CHAPTER 11: SOLIDS HANDLING

SOLIDS HANDLING PROCESSES
When a wastewater treatment plant is operating properly, most of the solids in the wastewater will be removed at the plant while the water itself will be discharged as effluent to the receiving waters. These solids, known as sludge, must be stabilized and reduced in volume before they can be reused or disposed of economically and safely. The processes used to stabilize sludge and reduce its volume are known as solids handling. Solids handling incorporates four functions; thickening, digestion, dewatering and sludge disposal/re-use.

DIGESTION
The sludge produced by wastewater treatment processes can be highly variable. Sludge from the secondary clarifiers of a treatment process such as extended aeration activated sludge is already partially stabilized while the sludge produced by primary clarifiers is unstable, odoriferous and full of pathogenic bacteria (raw). Solids must be thoroughly stabilized in order to avoid problems such as odors, human exposure to pathogenic organisms and attraction of vectors (mice, dogs, birds). Although stabilization can be done chemically and thermally, biological digestion is the process most often used to stabilize sludge generated by wastewater treatment plants. We can think of digestion as “breaking down” sludge into simpler components through the action of microorganisms. During digestion, a portion of the sludge is converted to gasses such as CO2, methane and water vapor. This reduces the volume of the sludge and, more importantly, reduces the volatile solids content. It is through a reduction in volatile solids content that the sludge is stabilized during digestion. Digestion can take place under aerobic or anaerobic conditions.

ANAEROBIC SLUDGE DIGESTION
Anaerobic digestion converts wastewater solids such as primary sludge, secondary sludge and scum into a substance that is relatively odor free, dewaterable and capable of being disposed of without causing serious problems. Pathogens are greatly reduced when the process is operated correctly. Anaerobic digestion can also reduce the volatile content of the sludge by 30 – 60% and produce invaluable methane gas as a by-product.

How Anaerobic Digestion Works
Anaerobic digestion relies upon the actions of two groups of bacteria living together in the same environment. One group consists of SAPROPHYTIC organisms, commonly referred to as the “acid formers”. The second group, which uses the acid produced by the saprophytes, is the “methane fermenters”. The methane fermenters are not as abundant as the acid formers in raw wastewater, in part because they only reproduce in a pH range of 6.6 to 7.6. The key to anaerobic digestion lies in balancing the rate of acid formation with the rate of methane fermentation. If the rate of acid formation is higher than the rate of methane production, the pH will begin to fall below the area that favors the methane formers.

Anaerobic digestion can occur within three distinct temperature ranges. The temperature range affects the rate at which digestion will go forward. At the lowest temperature range, (10 - 20º C), PHYCHROPHILIC, cold temperature loving, bacteria will predominate. Digestion at this temperature is slow and inefficient. Examples of digesters that operate in this range include; Imhoff tanks, septic tanks, unheated unmixed digesters and the anaerobic portion of lagoons. Carbon dioxide, hydrogen sulfide and water are the dominate by-products of this type of digestion. Only a little methane fermentation happens in this temperature range.

In the middle temperature range, (20 - 45º C), MESOPHILIC, medium temperature loving, bacteria will thrive. This is the most common temperature range for anaerobic digesters in use at wastewater treatment plants because it produces a high level of methane production with a short digestion time (normally around 25 – 30 days). The ideal temperature is about 35º C, (95º F), so digesters of this type are typically heated, often through combustion of the methane gas that they produce as a by-product. Mixing is included in this type of digester to ensure that the temperature is maintained evenly throughout and bacteria and food can come into contact with each other.

The highest temperature range, (49 - 57º C), is dominated by THERMOPHILIC, hot temperature loving, bacteria. Because of problems maintaining the high temperature, sensitivity of the organisms to temperature change and reported poor liquid/solids separation, few digesters run in the thermophilic range.

It is important to note that you cannot simply raise the temperature of a digester and have a successful operation in another range. The organisms take time to adjust to the new temperature. A good rule to follow for anaerobic digestion is never change the temperature more than one degree (Fahrenheit) a day to allow the organisms to become acclimated.

Anaerobic digesters in New Mexico are typically two stage, (primary and secondary), operating in the mesophilic temperature range. The first stage is heated and
Figure 11.1 - Anaerobic Digester Components
mechanically mixed. Up to 90% of the gas production occurs in the primary digester while the second stage is used for storage and solids/liquid separation. Mixing is usually provided for the second stage, but only used periodically. Supernatant is sometimes drawn from the secondary digester and returned to the treatment plant to make room for more sludge. The secondary digester also serves as a source of seed organisms for the primary digester in case it becomes upset.

**Mixing System**

Digesters can be mixed by several method. Mechanical mixers that utilize propellers and draft tubes are common. Mixers that work by compressing and bubbling methane gas into the sludge are also used.

**Gas System**

MESOPHILIC anaerobic digestion produces 8 – 12 cubic feet of gas for every pound of volatile matter added and 12 – 18 cubic feet for every pound of volatile matter destroyed. The gas consists mainly of methane (CH4) and carbon dioxide (CO2). The methane content will vary from 65 – 70% while the carbon dioxide content will vary from 30 – 35%. Digester gas contains a heat value of 500 – 600 BTU per cuft. (Natural gas contains 900 – 1200 BTU per cuft). Digester gas can be re-used in various ways such as; heating the digester, driving an engine/generator and heating plant buildings. The gas system for a digester serves to remove the gas to a point of use, provide safety features and burn off excess gas in a waste gas burner. The main components of the gas system include; the gas dome, pressure and vacuum relief valves, flame arresters, thermal valves, sediment traps, drip traps, gas meters, manometer, pressure regulators, and the waste gas burner.

**Digester Heating System**

A boiler fired off of digester gas, natural gas or propane typically provides the heat for the digester. Boiler water is best maintained at between 60 and 82º C. Two methods of heat exchange are common; sludge recirculation through an external heat exchanger or heat exchangers located inside the digester.

**Floating Cover**

Many digesters are equipped with floating covers, (most commonly located on the secondary digester) to provide a flexible space for digester gas storage. A properly designed floating cover can also keep the scum blanket mixed in with the digesting sludge, which will prevent the blanket from becoming excessive. Floating covers can move up and down as the level of gas and sludge increases or decreases. The interior of the digester is sealed off from the atmosphere by a sludge seal located between the annular space between the cover and the digester wall. If the level of sludge in the digester is allowed to drop low enough, the seal will be broken and an explosive mixture of methane and oxygen could develop. Explosions have occurred when an inattentive operator withdrew too much sludge from an anaerobic digester with a floating cover. EXTREME CAUTION MUST BE USED TO PREVENT AN EXPLOSION WHENEVER AN ANAEROBIC DIGESTER ISemptied OR DEWATERED FOR MAINTENANCE OR CLEANING.
**Sampling Well**
The sampling well consists of a 3 or 4 inch diameter pipe (with a hinged sealing cap) that extends down through the gas layer, at least one foot into the digesting sludge. The sampling well permits samples to be taken of the sludge without dangerously exposing the gas to oxygen. Be aware that some gas will always be present when the sampling well is first opened. Sampling wells are sometimes referred to as “thief holes”.

**Operation of Anaerobic Digesters**
As stated earlier, the key to operating an anaerobic digester lies in balancing the acid formation and methane fermentation processes. This is accomplished by maintaining the desired temperature (95º F), ensuring mixing to promote contact between the organisms and the food as well as promoting even heating. Of high importance is FEEDING AND WITHDRAWING SLUDGE AT PROPER RATES. It is a good rule of thumb not to withdraw more than 5% of a digester’s content in a 24 hour period.

The type of sludge being digested is important. Raw sludge from a primary clarifier typically contains around 4 – 5% total solids, of which 70 – 90% is volatile matter. On the other hand, waste activated sludge can range from 0.2 – 6% total solids (high end due to thickening) with 65 – 75% being volatile. Raw sludge digests rapidly while waste activated sludge digest slower and less thoroughly, in part because of its lower volatile solids content at the beginning. Care must be taken to balance the feeding of raw sludge and secondary sludge in order to avoid upsetting the digester.

Feeding sludge to a digester is best done several times a day rather than all at once to avoid lowering the temperature of the digester too far at one time. Pumping several times a day not only helps the digester but also help the clarifiers by avoiding holding sludge in primaries for too long and ensuring a consistently thick sludge. Every effort to pump as thick of sludge as possible should be made. This is because digester space is at a premium and sludge that contains too much water may dilute the buffering capacity of the digester. Buffering capacity refers to the digester’s ability to neutralize the organic acids that are being produced by the acid formers. Buffering capacity depends on the amount of alkalinity contained in the sludge within the digester. If a digester does not contain enough buffering capacity, the pH of the sludge will drop. This harms the methane formers because they can only reproduce in a pH range of 6.6 to 7.6. If the pH falls too far, methane production will taper off and the digester is said to be “sour” or “stuck”.

Several tests are used to monitor the condition of the digestion process. These are;
- Temperature. A thermometer is usually located in the sludge recirculation line from the digester to the heat exchanger. A temperature of between 95º and 98º F should be maintained. Never change the temperature more than 1º F per day.
- Volatile Acid/ Alkalinity relationship (VA/Alk ratio). As long as volatile acids remain low and the alkalinity (buffering capacity) remains high, the digestion process will remain stable. Each treatment plant has its own acceptable ratio of volatile acids to alkalinity. However, this ratio is usually less than 0.1 part volatile acids to each 1 part alkalinity (10 times as much alkalinity as volatile acids). A CHANGE IN THE VA/ALK RATIO PROVIDES THE FIRST INDICATION THAT SOMETHING IS WRONG WITH THE DIGESTER. For this reason it is imperative that the VA/Alk ratio be monitored at least weekly.
- Digester Gas Content (CO2 and methane). The percentage of CO2 in the digester gas is an indication of digester performance, however, the VA/Alk ratio will change before the CO2 content begins to increase. Good digester gas will have 30 – 35% CO2 and 65 – 70% methane. If the CO2 content exceeds 42%, the digester is considered to be in poor condition. If the content of CO2 is greater than 45%, the gas will not burn.
- pH. pH readings are normally taken on raw sludge, recirculated sludge and supernatant. Because the VA/Alk ratio will show changes long before the pH actually changes, pH measurements should be used for recording purposes but not for process control. A pH of 7.0 – 7.6 indicates good operations.
- Solids Content. The total solids should be determined for the feed sludge(s), the recirculating sludge, withdrawn sludge and supernatant. A TS content of 3 – 6% is typical for sludge in the digester. Volatile solids reduction of the sludge is a key indicator of digester performance. Volatile solids reductions of 50 – 60% are not uncommon.

**Trouble Shooting Anaerobic Digester Problems**
Careful process control and an understanding of the fundamentals will help operators avoid most anaerobic digestion problems. However, problems do arise. Table 11.1 shows common anaerobic digester problems, key process control indicators and possible solutions.
AEROBIC SLUDGE DIGESTION

Another method of biological sludge digestion is one that takes place in an aerobic environment. Aerobic digestion is quite different from anaerobic digestion. In fact, aerobic digestion is essentially just an extension of secondary treatment processes. Air and mixing are provided to solids held in a tank, but no artificial heating takes place. Because no food source is provided to the organisms in the tank other than more organisms (sludge), they devour each other. (This is known as ENDOGENOUS respiration). The cycle of organism eating organism breaks down the sludge and releases CO2 and water vapor. Aerobic digestion is not as efficient as anaerobic digestion. Volatile solids reductions of 20 – 40% are typical with solids detention times of around 20 – 30 days. If the solids are digested for a longer period, the volatile solids reduction can be slightly higher but rarely approaches anaerobic digestion rates. Because of predation from a wide variety of organisms, the level of pathogens in aerobically digested sludge is significantly lowered.

COMPONENTS OF AEROBIC DIGESTERS

Aerobic digesters, due to their simplicity, consist of only a few components. This makes the process attractive to small to medium sized treatment plants. Aerobic digesters are often included in “package plants” and medium sized extended aeration activated sludge plants and SBRs because of the readily available supply of air for aeration. Aeration can be accomplished with floating surface aerators, fixed bridge aerators or blowers using coarse bubble diffusers. Some flexibility to alter the level of aeration and mixing should be provided. (It is often desirable to be able to apply more air to the treatment process and less to the digesters when needed). If diffusers are used, some provision for retrieving them for cleaning should be included.

Sludge Inlet and Outlet Lines

Cast iron, ductile iron or steel lines are usually provided for the sludge inlet and outlet lines. The sludge inlet should be located above the high water level of the digester tank. The outlet line should be located at the bottom, or preferably in a slightly sunken sump in the digester floor to allow the tank to be completely emptied for cleaning (this is rarely the case). No matter how small the treatment plant, sludge lines should be a minimum of 3 inches in diameter to prevent plugging from grease, rags, etc.

Supernatant Tubes

Some aerobic digesters are equipped with supernatant tubes. Shutting off the aeration system for several hours will cause sludge will settle to the bottom of the digester. Using supernatant tubes, clarified liquid can be drawn off and returned to the head of the treatment plant. Supernating from aerobic digesters is not always a good practice. Aerobic sludge does not usually settle well and leave a clear supernatant (without the use of settling aids). Worse, if the digester aeration system cannot maintain at least 1.0 mg/L, the supernatant itself can be a source of filamentous...
organisms that can upset activated sludge treatment processes when returned to the plant influent flow.

**Operation of Aerobic Digesters**

There is not much involved in the operation of aerobic digesters. Sludge feed rates are based on the need to remove solids from the secondary treatment process. Sludge removal rates are determined by the level in the digester and by the availability of sludge dewatering and drying units. Around 1.0 mg/L DO should be maintained or the digesting sludge can produce a “rotten melon” odor that becomes progressively more offensive. Aerobic digesters should be taken off-line and completely cleaned at least once every three years in order to preserve the tank volume (remove sediment) and inspect submerged equipment. Monitoring tests that should be done at least weekly include:

- **pH.** The pH of the digesting sludge should be determined and recorded. The pH of aerobic digester sludge should always be above 7.0. If it is not, a problem in the secondary treatment process is indicated. An example would be un-wanted nitrification causing acidic conditions in waste activated sludge. A source of alkalinity such as lime may have to be added to the digester in this situation to maintain a neutral pH.

- **Total Solids.** The TS of the feed sludge, digesting sludge and of sludge withdrawn from the digester should be known. TS in aerobic digesters typically range from 1.5 – 4%.

- **Volatile Solids.** The volatile solids content of the feed sludge, digesting sludge and sludge withdrawn from the digester should be known. The reduction of volatile solids through the digester gives a measure of the effectiveness of the digestion process. Over time, the volatile solids reduction will decrease. This is due to sediment that reduces the digester’s volume (resulting in a lower digestion detention time). If the volatile solids reduction falls to unacceptable levels, cleaning of the digester to restore detention time is indicated.

- **Dissolved Oxygen.** D.O. in the digester should be measured with a calibrated D.O. meter. In order to avoid serious odor production, at least 0.5 mg/L of D.O. should be maintained.

**Chemical Sludge Stabilization**

Sludges which are not biologically digested can be made stable by the addition of large doses of lime. **The Addition of Lime to Sludge to Prepare It for Ultimate Disposal is Not a Common Practice.** Chemical stabilization is usually considered a temporary stabilization process and finds applications at overloaded plants or at plants experiencing digestion facilities upsets. The main drawbacks to chemical stabilization are the cost associated with the large quantities of chemical required and the quality of the end product.

Lime stabilization is accomplished by adding sufficient quantities of lime to the sludge to raise the pH to 11.5 - 12.0. This extremely caustic condition kills virtually all organisms in the sludge, thus preventing biological changes (temporarily) and killing off pathogenic organisms such as bacteria, viruses and parasites.

The best way to determine the amount of lime required to raise the pH of a particular sludge to within the desired range is to perform a bench scale test using 1 – 2 liters of sludge and then calculate the volume needed for full scale based on the results. An important drawback to lime stabilization of sludge is that, unlike other stabilization processes, the overall mass of solids is not reduced. In fact, it increases.

**Sludge Thickening and Dewatering Processes**

Even what is considered a “thick” sludge, (5 – 6% total solids), still contains over 90% water. Storing and transporting all the water along with the solids contained within it is not practical. For this reason, there are a number of methods of separating solids from water. These methods include; gravity thickeners, diffused air floatation (DAF) units, belt presses, centrifuges and sludge drying beds. Some of the methods are capable of thickening sludge, but it remains a liquid. Others can remove enough water that what is left is a semi-dry to dry solid. Some dewatering processes are located before digestion, others after. Most drying processes, like sludge drying beds, are only practical if located following digestion. Chemicals that are known as polymers can be used to enhance many of the sludge dewatering and drying processes.

**Gravity Thickeners**

Gravity thickening of wastewater sludge uses the force of gravity to separate solids from water. Solids that are heavier than the water will settle to the bottom and be compacted by the weight of the overlying solids. Gravity thickeners are typically circular or square in design and resemble secondary clarifiers. Their main components include; a feed line and baffle for good flow distribution, a sludge rake mechanism to move the sludge to the bottom center of the tank for removal, vertical steel “pickets” mounted on the sludge rake, an effluent overflow weir, a scum box or tilting weir for removal of floating scum and solids, and a sludge withdrawal line.
The successful operation of gravity thickeners depends upon these factors:

1. **Type of sludge being thickened.** Primary sludge thickens best in gravity thickeners, but must not be allowed to become septic. Secondary sludge can be difficult to thicken in this type of process due to their lower solids content and denitrification.

2. **Age of the feed sludge.** Older sludges are prone to **gasification** caused by denitrification and gasses produced by septic conditions that cause sludge particles to float.

3. **Sludge temperature.** Warmer sludge does not settle as well because of gasification due to the increase in biological activity.

4. **Sludge blanket depth.** The thickening action is due in large part to the compaction that occurs from the overlying sludge. A balance must be struck between maintaining a thick enough blanket to achieve compaction and removing the solids before gasification.

5. **Hydraulic and solids loading.** The unit must be designed to handle the hydraulic and solids loading experienced.

Gravity thickeners are typically capable of thickening sludge to between 2 – 4%. Solids concentration as high as 6% can be achieved with the addition of polymers or other thickening agents, but it is important to know whether or not the sludge pump in use can remove concentrations that are this high.

**Dissolved Air Floatation (DAF) Thickeners**

Dissolved air floatation thickening relies on a process similar to what happens to sludge during denitrification. Small air bubbles attach themselves to sludge particles and separate them from the remaining liquid by floating them to the surface where they accumulate into a sludge layer. This sludge layer is skimmed off into a hopper as thickened sludge. A large portion of the separated water is recycled to the feed sludge line after being saturated with air (this provides the bubbles for floatation). Effluent exits the far end of the unit and is returned to the treatment plant flow stream. Polymers are often used to enhance the separation and thickening characteristics of the feed sludge.

DAF sludge thickener performance guidelines are given in Table 11.2.

The performance of DAF units depends upon the following factors:

1. **Type of sludge.** Primary sludges are less adaptable to floatation than secondary sludges. Sludge age affects how well secondary sludge thickens. “Young” sludge thickens better than “old” sludge. Primary sludges tend to deposit grit and sediment in the bottom of DAF units so provisions must be made for removal of this material.

2. **Air to solids ratio.** The amount of air available to float the sludge is critical to the thickening operation. The air pressure in the saturation tank determines the quantity of air actually saturated into the recycle stream.

3. **Recycle rate.** The recycle flow carries the saturated air to the sludge feed inlet in the DAF tank. When the recycle stream goes from a pressurized condition to atmospheric pressure, numerous small bubbles form as the air comes out of solution (similar to opening a can of soda). Obviously, the higher the recycle rate the more air that is available for floatation. However, the air saturation ratio and the recycle rate are dependent upon one another.

4. **Thickness of floating sludge blanket.** Adjusting the speed of the surface sludge scrapers can vary the thickness of the floating sludge blanket. Increasing the scraper speed tends to thin out the floated sludge. Conversely, decreasing the scraper speed will tend to result in a thicker sludge. However, the sludge removal rate must be fast enough to prevent solids from carrying over into the effluent. The floating sludge blanket is usually 6 – 8 inches deep. DAF units should produce an effluent that has less than 100mg/L TSS when operating properly.

**Table 11.2 - DAF Sludge Thickener Performance Guidelines**

<table>
<thead>
<tr>
<th>Operating Parameter</th>
<th>Without Polymer Addition</th>
<th>With Polymer Addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids Loading, lbs/hr/sq ft</td>
<td>0.4 – 1.0</td>
<td>1.0 – 2.0</td>
</tr>
<tr>
<td>Hydraulic Loading, gpm/sq ft</td>
<td>0.5 – 1.5</td>
<td>0.5 – 2.0</td>
</tr>
<tr>
<td>Recycle, %</td>
<td>100 – 200</td>
<td>100 – 200</td>
</tr>
<tr>
<td>Air:Solids, ratio</td>
<td>0.01 – 0.1</td>
<td>0.01 – 0.1</td>
</tr>
<tr>
<td>Min. Influent Solid Concentration, mg/L</td>
<td>5000</td>
<td>5000</td>
</tr>
<tr>
<td>Thickened Sludge Concentration, %</td>
<td>2 – 4</td>
<td>3 – 5</td>
</tr>
</tbody>
</table>
BELT FILTER PRESS
Belt filter presses consist of two endless belts that travel over a series of rollers assembled on a galvanized steel frame. Sludge is conditioned with polymer and allowed to dewater in a drainage area before it is fed into the area between the two belts. As sludge travels between the belts, it is pressed between perforated and non-perforated rollers. This causes water to be forced from the sludge and out of the belts where it is collected and returned to the treatment plant. The sludge cake is scraped off of the belts and carried away on a conveyor while the two endless belts are washed to prevent plugging.

Figure 11.2 - Typical Dissolved Air Flotation (DAF) Unit
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The factors that affect belt filter presses are as follows:

1. **Sludge Type.** Belt presses are not suitable to all types of sludges. Undigested waste activated sludge generally lacks the qualities necessary for dewatering with a belt press. Undigested WAS is often simply squeezed out from between the belts without dewatering. However, if properly digested, WAS can be successfully dewatered using belt presses.

2. **Sludge Conditioning.** Sludge conditioning prior to passing through the belt press is probably the most critical factor to successful dewatering. Cationic polymers are generally used for conditioning of sludge. Polymer dosages must be optimized to ensure optimal dewatering. A consistent sludge feed is imperative in order to optimize polymer conditioning.

3. **Belt Tension Pressure.** The pressure applied to the sludge can be increased or decreased by changing the tension roller setting. The belts should be neither too tight nor too loose. Experience will demonstrate the best setting.

4. **Belt Speed.** The speed at which the belt can be operated depends upon the sludge flow rate and the concentration of influent sludge. The belt speed must be fast enough to spread the sludge over a sufficient area of the belt so that drainage can occur. If not, excess water will be carried along with the sludge being pressed between the belts and the result will be washout, which causes the effluent water quality to suffer. The belt speed should be as slow as possible and yet fast enough to avoid washout.

5. **Belt Type.** A variety of belt materials are available such as nylon and polypropylene, each with various porosity. Higher porosity belts drain fast but leave a poor quality effluent. Low porosity belts may bind or plug causing frequent washouts. To preserve the life of a belt, belt-cleaning equipment should be kept in good working order.

Belt filter presses generally require close operator attention to attain consistent results. Problems that arise are most commonly associated with feed sludge quality changes and less than optimal polymer dosages, (which are related). The following table outlines the typical performance of properly operated belt filter presses.

**Table 11.3 - Typical Belt Filter Press Performance**

<table>
<thead>
<tr>
<th>Sludge Type</th>
<th>Polymer, lbs/ton</th>
<th>Cake % TS</th>
<th>Hydraulic Load, gpm/ft*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>4 – 8</td>
<td>25 – 35</td>
<td>10 – 25</td>
</tr>
<tr>
<td>Secondary</td>
<td>9 – 20</td>
<td>17 – 20</td>
<td>5 – 15</td>
</tr>
<tr>
<td>Digested Primary</td>
<td>4 – 8</td>
<td>25 – 30</td>
<td>10 – 25</td>
</tr>
<tr>
<td>Digested Secondary</td>
<td>15 – 30</td>
<td>17 – 20</td>
<td>5 – 15</td>
</tr>
</tbody>
</table>

*Hydraulic loadings are based on the flow rate applied per unit of belt width. For example, a one-meter belt is approximately three feet wide and so could handle a sludge flow of 30 to 75 gpm.
exit the unit through the effluent line. Thickened sludge is discharged as a liquid or cake. There are several configurations of centrifuges on the market. The most common type of centrifuge in New Mexico is the scroll type centrifuge. Scroll centrifuges rotate a tapered bowl along a horizontal axis. An inner scroll is used to evenly distribute the feed sludge. An adjustable weir controls the discharge of the centrate.

The performance of centrifuges is affected by the following factors:

1. **Type of Sludge.** The type of sludge being thickened is important. Generally, centrifuges are not used to thicken primary sludge because the centrifuge sludge inlets are susceptible to clogging. Secondary sludges are well suited to thickening by centrifugation because they usually lack material that will plug the centrifuge inlets. Centrifuges are less affected than other thickening processes by adverse sludge characteristics such as bulking sludge, rising sludge and old sludge. It should be noted that unlike other sludge thickening processes, off gassing of sludges will occur due to the high separation forces applied. Adequate ventilation is required and consideration must be given to monitoring air quality.

2. **Solids and Hydraulic Loading.** Unlike gravity thickeners and DAF units, the hydraulic and solids loading of centrifuges is not related to units of area (gpm/sq ft or gpd/sq ft). The accepted loading terminology for centrifuges is gal/hr/unit and lbs./hr/unit. The size of the centrifuge sets the upper limit for solids and hydraulic loadings.

3. **Bowl Speed.** Increasing the bowl speed will increase the thickness of the sludge cake. However, unless the centrifuge is equipped with a hydraulic back drive, the speed cannot be changed except by changing the drive belt sheaves. Generally, once the ideal speed has been determined for a particular sludge there is no reason to change it.

4. **Differential Scroll Speed.** The scroll speed will affect the sludge cake thickness and the centrate quality. In general, as cake concentration increases, solids removal efficiencies decrease. Operator observation and experience is the best way to determine the scroll speed setting.

5. **Liquid Depth (pool depth).** The liquid level in the centrifuge can be varied by adjusting the effluent weirs. A deeper liquid depth results in greater solids capture but a lower thickness sludge cake. A shallower liquid depth results in less solids capture but a thicker sludge cake. Most wastewater sludge thickening operations run will a high liquid depth because solids capture is important to preventing disruption of the wastewater treatment system due to poor quality centrate.

6. **Sludge Conditioning.** Most centrifuges are operated with polymer addition to improve the thickness of the sludge cake and the solids recovery, which improves the quality of the centrate. Proper polymer dosages, steady sludge feed rates, and internal cleaning of centrifuge for accumulated greases/solids, are important to maintaining centrifuge performance.

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**Figure 11.4 - Scroll Centrifuge**

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Table 11.4 outlines the typical performance ranges for scroll type centrifuges.

Table 11.4 - Scroll Type Centrifuge Performance Ranges

<table>
<thead>
<tr>
<th>Capacity gpm</th>
<th>% Feed Solids</th>
<th>% Thickened Sludge</th>
<th>% Solids Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 – 150</td>
<td>&lt;4.0</td>
<td>5 - 30</td>
<td>90 - 99</td>
</tr>
</tbody>
</table>

**SLUDGE DRYING BEDS**

The use of sludge drying beds is usually limited to small to medium sized (< 5.0 MGD) plants in New Mexico due to land and manpower requirements. In the southern part of the state, the abundance of warm weather, sunshine, wind and land makes drying beds a good sludge drying process for many treatment plants. In the northern part of the state, this is not always the case. Sludge drying beds can be divided into three categories; (1) sand drying beds, (2) asphalt or concrete drying beds, and (3) vacuum filter beds.

**Sand Drying Beds**

Sand drying beds consist of shallow lined concrete or earthen basins with perforated pipe installed under a 12 – 18 inch layer of gravel with an 8 - 12 inch layer or sand placed at the top. Decant tubes are located in the corners of the bed to drain any pooled water off of the sludge in the bed. Sludge is poured on the bed to a depth of around 12 inches. Water evaporates from the sludge as well as percolated down through the sand layer and is collected and removed by the perforated pipe under-drain system. When the sludge in the bed has dried to the point that it has cracked all the way down to the sand, the sludge is removed using a shovel and wheelbarrow or a small skid loader. Many older drying beds cannot be cleaned with a skid loader because the under-drains system will be crushed.

The factors that most affect the performance of sludge drying beds are:

1. **Climatic Conditions.** Little can be done by operators to change climatic conditions. Some sludge drying beds remain frozen throughout the winter and can only be cleared after they thaw and dry out. Rain and snow are less of a detriment to sludge drying than freezing conditions, because dry or partially dry sludge does not take up much water.

2. **Depth of Sludge Pour.** Sludge should not be poured much deeper than 12 inches because the drying time will increase substantially. Sludge should never be poured onto a drying bed that already contains partially dry sludge. This practice is known as “capping” and should be avoided because the lower layer of sludge will get sealed off. This lower layer becomes what is called “green sludge”, which is extremely odoriferous and will not dry.

3. **Condition of Sand.** The sand should be carefully leveled before sludge is applied to a sand drying bed in order to avoid areas that dry more slowly than the rest of the bed. Older drying beds can become compacted and the sand will not permit water to permeate. If this happens, the best cure is to remove 2 – 3 inches of sand and replace it with fresh, pre-washed sand. Some drying beds use expensive screened and pre-washed sand while others work fine with what could best be described as “arroyo sand”. The best sand has no dirt or clay in it and is free of excessive fines, which are very small particles.

4. **Use of Polymers.** Polymers are often used to improve the performance of sand drying beds. If used properly, polymers can cut the sludge drying time in half. This has the effect of doubling a plant’s number of drying beds.

Sand drying beds are capable of drying sludge to > 95% Total Solids, but 70 – 80% is more typical.

**Asphalt Drying Beds**

Asphalt drying beds are similar in construction to sand drying beds, except that instead of sand and gravel they have a hard asphalt or concrete surface. The hard surface allows the use of sludge mixing equipment to speed the drying time and skid loaders to remove the sludge when it is dried. Decant tubes are an important feature of asphalt beds because pooled water would have to evaporate (taking too much time) if it could not be decanted off. Sludge can be poured to a greater depth (18 – 30 inches) in asphalt beds because the action provided by the mixing equipment will help it dry rapidly. Mixing can be accomplished using an ordinary tractor, backhoe or dedicated sludge mixing equipment like the units manufactured by Brown Bear™ and others. Asphalt beds have proven very successful in dewatering sludge prior to composting, especially in the southern part of the state.

**Vacuum Filter Beds**

Vacuum filter beds offer a relatively new method for dewatering sludge. Vacuum filter beds consist of a shallow concrete basin that has an under-drain system covered over with porous pumice bricks or stainless steel or plastic perforated panels. Sludge that has been conditioned with polymer is poured onto the bed and a vacuum pump is used to create a vacuum underneath the panels. The vacuum rapidly draws water from the sludge. Vacuum beds can
dewater sludge to 15 – 30% TS in a matter of hours or sometimes days. The bed is then cleaned out using a skid loader or small backhoe fitted with a front-loading bucket. Some systems using stainless steel or plastic panels, but without a vacuum pump system, are also in operation in New Mexico.

**SLUDGE RE-USE AND DISPOSAL**

Because sludge consists of nutrients, organic molecules and trace metals that are needed by plants for growth, it makes an excellent soil conditioner. In fact, in countries such as China, various forms of sludge have been used as a soil conditioner for thousands of years. The general public often expresses concern when the subject of using wastewater treatment sludge as a soil amendment comes up. Many of the public’s concerns have a basis in fact and must be addressed. However, some of the concerns are simply “knee-jerk” reactions that can be dispelled with good information. As the operator of a wastewater treatment plant in New Mexico, you may be involved in setting up or running a sludge beneficial use program. If you are, you have two responsibilities; (1) Follow all of the state and federal regulations carefully, and (2) provide a product that is as consistently safe as possible and ensure that it is properly used.

Sludge that has been treated for beneficial use is generally referred to as Biosolids. When applied to soil in the correct amounts, biosolids can greatly improve the soil’s ability to retain water as well as improve the aeration of the soil. Because the most prominent soil types in New Mexico are clay and sandy loam, these are tremendous benefits.

If it is not practical to beneficially use all or any of the sludge generated in a wastewater treatment facility, some safe and economical form of disposal will have to be employed. The alternatives for the beneficial use of biosolids generally involve some form of land application (either distributed in bulk or in bags). Sludge disposal is typically done by surface disposal or landfilling, although incineration is permissible. Be aware that state and federal laws are in place to regulate the use and disposal of all sludge generated by wastewater treatment facilities. FAILURE TO ABIDE BY THESE LAWS CAN LEAD TO CIVIL AND EVEN CRIMINAL PROSECUTION.

When dealing with sludge issues you may have to seek permits or approval from the federal Environmental Protection Agency as well as the New Mexico Environment Department’s Ground Water Quality Bureau (NMED-GWQB), Surface Water Quality Bureau (NMED-SWQB), and Solid Waste Bureau (NMED-SWB). Although it is not practical to outline all of the regulations surrounding each of the sludge use and disposal practices, the following is an overview of the practices most common to our state.

**LAND APPLICATION OF BIOSOLIDS**

Land application of biosolids is a beneficial use practice that involves applying sludge to vegetated land at or near the vegetation’s agronomic uptake rate. In addition to supplying the vegetation with nutrients, the condition of the soil is improved. Three major areas of concern exist with regard to sludge that is land applied. These are; (1) pathogenic contamination, which is generally measured with the indicator organism Fecal Coliform (2) vector attraction reduction (VAR) which prevents animals from being attracted to the sludge and (3) toxins or potential toxins such as heavy metals, PCBs and nitrogen compounds which could contaminate the natural environment.

The law that governs the disposal and use of wastewater sludge is Title 40 of the Code of Federal Regulations (CFR), part 503 (commonly referred to as the 503 sludge regulations). The 503 sludge regulations set forth treatment techniques that are to be employed to reduce the level of pathogens in sludge before it can be land applied. Two tiers of pathogen reduction through treatment exist: Class “A” and Class “B”. Class “A” sludge is of high quality and can generally be sold or given away to the general public if it also meets the VAR and heavy metals requirements of part 503. Class “B” sludge is of lesser quality, but can still be land applied in bulk when specific management practices are followed and the sludge meets the VAR and heavy metal requirements of part 503. Approval or even a permit from NMED-GWQB may also be necessary to land apply Class “B” sludge.

One of the most common Class “A” treatment options is the composting process. Composting is a thermal aerobic biological process. Generally speaking, sludge is placed in a pile, called a windrow, along with wood chips or other mulched green waste. Bacteria and other organisms in the pile begin to digest the sludge and green waste. The pile is mechanically aerated or turned to provide oxygen so that the aerobic organisms remain active. The activity of the organisms creates substantial heat and high temperatures in the compost pile will result. To meet Class “A” standards, a temperature over 55° C (131° F) must be maintained for fifteen days with five complete pile turnings during that time. Careful control of the mixture and moisture content are required to achieve such high temperatures through aerobic organism activity alone. The high temperature and digestion greatly lower the number of pathogenic organisms remaining in the finished product. A special “Compost Facility Operator” license is required by the state for the operators of compost facilities in New Mexico.
Mexico. These licenses are different from wastewater treatment facility operator’s licenses.

**Surface Disposal of Sludge**

If sludge cannot be beneficially used, it must be disposed of. Surface disposal is a common method of disposing of large amounts of sludge, both in liquid and solid forms. Surface disposal involves applying sludge to the land surface well above the agronomic uptake rate of any vegetation that may be present. The sludge can be injected as a liquid 1 – 3 ft below the surface or spread on the land as a solid and then plowed in to incorporate it into the soil. The 503 sludge regulations have specific requirements for surface disposal operations. These requirements mainly involve the maximum amount of heavy metals and other toxins that can be applied to the land (for all time) as well as VAR options, site restrictions and management practices that must be followed. A permit is required from the NMED-GWQB for all sludge surface disposal sites and ground water monitoring will most likely be required as part of the permit. Although it is not generally considered as environmentally friendly of an option as land application, surface disposal can be a safe and economical alternative when performed properly.

**Landfilling of Sludge**

Landfilling sludge is one of the least desirable options for sludge disposal; however, it is a common practice in New Mexico. It is undesirable because valuable landfill space is wasted on material that could be incorporated back into the soil as a benefit. Landfilling of sludge should only be practiced when economics or poor sludge quality make it practical. In order to landfill sludge, the NMED SWB requires that a sludge disposal plan be developed and that a hauler that is licensed to haul “special wastes” transport the sludge.

**References**

Office of Water Programs, California State University, Sacramento, *Operation of Wastewater Treatment Plants*, Volume II, 5th ed., Chapter 12
Office of Water Programs, California State University, Sacramento, *Operation of Wastewater Treatment Plants*, Volume III, 2nd ed., Title 40, Code of Federal Regulations part 503