CHAPTER 2
PRELIMINARY TREATMENT

Learning Objectives

This chapter examines the components of the preliminary treatment process at a wastewater treatment plant. At the end of this chapter, the student should be able to

- Explain the purpose of preliminary treatment and where it fits into the overall wastewater treatment process;
- Describe the major components of septage receiving stations and how they function;
- Identify the various types of screening equipment, their function, and the proper method of disposing the material that is collected;
- List the purpose and principles of operation of comminutors and grinders;
- Define the purpose of grit removal;
- Describe and discuss the principles of operation of the various types of grit removal systems;
- Discuss the common methods of flow measurement and flow management;
- Identify potential odor sources in a preliminary treatment system and alternatives for controlling the odors; and
- Describe safety concerns associated with preliminary treatment operations.

In this chapter, we will examine the steps involved in the preliminary treatment process at a wastewater treatment plant. Figure 2.1 shows schematics of example preliminary treatment processes. All of the components shown here may not be present in every preliminary treatment process. Depending upon the design of a specific collection system, the types of wastewater sources in the system and the downstream processes and equipment, it may not be necessary or cost-effective to have every type of preliminary treatment at a specific treatment plant.

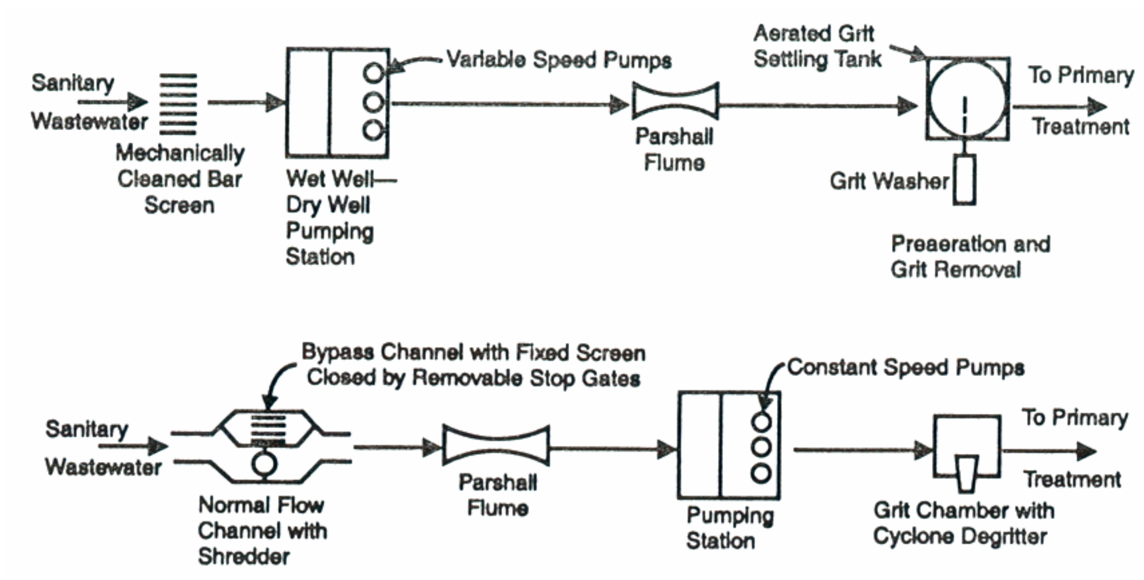


Figure 2.1 Schematic of Preliminary Treatment Processes

The first treatment steps that influent wastewater undergoes in a typical wastewater treatment plant are screening and/or grinding, grit removal, flow measurement, flow control, and sometimes odor control. These steps together are referred to as preliminary treatment. Raw wastewater contains sticks, rocks, sand, bottles, scraps of metal, rags, and many other similar items. These items can cause collector mechanisms to jam, damage pumps, plug pipes, and collect in tanks such as biological reactors, which, in turn, can damage equipment, reduce the volume available in tanks and lower the overall efficiency of the treatment plant. This can result in the discharge of pollutants to receiving waters. It is important, therefore, to remove these materials early in the treatment process, during preliminary treatment. Also, since many wastewater facilities are designed for optimal efficiency at design flows, flow conditions must be assessed as soon as possible to allow operators to react to and properly control flows in order to maintain the plant's efficiency. We will examine different strategies for flow measurement and control along with preliminary treatment in this chapter. The term headworks is sometimes used to refer to the equipment and facilities that make up the preliminary treatment process.

Some wastewater treatment plants have chosen to accept septage from haulers who pump out septic tanks, privies, recreational vehicle waste holding tanks and, in some cases, marina waste holding tanks. These septage receiving stations are usually placed at the beginning of the treatment plant since it contains many of the things (rags, grit, etc.) that preliminary systems are designed to remove. Although septage receiving stations are not really a component of preliminary treatment, they will be discussed here because of their location immediately prior to the preliminary treatment system.

Septage Receiving

Septage is wastewater that is pumped out of septic tanks and other various types of holding tanks. It can best be described as partially digested anaerobic wastewater. Septage is typically much higher in strength than domestic wastewater. It is removed from septic/storage tanks and hauled via truck for disposal. Figure 2.2 is a photo of trucks discharging their loads at a septage receiving station.

Figure 2.2 Septage Receiving Station

Since septage is transported to the wastewater treatment plant by truck, it is sometimes difficult to be sure where it came from. Slug loads of toxic waste can enter a plant through a septage receiving station and cause major upsets and even discharge violations if these flows are not carefully monitored and managed.

The following operational considerations are important when operating a septage receiving station:

- Maintain good records of who dumped, how much and when;
- Keep the station clean and orderly. Wash down any spills immediately to avoid odors and slip hazards. Require that trucks must connect by hose directly to the station in order to discharge. This will help minimize spills;
- Make sure that a means of sampling is available. This can help to identify loads with toxic components before they are released into the treatment plant. It can also be used to collect data for assessing user charges if your facility chooses to charge a fee based on the strength of the waste discharged;
- If possible, maintain a way to hold septage and pump it slowly into your plant. This will provide operational flexibility to minimize the impact that the septage will have on the rest of the treatment process;
- The septic nature of these wastes can lead to severe odor problems. If available, keep odor control systems maintained and operating properly to avoid unnecessary issues with neighbors.

Figure 2.3 is a sketch of an ideal septage receiving station. It provides all of the tools that will allow the operator to manage the septage receiving station in such a way that it will have little to no negative impact on the rest of the treatment facility. Without some of these tools, an operator will be forced to creatively manage this flow to minimize the risk of upsetting the downstream biological processes.

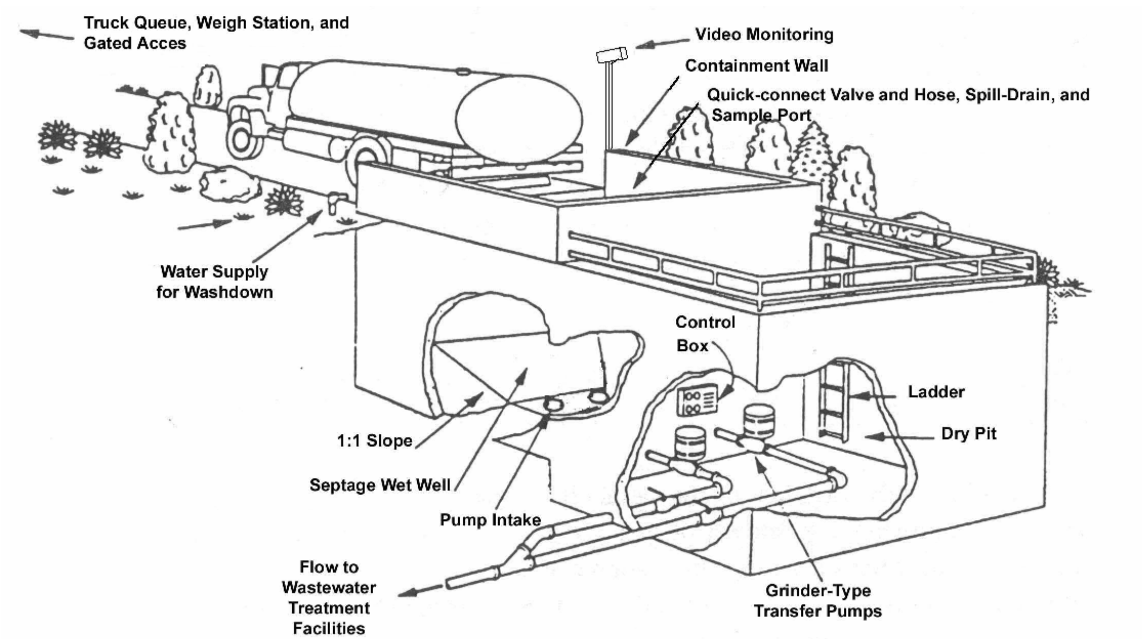


Figure 2.3 Schematic Drawing of a Septage Receiving Station

If the amount of septage to be received by a wastewater treatment plant is very small, it is sometimes simply discharged at a convenient location at the facility's headworks. As long as it is a small percentage of the plant's total influent flow and the plant has adequate preliminary treatment capacity, it can be mixed with the other wastewater entering your plant and adequately treated without having a negative impact on the overall wastewater treatment process.

Treating septage can cost a significant amount of money (extra labor, equipment, electricity, record-keeping, liability, etc.) Make sure that your system is set up in such a way that your costs are recovered from the dumping fees, etc. that you collect.

Screening

The purpose of screening wastewater is to remove larger, inorganic debris from the waste stream. This helps to prevent issues such as cans clogging pumps and rags getting wrapped around collector mechanisms. It is also really the only way to deal with inorganic materials that enter the plant. After all, wastewater treatment plants are designed to remove organic pollutants. The processes employed (activated sludge, physical/chemical) cannot breakdown materials such as plastics, glass and metals. The best thing to do is screen them out early in the treatment process and take them to the local landfill where all of the other garbage is being taken. The trick, however, is to make sure that minimal amounts of organic waste materials and water are removed with the screenings.

The first and most primitive type of screen is the bar rack (Figure 2.4). It is used to capture large, solid objects such as tree limbs, large rocks, construction materials, etc. Installing a bar rack can be considered "cheap insurance" to protect your more costly downstream equipment such as a mechanically-cleaned bar screen or whatever else the first piece of equipment in your plant may be.

Figure 2.4 Bar Rack

The bars that make up a bar rack are typically 50 to 100 mm (2 to 4 in.) apart. Since the bars are so far apart, most debris in raw wastewater moves through the rack. The volume of material that needs to be removed from a bar rack is usually fairly small. However, when something does get stopped by a bar rack (such as a tree branch or a bicycle) smaller debris in the flow coming into the plant will get caught on this item. Blockages can develop quickly and create excessive headloss. For this reason, many plants with bar racks have a water level sensor before the rack which will sound an alarm if water depths in the channel reach a certain depth. It is also critical to have an operator visually inspect a bar rack regularly and clean the rack to make sure something isn't present below the water level.

Bar screens, on the other hand, typically have bars that are 6 to 40 mm (0.25 to 1.5 in.) apart. Similar to bar racks, bar screens usually contain parallel vertical bars set at an angle within the wastewater influent flow channel. There are two types of bar screens: manually-cleaned bar screens and mechanically-cleaned bar screens.

Manually-cleaned bar screens are typically used at small plants or as standby units for mechanically cleaned systems. Figure 2.5 is a photo of a typical manual bar screen installation.

Figure 2.5 Manually-Cleaned Bar Screen

Debris in the wastewater collects on the screen and must be removed frequently. If too much material collects on the bars, it can block the channel and cause the wastewater to back up into the influent sewer. This can cause several different issues. If the wastewater flow slows down and backs up, organic materials will settle out in the sewer, deplete the dissolved oxygen in the wastewater and cause septic conditions. Septic wastewater produces hydrogen sulfide, a toxic compound that smells like rotten eggs and can deteriorate concrete, metal, and paint. Depending upon the configuration of the collection system, the back-up could also cause flooding and damage in the basements of nearby homes and businesses. Also, when the sewer is finally unblocked, the sudden increase in flow and septic solids into the plant can shock the plant processes. Such shock loads can result in poor quality plant effluent. Therefore, it is important that you carefully maintain bar screens to ensure that they are in proper operating condition, and that they are monitored and cleaned regularly.

Manually-cleaned bar screens are often cleaned by operators using a rake with teeth that are spaced to fit between the bars. Operators should take extra care when cleaning these screens. Water and grease around the bar screen can make the floor slippery. As shown in Figure 2.6, many manually-cleaned bar screens use a removable horizontal platform and handrail. You should use a safety line to anchor yourself to the handrail as you clean. The screenings are raked into a slotted or perforated trough or basket to allow water to drain from the screenings before they are disposed of.

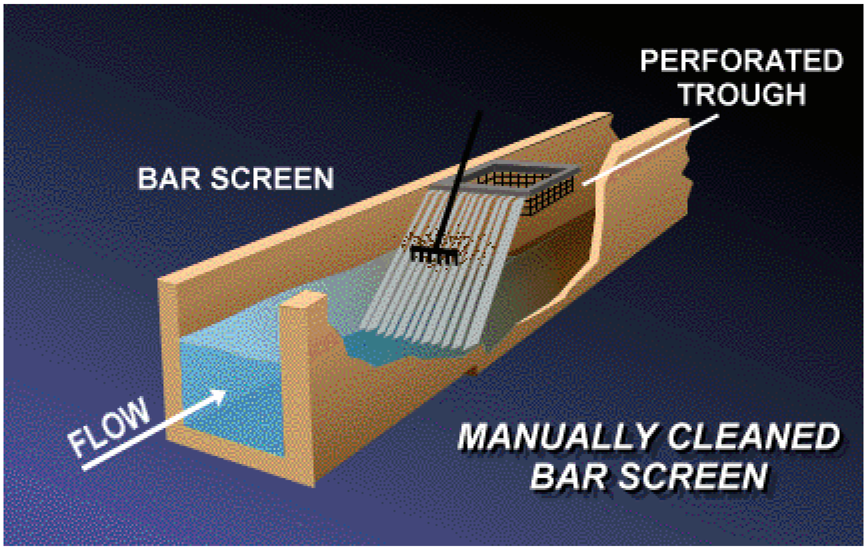


Figure 2.6 Cut-Away Sketch of a Manually-Cleaned Bar Screen

There are various types of mechanically-cleaned screens used in wastewater treatment plants. They are generally classified into two categories – medium screens and fine screens. We will not try to strictly define the difference between these two groups but instead give a rough rule of thumb. Fine screens are designed to take almost all solids out of the influent flow that are larger than grit particles. They trap a high percentage of the organic solids that enter the plant. Therefore, it is critical that this material be washed prior to disposal in order to allow proper biological treatment downstream and to avoid disposal problems. Medium screens fall in between the two extremes of the coarse bar screens and the fine screens. The goal is to size the openings of the medium screen so that all of the solids that are large enough to damage equipment are removed but that most of the organic material passes through. The opening size that will achieve this goal is different from plant to plant, depending on the type of contributors there are to the wastewater collection system.

First, we will examine various types of automatically-cleaned medium screens. Several of the more popular types are front-cleaning bar screens, back-cleaning bar screens, and belt filter screens. Regardless of the type of design, the cleaning mechanism is typically started by a timer, level sensors located upstream and downstream of the unit (to monitor headloss through the screen), or a combination of timers and level sensors.

The front-cleaning mechanically-cleaned bar screens (Figure 2.7) have large raking mechanisms that reach from one side to the other of the face of the screen. The rake starts at the bottom of the screen and slowly moves upward automatically. Once it reaches the top of the screen, the debris collected is deposited over the top of the screen, usually into a dumpster, onto a conveyor or into a hopper that goes to a compactor. Since the raking mechanism is slow-moving, water will drain by gravity from the debris while the raking mechanism is moving above the water level up to the top of the screen. Once the debris has been deposited from the raking mechanism, the rake is automatically lifted up off of the face of the screen and then returns to the bottom where it is placed back into contact with the bars of the screen and begins to travel upward again, collecting new debris that has just been deposited on the face of the screen. An operational issue with these screens is that stringy material can become wound around the rake mechanism. If this occurs, an operator must shut down the equipment and manually clear away the stringy materials. Also, since the raking mechanism is moving over the face of the screen where the debris is collecting, it is possible for the mechanism to get jammed or bent by debris.

Figure 2.7 Front-Cleaning Mechanically-Cleaned Bar Screen

Back-cleaning mechanically-cleaned bar screens are quite similar in design to the front-cleaning versions except that the raking mechanism moves up and down over the back-side of the screen. The rake mechanism usually has longer teeth in order to stick all of the way through the screen and catch and clear debris on the front. The concept behind moving the cleaning mechanism to the back is to keep the rake is out of the unscreened influent flow in order to prevent rags and stringy material from getting wound around the mechanism. Also, this design keeps the rake mechanism more protected behind the screen to avoid the rake from being damaged by large debris. One issue that can occur with these units is that the longer teeth on the rake may be susceptible to bending.

Belt filter screens are another type of automatically-cleaned medium screens. The screen portion is a grid of inter-locking pieces that form a continuous belt or loop that travels up, over a sprocket, down the backside of the screen, over another sprocket and then back up again. (Figure 2.8) The spacing between the pieces of the grid can range from 6 to 40 mm (¼" to 1 ½"). If the smaller spacing is used on municipal wastewater, it is recommended that a high-pressure wash water system be used to break up organic materials that are caught on the screen and wash them back into the influent flow. The inter-locking pieces of the screen belt are usually made of a high-density plastic which makes them impact-resistant and unbendable (unlike metal). The face of the screen has hooks that "catch" debris as it comes into contact with the screen. As the screen moves over the top sprocket, the hooks retract between the grid pieces of the belt, releasing the debris that they were carrying into a dumpster or onto a compacting/conveying system.

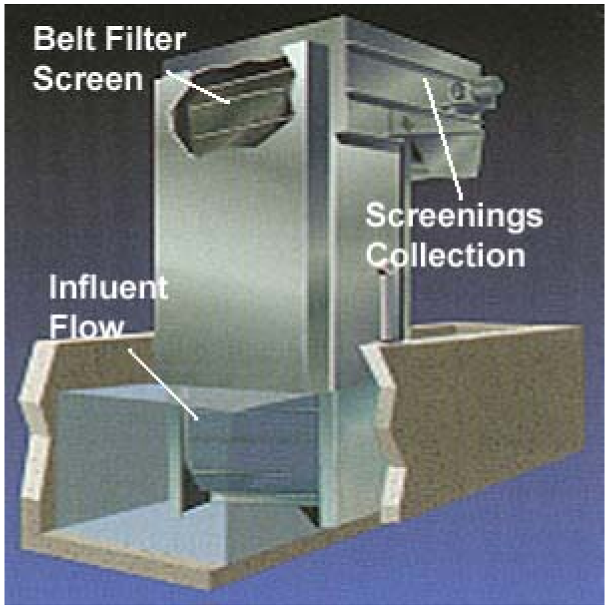


Figure 2.8 Cut-Away Sketch of a Belt Filter Screen

Sometimes, the materials collected on any automatically-cleaned screen cannot be removed by the cleaning mechanism alone. As a result, even if your plant uses an automatic screen, an operator must check it regularly. To find out if material has become stuck in the screen below the water level or if there are other mechanical problems, an operator can shut down and lockout/tag out the unit and then feel across the screen with a rake. If severe problems arise, the equipment may need to be inspected. Some screening equipment is designed to be pulled up and out of the influent flow for inspection and maintenance or repair. For systems where rotating the equipment out of the channel is not possible, influent flow must be diverted through another channel. Figure 2.9 is a sketch of a typical layout for a main screening channel where the mechanically-cleaned bar screen is installed and a secondary channel with a manually-cleaned bar screen is available for temporarily taking the main channel out of service. This arrangement also makes it much easier to periodically drain the main influent channel for inspection and cleaning.

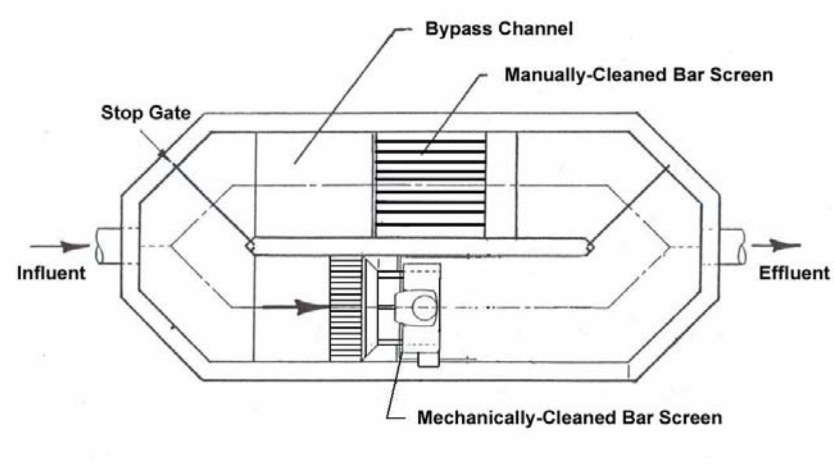


Figure 2.9 Mechanically-Cleaned Bar Screen Installation with Bypass Channel

Always make sure the equipment is turned off and locked and tagged before going near the equipment. Never reach into the operating range of a piece of equipment while it is running. Even slow-moving equipment can be dangerous because it is often "geared down" to be extremely powerful.

Depending on the types of downstream equipment in your plant, it may be important to remove as much debris as possible. These treatment plants may choose to use fine screens instead of bar screens. The screen material is a finer mesh, typically a stainless steel wedge wire with openings approximately 0.2 to 6 mm (0.01 to 0.25 in.) in size. It is extremely important to make sure that the organics trapped with the screenings in any fine screen process are returned to the process. If not, the BOD remaining in the screened influent may be insufficient for good biological treatment. It should be noted that fine screens should be used in conjunction with bar racks or coarse screens in order to avoid clogging and possible damage by large debris.

The first type of fine screen we will consider is the static wedgewire screen. It is a very simple screen with no moving parts. As shown in Figure 2.10, influent flows over the top of the screen. As it runs down the concave face of the wedge wire screen, the water run through the screen, is collected underneath and flows on through the rest of the plant. Solids are captured on the face of the screen. They are pushed down gradually by gravity and the weight of new screening collecting above them. Since there are no moving parts, the maintenance on these units is minimal. However, they require more monitoring and additional manual cleaning than units with moving parts. These units are not recommended for wastewater that contains grease.

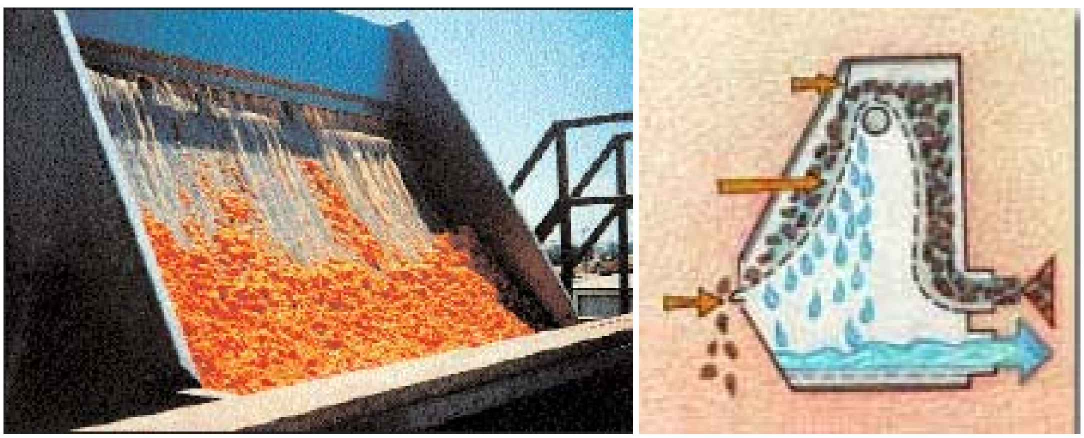


Figure 2.10 Static Wedge Wire Screen

Rotary drum screens are another type of fine screens. There are two basic designs for these units: internally-fed or externally-fed.

For internally-fed rotary drum screens, influent is fed into the center of the unit and is distributed evenly along the length of the drum (Figure 2.11). The drum is constructed of sections of curved rectangular stainless steel screens fastened together. As the influent flows onto the screens, debris is captured and the water flows through. A spray wash system, located outside of the rotating screen near the top of the drum, washes the debris off of the screen and down into a basket or trough. Then, the screenings are removed by an auger or a conveyor. The removal system is usually designed to squeeze the screenings and allow them to drain so that the end product is fairly dry and is ready to be sent to the landfill for disposal.

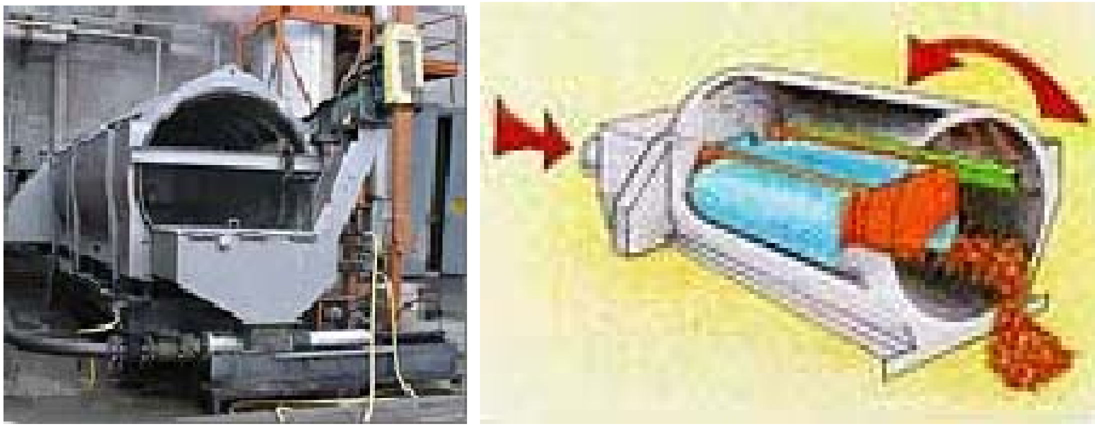


Figure 2.11 Internally-Fed Rotary Drum Fine Screen

For externally-fed rotary screens, influent is evenly distributed and applied all along the length of the outside of the rotating stainless steel screen (Figure 2.12). Solids and screenings collect on the outer surface of the screen while the water runs through the screen and is collected in the center of the unit, where it flows to the rest of the treatment plant. The screenings are removed from the outside of the screen by a doctor blade (scraper) and a spray wash system. The screenings are collected into a hopper where they are drained and then disposed of.

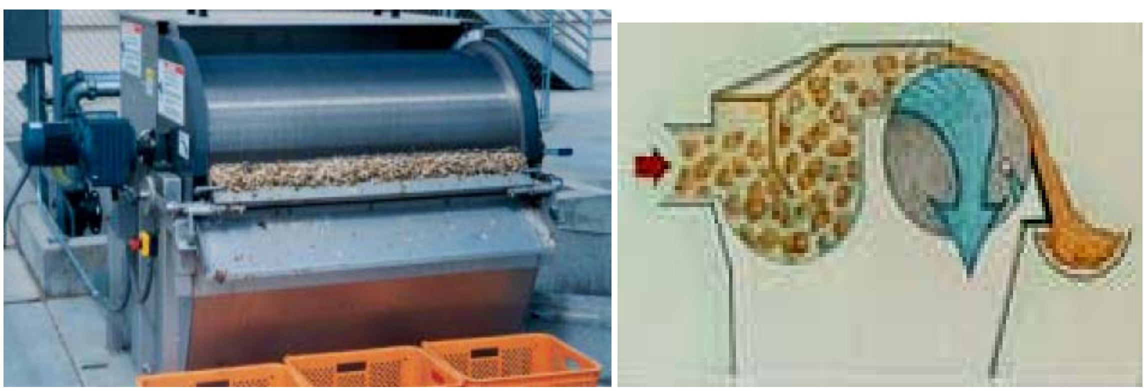


Figure 2.12 Externally-Fed Rotary Drum Fine Screen

The last type of fine screen that we will cover is the escalating step screen (Figure 2.13). This screen is installed in a channel and is made up of a step-like grid where every other bar is fixed. The other bars move upwards, moving around a top and a bottom axis. Debris that has been caught on the screen is carried up to the next higher step on each revolution of the screen. This slow progression up to the top of the screen allows for the water to drain from the debris before it is discharged.

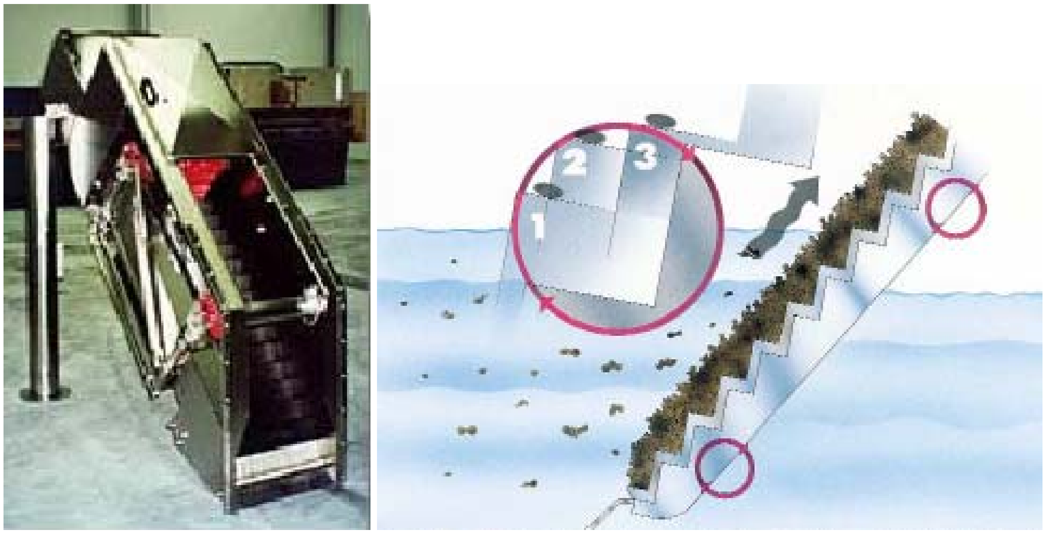


Figure 2.13 Escalating Step Fine Screen

As with all equipment in the plant, moving mechanical parts on screens should be kept well lubricated and adjusted. Always follow the maintenance procedures in the equipment manufacturer's operation and maintenance manual. If problems do arise with your screen, consult Tables 2.1 and 2.2 for troubleshooting tips for your screen setup.

Table 2.1 Troubleshooting for Mechanically-Cleaned Bar Screens

Indicator/Observation	Probable Cause	Check or Monitor	Solution(s)
Excessive grit in bar screen chamber	Surging in chamber because of increased water level	Depth of grit in chamber, irregular chamber bottom	Remove bottom irregularities or reslope bottom
Excessive screen clogging	Unusual amount of debris in influent	Screen size, velocity through screen and upstream conditions	Use a coarser screen or stop source of excessive debris
Rake inoperative but motor runs	Broken chain or cable Broken limit switch Broken shear pin	Inspect chain or cable Inspect limit switch Inspect shear pin	Replace chain or cable Replace limit switch Replace shear pin
Marks or metal against metal on screen binding	Screens needs adjustment	Operate screen through one cycle and listen/observe	Make manufacturer’s recommended adjustment based on O&M manual

Table 2.2 Troubleshooting for Fine Screen Systems

Indicator/Observation	Probable Cause	Check or Monitor	Solution(s)
Effluent solids too high	Drastic change in influent solids characteristics	Sample solids	A different type of screen medium may need to be used if problem persists
Excessive head loss	Influent flow exceeds design rate Influent solids too high Screen media clogged or blinded Low backwash water flow/pressure Buildup on screen surface	Influent flow rate Sample Check backwash system output and spray nozzles Check wash trough drain Check inline strainer and nozzles Check condition of media	Reduce flow rate to screen Increase screen speed and backwash Clean nozzles if dirty Apply appropriate cleaning solutions to screen as recommended
Excessive noise	Misalignment of sprockets Too little/too much chain slack Chain or sprocket worn out	Check alignment Tension or slack in chain belt Observe teeth and chain; verify their dimensions	Correct alignment Adjust centers; add or remove links or adjust take-ups for proper slack Replace chain and/or sprockets
Chain climbs sprockets	Chain worn out Excessive chain slack Material buildup in sprocket tooth pockets	Condition of chain Chain tension and slack Observe condition of sprocket teeth	Replace chain and sprockets Adjust center; remove links or adjust take-ups for proper slack Remove buildup; protect drive from material contact

The materials collected from screens are called screenings. Screenings are usually removed from the wastewater and deposited into containers or dumpsters. As we mentioned earlier, it is critical that excessive organics not be removed with the screenings. Some screens are outfitted with high pressure sprayers that will “wash” the screenings, breaking up organics and carrying them back into the influent flow stream. Other systems use “swirl washers” to separate the lighter organics from the heavier inorganic screenings. Once the screenings are washed, excess water is then allowed to drain by gravity or the screenings are conveyed to a compactor, where water is squeezed out (Figure 2.14). The water is then returned to the plant influent stream. Generally, the quantity of screenings collected from a conventional bar screen is approximately 30 to 45 liters of screenings per 1000 cubic meters (30-45 L/1000 m^3) or 4 to 6 cubic feet per million gallons (4-6 ft^3 /mil. gal).

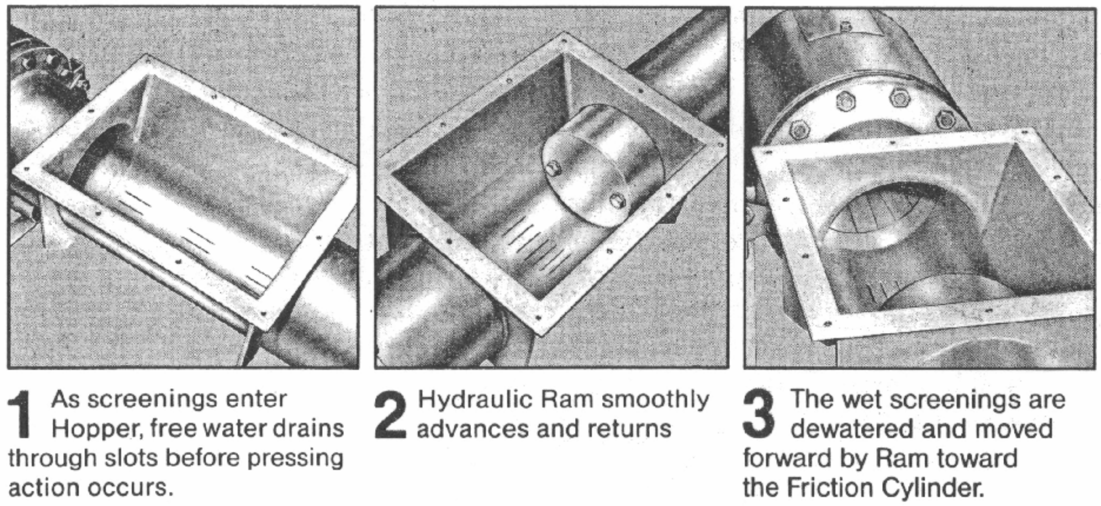


Figure 2.14 Example of a Screenings Handling System

The materials removed from the screens are quite offensive, and can be dangerous. Operators must use care when handling these materials. Screenings have a foul smell and attract rats and flies. They are generally disposed of separately from other plant byproducts. Screenings are typically either buried off site in an approved landfill or are incinerated. For landfill disposal, screenings must be dewatered enough to pass a paint filter test. A paint filter test measures the leaching effect of the screenings. Some treatment plants use screenings presses to remove water and reduce volume, which, in turn, reduces the number of trips to the landfill. Figure 2.15 is a photo of screenings that have been washed and compacted and are being collected before being conveyed to the landfill for final disposal.

Figure 2.15 Screenings Being Collected

Math Question:

You are the superintendent at a wastewater treatment that receives an average daily flow of 17 030 m^3/d (4.5 mgd). A new screen will be going into service next week. The system has a 1.2 m by 1.5 m by 1.8 m (4 ft by 5 ft by 6 ft) dumpster. Based on the rule-of-thumb screenings quantity given above, you have assumed that the new screen will remove 35 L/1000 m^3 (5 ft^3 /mil. gal). How often should you plan to have the dumpster emptied by the local trash hauler?

Let us first answer the question in metric units.

First, calculate the volume of the dumpster in m^3:

$$(1.2\ \text{m})(1.5\ \text{m})(1.8\ \text{m}) = 3.24\ \text{m}^3$$

Next, convert the volume of the dumpster to L:

$$(3.2\ \cancel{\text{m}^3})\left(\frac{1000\ \text{L}}{\cancel{\text{m}^3}}\right) = 3240\ \text{L}$$

Then, multiply the influent flow rate by the rule-of-thumb on your screen to calculate the amount of screenings removed:

$$\left(17\,030\ \frac{\cancel{\text{m}^3}}{\text{d}}\right)\left(\frac{35\ \text{L}}{1000\ \cancel{\text{m}^3}}\right) = 596\ \text{L/d}$$

Finally, divide the volume of the dumpster by the amount of screenings produced per day to determine how many days it takes to fill the dumpster. This number is also how often you will need to empty the dumpster:

$$\frac{3240\ \cancel{\text{L}}}{596\ \frac{\cancel{\text{L}}}{\text{d}}} = 5.4\ \text{d},$$ **approximately every 5 days the dumpster will need to be emptied**

Now, let us answer the question in English units.

First, calculate the volume of the dumpster in ft^3:

$$(4\ \text{ft})(5\ \text{ft})(6\ \text{ft}) = 120\ \text{ft}^3$$

Next, multiply the influent flow rate by the rule-of-thumb on your screen to calculate the amount of screenings removed:

$$\left(4.5\ \frac{\cancel{\text{mil. gal}}}{\text{d}}\right)\left(5\ \frac{\text{ft}^3}{\cancel{\text{mil. gal}}}\right) = 22.5\ \text{ft}^3\text{/d}$$

Finally, divide the volume of the dumpster by the amount of screenings produced per day to determine how many days it takes to fill the dumpster. This number is also how often you will need to empty the dumpster:

$$\frac{120\ \cancel{\text{ft}^3}}{22.5\ \frac{\cancel{\text{ft}^3}}{\text{d}}} = 5.3\ \text{d},$$ **approximately every 5 days the dumpster will need to be emptied**

A word of caution: events such as a large rain fall or sewer-cleaning activities out in the collection system can lead to sudden increases in the amount of screenings coming into the plant. It is a good idea to monitor events such as these and plan ahead so that the debris is quickly removed from the screens and properly disposed of without any problems occurring due to excessive headloss at the screen(s).

Screening systems have some specific safety issues that must be kept in mind. Most screens are located inside buildings in order to prevent rain water from entering the influent channel during rain events and to keep the screen and surrounding walkway from freezing in the winter. Since these systems are always installed on influent sewers, the atmosphere in this building must be monitored for the presence of harmful gases. Special safety precautions should be followed. Cleaning a bar screen requires that an operator work in close proximity to influent wastewater. Standard operating procedures should be developed to minimize or eliminate any direct handling of the screenings. Appropriate personal protective equipment should be worn at all times and proper hygiene should be practiced to avoid exposure to pathogenic organisms.

Grinders/Comminutors

In some wastewater treatment systems, equipment is used to grind or shred larger objects in the influent into smaller pieces instead of removing them with a screening device. This equipment is usually referred to as comminutors and grinders.

Comminutors are devices with cutters and screens that shred the solids and then return them to the wastewater stream. The comminutor is a rotating drum with slots for wastewater to pass through. Cutting teeth are mounted in rows on the drum. These teeth move through fixed combs so that materials are chopped up as they pass through the comminutor. Large pieces of wood and plastic are rejected and must be removed by hand. Before removing these materials, operators must be absolutely sure that the unit is turned off, locked and tagged out. The comminutor is mounted in the channel, and wastewater flows through it (Figure 2.16). The wastewater enters the drum through the slots and flows out the bottom. Usually, the drum rotates against the flow.

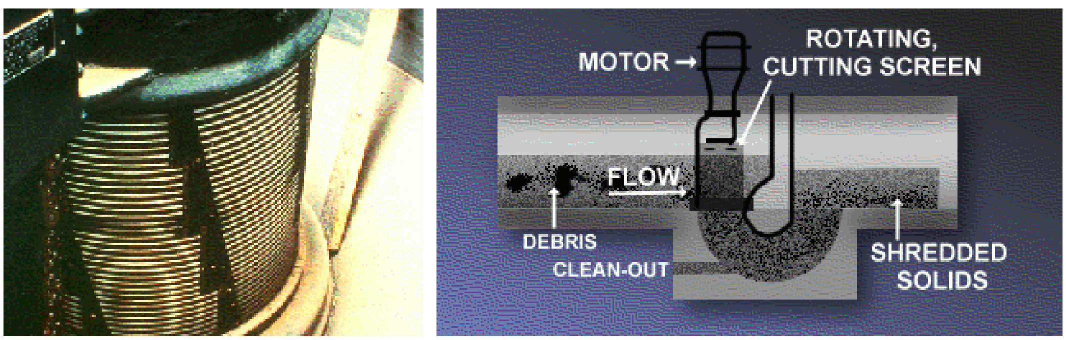


Figure 2.16 Comminutor System

Shredders or grinders (Figure 2.17), also help break up solids during preliminary treatment. When coarse solids reach the unit, two counter-rotating cutting shafts break up the material. The cutting blades of many shredders or grinders may rotate any where from sixty revolutions per minute (60 rpm) for macerators to as much as 2500 rpm for high-speed hammermills. If a large object becomes jammed between the cutting blades, the unit automatically reverses itself for a short period of time and then returns to normal operation. The unit will repeat this reversal action several times during a jam, then automatically shut down and sound an alarm.

Figure 2.17 Low-Speed Grinder (Macerator)

There has been an increasing trend over the years to do away with grinding and comminution due to downstream problems caused by ground up materials. It is often preferable today to remove all debris and grit from the influent using screens and grit removal rather than grind small debris and allow it to return to the flow stream. Often this ground-up debris accumulates in the system in a similar fashion as grit and can cause problems with downstream mechanical equipment and tanks.

Grit Removal

After screening, the next preliminary treatment step is grit removal. Grit is the term used to describe small particles of heavier inorganic and organic material in the incoming wastewater that will not decompose or break down readily. Grit, due to its smaller particle size, can pass easily through the screening process. It can scour and wear mechanical equipment in the plant or settle out in process tanks (such as primary clarifiers), decreasing tank capacity. Examples of grit are sand, gravel, glass particles, eggshells, seeds, and coffee grounds. The main function of the grit removal system is to take as much grit as possible out of the wastewater, while removing as little of the biologically treatable organic material as possible.

There are three main types of grit chambers used at wastewater treatment plants today: gravity-type grit chambers, aerated grit chambers, and vortex grit chambers. The gravity-type units, such as the long-channel and detritus-type units, are slowly being phased out and replaced by aerated and vortex-type grit removal systems. Each type of grit removal unit is designed to reduce the velocity or speed of the wastewater in the chamber until it is less than the velocity in the sewers but fast enough to keep the lighter organic particles from settling out. To keep solids suspended in the sewers, the accepted design practice is to maintain wastewater velocity at or above 0.6 m/s (2.0 ft/sec). In the grit chamber, the flow is slowed down to a rate of approximately 0.3 m/s (1.0 ft/sec). This decreased velocity allows the grit and some of the heavier organic solids to settle, yet keeps the lighter organic solids moving along to the next treatment process. Just as with screens, it is important to keep as many organics in the wastewater that flows on to the rest of the treatment process as possible.

First, we will review the operation of gravity grit chambers. To slow the wastewater flowing through a gravity grit chamber down to approximately 0.3 m/s (1.0 ft/sec), a device such as a proportional weir is used. The proportional weir restricts or slows down the flow of wastewater through the long channel by backing up water behind the weir. Sometimes, instead of using a restriction device, such as the proportional weir, flow is controlled by using a number of channels or tanks. In a multiple grit chamber system, when the influent wastewater flow is low, only one of the grit chambers may have to be used to keep the flow through the grit chamber at a rate of approximately 0.3 m/s (1.0 ft/s). If the influent wastewater flow is high, the flow through the grit chamber can be distributed to two or more units to keep the flow in all channels at the desired velocity (Figure 2.18). Grit is typically removed from these chambers using special rakes and blades that scoop the grit to a collection tank where it is temporarily stored before it is washed and then disposed.

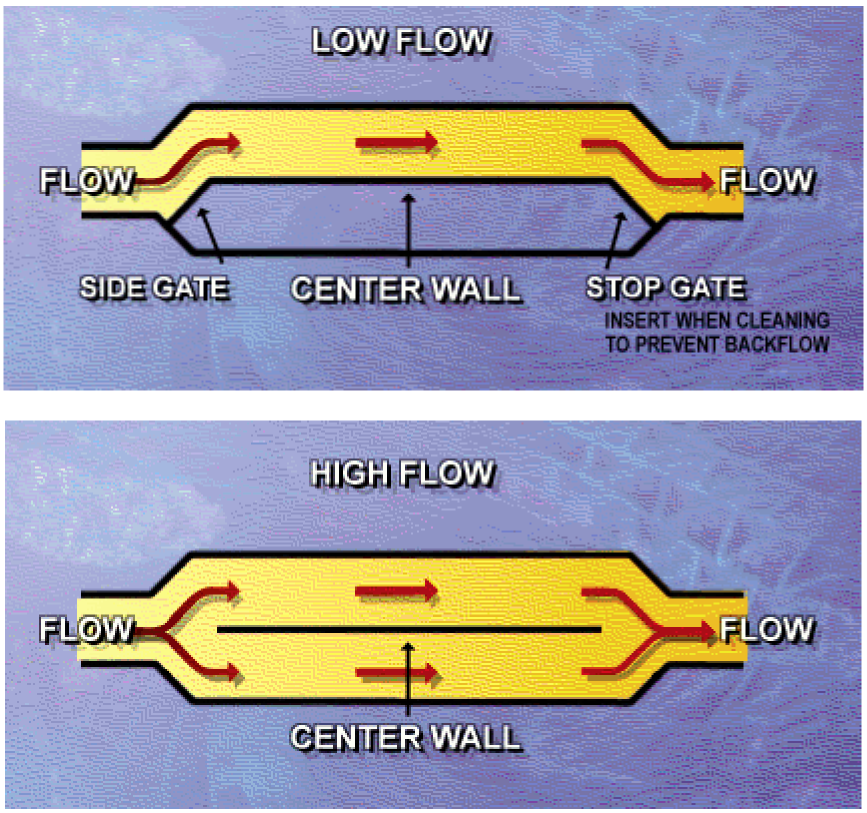
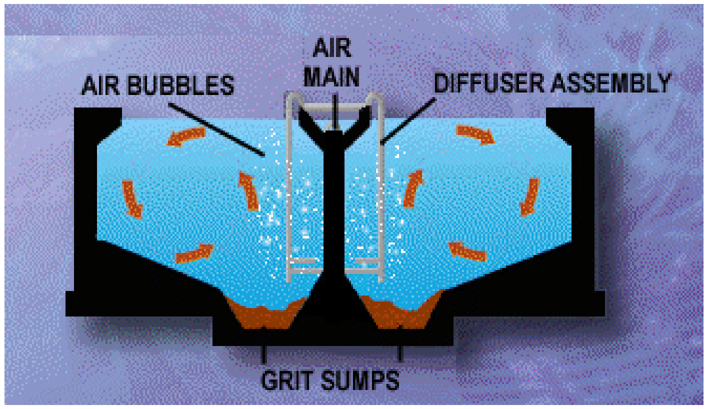


Figure 2.18 Multiple Channel Gravity Grit Removal System

Another type of grit removal chamber is the aerated grit chamber (Figure 2.19). The aerated grit chamber does the same thing as the gravity-type grit chamber, but in a slightly different way. In the gravity-type grit chamber, particles travel in a straight line. In the aerated grit chamber, however, the particles travel in a spiral direction. One advantage that aerated chambers have over gravity chambers is that shorter aerated channels can achieve the same removal rates as much longer gravity chambers. In an aerated grit chamber, diffused air is used to "roll" the wastewater as it flows through the chamber. The target velocity of the roll is usually 0.3 m/s (1.0 ft/sec) to allow the heavier grit particles to settle out while the lighter organic particles stay in suspension. Another advantage of the aerated systems is that the operator can easily adjust the air flow rate to find the optimum roll velocity for a specific plant. If there are too many organics in the grit removed by the chamber, the airflow rate can be adjusted to increase the roll velocity. This reduces the organics that settle out. The air will also scour the grit, helping to separate the organic material from the inorganic material and can break up larger organic solids, allowing more efficient biological treatment in downstream processes. If too much grit is being carried through to the rest of the plant, you can reduce the air flow to decrease the roll velocity. This may settle out more organics, but it will increase capture of the grit. The grit removal process must be monitored and adjusted until the best grit removal-efficiency is achieved without unnecessarily removing organics. Another advantage of the aerated grit chamber is the added benefit of grease removal. The aeration of the flow stream will encourage the grease to float to the surface where it can be removed by skimmers.



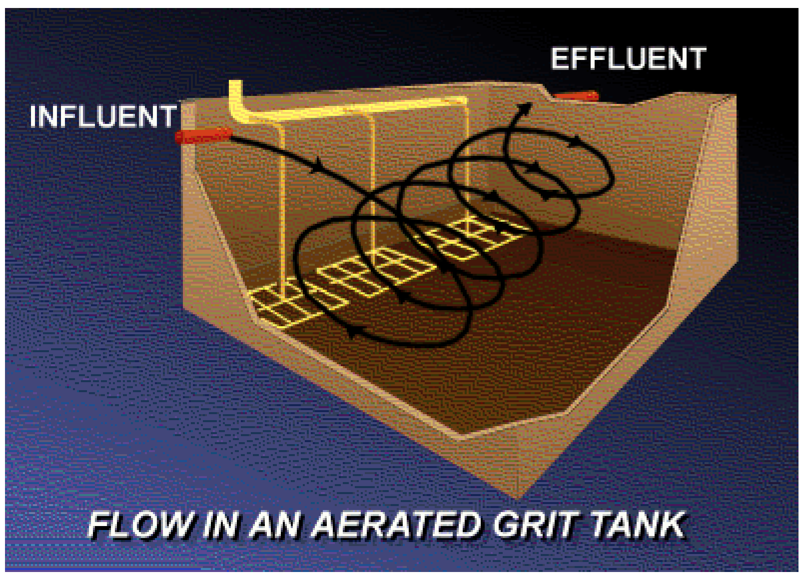


Figure 2.19 Schematic and Flow Pattern for an Aerated Grit Chamber

The third type of grit chamber is the vortex grit chamber. Vortex grit chambers utilize a swirl flow pattern caused by either the tank configuration, mechanical action or a combination of the two to increase the speed and the efficiency of the grit settling. The vortex actually pulls the grit in a downward to the bottom of the structure. The grit is then usually pumped to a grit classifier where it is further dewatered prior to disposal. Let us look at the two types of vortex units commonly used.

First, there are mechanical vortex systems (Figure 2.20). Influent flow enters the top of a circular tank. Effluent usually leaves at the top of the tank, opposite where the influent enters. Grit-laden water leaves the bottom of the tank. The circular tank causes the influent to flow in a vortex pattern, with the heavier grit particles spiraling downward toward the bottom of the tank.

The system uses mechanically-driven paddles near the bottom of the tank to agitate the grit as it settles and to control the velocity of the vortex and to scour lighter organic particles out of the grit, allowing the grit to settle to a hopper in the bottom while organics leave near the top of the tank with the effluent. The grit is usually pumped from the hopper, washed and then finally disposed.

Figure 2.20 Mechanical Vortex Grit Chamber

The other type of vortex grit chamber is commonly referred to as a "teacup" (or free vortex) design (Figure 2.21). Flow enters the chamber tangentially (along one edge of the cylindrical tank), and the tank's design promotes a vortex action in the flow. Effluent along with most of the organic solids exits the chamber through a small cylinder in the center top of the unit. Grit settles to a grit underflow chamber in the bottom of the unit where it is typically pumped to a grit classifier and a dewatering unit prior to disposal. These vortex systems are also useful in degritting primary sludge, when necessary.

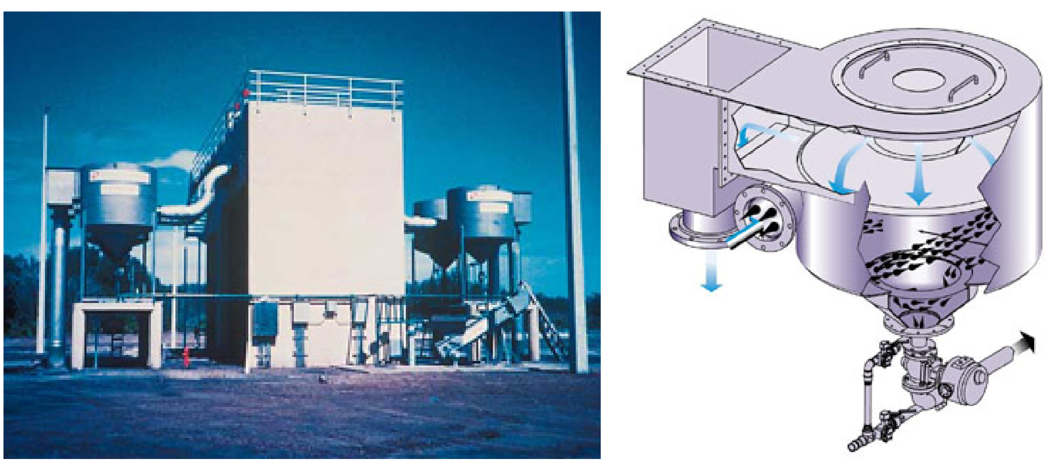


Figure 2.21 "Teacup" Grit Removal Chamber

Many types of grit removal systems allow grit to settle along the entire bottom of a central chamber. Mechanical equipment or manual labor must then be used to remove the grit from the system. Many of these systems use collection equipment such as buckets, scrapers or flights mounted on loop chains to move the grit to one location in the tank prior to removal. This simplifies the task of taking grit out of the chamber. Mechanical collectors can also be used to automatically lift grit out of the chamber and deposit it in a grit container. This enables grit removal without stopping the flow through the chamber. Another option for removing grit from along the entire length of a grit chamber is to use a small pump attached to a traveling bridge.

If no mechanical equipment is provided to lift grit out of the chamber, it must be removed by hand. The flow through a grit chamber can be diverted so that the grit can be shoveled into a wheelbarrow and taken away for disposal. Some plants have buckets called clamshell buckets used to remove grit. Pumps can also be used to lift grit out of the hopper. (Figure 2.22) The advantage of using pumps is that flow and aeration do not have to be stopped to allow for grit removal. How often the pumps run depends on the conditions in your plant. The pump can discharge directly to a long grit channel for settling and later collection of the grit or it can discharge directly to a grit-dewatering device.

Figure 2.22 Photo of Pumps for Grit Removal

Grit always contains at least a small amount of organic matter therefore requiring that it be disposed of in the same manner as screenings. A grit classifier (grit washer) can be used to wash the organic matter from the grit (Figure 2.23). Grit classifiers are available as small aerated chambers, reciprocating rake units, special static screens, or vortex concentrators with screw mechanisms. The water containing the organic matter flows out of the classifier and is returned into the flow entering the plant. The "washed" grit travels up a screw conveyor from the classifier and falls into a container for disposal. The slow movement up the screw conveyor allows for excess water to drain out of the grit.

Figure 2.23 Grit Classifiers

Grit can cause significant odor problems. It can also attract rodents and flies. The need to have operators come into contact with grit should be minimized. If it is unavoidable, proper safety precautions should be taken to avoid the spread of germs and disease. Grit should be disposed of promptly at an approved landfill.

Tables 2.3 and 2.4 provide basic maintenance and troubleshooting tips for common grit removal systems.

Table 2.3 Parts Maintenance Checklist for Common Grit Removal System Components

Chain and Flight Scrapers	Bucket Elevators	Pumps/Air Lifts	Grit Screws	Air Compressors
Chain wear	Chain wear	Pump volute	Screw wear	Motor
Chain tension	Chain tension	Pump impeller	Screw bearings	Coupling
Shoe wear	Bucket wear	Pump coupling	Trough wear	Compressor protective devices
Rail wear	Bucket condition	Pump packing (or mechanical seal)	Trough condition	Compressor belt condition
Flight condition	Bucket pivot conditions	Coupling alignment	Drive system motor	Compressor belt tension
Bearing condition	Shear pin condition	Motor	Drive system gear reducer	Compressor oil
Shear pin condition	Drive system motor	Seal water assembly	Drive system coupling	Silencers
Drive system motor	Gear reducer	Piping joint alignment		Piping joint alignment
Drive system gear reducer	Coupling	Air lift solenoid		

Drive system coupling	Air lift timer
	Air lift blower

Table 2.4 Troubleshooting Guide for Grit Chambers

Indicator/Observation	Probable Cause	Check or Monitor	Solutions
Grit packed on collectors	a. Collector operating at excessive speeds	a. Collector speed	a. Reduce collector speed
	b. Removal equipment operating at low speeds	b. Removal system speed	b. Increase speed of grit removal from collector
Rotten egg odor in grit chamber	a. Hydrogen sulfide formation	a. Total and dissolved sulfide concentrations	a. Wash chamber and dose with hypochlorite
	b. Velocity too low	b. Velocity	b. Increase velocity or add chemical to neutralize sulfide effects
	c. Submerged debris	c. Debris accumulation in chamber	c. Wash chamber daily
Low recover rate of grit	a. Diffusers covered by rags, grit, or grease-coated	a. Diffusers	a. Clean diffusers
	b. Bottom scour	b. Velocity	b. Main velocity near 0.3 m/s (1 ft/sec)
	c. Too much aeration	c. Aeration	c. Reduce aeration
	d. Not enough retention time	d. Retention period	d. Increase retention
High organic content in the grit	a. Inadequate air flow rate	a. Air flow rate	a. Increase air flow rate
	b. Velocity too low	b. Velocity control device	b. Increase velocity
No grit flow or inadequate grit flow from air lift	a. Inadequate air supply	a. Air supply pressure, operation of solenoid on air lift time	a. Correct air pressure, repair or replace control system
	b. Heavy grit – difficult to lift	b. Frequency and duration of operation, how heavy is the grit	b. Manually purge air lift, increase frequency and

			duration of operation
	c. Debris blocking the bottom end of the air lift	c. Air pressure and controls are working properly	c. Manually purge air lift, take grit tank out of service and drain to remove debris

Odor Control

Odor control can be a concern at wastewater treatment plants. Odors during preliminary treatment can originate from several sources: influent wastewater, plant recycle streams, screenings, grit, and septage-receiving stations. These odors can result from the presence of from materials dumped into the collection system as well as hydrogen sulfide or other substances created by partial decomposition of organic materials. Hydrogen sulfide is a common problem in influent wastewater since it is created whenever septic conditions occur in the collection system. Hydrogen sulfide is not only an extremely offensive and odorous gas, but it can also create deadly atmospheric conditions (Figure 2.24). In addition, it can cause structural damage such as concrete deterioration and equipment damage.

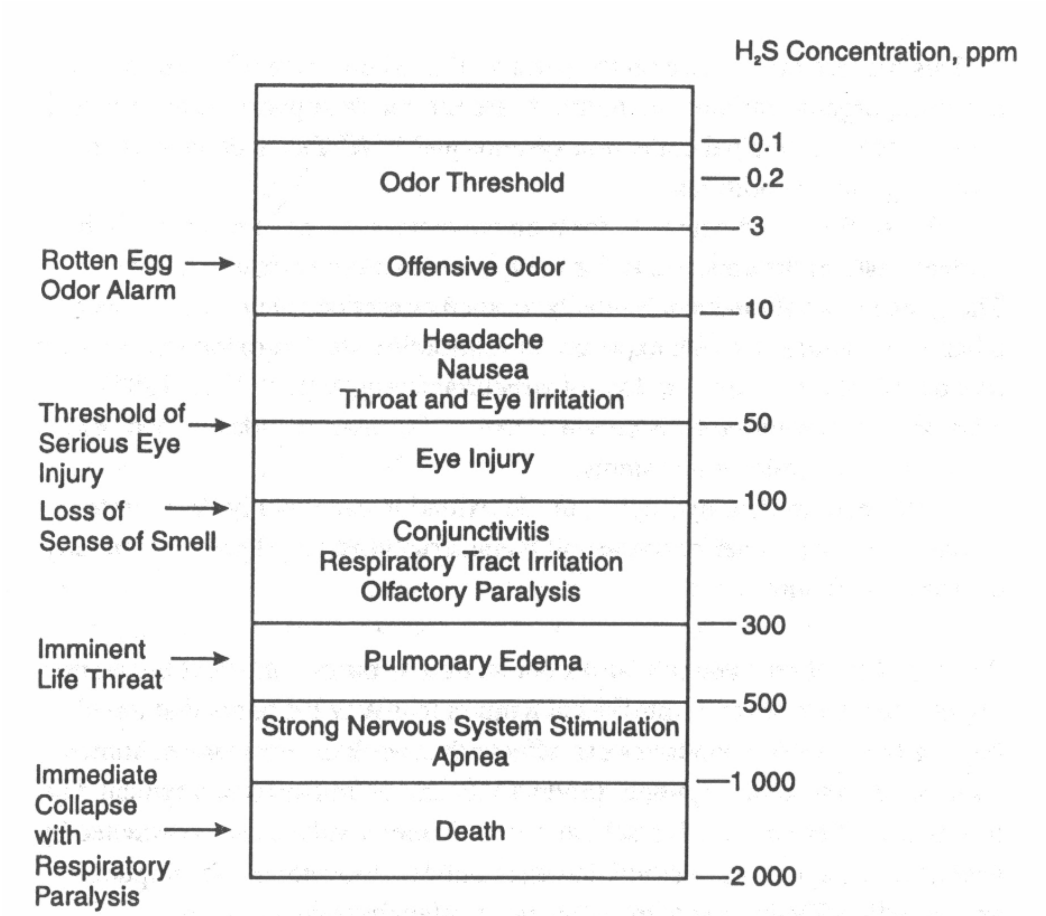


Figure 2.24 Hydrogen Sulfide Toxicity Chart

Odor control measures in a wastewater treatment plant include chemical addition, odor masking, gas collection and treatment, proper housekeeping, and sometimes, operational changes.

Chemicals can be added to the wastewater stream in order to eliminate the source of the odor or to oxidize, bind or precipitate the substance causing the odor. Chemicals used to control odors include chlorine, hydrogen peroxide, ferric compounds, potassium permanganate, and ozone. When using chemicals for odor control, operators must strictly follow all safety procedures for storage and handling.

Wastewater off-gases may also be collected and treated to eliminate odors. Gas collection and treatment units include wet scrubbers, activated-carbon systems and biological treatment. Wet scrubber units may require sodium hydroxide and sodium hypochlorite use in addition to the chemicals already mentioned. These units allow the odorous air to rise through a sealed tower while the scrubber solution is sprayed from the top. (Figure 2.25) As the air comes into contact with the solution, chemical reactions neutralize the odor-causing substances.

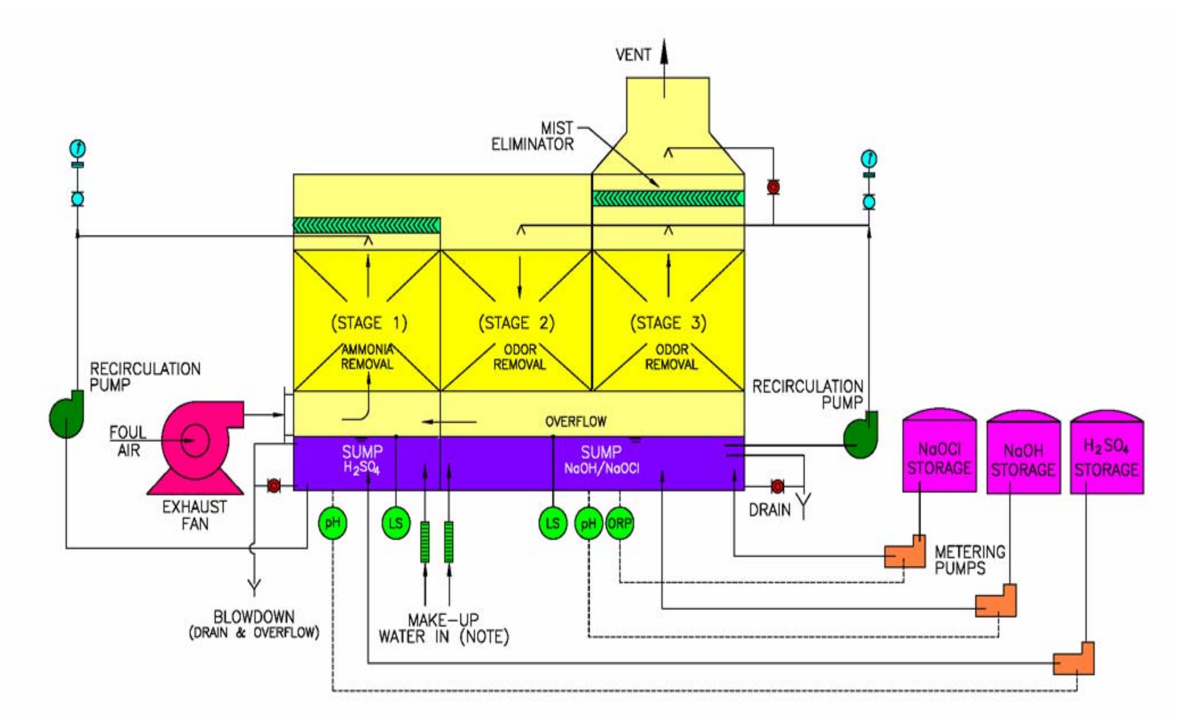


Figure 2.25 Schematic of a Wet Scrubber System

Activated-carbon systems are quite commonly used for odor control at wastewater treatment plants. (Figure 2.26) Odorous air is passed through a bed of granular activated carbon (GAC). Odor-causing substances are adsorbed onto (attached to the surface of) the granular carbon. Once all of the sites for adsorption are used, the system will not be able to remove any more odors. The carbon must be regenerated or replaced before the system will function properly again. This can result in a considerable cost to run the system.

Figure 2.26   Photo of an Activated Carbon Odor Control System

A third option for treating odorous gases that have been collected is biological treatment. In one of these systems, collected air is released underneath a soil or compost bed. As the air moves upward through the porous material, it comes into contact with microorganisms present. The temperature and the moisture content of the media used will greatly affect the activity of the microorganisms and, therefore, greatly affect the performance of the odor control system. The depths of soil or compost beds can range from 2 m to 3 m (6 to 10 ft). An advantage to using this type of a system is that there is little to no equipment that is visible from the surface. At some treatment facilities, plants and shrubs have been planted on top of the soil/compost beds to make an attractive addition to the overall appearance of the treatment facility. Another type of biological odor control system uses a specially designed unit filled with inorganic and biological media. These systems also utilize ancillary equipment such as a fan and humidifier (Figures 2.27 and 2.28) in order to properly maintain temperature and moisture content within the media.

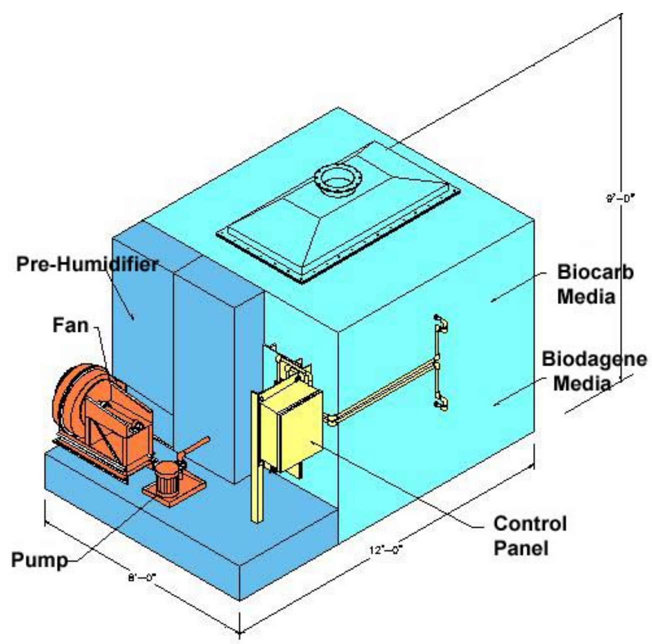


Figure 2.27   Schematic of a Biological Odor Control System

Figure 2.28   Photo of a Biological Odor Control System

General housekeeping will also control some odors with simple washing down of tanks, structures and dumpster areas. It is, of course, critical that this wash-down water be contained within the treatment tanks or collected and returned to the treatment process.

Operational changes that may reduce odors include increasing the disposal frequency of dumpsters, aerating recycle stream holding tanks, and adding screening and/or grit washes to the preliminary treatment process.

Flow Measurement

Flow-measuring devices are typically located in the preliminary treatment section of the plant. Accurate flow measurements will be needed to: properly adjust pumping rates, chlorination rates, aeration rates, chemical feed rates, and other processes in the plant. You will also use the flow information to determine the current plant loading. This information is needed to make good process control decisions. Flow data will also be used to determine plant and unit efficiencies. Process calculations for velocity and detention time are based on flow. These process measurements are called hydraulic loadings. Organic loadings should also be measured. Flows may be in design range, but addition of a new industry may increase BOD. Accurate flow data is essential to proper operation. To make adjustments to plant processes and understand plant hydraulic loadings and efficiencies, it is desirable to have plant flow information on a chart.

The most common types of flow-measuring devices found in wastewater treatment plants are Parshall flumes, V-notch weirs and magnetic flow meters - often called magmeters.

The Parshall flume is a calibrated channel in which the depth of wastewater in the channel is proportional to flow. By continuously monitoring the channel depth, you can receive information on the amount of flow flowing through that portion of the plant. A bubbler tube, a float, an ultrasonic measurement, or an admittance probe typically measures the varying water level through a Parshall flume. The signals from these devices are converted electronically to flow signals at the device indicator and recorder. It is important to note that you can doublecheck the accuracy of your equipment by manually measuring the depth through the flume. Charts supplied by the equipment manufacturer will enable you to convert this depth measurement into flow.

A v-notch weir works somewhat like a parshall flume in that the flow is measured according to the varying water depth up stream of the v-notch weir. The v-notch weirs have different flow ranges depending on the degree of the v-notch angle (22.5 - 90 degree typical sizes). V-notch weirs are more accurate for lower flows than parshall flumes.

Magnetic flow meters can be used in applications varying from measuring effluent flow to measuring the flow of thickened sludge. Magmeters (Figure 2.29) work using electromagnetic induction in which the induced voltage generated by a conductor moving through a magnetic field is linearly proportional to the velocity of the conductor. As the liquid (conductor) moves through the meter, the voltage produced is measured and converted to a velocity and thus a flow rate. Magmeters do require that the pipe be completely full in order to operate properly. It is also necessary to keep the electrode relatively clean (for example, grease in some sludges).

Figure 2.29 Magnetic Flow Meter Systems

Testing and calibration of flow-measuring equipment should be done as part of a regular treatment plant maintenance program. Suspected equipment malfunctions should be corrected immediately. Flow measurement information is essential for adjusting processes and determining plant hydraulic loadings and efficiencies.

Flow Management

Accurately measuring and monitoring the amount of flow entering the treatment plant is only the first step. An operator must have options available that will make it possible to properly manage the flow, if need be, once it is measured. When peak flows do occur, operational alternatives that will allow an operator to protect the performance of the treatment process as well as guard against damage to the equipment and infrastructure is critical.

When many wastewater treatment plants were first built back in the 1950s and 1960s, bypass structures were included in the headworks of the plant. They were designed so that when the plant received peak flows that the facilities could not handle, the excess influent flow could be diverted to a nearby waterway. The Clean Water Act of 1972 outlawed the bypass of untreated wastewater. Therefore, new methods for dealing with excess influent flows had to be developed. This new strategy is referred to as flow equalization. Tanks, lagoons, tunnels, etc. are designed into the system to provide enough capacity to hold the peak excess flow. Once the influent rate has dropped back to normal levels, this excess wastewater is slowly pumped back into the system and is treated by the plant. These holding structures are referred to as peak flow handling structures or flow equalization structures (Figure 2.30).

Figure 2.30 Photo of a Flow Equalization System

Flow equalization structures can be located before the preliminary treatment system, directly after the preliminary treatment system or immediately after the primary treatment system at a wastewater treatment plant. These different locations should be analyzed for every individual treatment facility to determine the most optimal placement. If flow equalization is located before the preliminary treatment system, all of the plant's equipment and structures are protected from the peak flows. This may allow smaller screening and grit removal systems to be installed. However, the screenings and grit in the influent may cause problems with the equalization mixers and pumps and debris that settles out of the wastewater while it is held in the structure can cause odor and clean-up problems. Locating flow equalization structures after the preliminary treatment system will eliminate problems with grit and debris in the holding structures. Preliminary treatment facilities will need to be sized to treat peak flows but preliminary treatment tanks can be sized to treat the lower equalized flows. Adequate mixing must still be provided to keep suspended solids from settling out of the wastewater. Settled material may still cause clean-up and odor problems. Locating the equalization system after the primary treatment process will minimize operational problems associated with settled material but this placement will not provide any equalization benefit to the preliminary or primary treatment systems.

Equalization systems can be used to dampen peak flows or peak pollutant loadings through a system or to achieve a combination of these two objectives. There are two basic designs for flow equalization systems – in-line systems and side-line systems.

An in-line system has an equalization basin directly after preliminary treatment along the flow path of the wastewater (Figure 2.31). This requires that all of the flow through the plant also pass through the equalization tank. This type of a configuration provides significant dampening of the peak flow as well as minimization of the effects of any peak organic loads or toxic slug loads. A drawback to this design is that typically larger tanks are required to achieve flow dampening.

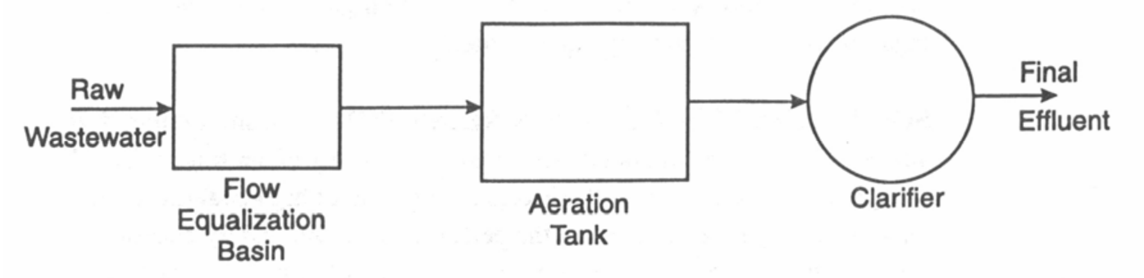


Figure 2.31 Schematic of an In-line Equalization Configuration

A side-line system is designed to "draw off" flows in excess of the plant's maximum influent flow and pump the excess back into the system after the flow returns to normal. The modified side-line system is primarily designed to hold plant recycle streams such as filter backwash and by-passes directly from the collection system. Figure 2.32 shows the layout for both of these systems.

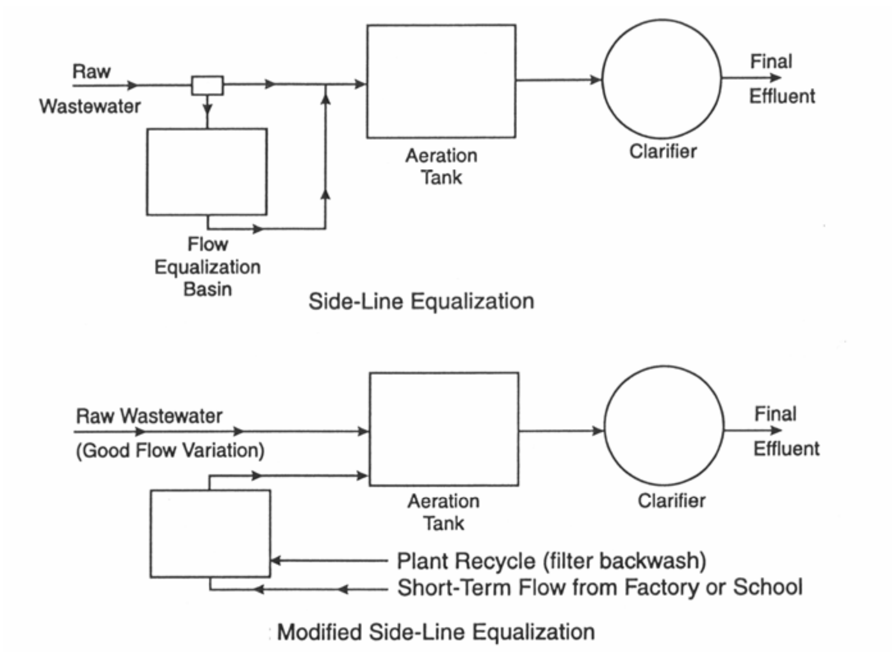


Figure 2.32 Flow Schematics for Equalization Systems

An equalization basin is not simply a holding tank, but also a treatment process in itself. Equalization basins must provide adequate aeration and mixing to keep the stored influent well mixed and prevent it from going septic before being reintroduced to the system. In fact, if properly designed, an equalization basin can also serve as an extra biological reactor in case of severe loading or in order to repair an existing biological reactor.

Safety

Operators must follow all appropriate safety procedures when working in the preliminary treatment area. Never place your hands near moving equipment. Remember: You are not faster than the speed of a motor shaft, and you are not stronger than a gear-reduction unit. Keep your hands out of moving equipment and always watch where you are walking. In addition, always follow proper lockout/tagout procedures. Remember that most equipment in the preliminary treatment area starts automatically based on flow rate, a timer or level differential.

Always turn off and lock out circuit breakers and tag them with a "Do Not Start" sign. Each person working on equipment should have his or her own lock so that equipment cannot be started until all work is completed. To prevent electrical shocks, a commercial-grade rubber mat should be placed on the floor in front of all control panels. Also, repairs on many pieces of preliminary treatment equipment, such as in-channel screens, may be classified as a confined space and therefore require the necessary permit and equipment. Operators must also be aware of the dangers they cannot see in the preliminary treatment area, such as toxic gases, oxygen-deficient conditions, explosive or flammable liquids or gas in the raw wastewater. The preliminary treatment area is not just odorous; exposure to it may require the use of respirators for long-term exposure to protect against common raw wastewater gases. Continuous gas detection meters or explosive chemical detectors are good safety precautions. To protect against pathogens, operators should also practice proper hygiene and wear protective clothing around screenings and grit. Hypodermic needles and other harmful materials may also be present in the screenings. Operators must continually remain alert for unseen dangers. Slip and trip hazards potentials are always present with the use of hoses, rakes, and water. Screenings, grease and water spilled on the floor could also become a slip hazard.

Chapter Quiz

1. Preliminary treatment includes screening, grit removal, and __________.

    a. clarification
    b. UV disinfection
    c. polymer conditioning
    d. flow measurement/control

2. Small amounts of septage, compared to a plant's influent flow, can be received __________.

    a. at a plant's headworks
    b. directly into the primary clarifier
    c. at the biological reactors
    d. at the disinfection process

3. Choose the most accurate statement. Manually-cleaned bar screens must typically be cleaned __________.

    a. more often than bar racks
    b. less often than bar racks
    c. once a month
    d. with special cleaning solutions

4. The two basic types of rotary drum fine screens are __________.

    a. vertical and horizontal
    b. above or below-channel
    c. fully or partially-submerged
    d. internally or externally-fed

5. A flowmeter in which the liquid measured acts as a conductor that generates a voltage which is converted into flow data is commonly called a(n) __________.

    a. ultrasonic meter
    b. bubbler tube
    c. admittance probe
    d. magmeter

Chapter Quiz Answers

Question 1

Answer: “d”
Reference: 2-1
Immediate Feedback: The first treatment steps that influent wastewater undergoes in a typical wastewater treatment plant are screening and/or grinding, grit removal, flow measurement, flow control, and sometimes odor control. These steps together are referred to as preliminary treatment.

Question 2

Answer: “a”
Reference: 2-3
Immediate Feedback: If the amount of septage to be received by a wastewater treatment plant is very small, it is sometimes simply discharged at a convenient location at the facility’s headworks. As long as it is a small percentage of the plant’s total influent flow and the plant has adequate preliminary treatment capacity, it can be mixed with the other wastewater entering your plant and adequately treated without having a negative impact on the overall wastewater treatment process.

Question 3

Answer: “a”
Reference: 2-5
Immediate Feedback: Because the bars of a bar screen are set closer together than those of a bar rack, debris collects on the screen more readily and must be cleaned more frequently. It is this reason why manually-cleaned bar screens are typically used at small plants or as standby units for mechanically cleaned systems.

Question 4

Answer: “d”
Reference: 2-10
Immediate Feedback: Rotary drum screens are another type of fine screens. There are two basic designs for these units: internally-fed or externally-fed. For internally-fed rotary drum screens, influent is fed into the center of the unit and is distributed evenly along the length of the drum. For externally-fed rotary screens, influent is evenly distributed and applied all along the length of the outside of the rotating stainless steel screen.

Question 5

Answer: “d”
Reference: 2-27
Immediate Feedback: With a magmeter, as the liquid (conductor) moves through the meter, the voltage produced is measured and converted to a velocity and thus a flow rate. Magmeters do require that the pipe be completely full in order to operate properly.