Chapter 2
Storage Covers

2.1 Introduction

Open basins, **lagoons**, and tanks are commonly used manure storage devices because of their low cost and operational flexibility. These open manure storage facilities may release **manure gases** to the atmosphere or overflow, polluting water resources. A storage cover is a physical barrier that isolates manure from the external environment, reducing the risk of contamination. Developed to create an oxygen-free environment for **anaerobic** digestion, covers may also be used with any open liquid storage facility to keep out rainwater, to reduce **greenhouse gas** emissions, and to control odor emissions, as summarized in **table 2.1**. Please see Chapter Five, Anaerobic Digestion for more information on anaerobic digesters and **biogas** production.

Table 2.1: Potential storage cover 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
2	Storage Covers	Bank-to-bank							√	√	√	√	√	√		
		Balloon							√	√	√	√	√			
		Modular							√	√	√	√	√	√		

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

Manure gases: Volatile compounds released from animal manure that may cause problems ranging from offensive odors to adverse environmental and human health impacts.

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

Greenhouse gas: A gas that captures heat emitted from the earth, contributing to global climate change.

Biogas: A combustible gas produced during the anaerobic decomposition of organic material. Biogas is primarily composed of methane, carbon dioxide, and hydrogen sulfide.

Ammonia volatilization: A process in which gaseous nitrogen-ammonia is released into the atmosphere.

Acid rain: Any form of precipitation with a pH less than 5.6, the normal pH of rain. Nitrogen oxides (NO_X) and sulfur dioxide (SO_2) released into the atmosphere, generally by anthropogenic sources, turn into acids, lowering the pH of precipitation. Acid rain is harmful to vegetation, soils, and waterbodies.

Airshed: A geographical area sharing the same air.

Eutrophication: A process where a water body becomes nutrient-enriched and eventually unable to sustain plant and animal life.

Manure gases: Volatile compounds released from animal manure. Many cause problems ranging from offensive odors to adverse human health and environmental impacts.

Methane: A gas (CH_4) produced when anaerobic bacteria decompose organic matter. Methane is a strong greenhouse gas. Methane can be used as fuel.

Flare: A method of burning biogas to prevent explosive gases from accumulating or entering the atmosphere.

Additionally, **ammonia volatilization** readily occurs from open facilities, reducing the amount of land required for nitrogen assimilation. Ammonia emissions can contribute to the deposition of **acid rain**. While ammonia is basic rather than acidic it can react with sulfur dioxide, increasing local deposition of acid rain. Volatilized ammonia can redeposit in an **airshed**, leading to air quality problems and **eutrophication** of surface waters.

This chapter focuses on the different designs and materials used to create storage covers. Different designs and materials provide varying levels of manure gas isolation, odor control, and exclusion of precipitation from the storage facility. Storage objectives, facility size, facility location, climate, management, and manure utilization must be taken into consideration when designing a manure storage cover.

Covering a manure storage facility is not a treatment technology. However, covers decrease environmental hazards while the manure is stored prior to or after treatment, and should be considered part of a complete manure storage and treatment system. Storage covers may benefit any sized livestock facility that stores liquid waste for any period of time, whether or not creating anaerobic conditions or biogas production are treatment goals. For most farms with liquid manure collection systems, especially those located in colder climates where land application of manure is limited by frozen and snow-covered ground, some kind of manure storage facility is usually necessary.

2.2 Advantages and Disadvantages of Storage Covers

Storage covers compliment manure treatment technologies. Covers should be used as part of a comprehensive manure management strategy.

2.2.1 Advantages

Storage covers can diminish some of the environmental risk associated with concentrating large volumes of manure in one location. Covers can provide an impenetrable boundary to **manure gases**, consequently limiting the escape of gases that may contribute to acid rain and global warming. If **methane** production is a treatment goal, an impenetrable boundary can create an anaerobic environment and prevent atmospheric gases from contaminating the methane. An air-tight cover can prevent ammonia volatilization, decreasing nitrogen losses to the atmosphere and the probability of acid rain, while reserving the nitrogen for the production of a nitrogen-rich fertilizer.

Waterproof covers decrease the chance of overflow conditions caused by the addition of precipitation to the manure storage volume. Shielding manure from rain and snow also stops dilution of the waste with excess water. This also reduces the amount of liquid for pumping and land application, which can translate into significant savings in pumping energy, cost of land application, and time.

2.2.2 Disadvantages

Storage covers are not without maintenance requirements. Depending on the material and design, a cover system may require operation and maintenance of pump, blower, and floatation equipment. The cover itself will require replacement. The frequency of cover replacement depends on the material and the wear and tear imposed by local weather conditions.

Covers that create an airtight environment foster anaerobic digestion, producing highly explosive biogas. Airtight covers should be equipped with a system for biogas collection and use or **flare**.

2.3 Types of Storage Cover Designs

The design of a cover system should take into account the local wind, rain, and temperature ranges. Shear forces created by high winds can rip or blow an improperly designed cover off the storage facility. An inadequate design or improper implementation may result in complete cover failure—the tearing and sinking of the cover into the manure. The weight of rainwater or snow can sink part or all of a cover. Temperature extremes may crack or melt the cover material. There are three main storage cover designs:

1. Bank-to-bank,
2. Balloon, and
3. Modular.

2.3.1 Bank-to-Bank

Bank-to-bank covers extend across the entire span of the storage facility. The edges are buried in trenches around the perimeter of the pond, pit, basin, channel or lagoon. Bank-to-bank covers are continuous with the ground surface or extend only slightly above the ground profile. **Figure 2.1** is a diagram of a bank-to-bank cover. This design must include floatation devices to keep the cover from sinking into the manure. Water pumping equipment is required to keep the cover free of standing water.

Figure 2.2: Photograph of a bank-to-bank cover (RCM Digesters, 2004).

The bank-to-bank design can collect all of the gases produced during storage and can provide a barrier to precipitation and air intrusion. This is the only design that is capable of creating a completely anaerobic environment, if the correct material is used. **Figure 2.2** is a photograph of a bank-to-bank cover.

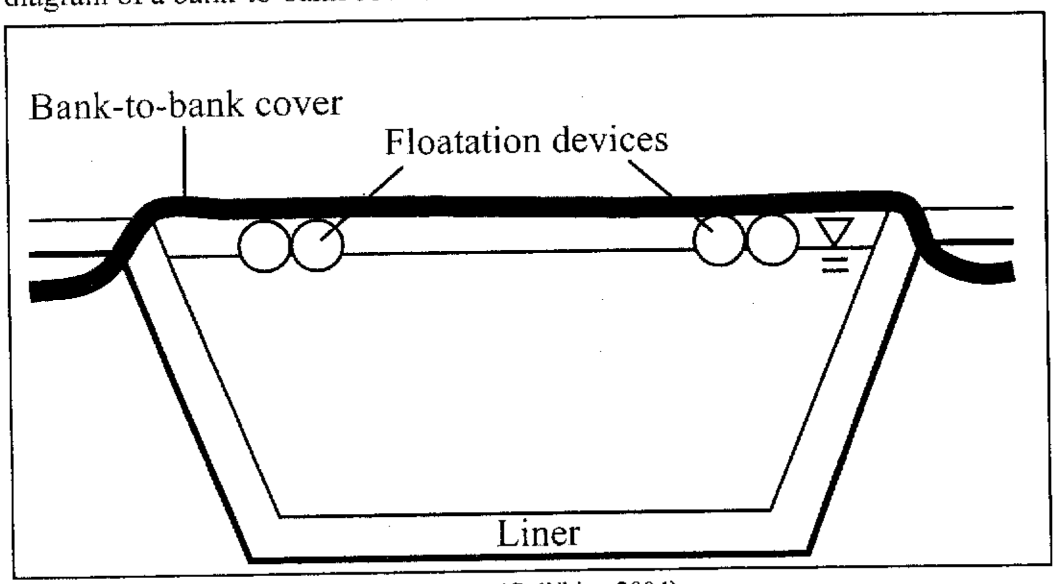

Figure 2.1: Diagram of bank-to-bank cover (C. White, 2004).

2.3.2 Balloon

A balloon cover is a variation of the bank-to-bank cover design. Balloon covers can contain manure gases and shield the storage facility from precipitation. They are essentially fabric pulled over the surface of the storage facility and kept aloft with fans and blowers. The fans and blowers create air pressure to inflate the cover. Pre-cast concrete posts or stainless steel poles may be used as supports for the cover, but care must be taken in using poles where freeze-thaw action occurs. A matrix of ropes placed on the manure may also be used to keep the cover from sinking into the manure in the case of power loss and deflation. **Figure 2.3** is a diagram of a balloon cover and **figure 2.4** is a photograph of a rope matrix being laid for a balloon cover installation.

The air delivery system consists of a low-pressure radial blade blower, variable fan controller, anti-backdraft flap, and a weight-balanced damper to control the positive pressure required to keep the tarp up. **Figure 2.5** is a diagram of the blower equipment and the balloon cover. The tarp and blowers create a dome over the manure surface strong enough to prevent snow accumulation—the higher the dome, the less snow will accumulate. Higher domes, however, are more susceptible to wind resistance and tearing from shear forces. The operation and maintenance of the blower equipment is a continuous expense.

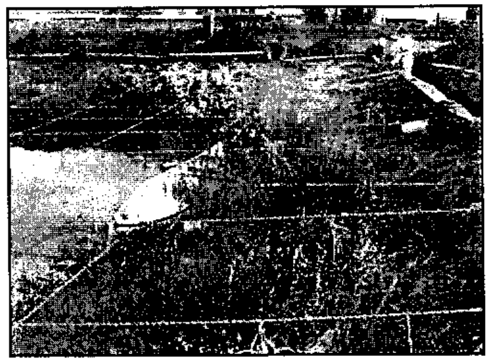

Figure 2.4: Photograph of rope matrix for balloon cover (Y. Zhang et al., 1999).

While the materials used in balloon covers are more durable than materials such as straw or foam, they are considerably more expensive. However, they are often less expensive than wood, concrete, or steel covers. Balloon covers may be fitted with vents and air traps, depending on other treatment process goals. The vent-air trap system allows liquid water to enter the storage area, but does not allow gases to escape to the atmosphere. Balloon covers are not appropriate for creating anaerobic conditions as air is pumped into the headspace above the manure to keep the cover aloft. **Figure 2.6** is a photograph of a balloon cover.

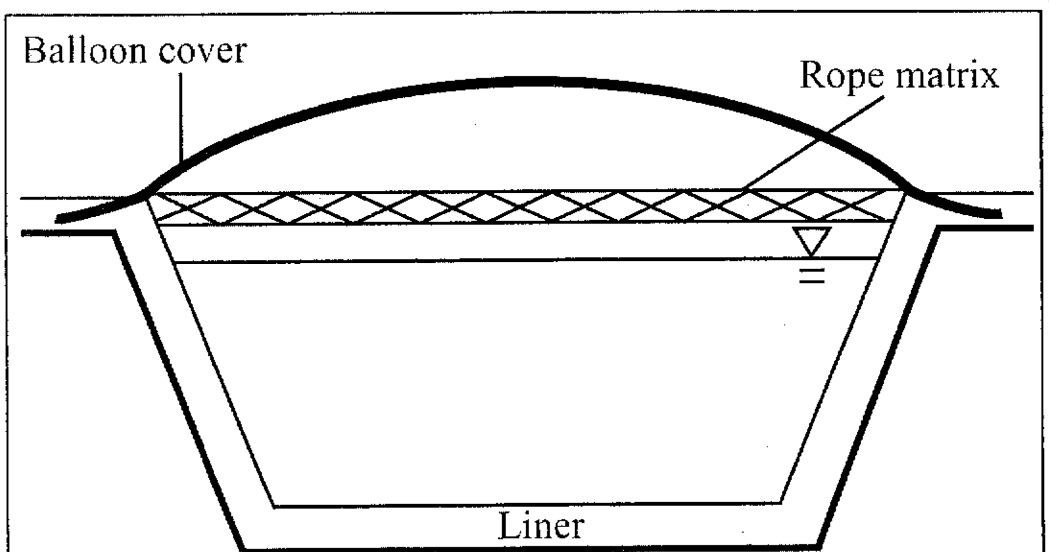

Figure 2.3: Diagram of balloon cover (C. White, 2004).

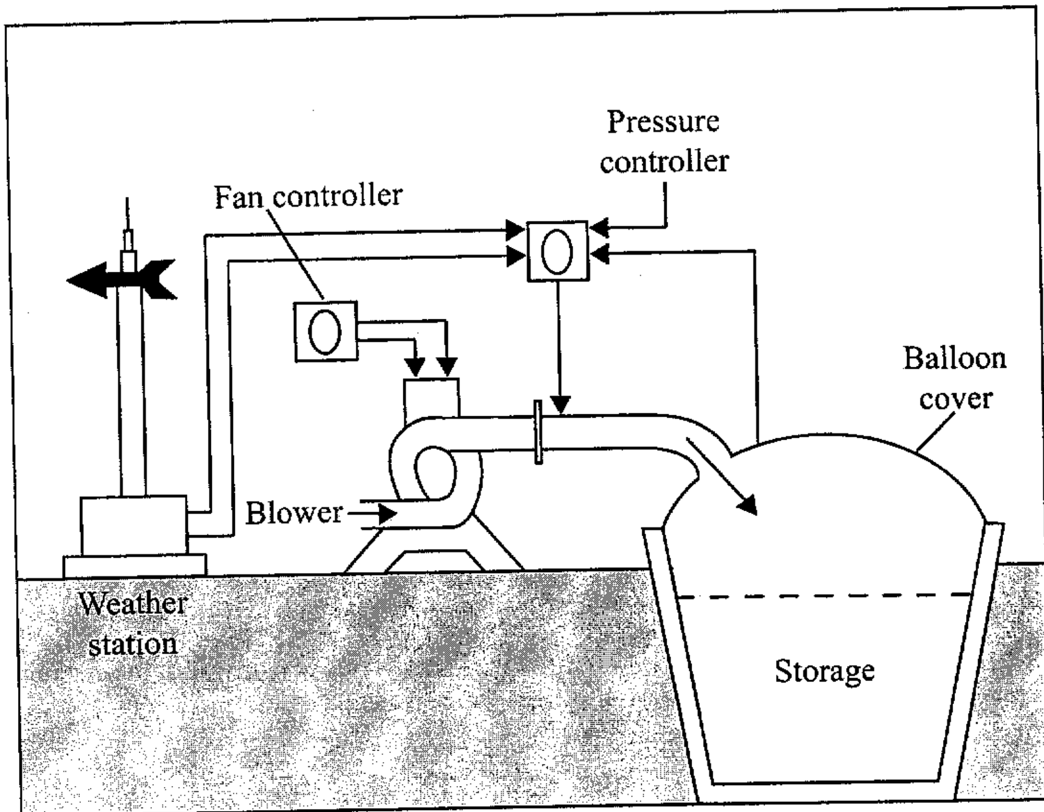

Figure 2.5: Blower equipment for balloon cover (Y. Zhang and W. Gakeer, 1996).

Figure 2.6: Photograph of balloon cover (Y. Zhang et al., 1999).

2.3.3 Modular

Modular covers may cover part or all of a storage facility—typically 50 to 100 percent of the facility's surface. Modular covers are particularly well suited for storage facilities that undergo frequent solids removal or for facilities with local climate or topographical features that demand only partial coverage. The modular units can be secured to the bank by trenching along the perimeter or by tether ropes. Floatation devices must be incorporated into the design to keep the inside edges of the units from tipping and sinking into the manure. **Figure 2.7** is a diagram of a modular cover.

A modular system may allow for the cost of the cover to be spread out since individual portions can be purchased and implemented slowly over time. However, a storage facility only partially covered will still receive precipitation and emit gases in the uncovered areas. **Figure 2.8** is a photograph of a modular cover.

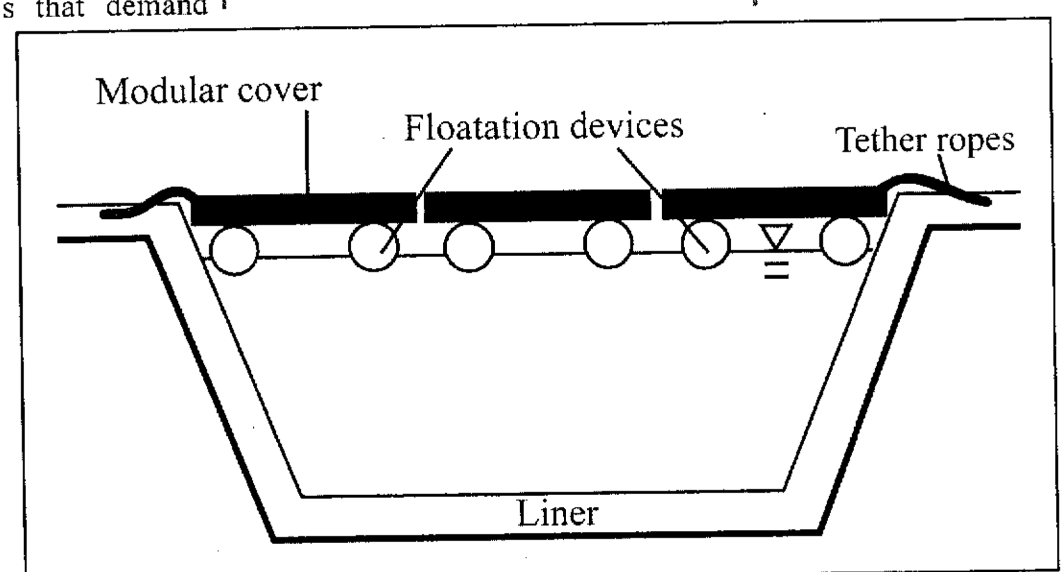

Figure 2.7: Diagram of modular cover (C. White, 2004).

Figure 2.8: Photograph of modular cover (Lemna Technologies, 2004).

Capillary action: The movement of a liquid through small spaces in a porous medium by the forces of adhesion, cohesion, and surface tension.

Hydrogen sulfide: A colorless, flammable, toxic gas (H_2S) that smells like rotten eggs, produced during the decomposition of organic matter.

2.4 Types of Storage Cover Materials

The critical issues in material selection are the design, material warranty, fabrication warranty, and price. Cover prices are based on the material, warranties, installation, and labor. The expected useful life expectancy and intensity of maintenance required should also be considered. Labor costs can be quite high although not all materials and designs require professional installation. While there are several commercial manufacturers of storage covers, it is important that designers have specific experience providing covers for livestock waste. Manure storage facilities and the management of manure storage facilities differ quite a bit from municipal or industrial waste storage facilities.

Bank-to-bank, balloon, and modular cover materials should be resistant to sunlight, UV light, wind, temperature extremes, and **capillary action**. Cover materials should also be able to withstand moisture and acidic conditions. Biogas is saturated and contains **hydrogen sulfide**, a highly corrosive compound. Climatic and chemical conditions may lead to tearing, blistering, and delamination of the cover and lead to cover failure if not properly controlled.

There are a range of materials to choose from. Straw and polystyrene are cheap, but require annual replacement. Geotextile and plastic covers are more durable, but more expensive and may require special disposal fees. Wood, concrete, and steel are permanent and durable, but are expensive.

2.4.1 STRAW

Straw is the cheapest cover available and is appropriate when odor control and moderate gas containment are the main goals. Straw covers have several limitations. The straw may be blown from the manure surface by wind. Over time, the straw may sink into the manure, creating clumps that can block pumping equipment and pipes during pump-down of the storage facility. Straw may be used to create a modular cover, shielding either a portion of the manure surface or the entire storage surface area. Straw is not a suitable material for creating anaerobic conditions, but it does create a biofilter, reducing odors and volatile gas emissions from the manure.

Barley is the most effective straw cover. It floats the best and lasts the longest. As a general rule, the longer the stalk the better—shorter straw has a greater tendency to sink. **Figure 2.9** is a photograph of a waste storage facility's straw cover. Peat moss has also been an effective cover to reduce odors. The moss forms an intact scum layer on the surface.

Straw covers are applied by blowing the straw either directly onto the manure surface or on top of a floatation device, such as polystyrene foam. Straw application is typically done using a bale processor that can shoot the straw across the surface of the storage facility, up to 22 meters (73 feet) (Call of the Land, 2003). Specialized bale processors that are equipped with a blower can be used to apply straw across distances up to 56 meters (183 feet) (Call of the Land, 2003). An alternative application method, that is also the least expensive, is to strategically place the straw on the manure surface and rely on the wind to increase the coverage distance.

No matter the application method, it is necessary that the straw be applied uniformly across the entire surface. By starting with an initial straw cover eight to ten inches thick, reapplication may be required only once per year whether applying directly to the lagoon's surface or on top of a floatation device.

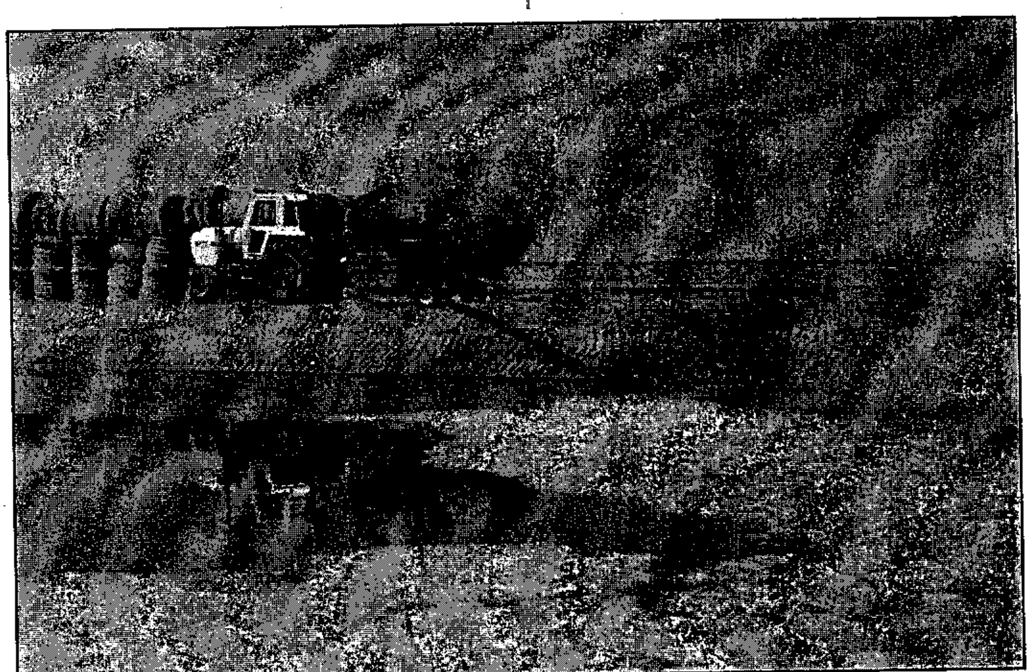

Figure 2.9: Straw storage cover (Highline Manufacturing Incorporated, 2004).