Water Environment Federation
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FACT SHEET

Liquid Stream Fundamentals: Tertiary Filtration

Tertiary filtration removes suspended solids from secondary effluent at water resource recovery facilities (WRRFs). It is a polishing step following biological treatment and secondary clarification in preparation for disinfection, final discharge, or reuse. Tertiary filtration is expected to grow in application with industry trends toward more stringent nutrient removal and increased reuse of secondary effluent.

Introduction

The primary objective of wastewater filtration is to meet effluent permit limits by removing suspended solids, including chemical precipitated solids such as phosphorus, and attached pollutants cost effectively. Particle removal is achieved by passing wastewater through a filtering media. The measure of performance is typically effluent total suspended solids (TSS) or turbidity, although other performance measures are sometimes used. Typically, filtration is used when effluent TSS or turbidity limits are less than 10 mg/L or 2 ntu, respectively. Filtration of suspended solids can remove particulate organics and nutrients, enhance disinfection efficiency, protect downstream treatment processes and irrigation devices, and remove some pathogens such as bacteria, viruses, and protozoan cysts. Tertiary filtration is often specifically required by regulatory agencies prior to public access reuse of reclaimed water.

Filtration facilities typically receive clarified secondary effluent. Whether flow to the filters is by gravity or pumped will depend on the WRRF's hydraulic profile for the headloss across the filter media. In addition to the hydraulic profile space required, site space is required for filter units with adequate consideration for peak hydraulic loading rates, redundancy, and backwash facilities.

Filters typically consist of filter media, flow control valves, influent weirs, and piping or channels for even feed flow splitting, filtrate collection, and uniform backwash distribution. To keep the filter media clean and restore process headloss, backwash water (typically filtered effluent) is supplied from either a storage tank (clearwell) or a downstream filtered effluent channel (depending on the volume requirements and design of the facility). Backwash of the filter is typically triggered when headloss across the filter media reaches a maximum, effluent quality deteriorates, or filtered runtime is exceeded.

Backwash reject water is the only return/recycle product from filtration processes. Typically, backwash reject water is recycled to the head of the plant for treatment and sometimes has a storage basin (mudwell) to control the rate of return. The ratio of backwash reject water returned to the head of the plant in comparison to the full forward flow of the plant as well as high TSS concentrations (500 to 1,000 mg/L) should be considered because of impacts to treatment plant capacity and operations.

Pre-Treatment

Upstream processes can impact tertiary filter performance. Low solids retention time (SRT) in the biological process results in poor bioflocculation and higher particle concentrations. Higher particle concentrations in the filter influent means more, smaller particles which in turn leads to degraded filter performance and high filter effluent turbidity. High SRT leads to better bioflocculation, larger particle sizes, and lower particle concentrations. When filter influent is comprised of fewer and larger particles, it leads to better filter performance and low filter effluent turbidity. Pretreatment with a coagulant can stabilize small particles and promote flocculation of particles so the filter is better able to achieve better removal rates. Provisions for filter chemical aids are typically considered and available for use on an as-needed basis. Chemical addition for phosphorus removal is also practiced with the filters serving to remove the precipitated phosphorus solids.

Technology Overview

Traditionally, WRRFs have used deep-bed, automatic backwash, and continuous upflow granular media filtration technologies. The types of filters used at WRRFs has expanded significantly in recent years to include membrane filters, synthetic media filters, disk filters, and others aimed at reducing footprint while enhancing water quality. Advancements have also been made in sizes and types of media, types of moving beds, and procedures for cleaning the filter media.

Table 1 shows some of the primary technologies used in tertiary filtration. Filtration is typically separated into the categories of depth filtration and surface filtration. Membrane filtration is a third category that will not be covered here. Filtration mechanisms include straining, sedimentation/impaction, interception, adhesion, flocculation, physical or chemical adsorption, and biological growth.

Deep Bed Granular Media Filters - Deep bed granular media filters use depth filtration and remove suspended solids by allowing the filter influent water to pass downward under the force of gravity. They typically have mono-, dual-, or multi-media beds contained in a square or rectangular box of concrete or steel. Some WRRFs use a dual-media filter of silica sand and anthracite at a depth of about 3 feet similar to those seen at potable water treatment facilities. Filtered water leaves the filter box via an underdrain system. As the bed retains solids, headloss increases until it reaches the head available. The filter is then removed from service and backwashed. To backwash, the filtered effluent is pumped back through the underdrains and is distributed up through the filter media from the bottom. Air scour is also typically applied to help clean the media. Because backwashing is a batch process, the design typically requires clearwells to store water for backwash and backwash reject tanks to equalize the rate of return of backwash reject water to the head of the plant.

Filter Type	Media Type, Depth, Nominal Pore Size	Driving Head Requirements (Typical)	Peak Hydraulic Loading Rate (Typical)	Backwash Duration	Backwash Reject Rate (Typical) (% of forward flow)
Depth Filtration					
Deep Bed Granular Media Filter	Granular, 3-6 ft, 10 micron	4-9 ft	5 - 8 gpm/sf	24 min	2-3%
Continuous Backwash Granular Media	Granular, 80 in, 10 micron	2-4 ft	5 gpm/sf	Continuous	2-15%
Automatic Backwash Granular Media Filter	Granular, 12 in, 10 micron	5 ft	2-4 gpm/sf	0.5-1 min per individual cell	5-6%
Compressed Media Filter	Synthetic fiber, 30 in, 0.44 mm (uncompressed)	6-12 ft	20-30 gpm/sf	20 min	1-5%
Surface Filtration					
Cloth Media Filter (Disk or Lateral)	Nylon, Acrylic or Polyester, 5-13 mm, 5-10 micron	2.5-4 ft	6-7 gpm/sf	6 min	1-3%
Microscreen Disk Filter	Woven Stainless Steel or Polyester, 150 micron, 10-20 micron	2.5-4 ft	3-7 gpm/sf	0.5-1 min	0.5-3%
Pulsed Bed Granular Media Filter	Granular, 10 in, 10 micron	6-9 ft	5 gpm/sf	3.5 min	1-3%

Table 1—Comparison of Filtration Technologies

Continuous Backwash Granular Media Filters - Continuous backwash filters operate with depth filtration. Water continuously flows through a recirculating bed of media that is being continuously backwashed. Media (sand) typically moves in a downward direction, while the water moves in an upward direction (counter-current), with some technologies having both the sand and water flow downward (concurrent). Secondary effluent is introduced approximately two-thirds of the way down the bed of sand where the sand is the dirtiest. The secondary effluent passes up through the sand. Most of the filtered water flows over the effluent weir after it leaves the bed of sand. A portion of the filtered effluent flows through a sand washer. A continuous backwash occurs as air is introduced at the bottom of an airlift pipe up the center of the filter. The introduction of air causes an air/water/sand mixture that has a density less than water to travel up the airlift and spill into the reject water compartment. The dirty sand falls down into a sand washer. As it falls through the sand washer, the accumulated solids are removed from the sand particles. The solids then flow up and over the backwash weir into the reject line while the clean sand falls down onto the filter bed and begins its downward migration through the filter again. There is no need for clearwells, backwash reject tanks, or backwash pumps in this design.

Automatic Backwash Granular Media Filters - Automatic backwash filters have a shallow bed of filter sand that is 10 to 24 inches in depth and use depth filtration. Mono- or dual -media is typically used. The sand bed is divided into individual cells (8 to 24 inches wide) to allow backwashing of each cell in sequence while all other cells remain in operation. Secondary effluent enters the filter through an influent chamber and passes downward through the media. The effluent is collected under the media support and discharged to an effluent channel. For backwashing, a traveling device (bridge, platform, carriage, or hood) moves along the filter on rails, attaches to the individual cell, and backwashes with a wash pump using the filtered effluent in an upward direction. Backwash reject water is typically recycled in the plant. Clearwells and backwash reject tanks are typically not required in this design because the backwash supply comes directly from the filter effluent plenum beneath the underdrains and the continuous sequencing of the backwash recycles the reject water at a relatively uniform rate.

Compressed Media Filter - Compressed media filters use depth filtration. The media is compressible balls made of synthetic fibers. Water flows through the media rather than around it like other depth filters. During normal operation, the water flows up through the media that has been compressed by a movable plate to the desired compression ratio. Effluent is collected in an effluent pipe. When headloss reaches a maximum setpoint, backwash is initiated. During backwash, the effluent valve is closed, the moveable plate decompresses the media, air scour is introduced, and the filter media is cleaned with the influent water. The moveable plate then compresses the media to the desired compression ratio and a flush cycle begins. The flush cycle removes the backwash water from the effluent side of the filter.

Cloth Media Disk Filters - The cloth media filters use surface filtration. The cloth fiber media is approximately 13 mm thick. The filters flow in an outside-in flow. The design of the cloth media filters includes both a disk and lateral design. In the disk design, secondary effluent enters the filter tank and submerges the static cloth disks. The secondary effluent passes through the cloth media, and filtrate is collected in the shaft in the center of the disks and discharged to the effluent chamber. Backwashing occurs by rotating the disks slowly and a static vacuum header draws the filtrate back through the disks and removes accumulated solids from the cloth. The lateral design is similar in that the same media is used, but in a lateral configuration (designed to retrofit automatic backwash filters). Secondary effluent enters the tank and submerges the laterals. The water passes through the media on all sides of the laterals and solids accumulate forming a mat. The filtrate is collected in each lateral and discharged to the effluent chamber. Backwash occurs by vacuuming solids off the surface of the laterals by backwash shoes that pump filtrate back through the media. The laterals are backwashed by a traveling drive platform that moves across the basin.

Microscreen Media Disk Filters - The microscreen filters use surface filtration. The microscreen fabric (typically polyester or stainless steel) is approximately 150 microns thick. The filters operate with an inside-out flow path. Influent enters the center drum and flows by gravity into the filter segments. The disks remain only partially submerged as the filtrate is collected in the filter tank. Solids accumulate on the inside of the media and are backwashed by counter-current flow or spray pipes and nozzles. The disks rotate continuously or only during backwash depending on the design.

Pulsed Bed Granular Media Filters - A pulsed bed filter is a shallow bed (about 10 inches), mono-media, gravity filter designed specifically for wastewater filtration. A fine sand media is used so the filter functions by surface straining solids. An air pulse cycle is used to break up the surface layer of solids that forms during filtration so the filter cycle can be lengthened before backwashing is required. Operation is similar to a deep bed granular media filter in that flow enters the top of the filter box and is distributed over the filter media. At a certain headloss, the pulse cycle starts. The effluent valve is closed, but the influent remains open. The backwash pumps force air trapped beneath the underdrain up through the filter bed while additional air is introduced above the bed by a series of diffusers. After about 20 seconds, normal filter operation resumes. This cycle repeats until available headloss is exceeded, and then a conventional backwash occurs.

Design

Variability in the filter influent quality must be considered in design of tertiary filtration facilities. The nature (typically organic) and size of the solid particles as measured by a particle size distribution (PSD) should be analyzed because removal efficiency in filters for one type and size particle is different for another type and size particle. The pre-treatment modifications mentioned above may be required if the PSD of the filter influent is not one that can be removed by the given filter technology. Key design parameters for filters include:

1. Peak hydraulic flow for filter sizing (gpm)
2. Hydraulic loading rate (HLR) as determined by regulations, manufacturer, or pilot testing (gpm/sq ft)
3. Solids loading rate (SLR) based on secondary clarifier performance, sludge volume index (SVI), and wet weather settleability (lb/day-sq ft)
4. Hydraulic driving head available and required
5. Effluent requirements for TSS, turbidity, total phosphorus, etc. The HLR or SLR will drive the quantity of filter media required.

Granular Media - The media size used in granular media filters has a greater effect on removal than hydraulic application rate. Fine media typically results in removal by surface straining in which the penetration of solids into a bed may be no more than two inches. With most WRRF applications, this results in rapid clogging and headloss development and correspondingly short filter runs between backwashes. Larger media will generally allow deeper particle penetration into the filter bed, thereby providing satisfactory performance and longer filter runs for a given headloss. Granular media types used for wastewater treatment applications typically are sand and anthracite, while some special applications use activated carbon, resin, garnet, and ilmenite. Media properties to consider include effective size, uniformity coefficient, shape, and density.

Underdrain System - The principle function of the underdrain system is to provide uniform collection of filtered water and distribution of the backwash water. The media support gravel (if required) also facilitates distribution of backwash water and supports and separates the media from the underdrain by preventing its migration downwards during operation or backwash. Multiple types of underdrain systems are available for wastewater filters including perforated pipe manifolds, precast plastic or ceramic blocks, Wheeler bottoms, strainers or nozzle bottoms, porous aluminum oxide or plastic plates, and perforated stainless-steel plates.

Media Depth and Size - The media depth to size ratio (L/D) is an important design parameter for granular media filters. Filtrate quality improves with smaller media size and larger media depths, but headloss also increases. Pilot testing is typically recommended to identify the correct design parameters for each WRRF.

Backwash - Effective backwashing is essential for keeping the media clean and maintaining filter performance long-term. Backwash can be achieved by media bed expansion with simultaneous air scouring with use of backwash pump and blowers. Rates of backwash water and air should be matched with the selected media and filter design so as to achieve appropriate cleaning without washing out the media with the backwash reject water. The rate of backwashing on granular media filters is affected by the wastewater temperature. Lower backwash rates are required at low temperature due to the higher water density. Backwash waste volume and solids concentration should be considered in overall facility design.

Flow Control - Three main flow control methods are used in filtration including constant-rate fixed head, constant-rate variable head, and variable declining-rate. Variable, declining-rate is the most common, can provide better effluent quality, and requires less available headloss because filtration rate declines toward the end of a filter run.

Avoiding Filtration Problems

Potential problems with filter operation usually include biological growth (biogrowth) on the weirs and in the filter media, mudball formation in the filter bed, media loss, and underdrain clogging or failure.

- Regular cleaning or chlorine addition to influent or backwash water can help to reduce biogrowth in the filter bed and on the filter troughs and weirs.
- Mudballs can form from biogrowth, overdosing chemical, and fats, oils, and grease in the wastewater. Mudball formation can be remedied with good air/water backwash design and chlorine addition. Many plant operators will also use a daily backwash to prevent excess build-up of material regardless of the filter headloss.
- Poorly designed backwash can lead to loss of media during the backwash sequence, while underdrain failure can lead to loss of media through the filter effluent.
- Poor underdrain design can lead to clogging with biogrowth or floatables, poor distribution of backwash water, and rupture of filter bottoms causing media loss.

References

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