may range from discrete grain particles to long strands of fibrous grasses or corn silage; dairy manure solids have value for reuse as a bedding material or as a potting mix if appropriately processed	The waste as flushed from the dairy is likely to be difficult to pump through conventional irrigation equipment without plugging the nozzles or becoming entangled in the impeller; if the flushwater is to be placed in a storage tank, the solids are likely to settle to the bottom and/or float to the surface and are difficult to resuspend
Dilute swine waste from a flush system	Depending upon the physical nature of the feed ration, the manure particles may range from discrete grain size to much smaller particles	Solids separation reduces the organic and nutrient load on downstream biological processing systems; solids removal also removes extraneous solids that may have entered the manure system
Treatment process, such as digester or **lagoon** effluent, that is destined for recycling or discharge	Floating or suspended biological mass such as clumps, bacterial cells, or foam	Biosolids left in an effluent may cause downstream pollution problems, may contribute to odors, or may have value if reclaimed and concentrated
Lagoons or storage basins that become filled with solids	Solids in lagoons that become filled are a mixture of manure solids and bacterial cells; runoff collection basins also may contain soil particles filling space needed for treatment	Removing solids restores the unit to appropriate functioning condition; trailer-mounted centrifuges have been used for this purpose as have sand filters and sand drying beds

3.2 Advantages and Disadvantages of Solids Separation

While most farms can benefit from some form of solids separation, not all separation methods will work in every situation. Before adding a solids separation system to a manure management plan, the characteristics of the manure both before and after separation should be considered. Estimates of the waste volume and the moisture and nutrient contents in both the solid and liquid fractions will enable the manager to select the appropriate technology, storage and transportation equipment, and the future treatment options.

3.2.1 Advantages

Solids separation has the potential to improve farm sanitation by reducing odors, pests, and environmental hazards. Separated solids are easily stacked for storage. They can be transported to distant areas more efficiently and economically than heavy liquid slurry. Solids separation partitions the organic and nutrient loads into a liquid fraction and a solid fraction. This is very important for **aerobic** and anaerobic digestion, nitrification-denitrification, and constructed wetlands, which are designed in part based on the organic and nutrient loads. Some of the treatment processes cannot tolerate high solids loads, and solids separation may be a cost-effective way to remove a portion of the load. Additionally, solids separation may allow for smaller-sized biological treatments, lowering capital costs. Solids separation can also prolong the life of new and existing liquid storage facilities since storage tanks, pits, ponds, basins, channels, and treatment lagoons can become filled with solids that settle to the bottom. The solids occupy an increasing amount of space over time, reducing the storage capacity and the life of storage facilities. Undersized anaerobic lagoons are particularly plagued with this problem. Solids separation removes the solids prior to storage or treatment, eliminating the problem.

The solids may be converted into value-added products such as compost or **soil amendments.** The solids can be directly incorporated into potting soils at nurseries to provide a slow-release source of organic matter and nutrients for the growing plants. The solids may be composted. Composting reduces the solids volume for easier handling, and concentrates the nutrients. When compost or raw solids are sold and removed from the farm, the associated nutrients are also removed—decreasing the amount of land required for nutrient utilization by growing crops.

The solids may also be used as bedding. Most dairy rations include high-fiber feeds such as hay, haylage, or silage that may end up in the waste stream. These materials can be reclaimed, dried, and composted for reuse as bedding. This practice is gaining in popularity as the cost of bedding materials continue to rise.

Some farms may use solids separation to recover grain particles from flushed waste. The grain can then be used as a ration component, most often for gestating sows. Re-feeding decreases the total cost for feed.

Slurry may plug nozzles, impellers, and flushing equipment. However, the liquid fraction after solids separation is suitable for use with irrigation equipment. The liquid is more

Aerobic: An oxygenated environment or requiring an oxygenated environment to survive.

Soil amendment: Compounds used to build and maintain the physical properties of soil.

Fertigation: The irrigation of nutrient-rich water for fertilizer using irrigation equipment.

Tilth: The physical condition of a soil in relation to its ability to sustain plant growth.

Macropore: Large opening in unsaturated soils formed by the shrinking and cracking of soils, plant roots, soil fauna, or by tillage operations. The presence of macropores may encourage preferential flow of water and contaminants to groundwater.

Tile drain: Also called a pipe drain; a buried pipe that conveys drainage water to a central drain or outflow to a stream. Flow from tile drains may be considered point-source pollution.

effectively controlled than slurry during land application and can be used in **fertigation**. The nutrient-rich liquid may be applied using soil injection equipment. Soil injection reduces the threat of surface runoff, but requires very dilute liquids to prevent clogging.

3.2.2 Disadvantages

Solids separation is not a treatment technology—the nutrient content and biological activity of the total manure is unchanged by separation. The nutrients simply become partitioned into liquid and solid fractions and still require careful storage, treatment, and transport.

The organic component of manure in the solid fraction after separation is important for developing good soil structure, **tilth,** and drainage characteristics. Using the liquid alone for fertilizer will not offer comparable improvement in soil health and quality as would a combined liquid and solid application.

Manure in liquid form is more prone to **macropore** movement. Macropore movement increases the potential for groundwater contamination. Surface runoff and flows from **tile drains** containing liquid manure may negatively impact surface water quality Macropore movement may also occur through the bottom of inadequately lined or sealed storage facilities. Storing any large volume of manure—whether liquid, solid, or slurry, can pose environmental hazards in the event of leaching, leaks, or catastrophic spills that contaminate ground or surface waters.

While the separated solids may be transformed into value-added products, there is a limited market for raw solids or manure liquids. Even compost may be a hard sell in regions with little demand and poor access to markets.

Different solids separation methods have varying degrees of efficiencies. The type of separator and nature of the manure dictate what the final solids and liquid contents of the two fractions are. Solids separation, in any form, will require management and maintenance in addition to the start-up and continuing costs.

3.3 Types of Solids Separation Designs

There are two categories of solids separations systems—source separation systems and delayed separation systems. While solids separation can occur at any point during manure handling and treatment processes, the separation methods used closest to the point of origin are significantly different than the methods used after the manure has been diluted or stored. Source separation divides the liquid and solids fractions before they have had time to combine. Gravity and mechanical systems are used for source separation. Delayed separation partitions the fractions after they have been mixed. Delayed separation may be driven by gravitational, mechanical, or chemical means.

3.3.1 Source Separation

Separating the solids from the liquids in the waste stream as early as possible has several merits. The first is a reduction in ammonia production. Ammonia is an air pollutant that if not adequately ventilated from the barn can cause health problems in both farm animals and workers. Volatilized ammonia can increase local deposition