

CHAPTER 5: SLUDGE TREATMENT FACILITIES

5.1 INTRODUCTION

Sludge treatment processes are often the most difficult and costliest part of sewage treatment. Untreated sludge is odorous and contains pathogens. Sludge stabilisation process reduce odours, pathogens, and biodegradable toxins, as well as bind heavy metals to inert solids, such as lime that will not leach into the groundwater. The resulting biosolids can be used or disposed safely. The limiting concentrations of heavy metals and faecal coliforms in sludge are mentioned in Table 6.14 in chapter 6 of Part-A Manual. If these concentrations exceed those values then land application shall not be permitted and the sludge shall have to be disposed or contained as per the Hazardous Waste (Handling and Management) rules of MoEF.

Sewage residuals include primary, secondary, mixed, and chemical sludge, as well as screenings, grit, scum, and ash. The concentration and characteristics of chemical sludge depend on the treatment chemicals (alum, ferric salts, or lime) used. It is typically, found at treatment plants that have tertiary treatment, such as phosphorus removal. The use or disposal method for residuals depends on how much treatment they have received. Biosolids are residuals that have been stabilized can be beneficially used as a soil filler. Combustible residuals, such as screenings, may be incinerated or landfilled. Non-combustible residuals, such as grit, may be landfilled.

5.2 SLUDGE THICKENING

The role of sludge thickening is to thicken the sludge of low concentration generated in STPs, and to make subsequent processes such as sludge digestion and sludge de-watering more effective. Thickened sludge may be of two kinds: primary sludge generated in the primary settling tank and excess sludge generated in the secondary settling tank. Sludge thickening may be broadly classified into four types, gravity thickening, centrifugal thickening, floatation thickening and belt-type thickening.

When sludge thickening is inadequate, the efficiency of subsequent sludge treatment will reduce, but also centrate containing large amount of suspended solids will return to the STP and degrade the quality of the treated sewage. For this reason, excess sludge for which gravity thickening is difficult is increasingly being mechanically thickened using centrifugal thickening machines or floatation thickeners. When the water content of sludge is more especially, separation and thickening should be considered.

5.2.1 Gravity Thickening

Gravity thickening is the most common practice for concentration of sludge and concentrates sludge through simple gravity sedimentation of the suspended solids.

This is adopted for primary sludge or combined primary and waste activated sludge, but is not successful in dealing with activated sludge alone. Independently, gravity thickening of combined sludge is not effective when activated sludge exceeds 40% of the total sludge weight, and other methods of thickening of activated sludge have to be considered.

A gravity thickener is shown in Figure 5.1

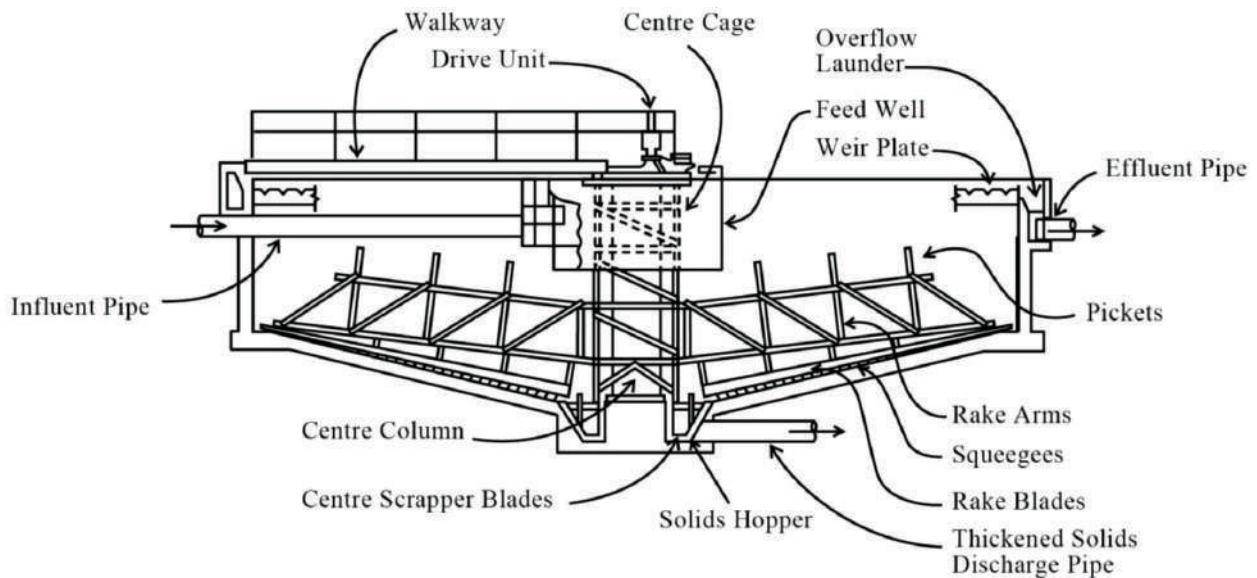


Figure 5.1 Example of a gravity thickener

Continuous flow tanks are deep circular tanks with central feed and overflow at the periphery. Better efficiencies can be obtained by providing slow revolving stirrers, particularly with gassy sludge.

It is necessary to ensure provisions for:

- Regulating the quantity of dilution water needed
- Adequate sludge pumping capacity to maintain any desired solids concentration, continuous feed and underflow pumping
- Protection against torque overload
- Sludge blanket detection
- Variable-speed drives may be used to increase rake speed to agitate the sludge blanket and release trapped gas bubbles. Prolonged operation at high speeds will reduce the ultimate solids concentration and reduce the life of the thickener drive mechanism.
- Scum removal equipment may include a skimmer and scum box. The ancillary equipment should include positive-displacement pumps (plunger, rotary lobe, diaphragm or progressing cavity pumps). Process control equipment includes sludge blanket indicators (light path, sonic, or variable-height taps), online process monitors on the feed or underflow, torque readouts on the rake drive, and timers to vary the pump on/off (or speed) sequences. In cold weather areas or areas where odours are a problem, thickeners are typically covered.

Gravity thickeners are either continuous flow or fill and draw type, with or without addition of chemicals. Use of slowly revolving stirrers improves the efficiency. Continuous flow tanks are deep circular tanks with central feed and overflow at the periphery.

5.2.1.1 Process Control

Greater attention to the thickener is required when thickening waste activated sludge because it has a large surface area per unit mass, resulting in low settling rates and resistance to being compacted.

Sludge tends to stratify in the gravity thickener while continuing biological activity, which includes the production of gases that can cause accumulated sludge to float.

Gravity thickener operation responds to changes in process temperatures; therefore, loading rates should be reduced to values at the lower end of the range when temperatures exceed 15 to 20°C, depending on the ratio of primary to secondary sludge. Higher temperatures will require additional dilution.

The following should be checked before and during operation:

- Avoid starting a thickener that contains accumulated sludge. To avoid overload, the sludge should be disposed of before starting the mechanism.
- Check and adjust the skimming mechanism to increase the amount of scum drawn into the scum box and to reduce the amount of supernatant carried with the skimming.

There are some types of thickener equipments where the entire rotating steam raker assembly can be raised initially to induce mixing only in the upper layers of sludge initially to avoid overloading the drive assembly once the mixing is induced for some time.

Thereafter the raker assembly is gradually lowered to the designed position.

5.2.1.2 Maintenance

- Visually examine the skimmer to ensure that it properly comes into contact with the scum baffle and scum box.
- Inspect skimmer wipers for wear.
- Install kick plates on the gravity thickener bridge to prevent objects from falling into the tank.
- An object lodged in the underflow discharge pipe or under the mechanism will quickly halt operation of the thickener. If an object falls into the tank, immediately halt thickener operation to prevent torque overload.
- During plant rounds, regularly observe and record the drive torque indicator, which is the best indicator of mechanical overload.
- Regularly check the underflow pump capacity because pumps wear rapidly in a thickened sludge operation.
- Follow the manufacturer's recommended lubrication schedule and use recommended lubricant types. Oil should typically be changed after the first 250 hours of operation and every 6 months thereafter.

5.2.2 Centrifugal Thickening

Thickening by centrifugation is chosen only when space is limited or sludge characteristics will not permit the adoption of other methods. This method involves high maintenance and power costs.

5.2.2.1 Configuration

Decanter centrifuges have a screw conveyor inside that transports the settled sludge along the bowl and out of the centrifuge. They thicken and de-water the sludge simultaneously.

In the centrifuge, the process is the same, varying only in degree. They use the principle of centrifugal force through the bowl assembly. Please see chapter 6 of part A manual for more details. They separate the liquids from solids based on the rotary speed.

5.2.2.2 Operation and Maintenance

All process devices benefit from a constant feed quality, and centrifuges are no exception. Common problems are varying ratios of primary to secondary sludge or feed material that has become septic. Septic sludge is more difficult to thicken than fresh sludge. Holding feed material in storage tanks under uncontrolled conditions is poor practice.

When in doubt, measure the pH drop through the storage.

The manufacturer generally sets the bowl speed. Assuming the present speed was the correct speed several years ago is not proof that it is the best speed now. The plant engineer should adjust the speed periodically, to confirm that it is correct and to remind operators that it is a variable.

It is a good policy to consult the manufacturer before changing the bowl speed.

A. Start-up

Most modern centrifuges have a one-button start. Manual systems take a few minutes, but are not difficult. The start-up sequence is as follows:

- Turn on the feed and polymer to about one-third of the normal rate.
- Reduce the differential revolutions per minute and/or pond to minimum.
- When the cake thickness reaches the normal value, begin increasing the differential and the polymer feed rate. Some plants can go directly to the normal operating condition as soon as the cake is sealed, while others have to ramp up more slowly.

B. Shutdown

Again, modern centrifuges have a one-button stop. The shutdown sequence is as follows:

- Shut off the feed and polymer and turn the flushing water on.
- When clear water exits both ends of the centrifuge, push the centrifuge stop button.

- At some point, as the centrifuge slows down, flush water will come around the feed tube or around the casing seals. Note how long it took between pressing the stop button and the water gushing out. Next time, shut the water off a minute or two sooner.
- With the flush water off, the centrifuge can usually come to a stop without operator intervention.

C. Sampling and Testing

Sampling and testing should include Total Suspended Solids (TSS), ammonia, and/or phosphorus (under some conditions) for centrate.

5.2.3 Air Floatation Thickening

Air floatation units employ floatation of sludge by air under pressure or vacuum and are normally used for thickening the waste activated sludge. These units involve additional equipment, higher operating costs, higher power requirements, and more skilled maintenance and operation. However, removal of grease and oil, solids, grit and other material and also odour control are distinct advantages.

In the pressure type floatation units, a portion of the subnatant is pressurised from 0.3 to 0.5 MPa and then saturated with air in the pressure tank. The effluent from the pressure tank is mixed with influent sludge immediately before it is released into the flotation tank. Excess dissolved air then rises up in the form of bubbles at atmospheric pressure attaching themselves to particles, which form the sludge blanket. Thickened blanket is skimmed off while the non-recycled subnatant is returned to the plant.

5.2.3.1 Configuration

Floatation thickeners are equipped with both surface skimmers and floor rakes. The surface skimmers remove floating material from the thickening tank to maintain a constant average float blanket depth. Floor rakes are essential for removing the non-floatable heavier solids that settle to the bottom of the floatation thickener. Most units are baffled and equipped with an overflow weir. Clarified effluent passes under an end baffle (rectangular units) or peripheral baffle (circular units) and then flows over the weir to an effluent launder. The weir controls the liquid level within the floatation tank with respect to the float collection box and helps regulate the capacity and performance of the floatation unit.

The saturation system typically includes a recycle pressurization pump, an air compressor, an air saturation tank, and a pressure release valve. Although the flow through the pressurization pump typically is recycle-flow, it can also be makeup water. The pressure release valve controls pressure loss and distributes the gas-saturated pressurized flow into the feed sludge as dissolved air emerges from the solution. The rapid reduction in pressure causes dissolved air (under pressure) to emerge from solution or “effervesce” into minute bubbles.

Other important equipment that forms part of an air floatation thickening system is the float handling and pumping system. After removal of the float from the air floatation thickening unit, float solids are deposited in a hopper and then pumped for further processing. This aspect of the operation requires special considerations because of the following characteristics of float solids:

The parameter that is manipulated by the operator to control the performance of a thickener is the effective drainage time. This parameter is controlled by:

- Adjustment of skimmer on-time,
- Adjustment of skimmer off-time, and
- Adjustment of skimmer speed.

5.2.3.2 Operation

A float total solid content of 4 % represents a typical minimum for floatation thickeners handling solids without primary sludge. Under optimum conditions, however, 5 to 6 % solids content can be expected.

Proper operation requires reducing variations of the feed rate and concentration. A feed sludge holding and mixing tank helps with intermittent operation.

Most units are operated continuously. Some are operated with a short period shut-down during weekends, while others are operated only during certain hours of the day.

The speed and the on-off times of the float skimmers should be set to maximize the float solids concentration, but should not be set too slow to cause excessive float-depth accumulation.

Dilution reduces the effect of particle interference on the rate of separation.

Concentration of the sludge increases and the concentration of effluent suspended solids decreases as the sludge blanket detention time increases.

A. Start-up

- Fill the tank with final treated sewage or plant non-potable water until overflowing.
- Continue the flow to the air floatation unit and engage the recycle system, including the compressor, if applicable. Adjust to proper pressures and flow and proceed after proper functioning.
- Ensure that the float and underflow pumps are functional by pumping some water.
- Prepare the polymer, if applicable, and engage the polymer addition at proper flow or as jar tests have indicated if starting after prolonged shutdown, start-up, or process changes.

B. Shutdown

- Stop polymer flow, if applicable, and at the same time stop waste activated sludge feed.
- If only down for a short time (30 minutes or so), there is no need to shut down the recycle system, including the compressor. If down for longer than this period shut down the recycle system.
- The float rake timer can be left on until most of the float is removed into the hopper and pumped for further processing.

- If the unit is going to be down for more than 24 hours, displace the tank contents with non-potable water or drain and clean the tank, all troughs, and pipelines.
- In a typical operation, only the recirculation pump and retention tank discharge valves are closed when stopping a unit's operation. All other valves remain open, with the exception of valves on drain lines.

5.2.3.3 Maintenance

- Checking all oil levels and ensuring that the oil fill cap vent is open.
- Checking all condensation drains and removing any accumulated moisture.
- Examining drive control limit switches.
- Visually examining the skimmer to ensure that it is in proper contact with the scum baffle and scum box.
- Inspecting skimmer wipers for wear.
- Adjusting drive chains or belts.
- Semi-annual inspections of major elements for wear, corrosion, and proper adjustment include:
 - Saturation systems - eductors (if used) or nozzles to be inspected for wear or cleaned whenever the efficiency begins to decline, or on a semi-annual basis;
 - Mechanical systems, including shaft bearings and bores, bearing brackets, baffle boards, flights and skimming units, suction lines and sumps, and sludge pumps.

5.2.4 Belt Type Thickening

Gravity belt thickeners work by filtering free water from conditioned sludge by gravity drainage through a porous belt. The gravity drainage area is usually horizontal but may be inclined under certain circumstances.

Chemical conditioning is generally required to flocculate the sludge and separate the solids from the free water. This may be accomplished by injecting the chemical through an injection ring and mixing it with the sludge. After chemical injection, the sludge velocity is reduced in a retention tank and the sludge is allowed to fully flocculate before overflowing by gravity onto the moving belt.

As the moving belt carries the sludge, plows clear portions of the belt for the filtrate to drain through and gently turn over the solids, thereby exposing more free water. Prior to the discharge, most gravity belt thickeners have some type of dam or an adjustable ramp.

The hydraulic capacity of the equipment is determined by multiple factors including sludge type, sludge concentration, polymer type and polymer dosage, belt speed, belt type, as well as the obvious machine width and length.

The gravity belt thickener is shown in Figure 5.2 overleaf.

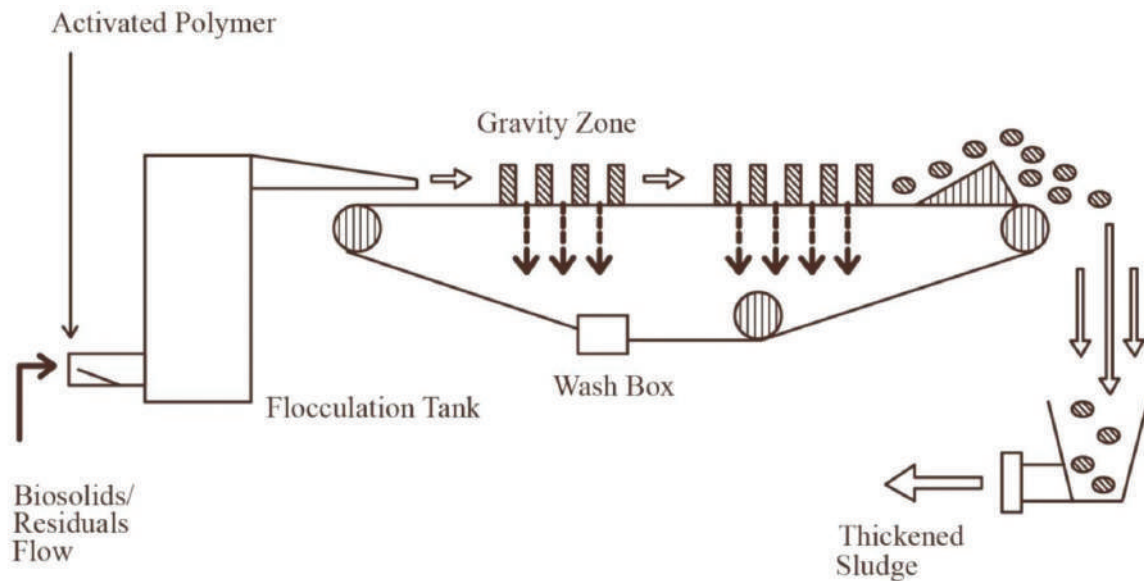


Figure 5.2 Gravity belt thickener process

5.2.4.1 Configuration

A. Polymer Addition

Polymer addition usually occurs by injection through a multiport injection ring; it is mixed with the sludge as it flows through an inline mixing device. In some cases, the polymer may be mixed mechanically in the retention tank. However, this generally results in higher polymer consumption.

B. Flocculation Tank

The flocculation tank allows the incoming sludge velocity to be reduced so that flocculation can fully occur before the sludge overflows onto the moving belt. Design of the tank is critical to prevent short-circuiting within the tank.

C. Belt and Supports

Belts are typically woven from polyester fibre. High pH and other unusual conditions may require special materials. The belt is supported on grid strips that also serve as wipers on the bottom of the belt. This wiping action increases the drainage capacity of the belt.

D. Belt Tensioning

Unlike a belt press, the performance of the belt thickener is not dependent on belt tension. Once the de-watering belt on a thickener is tight enough to prevent slippage on the drive roller, additional tension is unnecessary. Additionally, the belt tension on a thickener is not dependent on the type or amount of sludge loading. As such, the requirements for belt tension are much lower on a gravity belt thickener compared to a belt filter press.

Belt tension is a result of moving one roller closer to or further away from the other roller (s). This displacement may be through hydraulic, pneumatic, or mechanical actions. Once the belt is tensioned, it is not necessary to relax the tension until the belt is replaced.

E. Belt Drive

All belt thickeners have a variable-speed belt drive with a typical speed range of 8 to 40 m/min. The belt speed may be either mechanically or electrically varied with speed controls at the local control panel. Typically, the belt drive is attached to a rubber-coated drive roller.

F. Belt Tracking

During operation of a belt thickener, the belt should more or less remain in the center and not move laterally on the machine. Although the belt should not move, some type of belt tracking device is included on most machines. Comparatively, the belt on a belt thickener is similar to a conveyor belt; all tracking devices have some roots in the conveyor or paper making industry.

5.2.4.2 Operation and Maintenance

A. Start-up

- Start the hydraulic unit (or air compressor) and allow tension to develop in the belt.
- Start the belt drive and use an initial setting of approximately 20 m/min belt speed.
- Start the wash water pump and allow the belt to pre-wet.
- Start the polymer pump and allow the fresh polymer to reach the polymer injection point.
- After thickened sludge is available, start the thickened sludge pump (or the thickened sludge conveyor).

After the system is running, begin fine-tuning the process by adjusting the sludge flow, polymer dose, mixing energy, belt speed, and so on until the results are within the desired process parameters.

It is important to only adjust one item at a time and to allow time for the adjustment to take effect before making another change.

B. Shutdown

- Shut down sludge feed pump.
- Shut down polymer feed pump.
- As the thickened sludge hopper empties, shut down the thickened sludge pump (or thickened sludge conveyor).
- Drain the flocculation tank.
- Wash the machine down from top to bottom.
- Allow the belts to be completely washed (this could take 15 to 45 minutes) without sludge or polymer.
- Shut down the wash water pump.
- Shut down the belt drive.
- Shut down the hydraulic unit/air compressor.

C. Sampling and Testing

At a minimum, gravity belt thickeners should be sampled and analysed as follows:

- Sample influent feed for total solids, TSS, total volatile solids, pH, and flow.
- Sample wash water for TSS and flow.
- Sample thickened sludge for total solids and flow.
- Sample filtrate for TSS and flow.
- Measure flow and quantity of polymer used.
- Measure any dilution water used to make up polymer.

D. Process Control

Numerous variables affect the overall thickening process. Listed below are some of these variables:

- Sludge feed, polymer, dosage of polymer, mixing energy, retention time
- Belt speed, belt tension, belt type, ramp angle
- Upstream variables, slurry pump selection, solids concentration
- Biological sludge content, sludge storage time, wash water characteristics

5.3 ANAEROBIC DIGESTION

In anaerobic digestion, anaerobic bacteria thrive in an environment without dissolved oxygen.

Two major types of bacteria are present in the digester. The first group starts degrading the organic portion of the sludge to form organic acids and carbon dioxide gas. These bacteria are called acid formers. The second group breaks down the organic acids to simpler compounds and forms methane and carbon dioxide gas. These bacteria are called gas formers. The methane gas is usually used to heat the digester or to run engines in the plant. The production of gas indicates that organic material is being degraded by the bacteria. Sludge is usually considered properly digested when 50 % of the organic matter has been destroyed and converted to gas. The time taken is shown in chapter 6 of Part A manual.

Most digestion tanks are mixed continuously to bring the food to the organisms, to provide a uniform temperature, and to avoid the formation of thick, scum blankets. When a digester is not being mixed, the solids usually settle to the bottom, leaving a liquid known as supernatant above the sludge. In many plants, however, there is no separation of solids and liquids after two days of sitting without mixing due to the type of sludge. The supernatant is displaced from the tank each time a fresh charge of raw sludge is pumped. The displaced supernatant usually is returned from the digester back to the plant head-works and mixed with incoming raw sewage. Supernatant return should be slow to prevent over-loading or shock loading of the plant.

In most new plants, sludge digestion takes place in two tanks. The first or primary digester is mixed and sometimes the feed sludge is pre-heated and rapid digestion takes place along with most of the gas production.

In the secondary digester, the digested sludge and supernatant are allowed to separate, thus producing a clearer supernatant and better-digested sludge.

Digester sludge from the bottom of the tank is periodically removed for de-watering.

5.3.1 Digestion Types

Two different types in anaerobic sludge digestion process namely, Low rate and High rate, are used in practice. The basic features of these processes are shown in Figure 5.3.

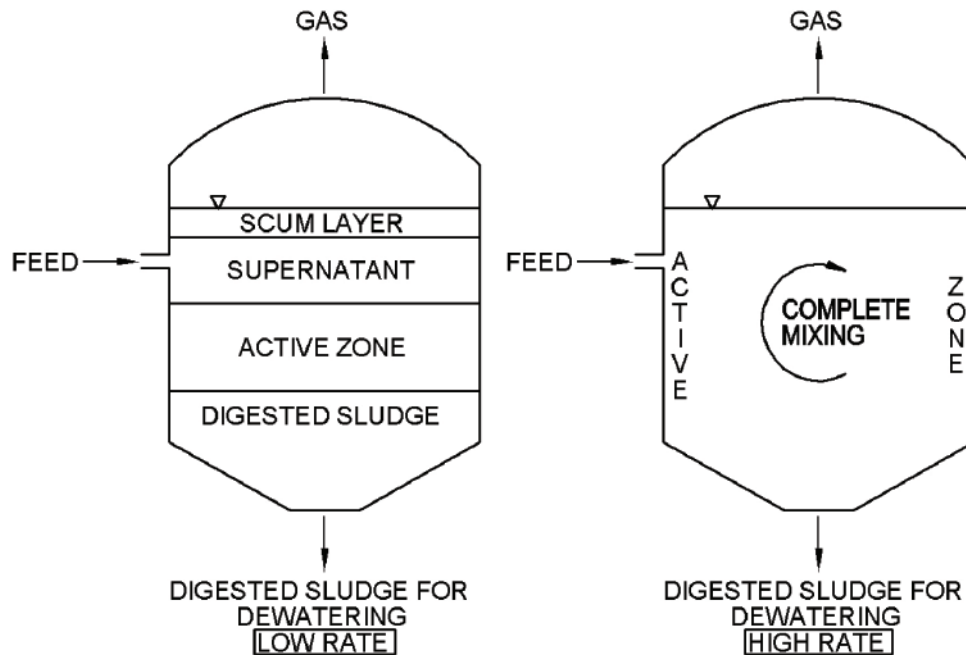


Figure 5.3 Sludge digestion system

5.3.1.1 Low Rate Digestion

Low rate digestion is the simplest and the oldest process; essentially a low rate digester is a large storage tank, occasionally, with some heating facility.

Raw sludge is fed into the digester intermittently. Bubbles of sewage gas are generated and their rise to the surface provides some mixing. In the case of few old digesters, screw pumps have been installed to provide additional intermittent mixing of the contents, say once in 8 hours for about an hour. As a result, the digester contents are allowed to stratify, thereby forming four distinct layers: a floating layer of scum, layer of supernatant, layer of actively digesting sludge and a bottom layer of digested sludge; essentially the decomposition is restricted to the middle and bottom layers.

The stabilized sludge, which accumulates and thickens at the bottom of the tank is periodically drawn off from the center of the floor.

The supernatant is removed from the digester and returned back to the STP.

5.3.1.2 High Rate Digestion

The essential elements of high rate digestion are complete mixing and more or less uniform feeding of raw sludge. Pre-thickening of raw sludge and heating of the digester contents are optional features of a high-rate digestion system. All these four features provide the best environmental conditions for the biological process and the net results are reduced digester volume requirement and increased process stability.

Complete mixing of sludge in high rate digesters creates a homogeneous environment throughout the digester. It also quickly brings the raw sludge into contact with microorganisms and evenly distributes toxic substances, if any, present in the raw sludge. Furthermore, when stratification is prevented because of mixing, the entire digester is available for active decomposition, thereby increasing the effective solids retention time.

5.3.2 Configuration

5.3.2.1 Anaerobic Digestion Tank

Anaerobic digestion tanks may be cylindrical or egg shape in shape. Most tanks constructed today are cylindrical. The floor of the tank is sloped so that sand, grit, and heavy sludge will tend to be removed from the tank. Most digesters have either fixed or floating covers.

A fixed cover digester may develop an explosive mixture in the tank when sludge is withdrawn if proper precautions are not taken to prevent air from being drawn into the tank. Each time a new charge of raw sludge is added, an equal amount of supernatant is displaced because the tank is maintained at a fixed level.

A floating cover moves up and down with the tank level and gas pressure. Normally, the vertical travel of the cover is about 2.5m, with stops (corbels) or landing edges maximum water level is controlled by an overflow pipe that must be kept clear to prevent damage to the floating cover by overfilling. Gas pressure depends on the weight of the cover. The advantages of a floating cover include less danger of explosive mixtures forming in the digester, better control of supernatant withdrawal, and better control of scum blankets. Disadvantages include higher construction and maintenance costs.

5.3.2.2 Agitator

Propeller mixers are found mainly on fixed cover digesters. Normally, two or three of these units are supported from the roof of the tank with the propeller blades submerged 3 to 3.5 m in the sludge. An electric motor drives the propeller stirring the sludge. The various types of mixers are described in chapter 6 of Part A manual. Digested sludge may contain some debris depending on the efficiency of screen and grit removal in the STP. This unit usually has reversible motors so the propeller may rotate in either direction. In one direction the contents are pulled from the top of the digester and forced down the draft tube to be discharged at the bottom. By operating the motor in the opposite direction, the digested sludge is pulled from the bottom of the tank and discharged over the top of the draft tube to the surface. Reversible motors also assist in minimizing accumulations of rags on the propeller.

If two units are installed in the same tank, an effective way to break up a scum blanket is operating one unit in one direction and the other unit in the opposite direction, thereby creating a push-pull effect. The direction of flow in the tubes should be reversed every day.

A limitation of draft tube-type mixers is the potential formation of a scum blanket. If the water level is maintained at a constant elevation, a scum blanket forms on the surface. The scum blanket may be a thick layer and the draft will only pull liquid sludge from under the blanket, not disturbing it. Lowering the level of the digester to just 7 –10 cm over the top of the drain tube forces the scum to move over and down the draft tube. This applies mainly to single-direction mixers.

Pumps are sometimes used to mix digesters. This method is common in smaller tanks. The tank may or may not be equipped with a draft tube positioned in such a way that the pump suction may be from the top or through valve from the bottom of the digester. Control of scum blankets with this method of mixing depends on how the operator maintains the sludge level and where the pump is pulling from and discharging to the digester. Pressure gauges should be installed on the pump suction and discharge pipes. A change in pressure could indicate that the pump is not functioning properly and the desired mixing may not be taking place in the digester.

5.3.2.3 Digester Gas Equipment

A. Gas Tank

Several types of gas storage are available. The most common means of low-pressure gas storage is the floating gas-holder cover. Membrane storage can be installed either on the digester, to serve both as cover and storage space, or on the ground as a standalone structure.

B. Flow Meter

Gas production is a measure of digester performance. Reliable monitoring equipment alerts plant operators to process malfunctions and gas leaks. The flow meters used for gas monitoring can be broadly classified as positive-displacement, thermal-dispersion and differential pressure flow meters.

Separate flow meters are recommended for each digester because digester gas-production rates vary. Separate flow meters are also recommended to monitor gas use by the utilization equipment. The gas may contain moisture and impurities, which may cause maintenance problems for the metering devices. The gas system safety and control devices are listed in Table 5.1 overleaf. The gas flow indication and metering are listed in Table 5.2 overleaf.

5.3.2.4 Gas Scrubbers

A. Foam and Sediment Removal

Many systems are equipped with sediment traps and foam separators for cleaning the digester gas. These devices provide a “wide spot” in the gas piping system for slowing velocities, collecting foam and particulates entrained in the gas, and removing collected condensate. The foam separator is a large vessel with an internal plate fitted with water nozzles that provide a continuous spray.

Table 5.1 Gas system safety and control devices

Type	Application	Operation and maintenance
Flame traps (large pipe) and flame check valves (small piping)	Used to stop flame propagation in a pipe. Flame traps are installed with thermal shutoff valves as noted below. Installed on gas supplies to engines, compressors, boilers, flares, or other sources of ignition. Also used on digester covers with pressure- and vacuum-relief valves.	Require periodic cleaning, typically monthly. May require insulation and heating in cold climates to prevent ice formation. Foam will blind the devices, rendering other devices, particularly relief valves, ineffective.
Thermal shutoff valves	Spring-loaded or pressure-operated isolation valves that trip and shut off at flame temperatures. Must be installed between flame trap and source of ignition.	Replace element periodically or when tripped. Usually includes an indicator to show that the valve has tripped. May require insulation and heating in cold climates to prevent ice formation.
Pressure- and vacuum relief valves	Provided for all digester covers to prevent over pressurization or vacuum conditions in the digester. Typically adjustable, weighted valves, built as common unit. Should be set below design limits of cover. Typically two sets provided for each cover to allow servicing of one set while keeping digester in service. Typically discharge to area around valves. Available with pipe to allow discharge away from valves.	Check seals periodically; replace if leaks develop. May require insulation and heating in cold climates to prevent ice formation. Relief valves are last safety measure for digester covers to prevent over pressure or vacuum. These valves do not provide liquid relief.
Back pressure valves	Typically provided with waste gas flares. Maintain pressure upstream by relieving overpressure to flare. Usually uses weights to set relief pressure; however, some use springs. Upstream sensing line should ideally be in gas collection piping header, away from the valve and large enough to reduce the potential for clogging.	Frequent maintenance required to prevent sticking (open or closed). These valves regulate pressure in the gas-collection piping system and are the first level of protection for over pressurization of the digester cover.

Type	Application	Operation and maintenance
Low-pressure check valves	Used to prevent backflow of gas. Typically constructed with leather or flexible flap to ensure operation at low pressure. Not commonly used.	Check flap and replace if not functioning.
Waste gas flare or burners	Provided to dispose of surplus gas. Usually provided with standing pilot or electronic ignition.	Provided for all plants to serve as a means of suitable disposal of gas. Untreated gas should not be freely released.
Open pipe or "candle flare"	Used for smaller plants and where stringent air-emissions control is not needed. Generally visible flame, gas disposal device.	Good pilot-gas supply is needed (may require natural gas or propane supply). Heat and corrosion make periodic replacement necessary. Pilot system requires frequent servicing.
Controlled combustion flare, ground flare, or emissions controlled flare	Used at plants where stringent air emissions are required and visible flame is not desired. Control air supply to maintain sufficient temperature to completely burn gas. These flares must be operated at a specific temperature to achieve emission limits. If oversized, auxiliary fuel may be required; this increases operating costs.	Require periodic system maintenance for controls and air blowers.
Pressure indication	Manometers used for low pressure. Gauges used for higher pressures, particularly for gas utilization lines.	Periodically clean manometers, replace fluid, and calibrate gauges. Pressure gauges should be provided with an isolating diaphragm to prevent gas contaminants from fouling the mechanism.

Source: WEF, 2008

Table 5.2 Gas-flow indication and metering

Type	Application	Operation and maintenance
Positive displacement	Used in many plants. Large devices that require bypasses when servicing. Accurate gas measurement unless dirty. Does not require u/s and d/s straight-pipe sections for accuracy.	Somewhat tolerant of dirty gas. Requires periodic cleaning and rebuilding.
Thermal dispersion insert	Increasingly used technology because of tolerance to dirty gas and simple installation. Accurate for low flows. Some accuracy problems with zero flow, such as for flares. Requires some upstream and downstream straight-pipe distances for accuracy. Can be inserted and removed through ball valve.	Smaller than most metering devices. Requires periodic cleaning of probe. Must not have liquid impinging on probe. No bypass needed, reducing need for piping and isolation valves to service.
Pressure differential orifices and Venturi	Commonly used in older plants. Upstream and downstream straight piping sections needed.	Requires frequent cleaning when used for dirty gas. Accuracy depends on instrument cleanliness. Can significantly constrict gas flow when fouled.

Source: WEF, 2008

The foam and sediment laden gas enters the vessel near the top and travels down through the spray wash under the baffle wall and up through a second spray wash, exiting the vessel through an elevated discharge nozzle. The spray wash and the internal plate reduce foam in the gas to prevent carryover to gas utilization equipment.

B. Hydrogen Sulphide Removal

The generation of hydrogen sulphide can also be inhibited by using ferric chloride injection into the digester. But this is usually very difficult as handling ferric chloride is not easy because it is very acidic and reactions with skin can be troublesome. Injection of ferric chloride can however be used as a temporary measure when sulphates in raw sewage become very high in drought situations when the population may use a lot of hard water for many purposes other than drinking, and which may increase the sulphate in raw sewage. Iron salts can be added at the following locations in the treatment process:

- The primary clarifier (helps settling and improves overall facility odour control)
- The suction side of the digester sludge-recirculation pump
- The forward side of a mechanical mixer

Iron salts should not be added directly upstream from the heat exchangers because this can result in deposits of vivianite on heat exchanger surfaces.

Refer to section 6.4.15.3 of the Part-A manual for the methods in use in India for removing hydrogen sulphide from digester gas.

C. Moisture Reduction

Moisture is condensed from digester gas as it cools. Gas piping should have a slope of at least 1% toward the condensate collection point. To effectively remove the moisture, the gas flow should not exceed 3.7 m/s countercurrent to condensate flow.

The condensate is collected in traps that should be located at low points in long pipe runs and wherever gas is cooled. Drip taps, which can be controlled manually or automatically, provide a convenient and safe means for removal of accumulated condensate. Manually operated drip taps are recommended for indoor applications. Float-controlled, automatic drip taps are also available, but these require frequent maintenance to keep the valves operating. Should the float stick, gas can escape to the surrounding atmosphere, which limits their use to outdoor installations (where permitted by local codes and safety considerations).

D. Carbon Dioxide Removal

Carbon dioxide can be removed from the digester gas by water or chemical scrubbing, carbon sieves, or membrane permeation; however, all of these technologies are expensive and their use may be cost-effective only if the gas is to be used for power generation.

E. Siloxane Removal

Siloxanes are components of toiletries and personal care cosmetics such as sprays, deodorants, lipsticks, gels, lotions, shaving creams, cleaning fluids, and so on. Their use is growing every year. Not much data is available on their removal in STPs. It has been reported that siloxanes find their way in digester gas. The concern is in cold climates, if digesters are to be heated to maintain temperature of about 35°C, silicon dioxide deposits on the heat exchanger tubes, which reduces heat transmission. Hence, it becomes necessary to protect equipment from siloxanes. This problem can occur also when digester gas is burned in gas engines. However, this has not been reported as a serious problem in digester gas usage in India. A typical photograph is shown in Figure 5.4



Source : Internet

Figure 5.4 Silicon dioxide deposits on boiler tubes

F. Activated Carbon Scrubbers

Activated carbon scrubbers can be used to remove siloxanes from digester gas according to the same principles as the carbon scrubbers used for odour control in STPs. The digester gas is passed through a vessel filled with activated carbon, which captures the organics, including siloxanes, hydrogen sulphide, and several other compounds in digester gas. With proper maintenance and replacement of the carbon, the siloxanes in the digester gas can be removed to less than detection limits. However, activated carbon is not selective with regard to siloxanes and will remove other compounds as well. Consequently, if the digester gas contains other organics, the carbon will require frequent replacement. In India, the coconut shell activated carbon is locally available and is economical. Removal of hydrogen sulphide before it passes through the carbon scrubbers will provide better siloxane removal and extend the life of the carbon bed.

5.3.2.5 Gas Power Generator

Refer to Sec.6.2.4 of the Part B Manual “Gas Engines”.

5.3.3 Operation and Maintenance

5.3.3.1 Feeding Schedule

Uniformity and consistency are keys to digester operation. Sudden changes in feed solids volume or concentration, temperature, composition, or withdrawal rates will inhibit digester performance and may lead to foaming. The ideal feeding procedure is a continuous, 24-hour-per-day addition of a blend of different types of feed solids (primary and WAS). Where continuous feeding is impossible, a 5 – 10min/h feed cycle is used. Smaller STPs that operate a single 8-hour shift use a schedule of at least three feedings: at the beginning, middle, and end of the shift. Typical causes of organic overloads include the following:

- Starting the digester too rapidly
- Excessive volatile solids loading as a result of erratic feeding or a change in feed solids composition
- Volatile solids loadings exceeding the daily limits by more than 10%,
- Loss of active digester volume because of grit accumulation, and
- Inadequate mixing

5.3.3.2 Withdrawal Schedule

Solids should be withdrawn from the primary digester immediately prior to feeding raw sludge to prevent short-circuiting. In digesters with surface overflow, the timing and rate of solids withdrawal and feed are coordinated to occur concurrently. Solids should be withdrawn at least daily to avoid a sudden drop in the active microorganism population. The primary digester may be regulated to simply overflow to the secondary digester or to the digested sludge storage tank as raw sludge is added. Solids may be withdrawn from the following locations:

- The bottom of the digester
- The overflow structure
- Any point within a well-mixed digester

A benefit of removing solids from the bottom of the digester is that it may also remove the grit that accumulates on the bottom of the digester. If possible, solids removal should be performed periodically.

It is important to recognize that because digestion destroys volatile solids, the concentration of the biosolids removed from the digester will be lower than the feed concentration unless the digester is decanted.

5.3.3.3 Scum Control

Scum accumulation in digesters is common. Scum is a combination of undigested grease & oil and often contains buoyant materials, such as plastics that are not removed at the plant's headworks. Scum floats on the digester liquid surface and can accumulate, forming a dense mat. Properly designed and operated digester mixing systems can typically blend the scum into the tank contents. If the digester operates without mixing for longer than 8 hours, scum may rise and float on the liquid surface. After mixing is restarted, the scum is re-suspended within the liquid. The primary method of scum control is to keep the digester mixing system well-maintained during operation.

5.3.3.4 Precipitate Formation and Control

The digestion process can produce crystalline precipitates that affect both the digestion system and downstream solids-handling processes. The precipitates can accumulate on pipes and de-watering equipment, causing damage and blockages and requiring costly and time-consuming maintenance. Common precipitates include struvite, vivianite and calcium carbonate. The constituents that form these precipitates are present in undigested sludge and are released during the digestion process and converted to soluble forms that can react and crystallize. Their formation varies from site to site, depending on the chemistry of the digested sludge and the treatment processes. Because precipitates preferentially form on rough or irregular surfaces, glass-lined sludge piping and long-radius elbows help minimize their accumulation.

5.3.3.5 Digester Upsets and Control Strategies

The four basic causes of digester upsets are hydraulic overload, organic overload, temperature stress and toxic overload. Hydraulic and organic overloads occur when the design hydraulic or organic loading rates are exceeded by more than 10% per day. The overload conditions can be controlled by managing digester feeding, as well as ensuring that the effective digester volume is not diminished by grit accumulation or poor mixing.

Digester feeding is controlled by proper operation of upstream headworks, clarifiers, and thickeners to ensure the feed sludge concentrations. In the event of a digester upset, an effective control strategy includes the following steps:

- Stop or reduce sludge feed
- Determine the cause of the imbalance
- Correct the cause of the imbalance
- Provide pH control until the treatment returns to normal

If only one digester tank is affected, the loading on the remaining units can be carefully increased to allow the upset unit to recover. If overloading is affecting several units, reducing the feed will require a method of dealing with the excess sludge by hauling it to another facility, providing temporary storage on site, or chemically stabilizing and disposing of the sludge.

5.3.3.6 Temperature

Temperature-related stress is caused by a change in digester temperature of more than 1 or 2°C in less than 10 days, which would reduce the biological activity of the methane-forming microorganisms. If the methane formers are not quickly revived, the acid formers, which are unaffected by the temperature change, continue to produce volatile acids, which will eventually consume the available alkalinity and cause the pH to decline.

The most typical causes of temperature stress are overloading sludge and exceeding the instantaneous capacity of the heating system. Most heating systems can eventually heat the digester contents to the operating temperature, but not a harmful temperature variation.

5.3.3.7 Toxicity Control

The anaerobic process is sensitive to certain compounds, such as sulphides, volatile acids, heavy metals, calcium, sodium, potassium, dissolved oxygen, ammonia and chlorinated organic compounds. The inhibitory concentration of a substance depends on many variables, including pH, organic loading, temperature, hydraulic loading, the presence of other materials, and the ratio of the toxic substance concentration to the biomass concentration.

5.3.3.8 pH Control

The key to controlling the digester pH is to add bicarbonate alkalinity to react with acids and buffer the system pH to about 7.0. Bicarbonate can be added directly or indirectly as a base that reacts with dissolved carbon dioxide to produce bicarbonate. Chemicals used for pH adjustment include lime, sodium bicarbonate, sodium carbonate, sodium hydroxide, ammonium hydroxide and gaseous ammonia. Lime addition can be messy and will produce CaCO₃. Although ammonia compounds can be used for pH adjustment, they may cause ammonia toxicity and increase the ammonia load on the liquid treatment processes through return streams.

Consequently, their use is not recommended.

Sodium salts will not cause precipitates.

During a digester upset, volatile acid concentrations may begin to rise before bicarbonate alkalinity is consumed. Because pH depression does not occur until alkalinity is depleted, it may be observed only after the digester is well on its way to failure.

5.3.3.9 Digester Foaming

Digester foam consists of fine gas bubbles trapped in a semi-liquid matrix with a specific gravity of 0.7 to 0.95. The gas bubbles are generated below the sludge layer and are trapped as they form. While some foaming always occurs, it is considered excessive if it plugs piping or escapes from the digester. Excessive foaming can cause the loss of active digester volume, structural damage, spillage and damage to the gas-handling system, as well as being malodorous and unsightly. The most common cause of digester foaming is organic overload, which results in the production of more VFAs (volatile fatty acids) than can be converted to methane. The acid formers (which release carbon dioxide) work much more quickly than the methane-forming microorganisms. The resulting increase in carbon dioxide typically increases foam formation. Factors that can contribute to organic overload include:

- Intermittent digester feeding
- Separate feeding or inadequate blending of primary sludge and waste activated sludge
- Insufficient or intermittent digester mixing
- Excessive amounts of grease or scum in digester feed (especially problematic if the digester is fed in batches)

Organic overload can be minimized by feeding the digesters continuously (or as often as possible), blending different feed sludge well before feeding, ensuring that the digester-mixing system is operable, and limiting the quantities of grease or scum in the digester feed.

5.4 SLUDGE DE-WATERING

Most of the digested primary or mixed sludge can be compacted to a water content of about 90% in the digester itself by gravity but mechanical de-watering with or without coagulant aids or prolonged drying on open sludge drying beds (SDBs) may be required to reduce the water content further. The de-watering of digested sludge is usually accomplished on sludge drying beds, which can reduce the moisture content to below 70%. But excess oil or grease in the sludge will interfere with the process. Where the required space for sludge drying beds is not available, sludge conditioning, followed by mechanical de-watering on centrifugation, belt press, filter press, screw press, rotary press and vacuum filters is the better choice.

5.4.1 Chemical Dosing Equipment

5.4.1.1 Coagulant

Chemical conditioning is the process of adding certain chemicals to enable coalescence of sludge particles facilitating easy extraction of moisture. The chemicals used are ferric and aluminium salts and lime, the more common being ferric chloride with or without lime.

Digested sludge, because of its high alkalinity exerts a huge chemical demand and therefore the alkalinity has to be reduced to effect a saving on the chemicals. This can be accomplished by elutriation. Polyelectrolytes show promise for sludge with finely dispersed sludge. The choice of chemical depends on pH, ash content of sludge, temperature and other factors.

Optimum pH values and chemical dosage for different kinds of sludge have to be based on standard laboratory tests. The dosage of ferric chloride and alum for elutriated digested sludge is of the order of 1.0 kg/m³ of sludge. Alum, when vigorously mixed with sludge, reacts with the carbonate salts and releases CO₂, which causes the sludge to separate and water drains out more easily. Hence for effective results, alum must be mixed quickly and thoroughly. Alum can be easier if used as Poly Aluminium Chloride (PAC) or Poly Aluminium Sulphate (PAS) as these can be used as true solutions with dosing pumps. The alum floc, however, is very fragile and its usefulness has to be evaluated as compared with ferric chloride before resorting to its application.

Feeding devices are necessary for applying chemicals; the mixing of chemicals with sludge should be gentle but thorough, taking not more than 20 – 30 seconds. Mixing tanks are generally of the vertical type for small plants and of the horizontal type for large plants. They are provided with mechanical agitators rotated at 20 – 80 rpm.

A. Inorganic Chemicals

Inorganic chemical conditioning is associated principally with vacuum and pressure filtration de-watering. The chemicals typically are lime and ferric chloride. Ferrous sulphate, ferrous chloride, and aluminium sulphate are also used, although less commonly.

i. Ferric Chloride

Ferric chloride solutions typically are used at the concentration received from the supplier (30 to 40%); however, some STPs dilute the ferric chloride to approximately 10% to improve mixing and reduce the acidity and corrosivity of the material. This can be done in day tanks or inline. Dilution may lead to hydrolysis reactions and the precipitation of ferric chloride crystals.

An important consideration in the use of ferric chloride is its corrosive nature. It reacts with water to form hydrochloric acid, which attacks steel and stainless steel. When diluted with sludge, the acidity is neutralized by the alkalinity of the sludge and thoroughly diluted so that the end product is quite benign. Interlocks must be used to ensure that ferric chloride is always added to sludge in the proper ratio and is never pumped into sludge lines or process equipment by itself.

Special precautions must be taken when handling this chemical. The best materials are epoxy, rubber, ceramic, polyvinylchloride and vinyl. Contact with the skin and eyes must be avoided. Rubber gloves, face shields, goggles and rubber aprons must be used at all times. Ferric chloride can be stored indefinitely without deterioration. Customarily, it is stored in above ground tanks constructed of resistant plastic and surrounded by a containment wall. Ferric chloride can crystallize at low temperatures, which means that the tanks must be kept indoors or appropriately warmed.

ii. Lime

Vacuum filters and filter press commonly use lime and ferric chloride to make the sludge easier to filter and improve the release of the sludge from the filter media. Lime is available in two dry forms—quicklime (calcium oxide) and hydrated lime [Ca(OH)₂].

When using quicklime, it is first slurried with water and converted to calcium hydroxide, which is then used for conditioning. Because this process (known as slaking) generates heat, special equipment is required.

Quick lime must be stored in a dry area, because it reacts with moisture in the air and can become pasty and unusable.

Hydrated lime is much easier to use than quicklime, because it does not require slaking, mixes easily with water with minimal heat generation and does not require any special storage conditions.

Lime typically is used in conjunction with ferric salts. Although lime has some slight dehydration effects on colloids, odour reduction and disinfection, it is used because it improves filtration and release of the cake from the filter media. The lime reacts with bicarbonate to form a precipitate of calcium carbonate, which provides a granular structure that increases porosity and reduces compressibility of the sludge.

B. Organic Flocculants

Organic flocculants are widely used in many industries and processes involving the separation of sludge from liquids. These liquid-sludge separation applications may involve processes related to the recovery of finished products, clarification or purification of liquids, and volume reduction of waste materials.

While polyelectrolytes are commonly used in applications involving liquid-sludge separation, the processes of sewage sludge thickening and de-watering are completely dependent on their use.

i. Polymer Characteristics

- The product characteristics of these complex and proprietary polyacrylamide flocculants may vary according to the following:
- Electronic charge (anionic, nonionic, or cationic)
- Charge density
- Molecular weight (standard viscosity)
- Molecular structure

ii. Polymer Specifications and Quality Control

Along with the product identification and type and form of product, the following standard product specifications should be obtained to determine storage conditions, pumping requirements, and potential hazards:

- Total solids
- Specific gravity
- Bulk viscosity

- Flash point
- Freezing point

5.4.1.2 Equipment

A. Liquid Feeders

A typical solution-feed system consists of a bulk storage tank, transfer pump, day tank (sometimes used for dilution) and liquid feeder. Some liquid chemicals can be fed directly without dilution, and these may make the day tank unnecessary, unless required by a regulatory agency. Nonetheless, dilution water can be added to prevent plugging, reduce delivery time and help mix the chemical with the sewage. However, sometimes, the dilution water can have adverse chemical effects. For instance, dilution water that has not been softened can potentially cause calcium carbonate scale to build up on the piping. Special consideration should be given to the final water chemistry of the solution before adding dilution water.

Liquid feeders are typically metering pumps and are generally of the positive-displacement type using either plungers or diaphragms.

Positive-displacement pumps can be set to feed over a wide range (10:1) by adjusting the pump stroke length.

The chemical addition rate can be set manually by adjusting a valve or the stroke / speed on a metering pump.

B. Dry Chemical Feeders

Lime and alum are typical of the kinds of chemicals used with a dry chemical-feed system. It consists of a feeder, a dissolver tank, and a storage bin or hopper. These systems are complex because of their many storage and handling requirements. The simplest method of feeding dry or solid chemicals is by hand. Solid chemicals may be pre-weighed and added or poured by the bagful into a dissolving tank. This method generally applies only to small plants where dry chemical-feed equipment is used.

Most dry feeders are of the belt, grooved-disk, screw, or oscillating-plate type. The feeding device (belt, screw, disk, etc.) is typically driven by an electric motor. Many belt feeders, particularly the gravimetric type, also contain a material flow-control device such as a movable gate or rotary inlet for metering or controlling flow of the chemical to the feed belt.

5.4.1.3 Operation

Many metering pump systems handle chemicals that coat or build a layer of residue or slurries that can settle out solids during operation. Strainers are helpful in removing large particulates, and the operator must keep these cleaned. Periodic flushing to remove residues and deposits is often required. Piping and valve arrangements should allow the system to be isolated so that a clear liquid, such as water, can be used to pressurize the system for flushing the residue or solid build up. These can be operated manually or automatically by solenoid valves with a timer control.

The systems where the metering pumps and piping are required to be periodically shut down will require flushing connections to remove solids.

Most feeders, regardless of type, discharge their material to a small dissolving tank equipped with a nozzle system or mechanical agitator, depending on the solubility of the chemical being fed. The surface of each particle needs to be completely wet before it enters the feed tank to ensure thorough dispersal and avoid clumping, settling, or floating. When feeding some chemicals, such as polymers, into dissolvers, care must be taken to keep moisture inside the dissolver backing up into the feeder.

5.4.1.4 Maintenance

Systems where the metering pumps and piping are periodically shut down will require flushing connections to remove solids. In addition, an allowance for T-and-Y cleanouts should be included for the piping system where longer horizontal piping runs cannot be adequately flushed.

A metering pump will lose capacity and become erratic when the suction or discharge valves become worn or when poor hydraulic conditions exist. These conditions will be indicated by the cylinder test. Also, debris in the chemicals being fed may obstruct or block the check valves, thus impeding their operation and decreasing the pump's performance.

- Check dust filters periodically.
- Periodically clean and calibrate level measurement and indication instrumentation in liquid and dry storage tanks.
- Check the level and condition of the oil in the gear reducer.
- Check the condition of all painted surfaces.
- Clean dirt, dust or oil from equipment surfaces.
- Check all electrical connections.
- Stop and start equipment, checking for voltage and amp draw and any movement restrictions because of failed bearings, improper lubrication, or other causes.
- Check the drive motor for any unusual heat, noise, or vibration.
- Check the packing for leakage and wear.

5.4.2 Sludge Feed Pump

5.4.2.1 Operation

The following operations directly affect sludge pump performance.

Positive-displacement pumps need a drive system that can operate the pump at the speed needed to perform adequately under all operating conditions. Sometimes, this involves manually and automatically timed starts and stops, as well as variable pump discharge rates. This variable-speed arrangement can be provided via mechanical variable-drives; variable pitch pulleys; direct-current,

variable-speed drives; alternating-current, variable-frequency drives; eddy-current magnetic clutches; or hydraulic speed-adjustment systems. Each has various advantages and disadvantages with respect to cost, amount and ease of maintenance required, efficiency, turndown ratio and accuracy. Because positive-displacement pumps are constant torque machines, operators should ensure that the output torque of variable-speed drive exceeds the pump's torque requirement at all operating points. Although variable-speed drives are often either a necessity or an enhancement to proper plant operation, the challenge is providing the continued maintenance and servicing required.

Operators should check the following items:

- Inlet and outlet flow rate
- Noise or vibration
- Bearing housing temperature
- Running amperage
- Pump speed
- Pressure

5.4.2.2 Maintenance

Following is the maintenance checklist for sludge pumps:

- Check the level and condition of the oil in the gear reducer
- Check the shaft alignment
- Check the condition of all painted surfaces
- Visually inspect mounting fasteners for tightness
- Clean dirt, dust or oil from equipment surfaces
- Check all electrical connections
- Stop and start equipment, checking for voltage and amp draw and any movement restrictions because of failed bearings, improper lubrication or other causes
- Check the drive motor for any unusual heat, noise or vibration
- Check mechanical seals and packing for leakage or wear

5.4.3 Mechanical De-watering

5.4.3.1 Centrifugal De-watering

Centrifugation is the process of separating solids from liquids by the process of solid liquid separation, enhanced by centrifugal force.

5.4.3.1.1 Operation

A centrifuge can thicken or dewater the sludge with only a minor change in the weir setting (also called pond setting). Likewise, it can de-water sludge to a moderate consistency at low polymer dose or produce very dry solids using higher polymer dosages.

A. Sludge Type and Quality

The operation of the wet end of the plant determines the quality of the sludge, which, in turn, greatly affects the dry end.

B. Polymer Activity and Mixing with the Sludge

If the polymer does not react well with the sludge, performance suffers. In addition, adding the polymer closer to or further from the centrifuge will affect performance.

C. Polymer Type and Dosage

Some polymers are designed to obtain drier cakes than others do.

Likewise, the dosage will increase and decrease with cake dryness. Some polymers become less effective at higher dosages. This will be apparent from a quick jar test or observing that adding more polymer results in either poorer operation or the same operation.

- Hydraulic Loading
- Centrifuges are less limited by the volume of water that passes through the centrifuge than filtration devices. As a result, thinner feed sludge will have less effect on performance than in filtration devices.
- Solids Loading
- The solids residence time is important. If there is more sludge to de-water, there will be less solids residence time and therefore wetter solids, all else being equal.
- Capture
- The solids capture is generally fixed by the plant management, and is not an operating variable.

D. Torque Control

In recent years, nearly all centrifuges have a controller that allows the operator to choose a scroll drive load or torque set point, and the controller then adjusts the differential speed to maintain that set point. In this manner, the torque and therefore the cake dryness is fixed.

One way of looking at the centrifuge is that it is a very expensive viscometer. The conveyor is turning at a controlled speed immersed in the sludge. The effort or torque, needed to turn the conveyor, is measured by the scroll drive device.

As the cake becomes drier, its viscosity increases, which, in turn, increases the torque or load on the scroll drive. When operating in load control, the controller automatically adjusts the differential revolutions per minute to maintain a constant torque level, and the operator's only task is to observe the centrate quality from time to time and adjust the polymer rate to maintain the desired centrate quality.

This is a simple control; one of its virtues is that the major operating cost—cake-dryness is fixed, and any operator error shows up in the centrate, which is easy to see and is not so costly if it is off slightly.

Consult the manufacturer of the centrifuge for a recommendation on operating speed changes.

E. Process Control

The following shutdown procedures are suggested:

- Stop sludge and polymer feed to the centrifuge
- Flush with treated sewage until the centrate is clear and the torque level begins to drop
- Turn the centrifuge off
- Continue flushing at 25% of normal feed flow until the centrifuge reaches 7 –800 r/min.
- Turn off the lubrication system and cooling water when the unit has completely stopped

5.4.3.1.2 Maintenance

During operation, the operator should check for the following:

- The oil level and the flow of oil to the bearings in circulating oil systems
- Flow of cooling water and oil temperature, to ensure it is operating in the proper range
- Machine vibration
- Ammeter reading on the bowl motor
- Bearing temperatures, by touching them
- System for leaks
- Centrate quality
- Scroll drive torque
- Because the centrifuge will shut itself down in the event of a fault, the operator typically only looks at the mechanical parameters once per shift.

5.4.3.2 Belt Filter Press De-watering Equipment

The operation of a Belt Filter Press (BFP) is based on the principles of filtration and is comprised of the following zones.

- Gravity drainage zone, where the feed is thickened
- Pressure zone
- Shear zone

A belt filter press is shown in Figure 5.5.

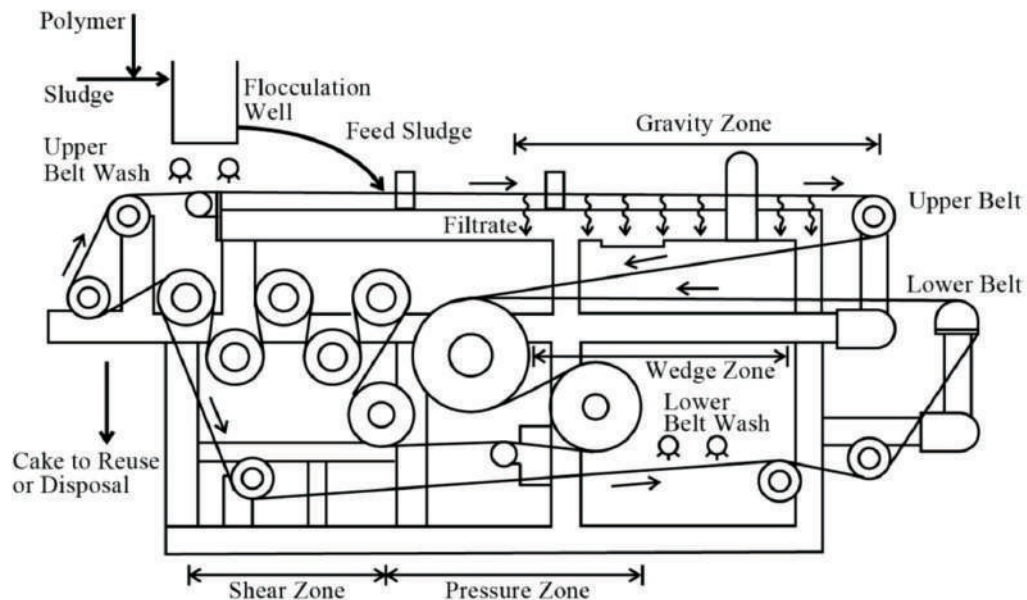


Figure 5.5 Belt filter press

5.4.3.2.1 Operation

A. Process Variables

There are several process variables that affect the performance of all de-watering systems. In general, de-watering devices must run at 95% capture or better, so capture is not really an operating variable. Of the remaining parameters—cake dryness, loading and polymer dosage—within limits, the operator can take from one to give to another. For drier cake, one can reduce the loading and/or increase the polymer dosage.

• Cake Dryness

Increased cake dryness comes at the price of lower capacity and/or higher polymer dosage. The ability to obtain higher cake dryness is, to a great extent, a function of the design of the press. Press with extended gravity zones to better pre-concentrate the feed and additional pressure rollers give longer sludge residence times and drier cake.

• Polymer Type and Dosage

Some polymers are designed to obtain drier cakes than others do. Likewise, the dosage will increase and decrease with the cake dryness. Some polymers become less effective at higher dosages. This will be apparent from a quick jar test or observing that adding more polymer results in either poorer operation or same operation.

- Hydraulic Loading

Belt filter Press (BFP) is limited by the volume of water that can go through the belts. As a result, thinner feed sludge will result in less quantity of dry solids produced, all else being equal.

- Solids Loading

Likewise, more solids will result in less solids residence time inside the press and therefore wetter sludge, all else being equal.

- Capture

The solids capture is typically fixed by the plant management and is not an operating variable like.

- Belt composition and condition, speed and tension
- Size and number of rollers
- Wash water flow, pressure and suspended solids concentration

B. Sequence of Operation

The sequence of operation for a BFP is typically set up in the following order:

- Open wash water valve
- Start wash water pump
- Start pneumatic/hydraulic belt tension system
- Start belt drive and de-watered cake conveyor
- Start polymer solution feed pump
- Start sludge feed pump

Modern BFP typically has a one-button start system, so the operator only has to manually start the feed and polymer pumps. In any event, one benefit of filling out the operating log is that the operating conditions the last operator used are known, as are the conditions of the previous week and month.

5.4.3.2.2 Maintenance

Rollers and bearings require frequent lubrication. Follow the manufacturer's O&M manual for lubrication schedule. This extends the life of the roller bearings and belt drive motor.

Replacement of filter belts is a common maintenance requirement.

The following procedures will extend the life of the BFP and reduce its operating cost:

- Wash down the BFP every day after finishing the dewatering shift. This prevents cake from drying and accumulating in different sections of the BFP.
- Confirm that all rollers are turning freely.

- Check the press weekly for damaged bearings.
- Check the grinder that prevents large particles from entering the press twice per year.
- Clean the wash water nozzles as frequently as necessary (this depends on the quality of the wash water). This ensures proper cleaning of the belts.
- Inspect and change sludge containment and washbox seals, as necessary.
- Inspect and clean doctor blades from any accumulated debris, hair, or any other foreign materials.
- Clean the chicanes (plows) in the gravity section after shutting down the press.
- For maintenance of complex mechanical parts of the BFP, contact the manufacturer for advice.

5.4.3.3 Filter Press

Filter Press for de-watering are generally either recessed plate filters or diaphragm filter Press. With the advent of better organic polymers, belt filters and centrifuges have largely displaced filter Press in the market. Filter Press can be attractive in unusual circumstances.

The fixed-volume recessed plate filter press consists of a series of plates, each with a recessed section that forms the volume into which the feed enters for de-watering. Filter media or cloth, placed against each plate wall, retains the cake-solids while permitting passage of the filtrate.

The plate surface under the filter media is specifically designed with grooves between raised bumps to facilitate passage of the filtrate while holding the filter cloth. Before pumping into the press, the feed must be chemically conditioned to flocculate the solids and release the water held within the solid mass. Most typical conditioning systems use inorganic chemicals and polymers.

High-pressure pumps force the feed into the space between the two plates. The filtrate passes through the cake and the filter media and out of the press through special ports drilled in the plate.

Pumping continues up to a given pressure and is stopped when solids and water fill the void volume between the filter cloths and filtrate flow slows to a minimal rate. The press then opens mechanically and the cake is removed, one chamber at a time.

5.4.3.3.1 Operation

A. Process Variables -Chemical Conditioning

Polymers have a narrow range of effective dosage. A dose that is too low or too high will result in a wet cake. Lime and ferric chloride have a broader range of effective dosage. While it is desirable for an operator to reduce the chemical usage to reduce costs, if erratic equipment operation or erratic feed qualities occur, a higher lime dose typically will protect against a wet cake. Polymer conditioning requires much less chemical per unit mass of solids de-watered, which results in more room in the press for organic sludge, and increased capacities.

- A torn cloth immediately results in a filtrate flow that is very dirty and heavy with solids
- Feed sludge concentration. A very thin feed may blow out through the plate surfaces during the initial high-volume fill of the press because there would be too much filtrate flow for the drain capacity. A thin feed will at least require a longer filtration time and produce a wetter cake. A thick feed typically will produce a drier cake with a much shorter filtration time.

For a conventional filter press, the operator can control the following machine variables:

- Feed application rate by varying the flow to the filter press.
- Overall filtration time, including such variables as the time at each pressure level in multiple pressure level operations.
- Use and amounts of pre-coat or body feed. Typically, pre-coat is unnecessary when inorganic chemicals, such as lime and ferric chloride, are applied. Pre-coat may be needed if particle sizes are extremely small, filterability varies considerably or a substantial loss of fine solids to and through the filter media is anticipated.
- Conditioning chemicals, type, dosage, location, and mixing efficiency. Polymer addition versus lime and ferric chloride conditioning typically are not interchangeable, as each chemical requires special mixing and flocculation energies and reaction times. Polymers only need a quick mix before injection to the press. Modifications to the piping and mixing systems are typically needed if a change in the type of chemical for conditioning is desired.
- Flocculation efficiency and energy vary with the type of chemical being used. Polymer floc shears easily and remains stable for only a few minutes. Lime floc is more durable and remains stable for a few hours.
- Filter media. Filter cloth media vary widely, with different filament composition, weave pattern, and weave tightness.

B. Operational Considerations

- The press is very noisy when in operation. Hearing protection may be needed.
- Never insert objects between the press plates as they are being discharged, without first shutting the unit down by tripping the light curtain or flipping the emergency shutdown switch.
- Lime treatment results in considerable ammonia fumes being released during cake discharge. Make sure that adequate ventilation pulls these fumes away from the operator, preferably with a high-capacity, down-draft blower system. If an adequate ventilation system is not operational, short-term exposure may be allowed. If an approved ammonia respirator is worn by all operators assisting with the cake discharge.
- Hydrochloric acid washing of the press releases volatile acid fumes, which should not be inhaled or exposed to moist body tissues, such as eyes and lungs. A high-capacity ventilation system, as previously noted, is essential. If approved, short-term exposure may be allowed, with an approved respirator and complete coverage of all exposed skin.

- Lime powder is very caustic when it comes into contact with moist body tissues. Therefore, an approved respirator and complete coverage of all exposed skin is necessary when working around lime.

5.4.3.4 Screw Press

Screw press dewater sludge first by gravity drainage at the inlet section of the screw and then by squeezing free water out of the sludge as they are conveyed to the discharge end of the screw under gradually increasing pressure and friction. The increased pressure to compress the sludge is generated by progressively reducing the available cross-sectional area for the sludge. The released water is allowed to escape through perforated screens surrounding the screw while the sludge is retained inside the press. The liquid forced out through the screens is collected and conveyed from the press, and the de-watered sludge drops through the screw's discharge outlet at the end of the press.

Screw speed and configuration, as well as screen size and orientation, can be tailored for each de-watering application.

Solids are combined with polymer and pumped into the flocculation vessel. After flocculation, sludge is transferred to the screw press. In the horizontal screw press configuration, sludge is fed by gravity from the flocculation tank into the screw press head box. If a rotary screen thickener is used, sludge flows from the flocculation tank to the rotary screen thickener and then to the screw press head box. Sludge then flows from the head box into the inlet of the screw press. A typical screw press is shown in Figure 5.6.

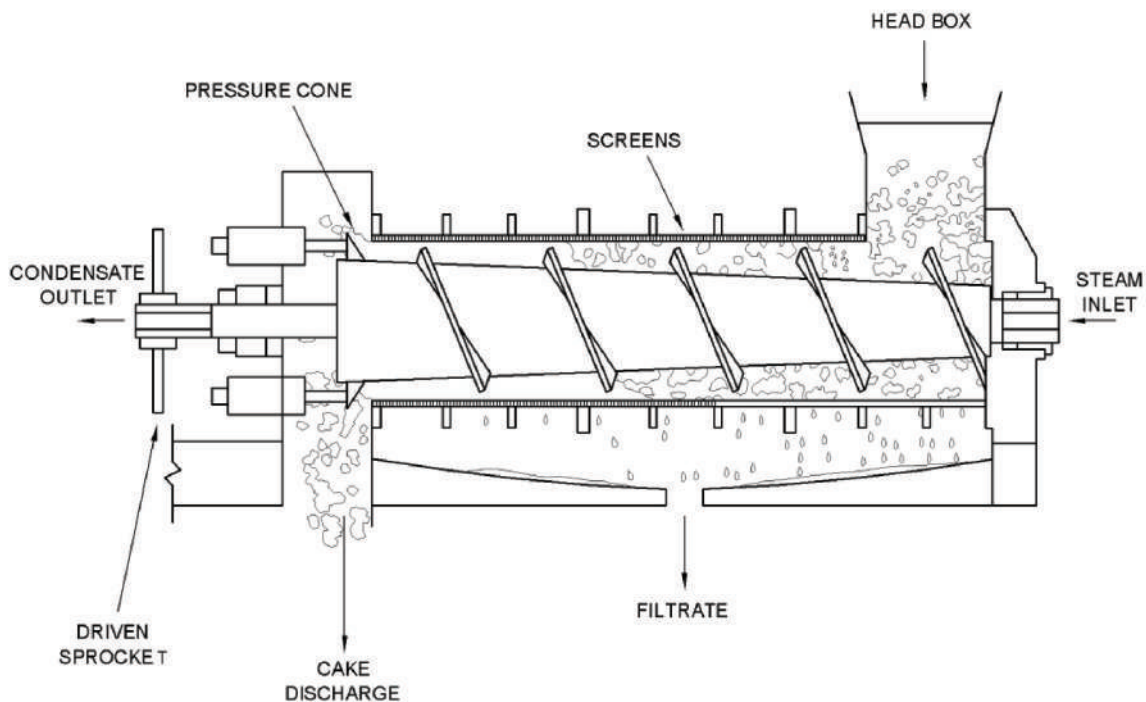


Figure 5.6 Screw press

5.4.3.4.1 Operation

Screw press operates continuously at low speeds and do not require close operator supervision; therefore, they are easy to maintain and have low power consumption. The manual cleaning schedule ranges from once per week to once every 30 days.

A. Chemical Conditioning

Polymer addition promotes particle flocculation and increases the de-watering and solids-capture rates. Jar testing and pilot testing can be used to estimate the type and quantity of polymer necessary for each application, because it may vary significantly depending on sludge characteristics. Polymer consumption is affected by multiple parameters (e.g., grit content of the sludge, the presence or absence of primary clarifiers, the type of biological treatment and the type and duration of sludge digestion).

B. Cleaning System

Screw press systems have automatic cleaning systems, which involve plant water and spray nozzles. During automated wash cycles, wash water from solenoid valves sprays onto the screw press screen to remove built-up sludge.

The brushes are made of nylon with stainless steel mounting hardware. This mainly cleans the screen to allow water to drain by gravity (especially in the lower part of the screen) and minimize resistance to water filtration. Clean screens require less de-watering pressure, which improves the solid capture rate.

The second cleaning process is an automatic spray wash system, which cleans the screen from the outside. It is comprised of a rotating spray-bar washing system and spray nozzles fed by solenoid valves.

C. Rotation Speed

Typical rotation speeds range from 0.1 to 2.0 rpm for horizontal screw press and from 0.5 to 2.0 rpm for inclined screw press. In general, an increase in screw rotation speed increases production capacity but decreases cake solids concentration. In a full-scale application, increasing rotational speed from 1 to 1.25 rpm reduced the cake concentration from 23 to 20%.

5.4.3.4.2 Maintenance

Maintenance checkpoints are as follows:

- Check the drive of the screw for abnormal sound and vibration during operation
- Check the screen for any damage or clogging
- Check the cleaning nozzle for clogging
- Check the amount and the leakage of lubricating oil
- Check the reading of the ammeter and indicator lamps

5.4.3.5 Rotary Press

Rotary Press is a relatively new technology that can achieve cake solids and solid capture performance similar to belt Press and centrifuges. Rotary press and rotary fan press de-watering technology relies on gravity, friction and pressure differential to de-water sludge.

The major elements of a rotary press are the polymer feed and mixing system, parallel filtering screens, a circular channel between the screens, the rotation shaft and a pressure-controlled outlet as shown in Figure 5.7.

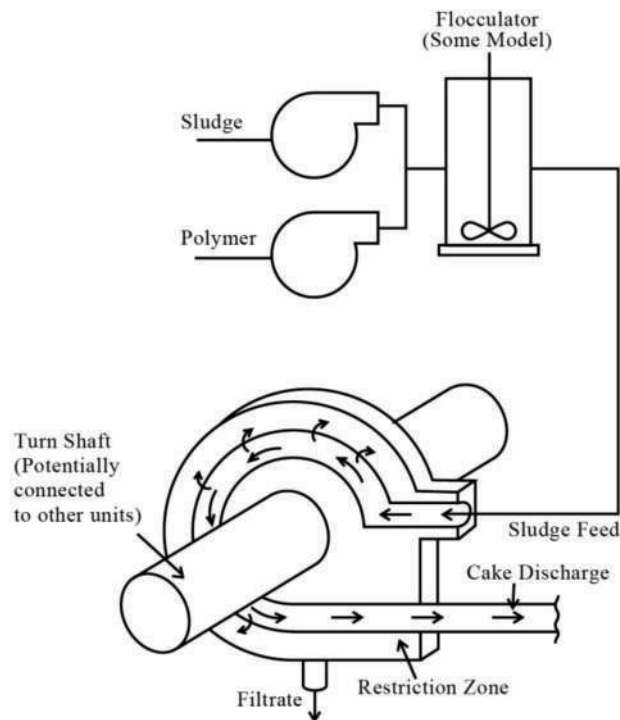


Figure 5.7 Schematic of a rotary press system

The press screens of rotary fan consist of fabricated wedge wire with small openings and linear gaps. The rotary press drive configuration allows up to six rotary press channels to be operated on a single drive. Each channel has bearings, and the combined unit has an outboard bearing cantilevered on one end. The rotary fan-press drive configuration uses a maximum of two rotary press channels on a single drive with isolated bearings in a sealed gearbox.

A key feature of both rotary press and rotary fan press de-watering technology is their slow rotational speed. Typical installations use speeds of 1 to 3 rpm. This provides low vibration, low shear and low noise.

5.4.3.5.1 Operation

A. Operational Control

Operators can control the performance of the rotary press or rotary fan press by changing polymer type and dosage, feed rate, feed pressure, wheel speed and outlet pressure.

Both types of press require minimal supervision and can be unattended between start up and shutdown.

- Hydraulic Loading Rate

The hydraulic loading rate is a function of the equipment's size and number of channels. The technology is modular, and the hydraulic loading rate of single-drive units ranges from 0.5 to 15 L/s, although a maximum hydraulic loading rate of 3 L/s per channel is typical. Rotary press provides better performance on residuals with higher fibre content (e.g., primary sludge).

- Chemical Conditioning Requirements

Chemical conditioning is mandatory to attain design performance in rotary press or rotary fan press dewatering. Polymer feed systems can be supplied by the manufacturer or can be procured independently. In both cases, the feed systems typically include a polymer storage tank and metering pump, which feeds the polymer into the mixing or flocculation tank, where it is blended with the sludge. Dry or emulsion polymers can be used.

- Solids Loading Rate

Because solids capture is a function of the adjustable back pressure, the solids loading rate varies with the hydraulic loading rate. At higher solids concentrations, residuals will accumulate in the outlet zone, form as a cake and extrude more quickly.

B. Cleaning System

Rotary Press and rotary fan Press include a self-cleaning system that must run for 5 minutes per day at the end of use to flush all lines and equipment. The system does not require high-pressure water for flushing. Typically, the normal in-plant water source has sufficient pressure, but in some cases, high-pressure booster pumps may be required.

5.4.3.5.2 Maintenance

Maintenance checkpoints are as follows:

- Check the drive of the rotary for abnormal sound and vibration during operation
- Check the rotary for any damage or clogging
- Check the amount and the leakage of lubricating oil
- Check the reading of the ammeter and indicator lamps

5.4.3.6 Vacuum Filter

The vacuum filter consists of a cylindrical drum over which a filtering medium of wool, cloth or felt, synthetic fibre or plastic or stainless steel mesh or coil springs is laid.

The drum is suspended horizontally so that one quarter of its diameter is submerged in a tank containing sludge.

5.4.3.6.1 Operation

A. Process Variables

The principal variables that affect vacuum filter operation are as follows:

- Chemical conditioning
- Filter media type and condition
- Drum submergence
- Drum speed
- Vacuum level

Chemical conditioning most significantly influences de-waterability, because it changes the physical and chemical nature of the feed. Conditioning agents produce a feed that releases water more freely, thereby producing a drier cake. Conditioning agents also add to the sludge to be discarded.

B. Sludge Conditioning

Sludge conditioning is accomplished by the addition of various coagulants or flocculating agents such as ferric chloride, alum, lime and polymers. The amount of chemical solution added to the conditioning tank is normally established by laboratory testing of sludge grab samples.

5.4.3.6.2 Maintenance

The installation of a blanket may require several days' work.

A blanket will usually last from 200 – 20,000 hours, but this depends greatly on the blanket material, conditioning chemical, backwash frequency and acid bath frequency. An improper adjustment of the scraper blade, or accidental tear in the blanket, will usually require its replacement.

Both cloth blankets and coil springs filters require a high pressure wash after 12 to 24 hours of operation and, in some instances, an acid bath after 1,000 to 5,000 operating hours.

5.5 SLUDGE DRYING BED

These are age-old practices in India and are still preferred in arid parts where land is available and affords employment opportunities to unskilled labour. Other areas, where rainfall is frequent are not suited for drying beds.

5.5.1 Applicability

This method can be used at all locations where adequate land is available and dried sludge can be used for soil conditioning. When digested sludge is deposited on a well-drained bed of sand and gravel, the dissolved gases tend to buoy up and float the solids leaving a clear liquid at the bottom, which drains through the sand rapidly. The major portion of the liquid drains off in a few hours after which drying commences by evaporation.

The sludge cake shrinks producing cracks, which accelerates evaporation from the sludge surface. In areas having greater sunshine, lower rainfall and lesser relative humidity, the drying time may be about two weeks while in other areas, it could be four weeks or more. Covered beds are not generally necessary unless in heavy monsoon and sludge holding tanks can be used.

5.5.2 Unit Sizing

The sludge drying process is affected by weather, sludge characteristics, system design (including depth of bed) and length of time between scraping and lifting of sludge material. High temperature and high wind velocity improve drying while high relative humidity and high rainfall retard drying.

5.5.3 Area of Beds

The area needed for de-watering and drying the sludge is dependent on the volume of the sludge, cycle time required to retain sludge for de-watering, drying and removal of sludge and making the sand bed ready for next cycle of application and depth of application of sludge on drying bed. The cycle time between two dryings of sludge on drying beds primarily depends on the characteristics of sludge including factors affecting its ability to allow drainage and evaporation of water, the climatic parameters that influence evaporation of water from sludge and the moisture content allowed in dried sludge. The cycle time may vary widely, lesser time required for aerobically stabilized sludge than for an aerobically digested sludge and for hot and dry weather conditions than for cold and/or wet weather conditions.

5.5.4 Percolation Type Bed Components

A sludge drying bed usually consists of a bottom layer of gravel of uniform size over which is laid a bed of clean sand. Open-jointed tile under drains are laid in the gravel layer to provide positive drainage as the liquid passes through the sand and gravel.

5.5.5 Operation and Maintenance

Sludge that is drawn to the beds contains 4 to 10 % solids depending upon the type of sludge. Wet sludge should be applied to the beds to a depth of 20 to 30 cm. After each layer of dried sludge has been removed, the bed should be raked and levelled. Sludge should never be discharged on a bed containing dried or partially dried sludge. It is preferable to apply the sludge at least a day or two after the sludge cakes are removed.

Removal of dried sludge from bed surfaces should be done with shovel, taking care that as little as possible of the sand is removed. When the sand layer is reduced to as low as 10 to 15 cm, it should be examined for clogging by organic matter and if found, the entire sand should be removed and the bed re-sanded to the original depth of 20 to 30 cm.

The dried sludge cakes may be sold as fertiliser. Some part of the sludge should be used in the plant itself for gardening, lawns, etc. to demonstrate its fertilizer value and to develop a market value for the digested and dried sludge. Suitable storage facilities may be provided for the dried sludge.

Records of operation of sludge drying beds should show the time and quantity of sludge drawn to each bed, the depth of loading, depth of sludge after drying time and the quantity of dried sludge removed. The solids content of wet digested sludge, its volatile portion and pH should be determined and recorded. Likewise, the moisture content and fertilizer value in terms of NPK of dried sludge should also be analysed and recorded. An operation sheet of sludge drying bed is in Table 5.3.

Table 5.3 Typical operation sheet of sludge drying beds

Date and Time	Check List
	Cleaning of weeds
	Quantity of sludge to respective SDB
	Depth of the wet sludge
	Depth of dried sludge
	Quantity of sludge removed
	Cleaning and scrubbing of splash plate, pipes etc
	Volume of sand added
	Cleanup-washing scrubbing of filtrate sump

Source: JICA, 2011

5.6 PREVENTIVE MAINTENANCE

All preventive maintenance of equipment is to be done as per the equipment manufacturer only. Preventive maintenance of process control resides only in digestion process and has been discussed above.

5.7 TROUBLESHOOTING

Refer to Appendix B.5.1.

5.8 RECORD KEEPING

There is no standard format for record keeping. Each STP has to have its own format. The crucial parameters to be recorded are the pH and temperature of the digesters on a daily basis. The gas analysis can be recorded once a week.

5.9 SUMMARY

Treatment of sludge, which is converted from organic matter removed from sewage, as well as quality and quantity of sewage inflow, and quality of treated sewage, are quite important in STPs.

Problems likely to be encountered in the course of operation are shown in Appendix B.5.1 as troubleshooting and the operators can make use of these to take appropriate remedial measures.