United States
Environmental Protection
Agency

Biosolids Technology Fact Sheet

Gravity Thickening

DESCRIPTION

Thickening is the process by which biosolids are condensed to produce a concentrated solids product and a relatively solids-free supernatant. Thickening wastewater solids reduces the volume of residuals, improves operation, and reduces costs for subsequent storage, processing, transfer, end use, or disposal. For example, thickening liquid-solids (slurry) from 3 to 6 percent will reduce the volume by 50 percent.

There are several different methods for thickening biosolids, including dissolved air floatation (DAF), centrifugal thickening, gravity belt thickening, and gravity thickening. Gravity thickening uses the natural tendency of higher-density solids to settle out of liquid to concentrate the solids.

Gravity thickeners consist of a circular tank (usually with a conical bottom) that is fitted with collectors or scrapers at the bottom. Primary and/or secondary solids are fed into the tank through a center well, which releases the solids at a low velocity near the surface of the tank. The solids settle to the bottom of the tank by gravity, and the scrapers slowly move the settled, thickened solids to a discharge pipe at the bottom of the tank. A v-notch weir located at the top of the tank allows the supernatant to return to a clarifier. In addition, many systems also use a skimmer to collect and remove any floatables and grease that have accumulated at the top of the tank.

The biosolids concentration and thickening that occurs in the tank is achieved through three different settling processes, which include gravity

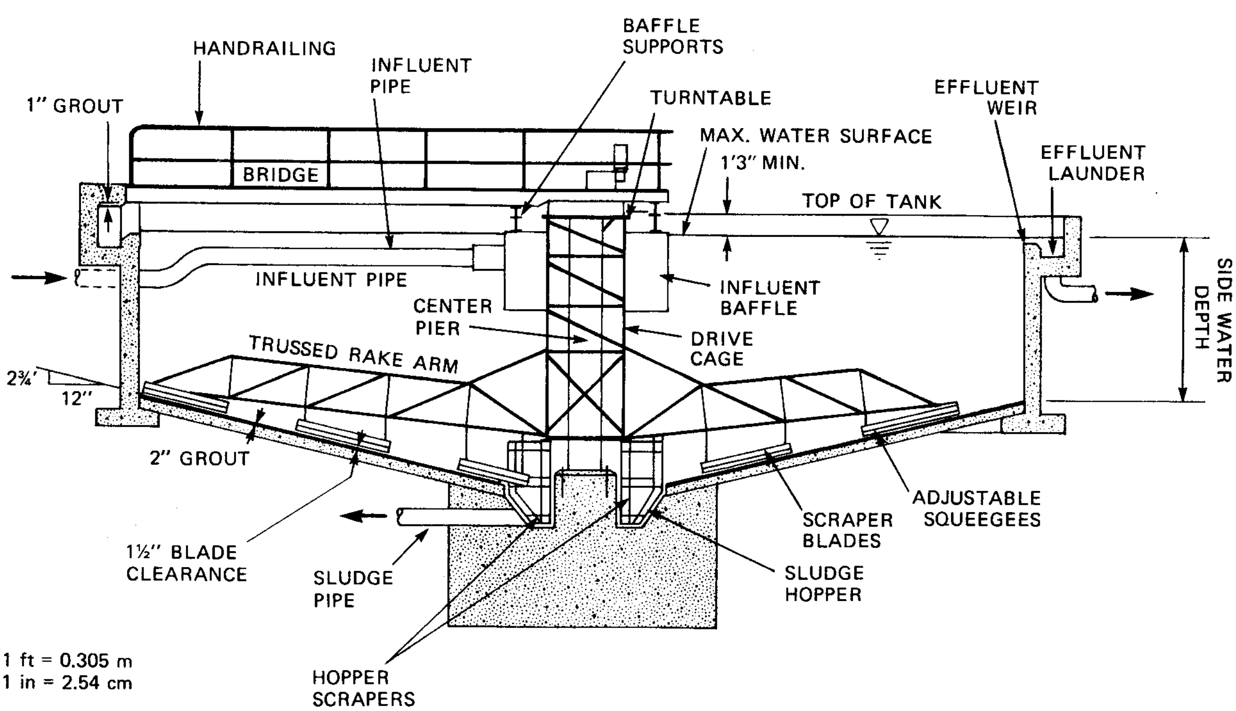

FIGURE 1 GRAVITY THICKENER

Source: U.S. EPA, 1987.

settling, hindered settling, and compaction settling. Gravity settling occurs when solid particles travel downward due to their weight. Settlement continues as solids begin to concentrate near the bottom of the tank, but the settlement rate decreases as the solids concentrations increase. This is known as “hindered settling.” Compaction settling occurs when bottom solids are further concentrated due to the pressure of solids on top of them.

Solids at the bottom of the tank can reach as high as 15 percent total solids (TS). A more typical result is 4 to 6 percent TS. Liquid at the surface of the tank is nearly clear, with suspended solids concentrations as low as 200 mg/L. The transition point between clear liquid and thickening solids that develops in the middle of the tank is called a "solids blanket."

APPLICABILITY

Solids thickening can prove beneficial at most wastewater treatment plants. However, solids thickening characteristics are unique to each wastewater treatment plant and facilities should develop a biosolids management plan to evaluate thickening technology options, including gravity thickening, DAF, centrifuge thickening, and gravity belt thickening. All of these technologies are commonly used, but they vary in performance criteria, such as solids concentration achieved, solids capture, odors, power demand, labor requirements, sensitivity to changing temperatures, and solids characteristics. In addition, pilot testing should be performed prior to design. Evaluation of gravity thickening as an option should include evaluation of the solids to be removed, as discussed below.

Primary solids are more easily thickened using gravity than are secondary solids. Primary solids tend to settle quickly and form a thick solids layer. The settled solids can be pumped out of the tank and do not require the addition of chemicals for extra thickening. Many field and laboratory tests have shown that introduction of waste activated solids with primary solids can aid in the settling process by increasing the retention time before the solids start to produce gas and rise to the surface. One potential disadvantage of this practice is that biosolids odor testing at some plants showed greater odors when primary and waste activated solids were co-thickened.

In contrast to primary solids, secondary solids have a large surface area per unit mass, which results in low settling rates and resistance to compaction. Thus, the use of gravity thickening alone usually cannot achieve the required thickening. Therefore, gravity thickening is usually accompanied by some other method of thickening for secondary solids.

Gravity thickening reduces the downstream requirements for further sludge processing, and thus it is often used prior to anaerobic digestion or lime stabilization. Historically, thickening was not employed prior to aerobic digestion because it was difficult to supply enough oxygen to the digestion process when the total solids content was greater than 2 percent. Recent improvements in aeration equipment have allowed some plants to aerobically digest 3-4 percent TS. Thickening prior to storage or transportation offsite is also common.

ADVANTAGES AND DISADVANTAGES

Advantages

- Gravity thickening equipment is simple to operate and maintain.

- Gravity thickening has lower operating costs than other thickening methods such as DAF, gravity belt or centrifuge thickening. For example, a well run gravity thickening operation will save costs incurred in downstream solids handlg steps.

In addition, facilities that land apply liquid biosolids can benefit from thickening in several ways, as follows:

- Truck traffic at the plant and the farm site can be reduced;

- Trucking costs can be reduced;
- Existing storage facilities can hold more days of biosolids production;
- Smaller storage facilities can be used;
- Less time will be required to transfer solids to the applicator vehicle and to incorporate or surface apply the thickened solids; and
- Crop nitrogen demand can be met with fewer passes of the applicator vehicle, reducing soil compaction.

Disadvantages

- Scum build-up can cause odors. This build-up, which can occur because of long retention times, can also increase the torque required in the thickener. Finally, scum build-up is unsightly.
- Grease may build up in the lines and cause a blockage. This can be prevented by quick disposal or a back flush.
- Septic conditions will generate sulfur-based odors. This can be mitigated by minimizing detention times in the collection system and at the plant, or by using oxidizing agents.
- Supernatant does not have solids concentrations as low as those produced by a DAF or centrifuge thickener. Belt thickeners may produce supernatant with lower solids concentrations depending on the equipment and solids characteristics.
- More land area is needed for gravity thickener equipment than for a DAF, gravity belt, or centrifuge thickener.
- Solids concentrations in the thickened solids are usually lower than for a DAF, gravity belt, or centrifuge thickener.

DESIGN CRITERIA

Preliminary Bench-Scale Study

If representative samples of wastewater solids are available, laboratory bench scale testing should be conducted to determine design parameters. This testing may be conducted by equipment manufacturers or consulting engineers. The pilot testing can help to determine:

- The optimum aspect ratio (depth and diameter) of the tank.
- The maximum detention time before septic conditions form gas bubbles and create floatation, which causes odors and inhibits gravity settling.
- The effectiveness of pickets (vertical bars on the bottom collector) in helping to vent gases from the biosolids, thus enhancing settlement.
- The effectiveness of polymer or oxidizing agents in improving settling and consolidation.
- The efficiency of thickening primary and secondary solids separately vs. thickening them together.
- The anticipated solids concentration after thickening and the design criteria for subsequent biosolids processing.

Specific Design Criteria

Nearly static conditions are required in gravity thickening tanks in order to induce settlement. Therefore, the tank design must ensure a smooth, continuous flow of liquid at the center well, the weirs, and the solids removal point. Gravity thickener designs usually include circular tanks, 3-4 m (10-13 ft) deep and up to 25 m (82 ft) in diameter. The dimensions are based on prediction of settling due to gravity alone. To assist solids transport, gravity thickener bottoms are constructed with a floor slope between 1:6 and 1:3. Rectangular units have been used as gravity thickeners. For example, obsolete rectangular clarifiers have been converted for use as gravity thickeners. However, rectangular units generally prove to be unsatisfactory.

Thickened solids are removed from the tank by pumping them from below the solids blanket. In some systems, an infrared (light path) blanket detector is used to determine when the blanket starts to rise. In other systems, the pumps are on timers, and thickened solids are drawn off at regular intervals.

Gravity thickeners are usually operated at collector tip speeds between 0.08-0.1 m/s (15 and 20 ft/min). This gentle action is intended to break down any matrix (flocs) that might form, while minimizing agitation and resuspension of the solids. However, moving the solids towards the discharge pipe at the bottom of the tank can require a large amount of torque. Therefore, gravity thickener mechanisms tend to be heavier in construction than clarifiers to compensate for these high torques. If high solids concentrations or high viscosities are anticipated, gravity thickeners may be supplied with a lifting mechanism, which raises the thickener collector arms above the solids blanket when torques are extremely high. As solids are removed from the tank and torque is reduced, the lift will lower the mechanism back into the solids blanket until it reaches its original position.

Gravity thickeners may be supplied with or without pickets, vertical pipes, or angles attached to the thickener arm. These devices can aid in releasing gas from the solids blanket, which reduces the potential for floating solids. This may be useful if the biosolids tend to gasify. However, there is concern that pickets may create eddy currents and disturb the static conditions needed for settling.

Thickened solids removal is best accomplished with positive displacement pumps, which should be located as close as possible to the solids draw-off point. The pumps should be positioned so as to create a positive head on the suction side (sometimes under the gravity thickener). Progressive cavity pumps may be used for draw-off, but they should only be used if there is efficient grit removal at the head of the plant, because grit can cause excessive wear on the pump's rotor and stator.

Ideally, solids removal will be done continuously. If solids removal is automated, the pump speed should be adjusted to maximize running time while maintaining good supernatant quality and avoiding "ratholing." Ratholing occurs if thickened solids are drawn off too quickly, and results in a cone of depression at the draw-off point. This phenomenon short-circuits the draw-off and results in poorly consolidated solids being removed, while concentrated solids remain in the tank.

There are two methods for handling in-house scum. The first option is pumping the skimmings to a digester or incinerator immediately after removal from the thickeners. The second option is pumping the skimmings to a thickener and consolidating them for subsequent handling. This can be difficult because gravity thickeners are rarely equipped with skimming equipment that is able to handle large amounts of scum - particularly accumulated scum that may have congealed and hardened.

PERFORMANCE

The operator can optimize thickening by monitoring the quality of the supernatant and the total solids concentration in the thickened solids, while also tracking feed rate, pumping times and rates, and solids blanket depth, and inspecting the tank surface for potential problems, including gas bubbles and odors. Gas bubbles cling to solid particles, increasing the solids' buoyancy and reducing their settling. Odors may be the result of septic conditions, which can also lead to the formation of gas bubbles. The operator should also check for turbulence in the tank. Turbulence can cause the solids to either miss the weirs, or to become unsettled.

Table 1 summarizes conventional gravity thickening performance for various types of wastewater solids. As shown in the table, the addition of chemicals may increase thickening. However, the effects on both solids and supernatant downstream processes must be considered. Metal salts of bacteriostatic agents may have inhibitory effects on the digestion process. The use of polymer in the thickener may have positive or negative effects on downstream dewatering.

TABLE 1 PERFORMANCE OF CONVENTIONAL GRAVITY THICKENING

Type of Solids	Feed (%TS)	Thickened Solids (%TS)
Primary (PRI)	2-7	5-10
Trickling Filter (TF)	1-4	3-6
Rotating Biological Contactor (RBC)	1-3.5	2-5
Waste Activated Solids (WAS)	0.2-1	2-3
PRI + WAS	0.5-4	4-7
PRI + TF	2-6	5-9
PRI + RBC	2-6	5-8
PRI + Lime	3-4.5	10-15
PRI + (WAS+ Iron)	1.5	3
PRI + (WAS+ Aluminum salts)	0.2-0.4	4.5-6.5
Anaerobically digested PRI + WAS	4	8

Source: WEF,1987.

Operators of gravity thickeners observe that operating with a high solids blanket results in better thickening. However, if operating at a higher blanket depth creates longer detention times, gases may begin to form. A reasonable detention time for primary solids is 24 to 48 hours. Combinations of primary and secondary solids may be retained between 18 and 30 hours.

Operators also observe that the highest solids concentrations are achieved during colder wastewater temperatures. Again, the reduction in biological activity prolongs the period before formation of gas bubbles.

Table 2 lists several other factors that may affect gravity thickener performance.

OPERATION AND MAINTENANCE

Operators should monitor operating parameters in the gravity thickener to ensure optimum performance. Routine monitoring should include the following:

- Sample the feed solids and the thickened solids once per day and analyze for TS. If thickened solids are not thick enough, it could be due to a high overflow rate, a high thickened solids pumping rate, or short circuiting of solids flow through the tank.
- Sample the supernatant once per day and analyze for SS.
- Sample the supernatant two times per week and analyze for BOD.
- Record the flow into the gravity thickener and the volume of solids removed.
- Record the type and amount of chemicals used.
- Measure the temperature in the thickener and the influent to the thickener once per shift.
- Record the depth of the solids blanket and note the transition in the solids liquid interface once per shift.

Weekly, monthly, and yearly maintenance should also be performed on the unit. Summaries of the recommended maintenance procedures are provided below.

Weekly Maintenance

- Check all oil levels and ensure the oil fill cap vent is open.
- Check condensation drains and remove any accumulated moisture.
- Examine drive control limit switches.

TABLE 2 FACTORS AFFECTING GRAVITY THICKENING PERFORMANCE

Factor	Effect
Nature of the solids feed	Affects the thickening process because some solids thicken more easily than others.
Freshness of feed solids	High solids age can result in septic conditions.
High volatile solids concentrations	Hamper gravity settling due to reduced particle specific gravity.
High hydraulic loading rates	Increase velocity and cause turbulence that will disrupt settling and carry the lighter solids past the weirs.
Solids loading rate	If rates are high, there will be insufficient detention time for settling. If rates are too low, septic conditions may arise.
Temperature and variation in temperature of thickener contents	High temperatures will result in septic conditions. Extremely low temperatures will result in lower settling velocities. If temperature varies, settling decreases due to stratification.
High solids blanket depth	Increases the performance of the settling by causing compaction of the lower layers, but it may result in solids being carried over the weir.
Solids residence time	An increase may result in septic conditions. A decrease may result in only partial settling.
Mechanism and rate of solids withdrawal	Must be maintained to produce a smooth and continuous flow. Otherwise, turbulence, septic conditions, altered settling, and other anomalies may occur.
Chemical treatment	Chemicals - such as potassium permanganate, polymers, or ferric chloride - may improve settling and/or supernatant quality.
Presence of bacteriostatic agents or oxidizing agents	Allows for longer detention times before anaerobic conditions create gas bubbles and floating solids.
Cationic polymer addition	Helps thicken waste-activated solids and clarify the supernatant.
Use of metal salt coagulants	Improves overflow clarity but may have little impact on underflow concentration.

Source: Parsons, 2003.

- Visually examine the skimmer to ensure that it is in proper contact with the scum baffle and the scum box.
- Visually examine instrumentation and clean probes.

Monthly Maintenance

- Inspect skimmer wipers for wear.
- Adjust drive chains or belts.

Yearly Maintenance

- Disassemble the drive and examine all gears, oil seals, and bearings.
- Check oil for the presence of metals, which may be a warning sign of future problems.
- Replace any part with an expected life of less than one year.

TABLE 3 CHEMICAL DOSE RATES

Type of Solids	$FeCl_3$ (mg/L)	CaO (mg/L)	K_2MnO_5 (mg/L)
Primary	1-2	6-8	10-40
Primary + tricking filter	2-3	6-8	10-40
Primary + WAS	1.5-2.5	7-9	10-40

Source: WPCF, 1987, WEF, 1996.

Chemical Addition

Chemical additives may be used to enhance performance and improve solids recovery and supernatant quality. Table 3 shows typical chemical dosages used in thickening. Polymer dosage will vary between 2.5-6 g/kg (5-12 lbs/ton) of dry solids.

Odor Control

Odors are frequently caused by long retention times or by attempts to store solids in the thickener. The principle producers of odors are hydrogen sulfide and ammonia, but odorous organics such as skatoles and indoles may be present. One mechanism for controlling odors is to increase the solids retention time in the activated solids system to produce less biologically active solids that generate fewer odors. Make-up water should be chlorinated to obtain a 1 mg/L residual in the supernatant for combating the formation of hydrogen sulfide. The presence of some dissolved oxygen in the thickener will reduce anaerobic activity that produces the most serious odor producing compounds. Other odor-reducing chemicals, such as ozone, potassium permanganate, chlorine, and hydrogen peroxide, may be effective, whereas efforts to chemically mask odors lead to unpredictable results. In worst cases, gravity thickeners may be covered with domes to contain the odorous atmosphere. The foul air can then be scrubbed using a commercially available odor control system.

Troubleshooting

Table 4 provides a listing of typical operating problems, their causes, and possible solutions.

COSTS

Any type of thickening equipment will have a significant capital cost. A biosolids management plan should be developed as part of a comprehensive economic analysis. It should identify both processing and end use or disposal alternatives. Odors at the processing facility and the end use locations should also be considered. If further processing, end use, and/or disposal costs can be reduced by thickening, the cost of construction, operation, and maintenance may be justified. Many smaller facilities find it more economical to haul thickened liquid to a larger wastewater treatment plant for dewatering than to install and operate their own dewatering equipment.

Capital costs for gravity thickeners vary based on the site conditions and the characteristics of wastewater solids. If the solids have poor settling characteristics, a larger tank and collector will be required. If pilot testing shows that solids are well suited to consolidation and compaction, the required tank may be smaller, but additional costs may be incurred for instrumentation and automation. Table 5 estimates construction costs based on data collected by the U.S. EPA during the construction grants program. Costs are adjusted for inflation.

Gravity thickening is a relatively inexpensive operation. Unit costs range from $0.30 to $3.00 per dry ton. Larger facilities (>100 MGD) will incur costs at the lower end of this range due to economies of scale. Operation and maintenance costs include power usage and mechanical maintenance. The addition of chemicals may add additional costs. Operator time can be reduced if instrumentation and automation are used. Table 6 estimates annual staff hours based on conventional thickener area.

TABLE 4 GRAVITY THICKENING TROUBLESHOOTING GUIDE

Indicators	Probable Cause	Check or Monitor	Solution
Septic odor, rising solids	Thickened solids pumping rate is too slow, thickener overflow rate is too low	Check thickened solids pumping system for proper operation, check thickener collection mechanism for proper operation	Increase pumping rate of thickened solids, increase influent flow to thickener-a portion of the secondary effluent may be pumped to thickener to bring overflow rate to 400-600 GPD/sq ft., chlorinate influent solids
Thickened solids not thick enough	Overflow rate is too high, thickened solids pumping rate is too high, short circuiting of flow through tank	Check overflow rate, use dye or other tracer to check for circulation	Decrease influent solids flow rate, decrease pumping rate of thickened solids, check effluent weirs: repair or re-level, check influent baffles: repair or relocate
Torque overload of solids collecting mechanism	Heavy accumulation of solids, foreign object jammed in mechanism, improper alignment of mechanism	Probe along front of collector arms	Agitate solids blanket in front of collector arms with water jets, increase solids removal rate, attempt to remove foreign object with grappling device, if problem persists drain thickener and check mechanism for free operation
Surging flow	Poor influent pump programming	Pump cycling	Modify pump cycling, reduce flow and increase time
Excessive biological growths on surfaces and weirs (slimes, etc.)	Inadequate cleaning program		Frequent and thorough cleaning of surfaces, apply chlorination
Oil Leak	Oil seal failure	Oil seal	Replace seal
Noisy or hot bearing or universal joint	Excessive wear, improper alignment, lack of lubrication	Alignment, lubrication	Replace, lubricate, or align joint or bearing as required
Pump overload	Improper adjustment of packing, clogged pump	Check packing, check for trash in pump	Adjust packing, clean pump
Fine solids particles in effluent	Waste activated solids	Portion of WAS in thickener effluent	Better conditioning of the WAS portion of the solids, thicken WAS in a flotation thickener

Source: WEF, 1987.

REFERENCES

Other Related Fact Sheets

Centrifugal Dewatering/Thickening
EPA 832-F-00-053
September 2000

Filter Belt Press Dewatering
EPA 832-F-00-057
September 2000

Land Application of Biosolids
EPA 832-F-00-064
September 2000

Odor Control at Biosolids Management Facilities
EPA 832-F-00-067
September 2000

TABLE 5 ESTIMATED CAPITAL COSTS FOR GRAVITY THICKENERS (ADJUSTED TO THE YEAR 2000)

Plant Capacity (MGD)	Construction Costs ($)	Construction+ Eng.&Adm.* ($)
2	162,000	199,000
4	348,000	426,000
8	745,000	914,000
15	1,488,000	1,825,000
20	2,042,000	2,504,000
25	2,610,000	3,200,000

Source: U.S. EPA, 1979
Eng.&Adm. = Engineering and Administration

TABLE 6 GRAVITY THICKENER LABOR REQUIREMENTS

Thickener Surface Area, sq. ft	Operation Labor, hr/yr	Maintenance Labor, hr/yr	Total
>500	310	180	490
>1000	350	200	550
>2000	420	240	660
>5000	680	370	1050

Source: WPCF, 1987.

Other EPA Fact Sheets can be found at the following web address: http://www.epa.gov/owm/mtb/mtbfact.htm.

1. Gabb, D., D.R. Williams, B.K. Horenstein, P.J. Suto, A.L Chacon, and E.H. McCormick, 1998. *Waste Activated Sludge Thickening: A Custom Fit for East Bay Municipal Utility District*. Water Environment & Technology.

2. Hentz, L. H., A.F. Cassel, and S. Conley, 2000. *The Effects of Liquid Sludge Storage on Biosolids Odor Emissions*. WEF Annual WEFTEC, 2000, Session 14.

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4. U.S. EPA, 1979. *Process Design Manual: Sludge Treatment and Disposal*. Environmental Protection Agency.

5. U.S. EPA, 1987. *Design Manual: Dewatering Municipal Wastewater Sludges*. Environmental Protection Agency.

6. Water Pollution Control Federation, 1987. *Operation and Maintenance of Sludge Dewatering Systems: Manual of Practice No. OM-8*. Water Pollution Control Federation, Water Task Force on Sludge Thickening, Conditioning, and Dewatering.

7. WEF, 1996. *Operation of Municipal Wastewater Treatment Plants*. WEF 5th ed., Vol. 3.

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