FACT SHEET

Liquid Stream Fundamentals: Grit Removal

Grit removal is an essential component of the wastewater treatment process. Not only does the removal of grit help protect downstream equipment from abrasion and wear, it prevents solids accumulation and loss of capacity in process tanks and channels.

Introduction

A common challenge for all wastewater resource recovery facilities (WRRFs) is the removal of grit from the wastewater early in the treatment process. Grit is generally composed of sand, gravel, cinders, and other heavy solid material with specific gravities substantially greater than the organic matter found in wastewater. It is important to remove grit from the wastewater to protect moving mechanical equipment from abrasion and abnormal wear, to reduce clogging from grit deposition in pipes or channels, and to prevent loading the treatment works with inert matter that interferes with liquid and solids treatment units such as the aeration tanks and the anaerobic digesters.

Grit removal is part of the preliminary removal treatment process (See Screenings Removal Fact Sheet for more information on preliminary treatment). It is critical for the protection of dewatering centrifuges and high-pressure progressing cavity, rotary lobe, and diaphragm pumps, all of which are damaged by grit. For facilities with primary clarifiers, grit not removed at the headworks will settle in the primary sludge and, if not removed from the primary sludge, will be transferred to the solids management units, such as thickeners, digesters and dewatering equipment. For plants without primary clarifiers, grit not removed at the headworks settles in the aeration basins where it accumulates over time. Periods of peak wet weather "first flushes" may result in high grit loadings which must be accounted for in the proper sizing of grit removal units and subsequent handling units.

Removed grit is typically concentrated and washed to remove lighter organic material that is captured with the grit. The degree of washing and concentration of the grit slurry depends on several factors, including the degree of odor control and vector attraction required during storage, and costs and regulations associated with disposal.

Grit Characteristics and Quantities

The quantity and characteristics of grit entering a WRRF varies based on a number of factors, including the type of collection system (combined or separate), characteristics of the drainage area, use of household garbage grinders, condition of the sewer system, sewer grades, and types of industrial waste. In most cases, grit accumulates in the collection system due to its faster settling properties and is flushed into the WRRF in large quantities during peak flows.

To estimate the volume, size and settling characteristics of the grit entering a WRRF, sampling can be performed. This allows for proper design and performance assessment of grit removal processes. The samples may be taken from the raw wastewater influent and screened influent. Sampling of the influent and effluent to the grit removal process will define the removal efficiency of the grit removal process.

The three most common grit sampling methods include:

- Cross-channel sampling
- Full depth sampling
- Primary sludge sampling

The first two sampling methods typically take grit from the influent channel downstream of the headworks screens and ahead of the grit removal process. The sampling devices are different as each measures a different profile of the water in the channel. The most appropriate sampling methodology is based on the hydraulics in the sampling area. For example a long, non-mixed channel will have most of the grit traveling along the bottom of the channel, where as a highly mixed channel will have grit throughout the water column. The samples are typically placed through sieves to determine the particle size distribution of the grit. The sieve analysis can be performed wet or dry, to determine the various size fractions of the grit. Some test methods include measurement of the grit settling velocity and the Sand Equivalent Size (SES).

Primary sludge sampling, when combined with the amount of grit removed from the existing grit removal process, can be used to determine the total quantity of grit entering a facility. This method assumes all of the grit settles out in the primary clarifiers. Primary sludge sampling requires large and frequent sampling volumes of highly odorous and pathogenic primary sludge, which creates a large burden on the laboratory.

Overall, there is a lack of standardization in grit testing methods, resulting in most facilities choosing not to test the grit before or after construction of grit removal systems. This may lead to poorly informed decisions about the effectiveness of these systems, and potentially the acceptance of poorly performing systems which increases maintenance and operating costs for downstream processes. To lead the effort in resolving these issues WEF has published Guidelines for Grit Sampling and Characterization that provides detailed information on the currently used grit sampling methods (WEF, 2016).

Grit Removal Technology

The most common types of grit removal technologies are summarized in Table 1 below.

Grit Removal Method	Advantages	Disadvantages
Horizontal Flow Grit Chambers	• Outlet flow control device allows for flexibility • Construction is relatively simple • Grit not requiring further classification may be removed with effective flow control	• Difficult to maintain target velocity • Excessive wear on chains, flights, and bearings • High amounts of organic material removed if flow control is ineffective • Excessive headloss • High velocities at channel bottom may be generated, leading to bottom scour
Aerated Grit Basins	• Consistent removal efficiency over a wide flow range • Relatively low organic content • Pre-aeration may improve performance of downstream units • Versatile, allow for chemical addition, pre-aeration, and flocculation	• May release harmful volatile organics and odors • High power requirement • High maintenance and control required
Mechanically Induced Vortex Tanks	• Consistent removal efficiency over a wide flow range • No submerged bearings or parts which require maintenance • Relatively small footprint • Minimal headloss	• Paddles may collect rags • Deep excavation required which increases construction costs • Grit sump may clog, requires high-pressure agitation to loosen grit
Detritus Tanks	• No flow control required as all bearings and moving parts are above water line • Minimal headloss	• Difficulty achieving uniform flow distribution over a wide range of flows • May removes large quantities of organic material • Grit may be lost in shallow installations due to rake arm agitation
Multi-Tray Vortex	• Removal of grit ≥ 75 micron • No moving parts • Short settling distance • Small footprint • Expandable	• Proprietary design • Water consumption • 12" Headloss
Hydraulically Induced Vortex	• Removal of grit ≥ 75 micron • No moving parts • Small footprint	• High headloss (>36" typical • Pumped influent required.

Table 1— Common Grit Removal Technologies

Horizontal Flow Grit Chambers

One of the earliest types of grit removal systems, horizontal flow (also known as velocity controlled) grit chambers use physical controls and chamber geometry, such as proportional weirs and rectangular control sections, to vary the depth of flow and maintain the velocity within the chamber at a constant 1 foot per second (fps). Operational experience has shown that this velocity allows heavier grit particles to settle and promotes lighter organic particles to remain suspended and eventually be carried out of the chamber. In designing a horizontal flow grit chamber, the settling velocity of the target grit particle and flow depth relationship determine the required length of the channel. The grit that builds up on the channel floor is then collected by a conveyor with scrapers, buckets, or plows. Screw conveyors, bucket elevators, or grit slurry pumps are used to elevate the grit for washing, dewatering, and disposal.

Aerated Grit Basins

Aerated grit removal tanks are constant liquid level, short detention time rectangular settling chambers. Air is introduced along one side of the tank through submerged diffusers which creates a spiral flow pattern that moves perpendicular to flow through the tank. The velocity of the spiral flow pattern controls the size and specific gravity of the particles that will be removed. If the velocity is too great, grit will be carried out of the chamber; if the velocity is too low, organic material will settle out with the grit.

The bottoms of the tanks are sloped downwards towards the air diffusers. Beneath the air diffusers, a trough is provided along the length of the tank to collect the settled grit. The trough may be several feet deep to prevent grit from being agitated and re-suspending in the wastewater. Settled grit collected in the troughs is typically transported to a grit hopper utilizing a screw conveyor (auger) or chain and flight. Once in the grit hopper, grit slurry is pumped by dedicated grit slurry pumps to the grit handling equipment for further processing.

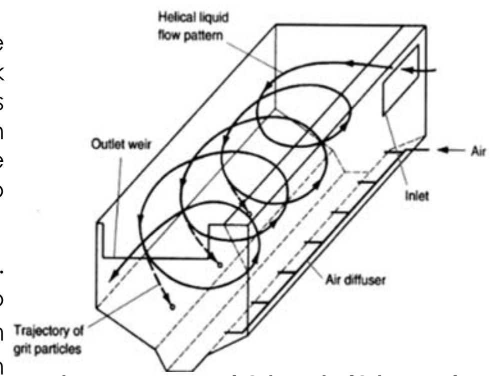

Figure 1—Aerated Grit Basin (Crites and Tchobanoglous)

Vortex Tanks

Vortex grit removal tanks are circular in shape and rely on a mechanically induced vortex to capture grit solids in a center hopper. The hydraulic flow pattern created by this shape forces the grit to the chamber floor within one revolution inside the chamber. Incoming flow straightens in the inlet flume to minimize turbulence at the inlet of the chamber. At the end of the inlet flume, a ramp causes grit that may have already been on the flume bottom to slide downward along the ramp until reaching the chamber floor where the grit is captured. At the end of the flume, an inlet baffle may be positioned such that flow entering the chamber and flow inside the chamber impinge on its sloped surface. At the center of the chamber rotating paddles maintain the proper circulation within the chamber for all flows. The combination of rotating paddles, inlet baffles and inlet flow produces a spiraling flow pattern that tends to lift lighter organic particles and settle the heavier grit particles. The captured grit moves inward and drops into a center storage hopper. Grit slurry is pumped by dedicated grit slurry pumps from the storage hopper to the grit handling equipment for further processing.

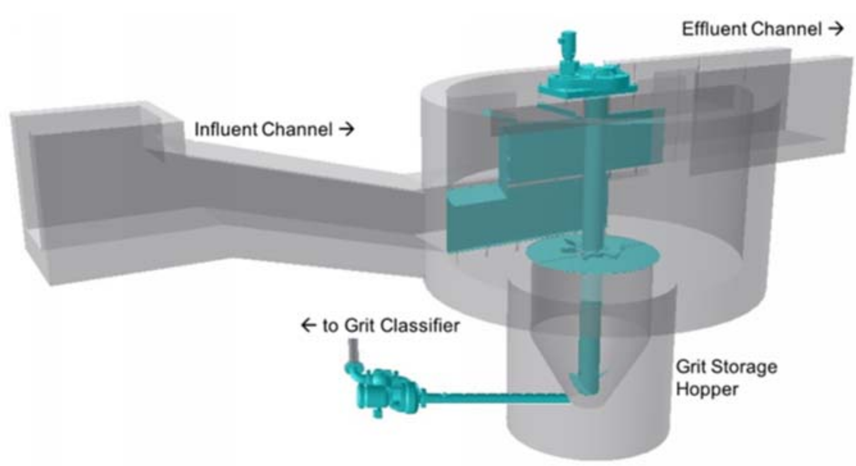

Figure 2— Mechanically Induced Vortex Tank (Smith & Loveless Inc.)

Detritus Tanks

Detritus grit removal tanks are constant liquid level, short detention time settling chambers. They are typically square in shape and relatively shallow, approximately 18 to 36 inches deep. Influent wastewater is distributed along one edge of the tank and typically flows over an effluent weir along the opposite side of the tank, creating a cross tank flow pattern. Grit settles along the tank floor and is swept by the grit collector rake arms to a grit collection sump. At the grit collection sump, grit is pumped by dedicated grit slurry pumps to the grit handling equipment for further processing.

Efficient detritus tank operation relies on the proper distribution of flow across the tank. Allowances are made for inlet and outlet turbulences as well as short circuiting when determining the required detritus tank area. Good detritus tank design practice is to apply a safety factor of 2.0 to the required overflow rate to account for these hydraulic inefficiencies. Detritus tanks are not recommended for facilities with widely varying flows.

Detritus tanks are sized on the basis of an overflow rate determined by the size of the grit particle required to be removed. They are also designed such that the horizontal velocity is 1.0 fps at maximum flow. This means that at low flow, a portion of the influent organic material may settle with the grit.

Multi-Tray Vortex

Multi-tray vortex technology was introduced in 1999 as a means to target fine grit in an effort to increase overall system capture efficiency. Conically shaped trays are stacked vertically in a stainless steel support frame. An inlet duct delivers influent onto the trays tangentially while evenly distributing flow to each tray. Low surface overflow rate and short settling distances allow capture of grit particles ≥ 75 micron. Degritted effluent exits a fixed weir that runs the width of the basin and is set 1' above the top tray whereby the unit is submerged while in operation. Captured grit collects in the bottom center where it is pumped to grit further processing.

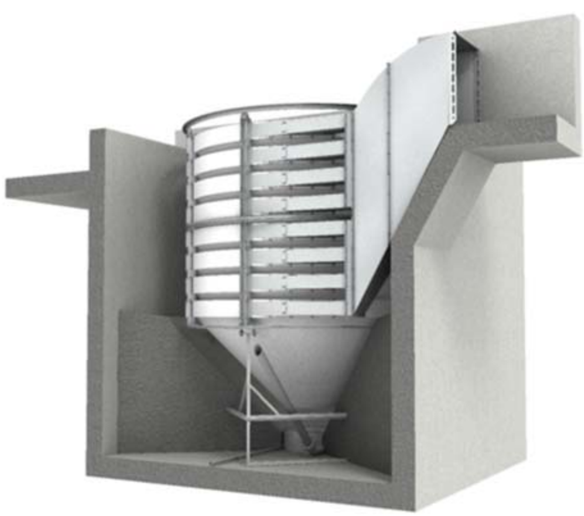

Figure 3— Multi-Tray Vortex Tank (Hydro International)

Hydraulically Induced Vortex

Hydraulic vortex units are centrifugal separators relying on accelerated gravity to remove grit from influent. Capture of grit particles ≥ 106 micron are retained. A cylindrical above ground tank with conical bottom receives a tangential feed where energy of the influent flow creates a vortex with no moving parts. Grit moves to the tank wall and settles by gravity in the bottom cone where it resides until discharge. Degritted effluent is forced to exit at the top-center and is discharged via a piped connection.

Figure 4: Hydraulically Induced Vortex Tank (Hydro International)

Primary Sludge Degritting

As liquid stream grit removal processes were established, the removal of grit from primary sludge became less common. Today, sludge degritting is mainly used in cases of poorly performing liquid stream processes. Devices used for washing and dewatering grit slurry are used to remove grit from sludge for less cost than installing new liquid stream grit removal processes. Conventional cyclone/classifiers and induced vortex systems are used for this process. When degritting primary sludge, sludge solids must be pumped at concentrations of 0.5% to 1% for the process to function properly, requiring frequent pumping of the sludge or an addition of dilution water. The grit removed from primary sludge degritting has high organic content which requires a high degree of grit washing.

Grit Slurry Pumping

Grit pumping is the most commonly used method for transporting collected grit. The following items should be considered when designing a grit pumping system:

- Make suction lines straight and provide flushing connections to minimize the potential for plugging.
- Size the suction and discharge lines to prevent grit deposition. Use a minimum pipe diameter of 4 inches.

- Provide fluidizing lines in areas where grit will be collected from the tank.
- Use only long radius fittings and multiple 45° fittings.
- Use recessed impeller centrifugal pumps with hardened impeller material to withstand grit erosion. Limit the solids concentration in the grit slurry to 1%.
- Flooded suction configuration is typically preferred over self-priming.
- Avoid the use of check valves on discharge lines. Use valves with full open port configurations such as pinch or plug valves.
- Allow for redundant pumps.

Cyclones and Classifiers

Cyclone systems use centrifugal forces to separate grit from organic material in grit slurries. Heavier grit and suspended solids concentrate along the sides and bottom of the cyclones, while lighter material exits through the top. Cyclones operate best at constant flow and pressure. Sizing is based on feed flow rate and a target grit slurry solids concentration, ideally less than 1%. The cyclonic action of the separator concentrates the solids content to an average of 5% to 15%. This flow volume reduction saves on transportation and storage, and it reduces the required classifier size.

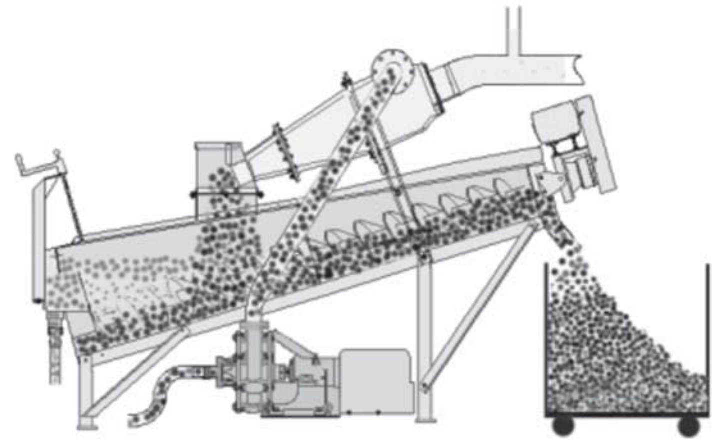

Figure 5: Cyclone and Classifier (Wemco, Inc.)

Grit classifiers effectively wash grit by rinsing organic materials from the inert grit particles. Classifiers are more commonly inclined screw type equipment but are also available as escalator type. Classifier sizing should be based on particle settling velocity, feed flow and solids conveying capacity anticipated during peak grit loading. For a target particle size and flow rate, a minimum pool area and overflow weir length will be selected. The classifier slope is selected to target removal of the minimum desired particle size; flatter slopes will settle out more fine particles. An example of a grit cyclone and classifier is shown in Figure X.

Conical Grit Washers

Conical grit washers utilize stainless-steel, conical-shaped vessels to capture grit slurry. Rotating arms within the vessel slowly mix the settled grit and a washing jet at the bottom of the unit vigorously washes it. Lighter organic material continuously overflows the unit and heavier organic material is blown off at regular intervals from a midlevel overflow. Washing provided by these units is superior to traditional cyclone classifiers with a final organic content of less than 5%.

Transport, Storage, and Disposal

Grit can be conveyed directly to trucks, dumpsters, or storage hoppers. Containers should be covered to prevent odors during storage and hauling. Conveyors frequently are used for transporting grit from handling facilities to containers. Overhead storage hoppers that discharge to truck containers avoid the need to keep a truck at the facility.

References

- Wastewater Engineering Treatment and Resource Recovery, Metcalf and Eddy/AECOM 5th ed. New York: McGraw-Hill Education, 2014.
- Design of Water Resource Recovery Facilities, WEF MOP 8, 2017
- Wastewater Technology Fact Sheet: Screening and Grit Removal, EPA, 2003

Acknowledgments

WEF Municipal Resource Recovery Design Committee

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