By Kenny Oyler

Headworks:

Removing Inorganics and Preventing Wear

The "headworks" of a wastewater treatment plant is the initial stage of a complex process. This process reduces the level of pollutants in the incoming domestic and industrial wastewater to a level that will allow the treated wastewater or effluent to be discharged into a stream, river or lake. This treated effluent also may be sprayed onto dedicated land areas where it is used for the irrigation of crops and even golf courses. The complete process includes preliminary treatment, primary treatment, secondary treatment and often tertiary treatment.

The treatment processes of a wastewater plant have become more and more sophisticated and the performance of the headworks is more important than ever. The function of the headworks is to remove inorganics such as sticks, stones, grit and sand from the wastewater stream to protect and reduce wear on the downstream process equipment. Equipment in the headworks may include pumps, mechanical screens, screening compactors, grit removal systems and grit washing systems.

Pumps

During the design of the headworks, the engineer is confronted with a variety of pumps that can be used to pump the wastewater from an influent wet well to the headworks building. Pumps are classified as centrifugal, airlift, positive displacement and screw type. When selecting the type of pump, the engineer must match the pump performance with the head capacity curve for the system design.

Centrifugal pumps are classified into radial flow, mixed flow and axial flow types, according to the direction of flow in reference to the axis of rotation. The rotation axis of the pump shaft determines whether the pump is a horizontal or vertical unit. Horizontal dry pit non-clog, vertical dry pit nonclog and submersible types typically are used in wastewater treatment applications.

Radial-type pumps derive their non-clog characteristics from the type of impeller that is used in their construction. These pumps include types that will operate in both wet and dry well installations. The impellers are designed to be rounded and free of sharp corners and projections that would be likely to catch and hold rags and other stringy type materials.

Axial pumps, commonly used in wet well installations, move liquid by the propelling or lifting action of the impeller vanes. This pump is used primarily for clean water, or treated effluent, and should not be used for raw wastewater or sludge applications since large solids and stringy material can easily cause plugging.

The vortex, or torque flow, pump has an impeller completely recessed from the volute area. The multi-vane, semi-open impeller is recessed into the discharge casing and is completely removed from the volute area. This positioning generates a whirling, circular motion that extends into the suction opening. The vortex action created directs the flow of both the fluid and entrained solids entering the pump into the volute area, where centrifugal force pushes the flow out. The fluid and entrained solids do not enter the impeller, but pass from the suction line through the volute into the discharge line.

The mixed flow impeller is an intermediate design that has the characteristics of both the radial and axial flow propeller. These pumps are quite suitable for handling wastewater or stormwater because they are designed with wide, unobstructed passages.

For a comparable pump discharge size, the non-clog—or radial—pump will pass larger solids. However, the mixed flow pump is available in large discharge sizes that are suitable for many wastewater and stormwater applications that produce very large volumes of inflow.

The quantity of material removed from the waste stream varies significantly depending on the opening that is established between the screening bars.

Horizontal or vertical centrifugal grinder pumps are used to handle raw domestic or industrial wastewater containing large solids. The use of this type of pump is increasing due to the requirement of pumping septage and holding tank waste. Discharge heads are limited, and pumping efficiencies are low.

Positive displacement pumps are used because of their ability to move heavy and concentrated sludge containing entrained gases without losing prime. Efficiency rarely is a factor in pump selection.

Screw pumps range in size from 24″ to 120″ in diameter. The normal-rated capacity may range from 100 gpm to 35,000 gpm. These are large, uncomplicated pumps that operate on Archimedes' principle for lifting water.

Screw pumps with both open and enclosed configurations are used for high-capacity and non-clog requirements. An open screw has a lifting height limitation of 38′. Pump length is restricted due to deflection and strength considerations, and the incline angle is limited to 30 or 38 degrees. The enclosed screw pump can be installed at an angle of 38 or 45 degrees and will have a vertical lift of up to 60′.

The efficiency of the screw pump increases from its minimum capacity to its rated capacity, with near maximum efficiency realized within the top 70 to 80 percent of the pumping range. These units are well suited for variable capacity operation because the rate of discharge is controlled by the fluid level at the screw inlet. Therefore, a variable speed drive is unnecessary. The horsepower varies almost directly with the pumping capacity, resulting in higher efficiencies over a wide range of pumping capacities.

Screening Systems

Wastewater reuse and sludge recycling is common. Screens are no longer used just to protect the downstream equipment, but are critical to the removal of plastic feminine applicators and condoms from the wastewater stream and therefore, the sludge. With fine screening the undesired removal of organics and fecal matter also is a concern. Therefore, washing and dewatering of the screenings is critical to maintaining a good screening process.

Screens can be classified as coarse, fine and micro. (Increasingly, treatment plants use a combination of coarse screens and fine screens.)

Coarse screens, with openings more than 6 mm (¼″), remove large solids, rags and debris from the wastewater. Fine screens, with openings of 1.5 mm to 6 mm, are used to remove smaller materials and may significantly increase downstream liquid and sludge processes, particularly in systems without primary treatment.

There are many types of mechanical bar screens including

- Chain and Rake Bar Screens
- Cable Operated Bar Screen
- Reciprocating Rake Bar Screens
- Catenary Bar Screens

Screw pumps reach near maximum efficiency within the top 70 or 80 percent of the pumping range. These units are well-suited for variable capacity operations.

- Continuous Self-Cleaning Screens
- Step-type Screens
- Screw-type Screens.

The quantity of screenings material removed from the waste stream varies significantly depending on the opening that is established between the screening bars. In addition, flow characteristics of the municipality and type of collection system will affect the amount of screenings that are collected.

The quantity of screenings removed also will be affected by the length and slope of the collection system. The use of multiple pumping stations may reduce the size of the organics received at the headworks. It can be assumed that the volume of screenings removed may be greater with a short, gently sloping collection system with little pumping and low turbulence. This difference stems from disintegration of solids exposed to long periods of turbulence. The impact of turbulence will be more significant for smaller bar screen openings.

Composition as well as volume affects the disposal of screenings. Coarse screenings consist of rags, sticks, leaves, food particles, bones, plastics and stones. With smaller openings (6 mm and under) cigarette butts, fecal matter and other organic matter may be included in the screenings.

Screenings normally contain about 10 to 20 percent dry solids and will have a bulk density of between 40 and 70 lb./cu. ft. Openings of 19 mm or smaller should adequately protect downstream equipment. Smaller openings between the screen bars will produce larger volumes of solids removal and can offer a greater degree of protection for downstream equipment. (Caution should be used when selecting openings smaller than 13 mm for plants served by gently sloping gravity collection systems because of the potential for the removal of unwanted fecal matter.)

Proper bar screen selection and sizing will ensure satisfactory mechanical and process performance and could increase the efficiency of downstream equipment and processes in the treatment plant. The following are criteria usually used to determine the type of screen best suited for a particular application.

- Particle size and volume of screenings to be removed
- Flow variations and influent characteristics
- Minimum and maximum water levels
- Plant hydraulics and allowable headloss

As with most types of mechanical equipment, maintenance requirements and reliability are very important aspects of design and equipment selection. When called on to operate, the bar screen should be expected to perform efficiently and effectively with a minimum of operator attention.

Due to operation and maintenance considerations, two narrow bar screens are recommended over a single, wide screen. When two or more screens are used, the screening channel and screening equipment should be designed so that one screen can be taken out of service without adversely affecting the operation of the facility or the remaining screen.

Screen headloss and the volume of solids removed increases dramatically as the size of the screen opening decreases. Therefore, the application of a fine screen necessitates a careful review of the plant hydraulics and processes. This review is especially important in a retrofit installation where a coarse bar screen is being replaced by a fine screen.

Large quantities of solids removal attributed to fine screens may result in a reduction of BOD levels by 5 to 25 percent, TSS by 15 to 30 percent, grease by 30 to 50 percent and up to 90 percent of all floatables. If recognized by the engineer, reduction in BOD could be reflected in the downsizing of downstream processes.

The various types of fine screens may be categorized and differentiated by the way they are positioned relative to the flow, the screening medium used or the cleaning mechanism employed. When locating a screen, the engineer needs to consider the effects of the backwater caused by the head loss through the screen. Some installations include an overflow weir to a bypass channel to prevent upstream surcharging if the screen becomes blinded.

The hydraulic consideration is very important in the screen design. The velocity distribution in the approach channel has an important influence on the screen operation. A straight channel ahead of the screen ensures good velocity distribution across the width of the screen.

The engineer must ensure that the wastewater's approach velocity to the screen does not fall below a self-cleaning value or rise enough to dislodge screenings. Extremely low channel velocities may result in the settling of solids in the channel ahead of the screen. Ideally, the velocity in the approach channel should exceed 1.3 feet per second, at minimum flows. This is to avoid grit and other solids from settling in the approach channel. Solids settling in the channel ahead of the screen may hinder the operation of the screen and in some cases may damage the screen. Factors to consider when evaluating screens are shown in Table 1.

Grit Systems

Grit removal is an important part of the wastewater treatment process. Grit removal helps reduce maintenance costs of downstream equipment. Grit causes wear on pumps, clogs pipes and channels and can take up valuable space in the sludge digestion tanks.

Depending on the type of grit removal process used, the removed grit can be further concentrated in a cyclone, and washed to remove lighter organic material captured along with the grit. The washed grit can be more readily stored without odor problems and is more easily disposed of than unwashed grit.

The quantity and characteristics of grit, and its potential adverse impact on downstream processes, are important considerations in selecting a grit removal process. Other considerations include headloss requirements, space requirements, grit removal efficiency, organic content and economics. A variety of grit systems is available. The basic categories are vortex, chain and bucket (aerated and non-aerated), chain and scraper (aerated and non-aerated), aerated screw and screw.

For design purposes, grit particle sizes traditionally have included particles larger than 65 mesh (0.008″) with a specific gravity of 2.65. Removal of at least 95 percent of these particles always has been the target of grit removal design. Grit removal designs are now capable of removing up to 75 percent of 100 mesh (0.006″) material because of the recent recognition that plants often need to remove particles that are small to avoid adverse effects on the downstream processes. Similar to screen designs, flow extremes must be identified so the grit chamber can be designed to efficiently remove grit.

The quantity of grit entering the treatment plant usually is greatest during peak flows. Grit chambers are sized to remove grit effectively at peak flows and to avoid removing excessive organic material at lesser flows.

Grit Removal

Removal of grit from the grit chamber can be accomplished in many ways, depending on the type of grit system used. Four methods that will automatically remove grit are

- screw or tubular conveyor,
- chain and bucket elevators,
- clamshell buckets, and
- pumps.

Grit Washing and Dewatering

After removing the collected grit from the grit chamber, the grit normally is washed to ease handling. In most cases, a reduction in grit volume by removing the water contained in grit saves transportation costs and eases transport and handling during disposal. Washing the grit to remove putrescible organic material makes grit handling and disposal more manageable. Removing putrescible organic material prevents odors and nuisance conditions caused by the decomposition of organic material.

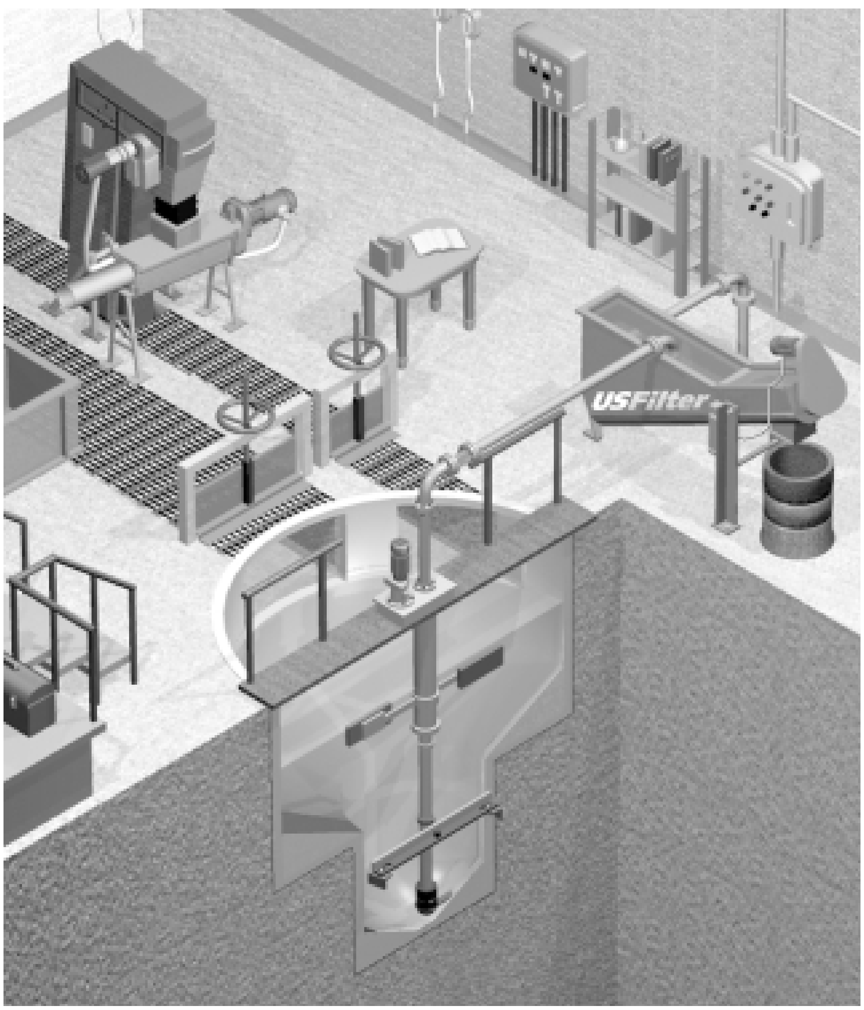
A hydrocyclone separator concentrates grit centrifugally, requiring a steady feed of the grit slurry at an inlet pressure to the grit classifier of 5 psi to 20 psi. The constant feed rate typically will be within the range of 200 to 500 gpm, depending on the size of the cyclone. Cyclone separator sizing is based on the cycled feed rate and the grit slurry solids concentrations. Cyclones work best at feed concentrations less than 1 percent solids. The centrifugal action created in the cyclone separators increases the solids content to an average of 5 to 15 percent. Approximately 90 to 95 percent of the feed flow rate discharges through the vortex finder at the top of the cyclone. This flow volume reduction saves transportation and storage and reduces the required size of the grit classifier.

Grit classifiers (i.e., the inclined screw or reciprocating rake type) wash the grit by separating the putrescible organic from the grit. Classifiers are sized based on the settling velocity of the particles to be removed, the feed flow capacity and grit capacity. For a target particle size and flow rate, the design engineer selects a minimum pool area (surface area) and overflow weir length.

Classifiers are inclined from 15 to 30 degrees from the horizontal. In addition to slope, proper flight tip speed and pitch assist in the particle removal. Sectional flight construction may perform better than helicoid flights. Hardened flight edges should be used to resist the abrasive action of the grit.

Table 1: Screen Evaluation Factors

- **Hydraulic Efficiency:** Ability of the screen to pass peak flow.
- **Cleaning Efficiency:** Ability of the screen to remove the captured debris.
- **Cycle Time:** Time required to remove the captured debris.
- **Material of Construction:** Ideally, screens should be manufactured from a corrosion-resistant material.
- **Headroom Requirements:** Overall height of the screen above the operating floor.
- **Controls:** Ability of the screen to operate efficiently.
- **Ease of Maintenance:** Accessibility of components for routine maintenance.



After removing grit from the water, the grit normally is washed to ease handling. In most cases, a reduction in grit volume by removing water saves transportation costs and eases transport and handling during disposal.

Reference:
Design of Municipal Wastewater Treatment Plants Volume I, WGF Manual of Practice No. 8, ASCE Manual and Report on Engineering Practice No. 76, 1992

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