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Biosolids
Technology Fact Sheet
Centrifuge Thickening and Dewatering

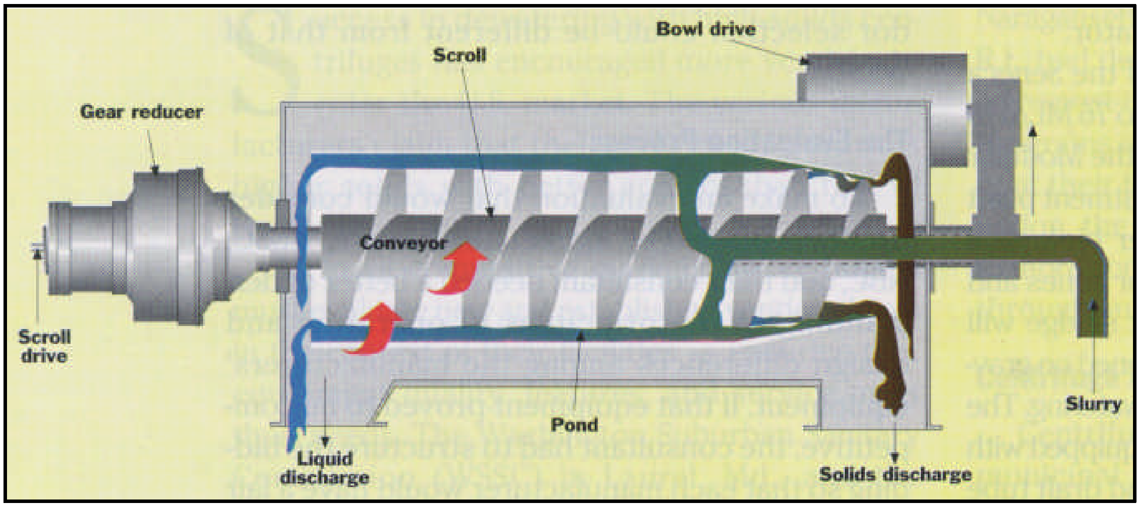
DESCRIPTION

Centrifugal thickening and dewatering is a high speed process that uses the force from rapid rotation of a cylindrical bowl to separate wastewater solids from liquid (U.S. EPA, 1987). Centrifuges have been used in wastewater treatment since the 1930s. Thickening before digestion or dewatering reduces the tankage needed for digestion and storage by removing water. Dewatering removes more water and produces a drier material referred to as "cake" which varies in consistency from that of custard to moist soil.

Dewatering offers the following advantages:

- Reduces volume, saving money on storage and transportation.
- Eliminates free liquids before landfill disposal.
- Reduces fuel requirements if the residuals are to be incinerated or heat dried.
- Produces a material, which, when blended with a bulking agent, will have sufficient void space and volatile solids for composting.
- Eliminates ponding and runoff, which can be a problem when liquid is land applied on the surface rather than injected.
- Optimizes air drying and many stabilization processes.

Centrifuges operate as continuous feed units which remove solids by a scroll conveyor and discharge liquid over the weir. The bowl is conical-shaped which helps lift solids out of the liquid allowing them to dry on an inclined surface before being discharged (Kemp, 1997). Figure 1 shows a typical centrifuge thickening and dewatering system.



Source: Ireland and Balchunas, 1998.

FIGURE 1 TYPICAL CENTRIFUGE THICKENING AND DEWATERING SYSTEM

Success in dewatering with high-solids centrifuges makes this equipment worthy of consideration. Although more expensive than other dewatering systems, centrifuges generally achieve a higher solids concentration. The most cost effective method of biosolids dewatering depends on many factors including plant size, the cost of further processing, end-use and disposal, odor control requirements, and space limitations.

APPLICABILITY

Thickening and dewatering systems can result in significant savings in the cost of biosolids storage, transportation, and end use or disposal. Thickening liquid biosolids from three to six percent total solids will reduce the volume by 50 percent. Thickening is often used before anaerobic digestion or lime stabilization to reduce the capital costs of stabilization equipment. Thickening before storage or transportation off site is also common but is not usually performed before conventional aerobic digestion because it is difficult to supply enough oxygen when total solids are greater than 2 percent.

Centrifuges may be used to thicken or dewater (U.S. EPA, 1987). The percent solids of the output can be varied by changing operational parameters. A wastewater treatment plant may want to recycle biosolids in liquid form on sunny days when the fields are open, while at other times they may wish to dewater biosolids for storage or disposal.

Like all dewatering equipment, centrifuges require a capital investment and labor to operate. Mechanical dewatering equipment may not be the most cost effective alternative for wastewater treatment plants operating at less than four million gallons per day (MGD). The selection of dewatering equipment should be based on the results of a site specific biosolids management plan which identifies processing, end use alternatives, and costs. It may be less expensive to haul liquids to another facility for dewatering and processing or disposal rather than installing dewatering equipment. Smaller facilities should evaluate non-mechanical dewatering methods, such as drying beds or reed beds. Nonetheless, centrifugal thickening can be cost effective for small plants.

Wastewater treatment plants that must landfill wastewater solids may benefit from the use of a centrifuge. Landfills require that biosolids contain no free liquids during a paint filter test (material of approximately 20 percent solids can usually pass this test). Facilities with beneficial use sites more than 30 minutes away may find it economical to dewater before land application.

ADVANTAGES AND DISADVANTAGES

Advantages

- Centrifuges may offer lower overall operation and maintenance costs and can outperform conventional belt filter presses.

- Centrifuges require a small amount of floor space relative to their capacity.

- Centrifuges require minimal operator attention when operations are stable .

- Operators have low exposure to pathogens, aerosols, hydrogen sulfide or other odors.

- Centrifuges are easy to clean.

- Centrifuges can handle higher than design loadings and the percent solids recovery can usually be maintained with the addition of a higher polymer dosage.

- Major maintenance items can be easily removed and replaced. Repair work is usually performed by the manufacturer.

Disadvantages

- Centrifuges have high power consumption and are fairly noisy.

- Experience operating the equipment is required to optimize performance.

- Performance is difficult to monitor because the operator’s view of centrate and feed is obstructed.

- Special structural considerations must be taken into account. As with any piece of high speed rotary equipment, the base must be stationary and level due to dynamic loading.

- Spare parts are expensive and internal parts are subject to abrasive wear.

- Start-up and shut down may take an hour to gradually bring the centrifuge up to speed and slow it down for clean out prior to shut down.

DESIGN CRITERIA

Centrifuges are sized on the basis of the weight or volume of biosolids to be dewatered. To determine the number and size of centrifuges needed, the following information is required:

- Amount of primary solids flowing through the plant per day.

- Amount of waste activated sludge produced per day.

- Seasonal variation in the quantity of solids produced.

- Volume of thickened solids to be dewatered per day.

- Estimate of the range of solids concentration in the feed solids.

- The hours per day and number of days per week of operation.

- Estimate of future increases in biosolids.

- Anticipation of changes in sewer discharges or operation that could alter biosolids quality, such as the organic matter content.

In addition to the above information, an effective biosolids management plan should provide excess capacity to ensure that all incoming biosolids can be dewatered during operating hours. Allowing for excess capacity also ensures that the plant will not experience a build-up of biosolids if a unit is out of service. If only one unit is planned, the plant should have an alternate program to remove biosolids in liquid form and haul them to an alternate processing site.

Automation can reduce the number and size of centrifuges required. A wastewater treatment plant staffed only one shift per day can operate an automated centrifuge 24 hours per day (Brady and Torpey, 1998; Matheson and Brady, 1998).

A poorly designed polymer system can result in high polymer costs and reduced centrifuge efficiency. Polymer systems should have sufficient mixing and aging capacity. It is also important to introduce and blend the polymer with the solids feed to provide sufficient contact and laminar (not turbulent) mixing.

Feed pumps that have been used successfully include adjustable speed progressive cavity pumps and rotary lobe pumps. These semi-positive displacement pumps supply consistent feed without destroying the effectiveness of the polymer (low sheer forces).

A high solids centrifuge incorporates wear resistant materials, faster bowl speed, deeper ponds, higher torque rating, and better controls to hold solids in the machine longer (Ireland and Balchunas, 1998).

The choice of dewatering technique and chemical polymer or salts will affect dewaterability and the potential for odor during further processing or recycling. The designer must relate plant processing to the potential for odor production during further processing and recycling. This factor has only recently been recognized as an important consideration during the design stage.

Odor complaints at wastewater treatment plants and end use sites can interfere with implementation of the most cost effective biosolids management options, so control measures should be included in design of dewatering facilities. Odor control is addressed in more detail in another fact sheet, but briefly, the methods include:

- Adding potassium permanganate or other oxidizing agent.

- Minimizing liquid storage prior to dewatering to less than 24 hours. The longer the biosolids are stored, the lower the pH, the higher the liquid ammonia concentration, and the higher the organic sulfide emissions.

- Conducting bench-scale and full-scale testing of liquid sludge to determine if combined storage of primary and waste activated sludges accelerates the deterioration of biosolids.

- Specifying polymers that are stable at elevated temperatures and pH. This is especially important at facilities using lime stabilization or high temperature processing such as heat drying, thermophyllic digestion, or composting.

Design specifications should include requirements for ancillary equipment for efficient operation of a centrifuge, including:

- Polymer mixing, aging, and feed systems.

- Liquid feed day tank.

- Liquid residuals feed pump.

- Odor control and ventilation.

- Conveyor and/or pump to move dewatered cake.

- An enclosed area to load trucks or containers.

PERFORMANCE

Manufacturers should be consulted for design and performance data early in the planning stage. These data should be confirmed with other operating installations and/or through pilot testing. Evaluation of equipment should consider capital and operating costs, including polymer, electricity, wash water, ventilation, and odor control. The operator can ensure system integration by requiring that the centrifuge feed pump and the polymer system be provided by a single supplier.

Feed rate, polymer dosage, and differential scroll speed can be adjusted during operation for optimum performance (Kemp, 1997). The use of polymers improves centrate clarity, increases capacity, improves the conveying characteristics of the discharged solids, and increases cake dryness (U.S. EPA, 1987).

Table 1 shows the range of performance of a centrifuge with various types of wastewater solids. The solids content for a blend of primary and waste activated sludge (WAS) will vary depending on the percentage of each type of solid. Wastewater solids with a higher percentage of primary can be dewatered to the higher end of the range of total solids cake. Wastewater solids with a higher percentage of WAS will probably dewater to the lower end of the range and require polymer to reach the higher end of the range.

Biosolids must be conditioned with polymers to ensure optimum performance. Polymer feed pumps should be designed to inject polymer at several locations to ensure flexibility, optimum performance, and biosolids/polymer effectiveness. The biosolids/polymer mixture should be gently mixed because turbulent conditions can sheer the floc, minimizing polymer effectiveness. Polymer dilution and aging systems should be large enough to optimize polymer usage.

The operator should be able to add potassium permanganate or other oxidizing agents to the system, for the following reasons:

- To destroy sulfides which cause odors at the dewatering facility and in the end product.

- To reduce polymer usage and increase biosolids cake solids.

- To reduce odors associated with biosolids cake.

TABLE 1 RANGE OF EXPECTED CENTRIFUGE PERFORMANCE

Type of Wastewater Solids	Feed %TS	Polymer lb/DTS	Cake %TS
Primary Undigested	4-8	5-30	25-40
WAS Undigested	1-4	15-30	16-25
Primary + WAS undigested	2-4	5-16	25-35
Primary + WAS aerobic digested	1.5-3	15-30	16-25
Primary + WAS anaerobic digested	2-4	15-30	22-32
Primary anaerobic digested	2-4	8-12	25-35
WAS aerobic digested	1-4	20	18-21
Hi-Temp Aerobic	4-6	20-40	20-25
Hi-Temp Anaerobic	3-6	20-30	22-28
Lime Stabilized	4-6	15-25	20-28

Source: Various centrifuge manufacturers; Ireland and Balchunas, 1998; Henderson and Schultz, 1999; Leber and Garvey, 2000.

Facilities of many different sizes are achieving some or all of the above benefits.

OPERATION AND MAINTENANCE

It is important to monitor operating parameters to achieve optimum performance. The operator should ensure that the biosolids are properly conditioned and observe the conditioned biosolids using jar tests. Operation and maintenance training should also be provided.

Centrifuge operations can be fully automated, but starting the bowl and putting feed into the machine are usually performed manually. Routine maintenance is relatively simple because it is usually performed by the manufacturer. A good grit removal system should be incorporated into the plant design in order to reduce abrasive wear.

Centrifuges are normally operated to obtain maximum solids concentrations, while maintaining a 95 percent solids capture. Operators can adjust the solids feed rate, polymer dosage, and differential scroll speed to optimize performance operators can judge performance by sampling the centrate stream and cake solids. As with all mechanical dewatering equipment, feeding from well-mixed digesters or day tanks is important for optimum operation.

Responsibilities of the centrifuge operator include polymer mixing, dosing and monitoring usage; observation of the feed and cake several times per day and adjustments, if necessary; and operation and lubrication of ancillary equipment, including feed pump and cake conveyor or pump.

It is important to keep records of all performance parameters including volume of biosolids fed to the centrifuge and chemicals used. A sample of the feed biosolids to the centrifuge, cake discharge, and centrate should be taken each shift and analyzed for total solids. Prior to shut down, the centrifuges should be emptied and the speed gradually reduced. The amount of labor is relative to plant size. A plant with a single centrifuge requires four to eight staff hours per day (including lab testing) whereas six to eight centrifuges could be operated with eight to ten staff hours per day. Large plants use less operating effort for dewatering (per ton of solids processed). Highly automated systems reduce labor requirements, but operators must have access to an instrumentation specialist to maintain the automation system.

COSTS

In the past, engineers believed that centrifuges had higher capital and operating costs than belt presses. However, recent innovations in equipment design and polymers, combined with increased concerns over odors and worker health, have changed the economics. The choice of the most economical equipment should be based on an economic analysis, bench testing, and the method of end use or disposal.

A centrifuge sized to process 750 pounds of solids per day in an eight hour shift will cost about $215,000. To install the equipment in an existing building with a polymer feed system and odor control will run about $650,000. Construction of a building, conveyor, and truck loading area are additional costs.

Polymer costs are lowest when the machinery is running at reduced capacity. Typical polymer conditioning costs for centrifugal dewatering range from $2.65 to $91.15 per million gallons of biosolids processed, with an average of $24 per million gallons. Permanganate adds about $1 per million gallons to the cost of dewatering. Costs vary widely depending on the source of the residuals. The polymer costs for raw primary solids may cost $12 per dry ton solids (DTS) whereas residuals that are difficult to dewater may cost $80/DTS. Overall operation and maintenance costs range from $65/DT to $209/DT (Bain, et al., 1999; Leber and Garvey, 2000; Rudolf,1992).

Capital costs of a centrifuge are more than a belt press but operation and maintenance can be less expensive depending on size of plant, cost of polymer, cost of labor, local electric rates, whether wash water is plant water or potable water, as well as other factors. The range of $65 to $209 does not include debt service and is based on documented actual operating costs.

REFERENCES

Other Related Fact Sheets

Alkaline Stabilization for Biosolids
EPA 832-F-00-052
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In-Vessel Composting
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September 2000

Land Application of Biosolids
EPA 832-F-00-064
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Odor Management in Biosolids Management
EPA 832-F-00-067
September 2000

Belt Filter Press
EPA 832-F-00-057
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Filter Press, Recessed Plate
EPA 832-F-00-058
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Other EPA Fact Sheets can be found at the following web address:
http://www.epa.gov/owmitnet/mtbfact.htm

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15. Sharples (R) Field Report 14: 32% Cake Daily at Ashbridges Bay.

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ADDITIONAL INFORMATION

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