**Table 3.5:** Typical constituent removal for a sloping screen receiving beef or dairy cow manure slurry with an initial solids concentration between one and two percent (Miner et al., 2000).

| Parameter | Range (percent) |
|---|---|
| Total solids (TS) removal | 50-70 |
| Volatile solids (VS) removal | 50-75 |
| **Biochemical oxygen demand** (BOD) removal | 40-60 |
| **Chemical oxygen demand** (COD) removal | 40-60 |
| Organic nitrogen (N) removal | 30-50 |
| Ammonia nitrogen removal | 20-30 |
| Solid phase solids content | 13-20 |

*2. Vibrating Screen*

Vibrating screen systems are the second most common mechanical method for solids separation. The slurry is applied at the top of a vibrating perforated screen. The liquids flow through the perforations, and the vibrations keep the perforations clear by shaking the solids off the edge of the screen. **Figure 3.13** is a diagram of a vibrating screen.

This system works best with relatively dilute slurry, but even with dilute slurry the vibrations alone will not keep the screen from clogging. The mesh requires periodic maintenance to prevent biomass accumulation from obstructing the perforations. **Figure 3.14** is a photograph of a vibrating screen.

**Biochemical oxygen demand (BOD):** A measure of the amount of oxygen needed by aerobic microorganisms to break down solids and organic matter present in waste-water. Although BOD is not a specific compound, it is defined as a con-ventional pollutant under the federal Clean Water Act. The $BOD_5$ test is a five-day laboratory test to determine the amount of oxygen available for bio-chemical oxidation in a sample.

**Chemical oxygen demand (COD):** A measure of the oxygen-consuming capacity of inorganic and organic matter present in waste-water. COD may be higher than BOD because the chemical oxidant may react with substances that bacteria do not consume.

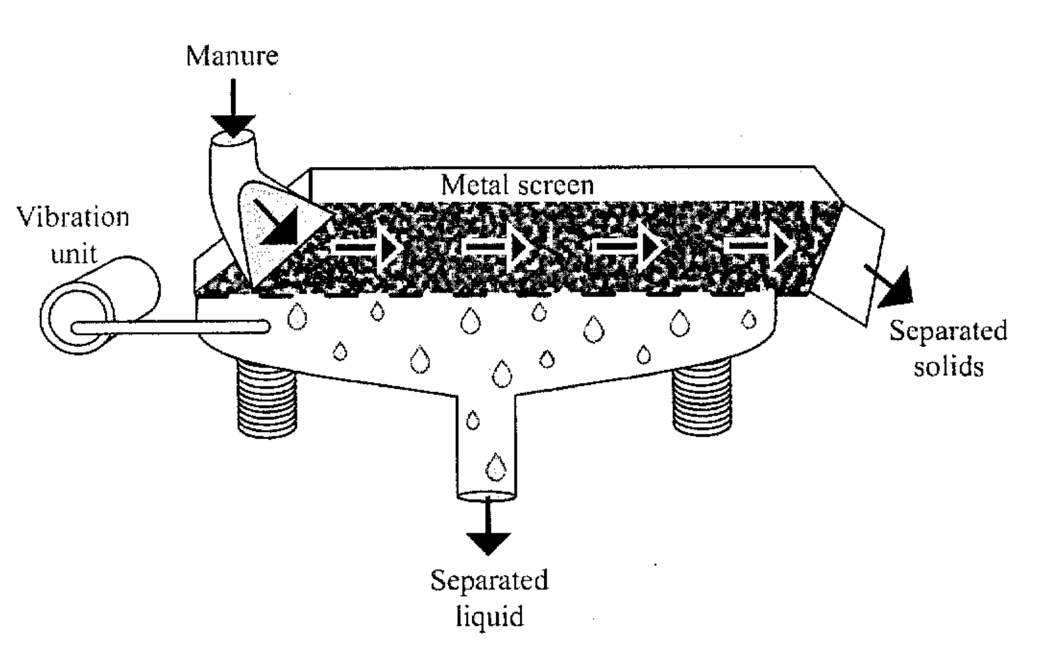


**Figure 3.13:** Diagram of vibrating screen (University of Minnesota, 2004).

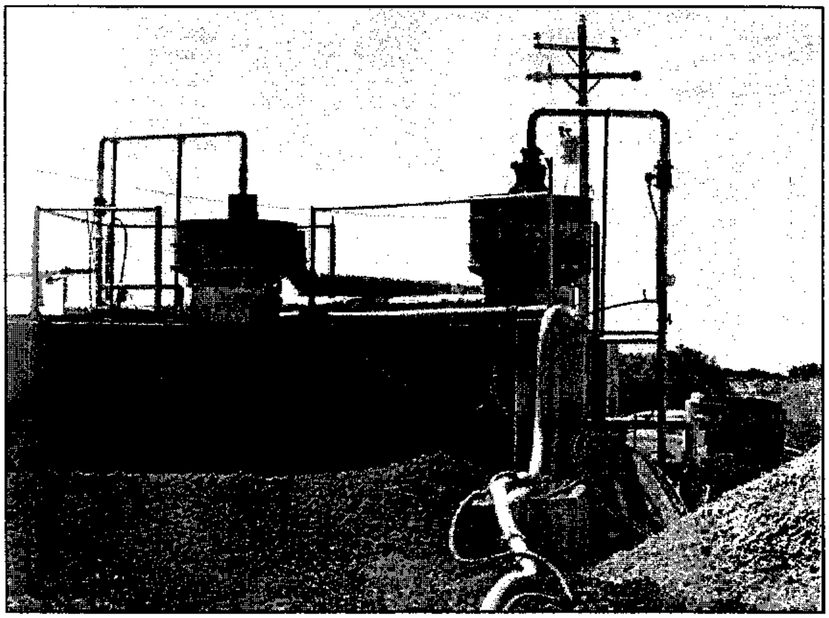

**Figure 3.14:** Photograph of vibrating screen (J. Robbins, 2004).

**Hopper:** A funnel-shaped receptacle that moves the manure via gravity to storage or treatment units.

The efficiency of the vibrating screen is similar to that of sloping stationary screens.

A vibrating screen system is not an appropriate pretreatment method for flushed swine waste destined for anaerobic digestion. In swine waste, a large portion of the carbon is partitioned in the liquid, not in the solids. The anaerobic bacteria require carbon for growth—removing it from the waste stream would have a detrimental effect on the bacteria, reducing the efficiency of the digestion process. Please see Chapter 5, Anaerobic Digestion for more information.

*3. Screw Press*

The slurry enters a **hopper**, and then the screw press, which consists of a screw auger rotating inside of a cylindrical perforated screen. The slurry is put under pressure by the auger as it moves toward the discharge end. The pressure forces the liquid through the perforations in the screen. **Figure 3.15** is a diagram of a screw press.

The efficiency of the solids separation can be changed by adjusting a counterweight at the discharge end. By increasing the pressure more liquid will be forced through the screen. **Figure 3.16** is a photograph of a screw press.

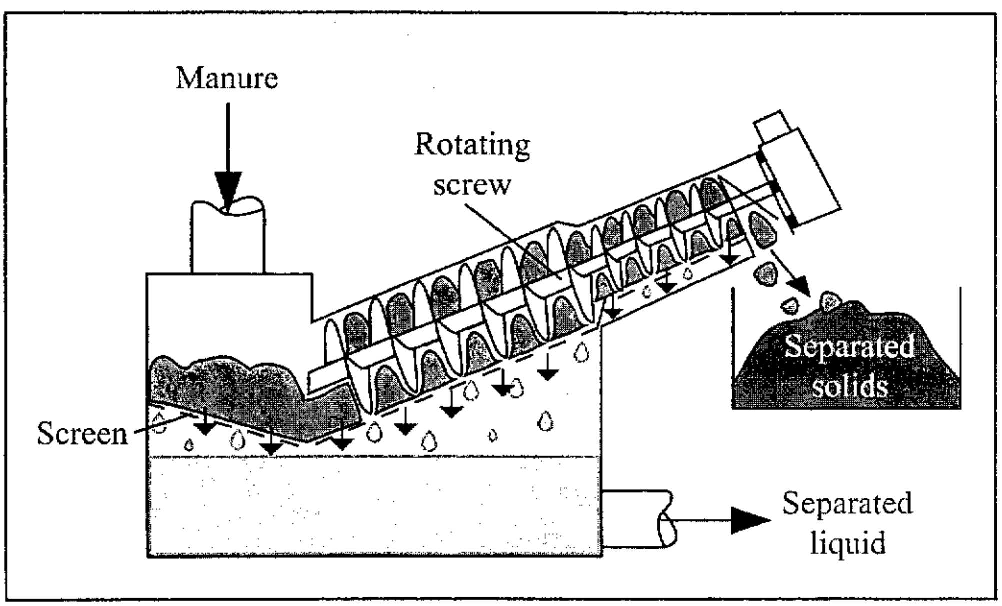


**Figure 3.15:** Diagram of screw press (R. Sheffield, 2000).

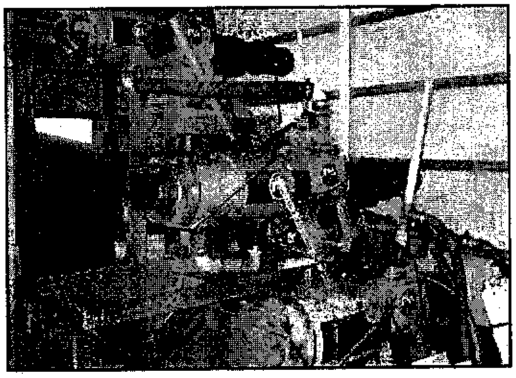

Figure 3.16: Photograph of screw press (J. Robbins, 2004).

*4. Drag Chain*

In a drag chain system, the slurry is applied to a perforated screen. Free liquid flows through the perforations and into a collection basin. Chains equipped with paddles pass over the surface of the screen, pushing the solids to a collection area. **Figure 3.17** is a photograph of a drag chain separator.

Variations in the slurry's solids content or degree of dilution will influence the solids volume and efficiency of the separation process. Like stationary incline screens, drag chain systems can be paired with other solid separators to increase the separation efficiency. A roller or a press can easily be tacked onto the end of the drag chain system.

Figure 3.17: Photograph of drag chain separator (P. Wright, 2004).

*5. Roller Presses*

A roller press consists of a rotating perforated drum and one or more rollers. First, the slurry enters the drum where free liquids pass through the perforations, and the slurry moves to the end of the drum. As the slurry moves under the rollers, more liquid is squeezed out. The solids are scraped off the drum and roller apparatus and into a storage container. Roller presses are able to efficiently separate slurries with a solid content of nine percent or less (Hartzell, 2001). **Figure 3.18** is a photograph of a roller press.

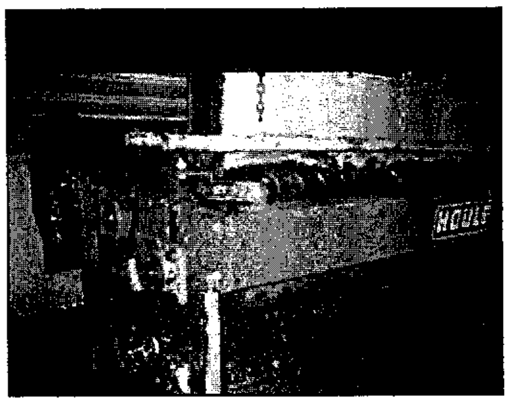

Figure 3.18: Photograph of roller press (P. Wright, 2004).

*6. Centrifuge*

A centrifuge rapidly spins the slurry, pulling the liquids to the outside and through perforations. The solids remain on the inside wall of the perforated drum. Centrifuges are one method of mechanical separation that utilize the solid particle density to achieve separation. **Figure 3.19** is a diagram of a centrifuge.

Centrifuges are frequently found in industrial applications, and can handle several hundred gallons of waste per minute. They are compact in size, and filters can be added to improve the efficiency. **Figure 3.20** is a photograph of a centrifuge.

*Comparison of Gravity and Mechanical Separation*

Gravity systems and mechanical systems work in different ways, with different outcomes. In general, gravity systems can separate solids from only free liquid while mechanical systems can separate solids from some bonded liquid as well. However, the removal of **bonded liquids** may also include the removal of a small portion of the solids as well.

**Bonded liquid:** Liquid physically or chemically bound to solid particles.

Gravity systems tend to work best with slurries that are equal to or less than eight percent solids and slurries that do not contain **floatable bedding.**

**Floatable bedding:** Any type of bedding that will float or stay in suspension, including wood shavings and grain hulls.

Gravity systems are initially less expensive than mechanical systems, but may prove more costly in the end if they are not maintained properly. Mechanical systems offer more flexibility for solids collection and storage—mechanically separated solids can be stacked, require less area for storage, and have less potential to leach.

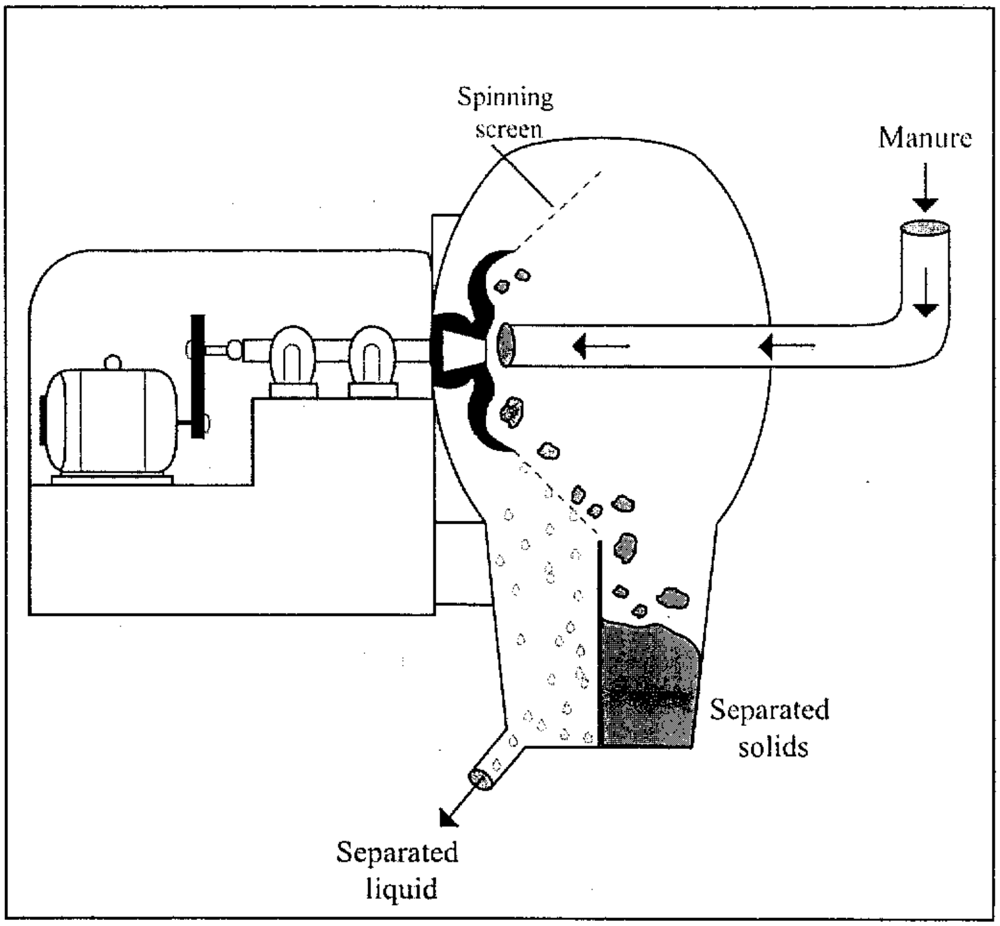


**Figure 3.19:** Diagram of centrifuge (R. Sheffield, 2000).

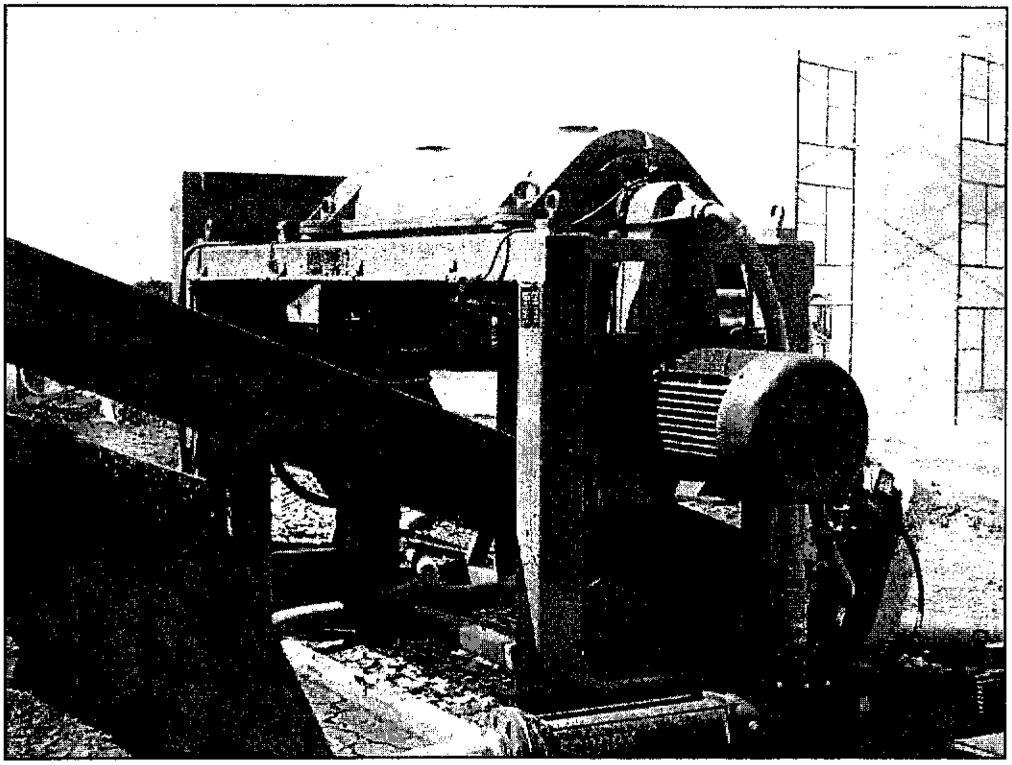

**Figure 3.20:** Photograph of centrifuge (J. Robbins, 2004).

**Table 3.6** gives some solids removal data for centrifuges used in dairy and beef operations.

**Table 3.6:** Anticipated solids removal efficiencies of centrifuges treating dilute manure slurries (adapted from Miner et al., 2000).

| Parameter | Dairy Manure Slurry (percent) | Beef Manure Slurry (percent) |
|---|---|---|
| Total solids (TS) removal | 60-70 | 60-70 |
| Biological oxygen demand (BOD) removal | 30-40 | 25-35 |
| Solids fraction | 20-25 | 20-30 |

c. Chemical Separation

Chemical separation requires the addition of special chemicals to force the compounds in the manure to **precipitate** out of solution. The chemicals used depend on the compounds to be extracted from solution; not all chemical separators are suited for every kind of waste. The treatment efficiency depends both on the characteristics of the waste and the chemical separator utilized.

Aluminum sulfate, referred to commonly as alum, is used as a **flocculant** to separate phosphorus from the liquid waste. Alum reacts with phosphorus, drawing it out of solution. The alum and the phosphate bind, forming aluminum phosphate. The aluminum phosphate will precipitate out of solution. Pretreatment of the waste with a strong acid may reduce the amount of alum needed; 5.5 to 6.5 is the optimal pH range for phosphorus removal when using alum.

Other salts of aluminum, polymers, iron, and calcium have also been used for solids separation. Iron chloride, lime, and polymers used to separate flushed waste also removed 82 percent of inorganic phosphates (Jones and Brown, 2000).

Chemicals used to separate solids may affect the future uses of the solids or liquids after separation. This depends on the chemical used, the precipitate formed, and the proposed use. The use of chemicals for solids separation is a continuous expense. Additional expenses may be incurred if special disposal is required for the solids. Chemicals should be stored conscientiously to minimize environmental threats and to ensure worker safety. All chemicals used on a farm should be kept in a locked storage area.

### 3.4 Summary

Solids separation can improve manure storage and handling and prepare manure for future treatment by reducing the moisture content, organic loading, and nutrient loading. Solids separation may reduce odors, pests, and improve farm sanitation. The separation process uses one of two traits of the solids to be removed—either their density in relation to the density of water or the average size of the particle. Solids separation may occur at any step of the manure treatment process. Manure may be separated before storage, as with belt systems, or after a period of time has passed or dilution has occurred. There are three types of delayed separation methods: gravity, mechanical, and chemical.

**Precipitate:** The conversion of a slightly soluble substance into an insoluble substance that settles out of a solution.

**Flocculant:** A substance added to a solution to help particles bind together.

## 3.5 A Closer Look At Solids Separation

The DeVries Dairy is located near the Bosque River, in central Texas. The dairy is owned by George DeVries, who currently milks about 1250 cows. George has operated this dairy since 1989, but has been dairying for 26 years.

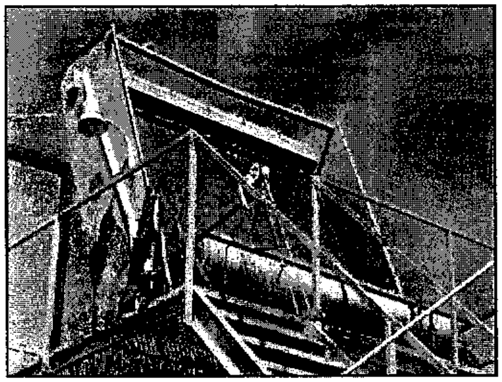

**Figure 3.21:** Inclined screen separator (J. Robbins, 2004).

The DeVries Dairy came under legal scrutiny in early 2003 along with ten other Waco-area dairies because of concerns over the pollution of a drinking water source for the city of Waco. However, plans for alternative treatment technologies were already in the works to mitigate the impacts of the large dairy.

In July of 2003, a treatment system was installed at the dairy for evaluation. The system consists of a bacterial contact chamber, anaerobic and anoxic digestion reactors, and solids separation. The system is designed for nitrogen and phosphorus removal through uptake and transformation by bacteria (nitrification-denitrification and luxury microbial uptake of phosphorus), but also contains a comprehensive solids separation system.

The flushed manure and milking parlor waste is run through the contact chamber and then an inclined screen separator and a vibrating screen separator. The liquid is then subject to the biological treatment and then runs through a centrifuge separator before the liquids receive further treatment. The solids separation units are depicted in **figures 3.21 - 3.23.** A portion of the total solids separated is used to seed the contact chamber with bacterial biomass, but the bulk of the solids undergo further processing to become a soil amendment used on the farm or marketed as BionSoil™.

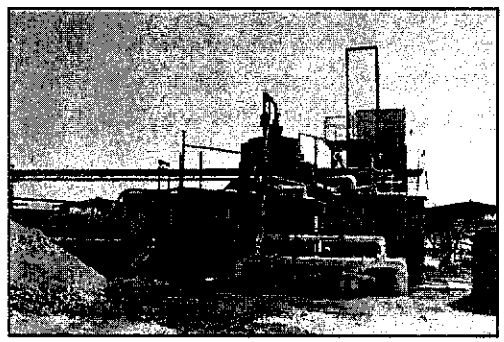

**Figure 3.22:** Vibrating screen separator (J. Robbins, 2004).

The intensive treatment system at the DeVries Dairy requires skilled technicians and monitoring to keep the entire system working at optimal conditions. The moving parts of the solids separation units require periodic maintenance and repair. While the results of a recent study at the DeVries Dairy may be promising and have prevented legal action against the dairy so far, the long-term economic and pollution-prevention efficiency of the overall system is yet to be determined.

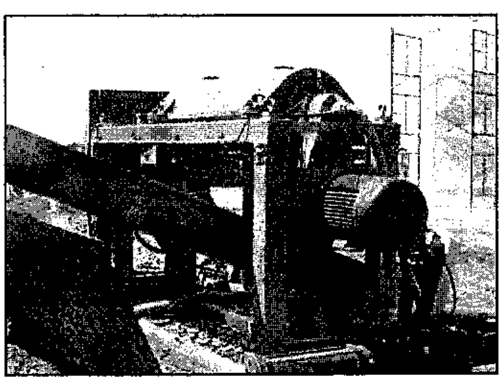

**Figure 3.23:** Centrifuge separator (J. Robbins, 2004).

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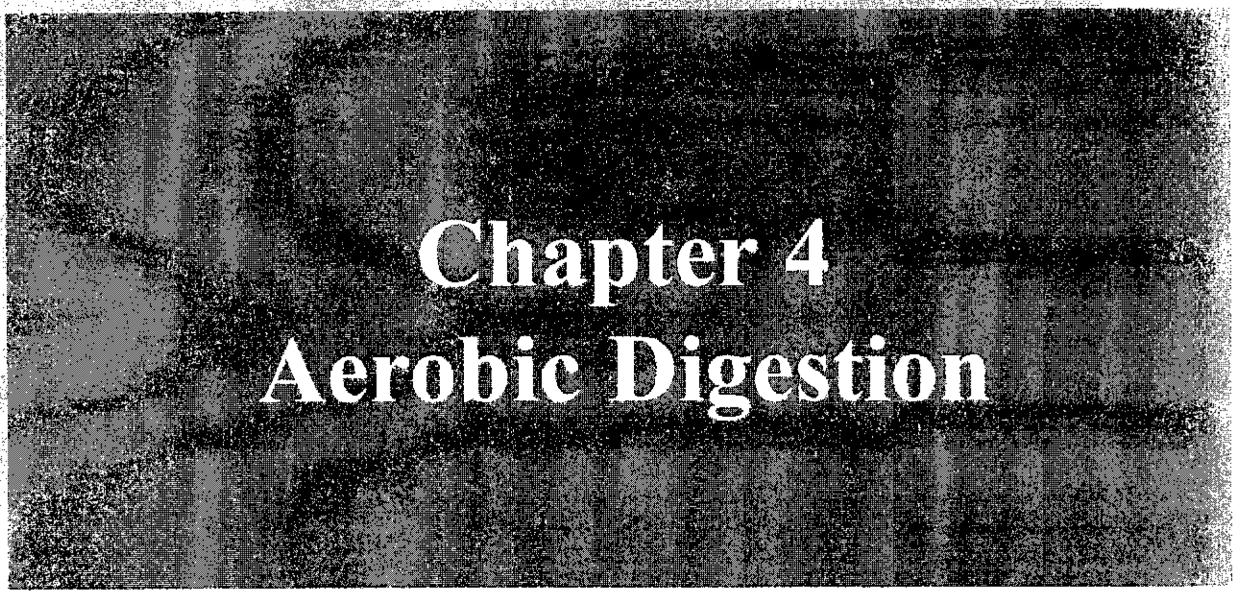

# Chapter 4
# Aerobic Digestion

## 4.1 Introduction

**Aerobic** digestion is a biological process driven by oxygen-loving bacteria. The bacteria feast upon the manure and assimilate the nutrients into their bodies or biochemically convert the nutrients into more stable forms. Aerobic bacteria stabilize the manure—it no longer readily degrades. Aerobic digestion reduces odor, **ammonia volatilization**, and **methane**, a **greenhouse gas**. Depending on the degree of aeration, it is possible to achieve nitrogen reductions and the partition of phosphorus into the solid fraction. **Table 4.1** displays potential benefits associated with aerobic digestion.

Currently, aerobic digestion of manure represents over 90 percent of manure treatment systems in France, where environmental regulations are quite stringent (Béline et al., 2002). However, aerobic digestion can be an expensive and land intensive technology.

**Table 4.1:** Potential aerobic digestion 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Aerobic Digestion | Aerobic digestion | √ | √ | √ | √ | | √ | √ | √ | √ | √ | | | | |

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

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

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

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

**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.

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

**Pathogen:** A disease-causing organism.

**Exothermic:** A process that gives off heat.

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

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

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

As environmental regulations tighten in the US, farms that need to decrease odor, methane, and ammonia emissions may find aerobic digestion an effective treatment option. Additionally, aerobic digestion is a pretreatment option for those considering or using **nitrification-denitrification** systems.

## 4.2 Advantages and Disadvantages of Aerobic Digestion

Aerobic digestion is just one of many manure treatment technologies. Several variables impact whether aerobic digestion is suited for a particular farm—the climate, amount of land available, cost, management, current infrastructure, and specific treatment goals. A system of treatment technologies is always more robust and will be able to meet more treatment objectives than a single treatment unit process.

### 4.2.1 Advantages

Aerobic digestion reduces odor, methane, and ammonia emissions, which are associated with **anaerobic** decomposition. Methane is a greenhouse gas and ammonia is an air pollutant. Bacteria involved in aerobic digestion convert ammonia to nitrate.

Another benefit is that **pathogen** reductions may be achieved. Since aerobic digestion is an **exothermic** process, the heat released during microbial activity can be high enough to kill pathogens and weed seeds. Digester temperatures must reach 50 to 60° C (122 to 140° F) for pathogen elimination (Danesh et al., 2000). Pathogen destruction allows for the solids produced during digestion to be safely used as fertilizer for a variety of crops and landscape uses.

Aerobic digestion stabilizes manure. Stabilized manure does not readily degrade, so no gases, including methane, are released during storage. The aeration associated with aerobic digestion improves manure homogeneity. In some cases, the aerated liquid portion may be recycled as flushwater to clean barns.

### 4.2.2 Disadvantages

Aerobic treatment can be costly to maintain. Aerators, and in some cases mixers, require constant power, increasing electricity costs. Mixing may cause foaming, which requires extra equipment to break the surface foam. Additional power needs also stem from pre-digestion solids separation processes, as aerobic digestion requires fairly dilute slurry.

Aerobic bacteria are less able to degrade cellulose than anaerobic bacteria. This may be a significant issue for dairies or beef operations with large amounts of fibrous feeds and plant-based bedding. Additionally, the **inert** insoluble portion of manure is unaffected by aerobic digestion. If the wastewater is inadequately aerated, odor and anaerobic processes flourish. In that case, ammonia, methane, and other **manure gases** may be released. Ammonia volatilization or complete nitrification-denitrification convert plant-available nitrogen to gas. This may be undesirable if a nitrogen-rich **soil amendment** is an end goal.

Aerobic digestion produces byproducts that require further treatment or disposal. Biosolids accumulation is a significant maintenance issue for aerobic digesters. Aerobic microorganisms produce considerably more cell mass than anaerobic microorganisms. Approximately 50 percent of carbon in