What every operator should know about trickling filters

Greg Farmer

<table>
<tr><th>Knowledge</th><th>Principle</th><th>Practical considerations</th></tr>
<tr><td>History</td><td>The technology was developed in the U.S. and Great Britain in the 1890s. The first U.S. installation was in Madison, Wis., in 1901.</td><td>Trickling filters became the dominant secondary treatment process in the U.S. by the 1950s. Trickling filters fell out of favor in the 1970s when the U.S. Environmental Protection Agency issued its definition of secondary treatment standards – activated sludge was better able to meet the new standards.

Improvements in secondary clarifier design and the introduction of coupled processes – such as trickling filter/solids contact – and nitrifying trickling filters have led to a resurgence of the technology.</td></tr>
<tr><td>System components</td><td>Distribution system: provides for even distribution of wastewater over the media.

Containment structure: provides structural support to contain the media within the bioreactor.

Filter media: Rock media commonly are found in older trickling filters. Almost all new installations use plastic media.

Rock media are more likely to plug due to smaller voids, which also restrict airflow. Plastic media, available as cross-flow or vertical, provide for better oxygen transfer, and are lighter than rock, so media can be deeper. Vertical-flow media are used in roughing and industrial applications.

Underdrain: collects treated wastewater and creates a plenum that facilitates oxygen transfer throughout the trickling filter.

Ventilation: Trickling filters for biochemical oxygen demand (BOD) removal and nitrification are aerobic processes and require air exchange to sustain aerobic conditions.</td><td>Rotary distributors can be hydraulically or mechanically driven. Modern hydraulic and electric drives provide the ability to control rotational speed.

For containment, precast concrete panels or tanks typically are used. If flooding ability is desired for macro fauna control, then post-tensioned tanks are required.

Media types
<table>
<tr><th></th><th>Rock</th><th>Vertical flow</th><th>Cross flow</th></tr>
<tr><td>Advantages</td><td>Longest-lasting

Use of local materials possible</td><td>Least likely to plug

Best ventilation</td><td>Redistributes wastewater

Higher hydraulic retention time</td></tr>
<tr><td>Disadvantages</td><td>Poor ventilation

High flushing rate necessary to minimize nuisance organisms</td><td>Higher in cost

Redistributes wastewater only at module interface</td><td>Increase in density may result in reduced oxygen transfer and increased biofilm thickness</td></tr>
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Note: Some trickling filters have used a combination of vertical-flow and cross-flow media; these are referred to as “mixed-flow media.”

The space between the media and the bottom of the containment structure is the underdrain. A larger area promotes better air distribution.

Older trickling filter installations use passive ventilation resulting from a difference in ambient air temperature inside and outside of the trickling filter. When temperatures are near equal, air movement stops.

Modern trickling filters are covered and equipped with forced-air ventilation systems using low-pressure fans to maintain air movement at all times. The exhaust air typically is treated in chemical scrubbers to minimize odors.</td></tr>
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<tr><td>How it works</td><td>The basic concept of trickling filters is to provide a surface on which microbial films grow.

Microorganisms use contaminants in wastewater as nutrients to sustain growth and oxygen for respiration.</td><td>Wastewater containing necessary nutrients intermittently passes over the microorganisms to grow a biofilm on media. Nutrients diffuse into the biofilm and are metabolized by the stationary (fixed) microorganisms.

■ Carbon-oxidizing trickling filters utilize heterotrophic bacteria.
■ Nitrifying trickling filters utilize autotrophic bacteria.</td></tr>
<tr><td>Expected performance</td><td>Most trickling filters are designed to remove carbonaceous BOD (CBOD) and/or nitrogen.</td><td>
<table>
<tr><th>Filter type</th><th>Organic loading (lb BOD per 1000 ft^3 per day)</th><th>Percent soluble CBOD/ammonia–nitrogen removal</th><th>Media suitability</th></tr>
<tr><td>Roughing filters</td><td>100–220</td><td>50% to 75%</td><td>Vertical flow, mixed flow</td></tr>
<tr><td>Carbon oxidizing filters</td><td>20–60</td><td>Up to 90%</td><td>Vertical flow, cross flow</td></tr>
<tr><td>Combined BOD and nitrification filters</td><td>5–20</td><td>$<$ 10 mg/L soluble CBOD
$<$ 3 mg/L ammonia</td><td>Cross flow, standard or medium density</td></tr>
<tr><td>Nitrification filters</td><td>$<$ 20 mg/L or filter will fail</td><td>$<$ 3 mg/L ammonia</td><td>Cross flow, medium or high density</td></tr>
</table>
</td></tr>
<tr><td>Rotational speed/flushing intensity</td><td>Distributor-arm rotational speed regulates flushing intensity.

Maintaining a relatively slow rotational speed and high flushing intensity offers several benefits, such as biofilm thickness control, macro fauna control, and increased wetting efficiency.

Generally, the higher the organic loading, the greater the flushing intensity required.</td><td>Although many trickling filters have hydraulically driven distributors, some distributors are equipped with mechanical or other speed controls. As a result, distributors previously operated at 30 seconds to 2 minutes per revolution. Speed-control distributors now often allow normal operational speeds ranging from 4 to 10 minutes per revolution. More importantly, many speed-control distributors allow specifying a regular (daily or weekly) “flushing” speed that may slow the distributor to more than 60 minutes per revolution.

The combination of slow distributor speed and pumped flow results in dosing rates – sometimes referred to as “Spulkraft” – that are much higher than previously possible. Suggested dosing rates – which vary with media type, depth, and loading – for normal operation range from 25 to 200 mm (1 to 8 in.) per pass; suggested flushing rates range from 100 to 600 mm (4 to 24 in.) per pass.</td></tr>
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Knowledge	Principle	Practical considerations
Macro fauna	Snails are the No. 1 reported predator within trickling filters. Detrimental effects of snail infestations include grazing of nitrifying biofilm and accumulation in aeration basins, process channels, and digesters. Trickling filters with higher organic loading rates typically do not undergo problems with snails. Filter (*Psychoda*) and crane flies (look like large mosquitoes) lay eggs on the media. The larvae graze on the biofilm.	Many problems associated with macro fauna can be controlled by increasing flushing intensity. Snail-control mechanisms include filter flooding – either alone or with the addition of sodium hydroxide to raise pH – or maintaining high concentrations of ammonia, which is toxic to snails. Some facilities have developed snail traps to contain and remove snails from trickling filter effluent lines and aeration tanks.
Recirculation and hydraulic wetting	The ability to recirculate flow to the trickling filter can be used to increase oxygen or ensure good wetting of the media. The hydraulic wetting rate is the application rate of wastewater to the trickling filter, including recirculation, expressed as gal/min•ft^2.	Recirculation provides the ability to maintain a consistent flow to the trickling filter during diurnal flow variations, provides for consistent rotation speeds for hydraulically driven distributor arms, and maintains proper wetting rates. Low wetting rates can result in nonuniform application of wastewater and unwetted areas that can attract snails and filter flies. Biofilm that is not wetted continuously and supplied with food from the wastewater becomes ineffective. The typical suggested hydraulic wetting rate range for BOD removal systems is 30 to 40 L/min•m^2 (0.75 to 1.0 gal/min•ft^2). For nitrification systems, the range is 30 to 80 L/min•m^2 (0.75 to 2.0 gal/min•ft^2). For speed-controlled distributors, the introduction of regular flushing of the trickling filter and improved wetting through high instantaneous dosing rates make past criteria for hydraulic wetting and recirculation of secondary or little concern. Operators should track the past criteria but may find better operation by establishing a good dosing program.

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