# CHAPTER 6

# Fixed Film Reactors

FIXED FILM REACTORS

## 6.1 Trickling Filters

### 6.1.1 General

Trickling filters may be used for treatment of wastewater amenable to treatment by aerobic biological processes. This process is less complex and has a lower power requirement than some of the other processes.

### 6.1.2 Pretreatment

Trickling filters shall be preceded by effective clarifiers equipped with scum removal devices or other suitable pretreatment facilities. (See Chapters 4 & 5)

### 6.1.3 Types of Processes

Trickling filters are classified according to the applied hydraulic and organic loadings. The hydraulic loading is the total volume of liquid applied, including recirculation, per unit time per square unit of filter surface area. Organic loading is the total mass of BOD applied, including recirculation, per unit time per cubic unit of filter volume.

#### 6.1.3.1 Low or Standard Rate

These are loaded at 1 to 4 million gallons per acre per day (mgad) and 5 to 25 pounds BOD per 1,000 cubic feet per day (lb BOD/1000 cu ft/day. Nitrification of the effluent often occurs.

#### 6.1.3.2 Intermediate Rate

These are loaded at 4 to 10 mgad and 10 to 40 lb BOD/1000 cu ft/day. Nitrification is less likely to occur.

#### 6.1.3.3 High Rate

These are loaded at 10 to 40 mgad and 25 to 300 lb BOD/1000 cu ft/day. Nitrification is not likely to occur.

#### 6.1.3.4 Super Rate

These are loaded at 15 to 90 mgad (not including recirculation) and up to 300 lb BOD/1000 cu ft/day. Filters designed as super rate require a manufactured media. Nitrification is not likely to occur.

6.1.3.5 Roughing

These are loaded at 60 to 180 mgd (not including recirculation) and 100 lb BOD/1000 cu ft/day. Nitrification will not occur. Roughing filters shall be followed by additional treatment, and will be equipped with manufactured media.

6.1.4 Considerations for Design

The following factors should be considered when selecting the design hydraulic and organic loadings:

Characteristics of raw wastewater
Pretreatment
Type of media
Recirculation
Temperature of applied wastewater
Treatment efficiency required

The following table presents allowable ranges for the design of trickling filters. Modifications of these criteria will be considered on a case-by-case basis.

| Design Loading Table | | | | | |
|---|---|---|---|---|---|
| Operating Characteristics | Low or Standard Rate | Intermediate Rate | High Rate | Super High Rate Manufactured Media | Roughing |
| Hydraulic Loading Mgd/acre<br>gpd/ sq ft | 1-4<br>25-90 | 4-10<br>90-230 | 10-40<br>230-900 | 15-90<br>350-2000* | 60-180*<br>1400-4200* |
| Organic Loading lb BOD/acre-ft day<br>lb BOD/1000ft3/day | 200-1000<br>5-25 | 700-1400<br>10-40 | 1000-12,000<br>25-300 | Up to 300 | 100+ |
| Depth ft<br>BOD Removal % | 5-10<br>80-85 | 4-8<br>50-70 | 3-6<br>65-80 | 3-8<br>65-85 | 15-40<br>40-65 |
| *does not include recirculation | | | | | |

6.1.5. Estimation of Performance

A number of equations are available for use in estimating trickling filter performance.
Any design should evaluate several different formulas to compare the various parameters in different combinations with one another. Winter operating

conditions must be analyzed since winter operations normally result in lower efficiency than summer operations. The trickling filter design must evaluate the impacts of recirculation, air draft temperatures and medium.

6.1.5.1 Recirculation

Recirculation capability is required for all variations of the trickling filter process except roughing filters provided that minimum hydraulic loading rates are maintained at all times. The recirculation ratio should be in the range of 0.5 to 4.0. Recirculation should be provided for manufactured media to maintain 0.5 to 1.0 gallon per minute per square foot (gpm/sq ft) or the manufacturer's recommended minimum wetting rate at all times. Recirculation ratios greater than 4.0 should not be used to calculate effluent quality.

6.1.5.2 Staging

Staging of filters can be considered for high-strength wastes or for nitrification.

6.1.6 Special Details

6.1.6.1 Media

a.Rock, Slag, or Similar Media

Rock, slag, and similar media should not contain more than 5 percent by weight of pieces whose longest dimension is three times the least dimension. They should be free from thin, elongated and flat pieces, dust, clay, sand, or fine material and should conform to the following size and grading when mechanically graded over a vibrating screen with square openings:

Passing 4-1/2 inch screen: 100 percent by weight

Retained on 3-inch screen: 90-100 percent by weight

Passing 2-inch screen: 0-2 percent by weight

Passing 1-inch screen: 0 percent by weight

Hand-picked field stone should be as follows:

Maximum dimension of stone: 5 inches

Minimum dimension of stone: 3 inches

Material delivered to the filter site should be stored on wood-planked or other approved clean hard-surfaced areas. All material should be rehandled at the filter site, and no material should be dumped directly into the filter. Crushed rock, slag, and similar media should be rescreened or forked at the filter site to remove all fines. Such material should be placed by hand to a depth of 12 inches above the tile underdrains, and all materials should be carefully placed so as not to damage the underdrains. The remainder of the material may be placed by means of belt conveyors or equally effective methods approved by the engineer. Trucks, tractors, or other heavy equipment should not be driven over the filter during or after construction.

b.Manufactured Media

Application of manufactured media should be evaluated on a case-by-case basis. Suitability should be evaluated on the basis of experience with installations handling similar wastes and loadings.

Media manufactured from plastic, wood, or other materials are available in many different designs. They should be durable, resistant to spalling or flaking, and relatively insoluble in wastewater. They are generally applied to super high rate and roughing filter designs.

6.1.6.2 Underdrainage System

a. Arrangement

Underdrains with semicircular inverts or equivalent should be provided and the underdrainage system should cover the entire floor of the filter. Inlet openings into the underdrains should have an unsubmerged gross combined area equal to at least 15 percent of the surface area of the filter.

b.Slope

The underdrains should have a minimum slope of 1 percent. Effluent channels should be designed to produce a minimum velocity of 2 feet per second at average daily rate of application to the filter.

c.Flushing

Provision should be made for flushing the underdrains and effluent channel.
In small filters, use of a peripheral head channel with vertical vents is acceptable for flushing purposes. Inspection facilities should be provided.

d.Ventilation

The underdrainage system, effluent channels, and effluent pipe shall be designed to permit free passage of air. The size of drains, channels, and pipe should be such that not more than 50 percent of their cross-sectional area will be submerged under the design hydraulic loading. Provision should be made in the design of the effluent channels to allow for the possibility of increased hydraulic loading.

6.1.6.3 Dosing Equipment

a.Distribution

The sewage shall be distributed over the filter by rotary distributors or other suitable devices which will permit reasonably uniform distribution to the surface area. At design average flow, the deviation from a calculated uniformly distributed volume per square foot of the filter surface should not exceed plus or minus 10 percent at any point. Provisions must be made to spray the side walls to avoid growth of filter flies.

b.Application

Sewage may be applied to the filters by siphons, pumps, or by gravity discharge from preceding treatment units when suitable flow characteristics have been developed. Application of sewage should be practically continuous. Intermittent dosing shall only be considered for low or standard rate filters. In the case of intermittent dosing, the dosing cycles should normally vary between 5 and 15 minutes, with distribution taking place approximately 50 percent of the time. The maximum rest should not exceed 5 minutes, based on the design average flow.

c. Hydraulics

All hydraulic factors involving proper distribution of sewage on the filters should be carefully calculated. For reaction-type distributors, a minimum head of 24 inches between the low-water level in the siphon chamber and center of the arms should be required. Surge relief to prevent damage to distributor seals, should be provided where sewage is pumped directly to the distributors.

d. Clearance

A minimum clearance of 6 inches between medium and distributor arms should be provided. Greater clearance is essential where icing occurs.

e. Seals

The use of mercury seals is prohibited in the distributors of newly constructed trickling filters. If an existing treatment facility is to be modified, any mercury seals in the trickling filters shall be replaced with oil or mechanical seals.

6.1.6.4 Recirculation Pumping

Low-head, high-capacity pumps are generally used. Submersible pumps are commonly used. A means to adjust the flow is recommended in order to maintain constant hydraulic operation.

6.1.6.5 Waste Sludge Equipment

Pumps for trickling filter sludge should be capable of pumping material up to 6-percent solids (or more if needed) when pumping directly to the digester. Time clock controlled on-off control is desirable. When secondary sludge is pumped to the primary clarifier, the sludge pumps should be designed to pump material with low solid concentrations and high flow rates.

6.1.6.6 Miscellaneous Features

a. Flooding

Consideration should be given to the design of filter structures so that they may be flooded.

b. Maintenance

All distribution devices, underdrains, channels, and pipes should be installed so that they may be properly maintained, flushed, or drained.

c. Flow Measurement

A means shall be provided to measure recirculated flow to the filter.

## 6.2 Rotating Biological Contactors

### 6.2.1 General

6.2.1.1 Description

This section presents the requirements for fixed-film reactors using either partially submerged vertical media rotated on a horizontal shaft or other designs with similar concepts.

6.2.1.2 Applicability

Rotating biological contactors (RBC) may be used for treatment of wastewater amenable to treatment by aerobic biological processes. The process is especially applicable to small communities. These requirements shall be considered when proposing this type of treatment.

6.2.1.3 Pretreatment

Primary clarifiers or fine screens should be placed ahead of the RBC process to minimize solids settling in the RBC tanks. (See Chapters 4 & 5)

6.2.2 Media

6.2.2.1 Description

Typical media consists of plastic sheets of various designs with appropriate spacings to maximize the surface area, allow for entrance of air and wastewater, the sloughing of excess biological solids and prevention of plugging. The medium is mounted on a horizontal steel shaft. Other similar systems will be considered on a case-by-case basis.

6.2.2.2 Types

Two types of medium are currently available.

a. Standard Density

Standard-density medium is available in sizes up to 100,000 square feet (sq ft) per shaft. It should be used for all secondary treatment applications.

b. High Density

High-density medium is available in sizes up to 150,000 sq ft per shaft.
It should be used only for nitrification or effluent polishing where the influent BOD is sufficiently low to ensure that plugging of the medium will not occur.

### 6.2.3 Design Loadings

#### 6.2.3.1 RBC Media

Design loadings should be in terms of total organic loading expressed as pounds $BOD_5$ per day per 1000 square feet of media surface area (lb $BOD_5$/day/1000 sq. ft.). The development of design loadings should consider influent BOD, soluble BOD, effluent BOD, flows, temperature, and the number of treatment stages. The design loading should generally range between 2.5 and 3.5 lb $BOD_5$/day/1000 sq. ft.

#### 6.2.3.2 Final Clarifiers

The following requirements are in addition to those set forth in Chapter 5, "Clarifiers."

The overflow rate should be less than or equal to 600 gpd/sq ft at the average daily design flow.

### 6.2.4 Special Details

#### 6.2.4.1 Enclosures

Enclosures should be provided for the RBC medium to prevent algae growth on the medium and minimize the effect of cold weather. Enclosures may be either fabricated individual enclosures or buildings enclosing several shafts. Buildings may be considered for installations with several shafts or, where severe weather conditions are encountered, to promote better maintenance.

a. Fabricated Individual Enclosures

Enclosures should be made of fiberglass or other material resistant to damage from humidity or corrosion. The exterior of the enclosures should be resistant to deterioration from direct sunlight and ultraviolet radiation. Access points should be provided at each end of the enclosure to permit inspection of shafts and to perform operation and maintenance. Enclosures shall be removable to allow removal of the shaft assemblies. Access around enclosures shall be sufficient to permit suitable lifting equipment access to lift covers and shafts.

b. Buildings

Adequate space should be provided to allow access to and removal of shafts from enclosures. Buildings should be designed with provisions to remove shafts without damage to the structure. Buildings should be designed with adequate ventilation and humidity control to ensure adequate atmospheric oxygen is available for the RBC shafts, provide a safe environment for the operating staff to perform normal operation and maintenance, and minimize the damage to the structure and equipment from excess moisture.

6.2.4.2 Hydraulic Design

The RBC design should incorporate sufficient hydraulic controls, such as weirs, to ensure that the flow is distributed evenly to parallel process units. RBC tank design should provide a means for distributing the influent flow evenly across each RBC shaft. Intermediate baffles placed between treatment stages in the RBC system should be designed to minimize solids deposition. The RBC units should be designed with flexibility to permit series or parallel operation.

6.2.4.3 Dewatering

The design should provide for dewatering of RBC tanks.

6.2.4.4 Shaft Drives

The electric motor and gear reducer should be located to prevent contact with the wastewater at peak flow rates.

6.2.4.5 Recycle

Effluent recycle should be provided for small installations where minimum diurnal flows may be very small. Recycle should be considered in any size plant where minimum flows are less than 30% of the average design flow.

6.2.4.6 Access

Access shall be allowed for lifting equipment to provide maintenance in the event of a failure.

## 6.3 Activated Biofilter

### 6.3.1 General

#### 6.3.1.1 Description

The activated biofilter (ABF) process is a combination of the trickling filter process using artificial media and the activated sludge process.

#### 6.3.1.2 Applicability

The activated biofilter process may be used where wastewater is amendable to biological treatment. This process requires close attention and competent operating supervision, including routine laboratory control. These requirements should be considered when proposing this type of treatment. The process is more adaptable to handling large seasonal loading variations, such as those resulting from seasonal industries or changes in population, than are some of the other biological processes. Where significant quantities of industrial wastes are anticipated, pilot plant testing should be considered.

### 6.3.2 ABF Media

Artificial media are used in the trickling filter portion of the process to allow high BOD and hydraulic loadings and permit recycle of activated sludge through the trickling filter without plugging. Either wood or plastic artificial medium may be used. Medium depth typically ranges from 7 to 25 feet.

### 6.3.3 Design

#### 6.3.3.1 General

Calculations shall be submitted to justify the basis of design of the ABF tower pump station, ABF tower, aeration basin, aeration equipment, secondary clarifiers, activated sludge return equipment, and waste sludge equipment.

#### 6.3.3.2 ABF Tower Pump Station

The ABF tower pump station shall be designed to pump the peak influent flow plus the maximum design ABF tower recirculation and return activated sludge flows. Application of wastewater to the ABF tower should be continuous.

#### 6.3.3.3 ABF Tower

The ABF tower shall be designed based on organic loading expressed as pounds of influent BOD per 1,000 cubic feet per day (lb BOD/1,000 cu ft/day). The organic loading should be established using data from similar installations or pilot plant testing.  A minimum hydraulic wetting rate should be maintained and be expressed as gallons per minute per square foot (gpm/sq ft).

Typical values for organic loading range from 100 to 350 lb BOD/1,000 cu ft/day (4,300 to 15,000 pounds BOD per acre-foot per day), and hydraulic wetting rates range from 1.5 to 5.5 gpm/sq ft, including recirculations and return flows.

#### 6.3.3.4 Aeration Basin

The aeration basin should be designed in accordance with Chapter 7, "Activated Sludge," based on the food-to-microorganism (F/M) ratio expressed as pounds of influent BOD per day per pound of mixed liquor volatile suspended solids (MLVSS).  The F/M ratio should be based on the influent total BOD to the ABF tower or the estimated soluble BOD leaving the ABF tower. Designs using total BOD to the ABF tower should be based on data from similar installations or pilot plant testing.  Designs using the estimated soluble BOD leaving the ABF tower should use typical F/M ratios (presented in Chapter 7, "Activated Sludge"). Estimate of BOD removal in the ABF tower should be based on similar installations or pilot plant testing.  Calculations of mixed-liquor suspended solids should include the influent suspended solids and solids sloughing from the ABF tower in addition to growth of activated sludge due to removal of soluble BOD.  Determination of aeration basin volume should include consideration of aeration basin power levels (using aeration equipment horsepower) expressed as horsepower per 1,000 cubic feet of basin volume.  Aeration basin power levels should be limited to prevent excessive turbulence, which may cause shearing of the activated sludge floc. Aeration prior to the ABF tower may also be considered.

#### 6.3.3.5 Aeration Equipment

Oxygen requirements should be estimated as outlined in Chapter 7, "Activated Sludge," for the ABF tower effluent plus the oxygen requirements of the sloughed solids from the ABF tower.

#### 6.3.3.6 Secondary Clarifiers

Secondary clarifiers should be equipped with rapid sludge withdrawal mechanisms and be designed in accordance with Chapter 5, "Clarifiers," and Chapter 7, "Activated Sludge."

#### 6.3.3.7 Return Sludge Equipment

Return sludge equipment should be designed in accordance with Chapter 5, "Clarifiers."

#### 6.3.3.8 Waste Sludge Equipment

Waste sludge equipment should be designed in accordance with Chapter 12, "Sludge Processing and Disposal."

#### 6.3.3.9 ABF Tower Recirculation

ABF tower recirculation should normally be provided. At a minimum, recirculation capacity should meet the requirements for the minimum hydraulic wetting rate.

### 6.3.4 Special Details

#### 6.3.4.1 ABF Tower

The ABF tower dosing equipment and underdrainage system should be designed in accordance with Section 6.1.6.3 "Dosing Equipment." Fixed or rotating distributors may be used. In addition, the design of the ABF tower should incorporate a skirt around the top to prevent spray from falling to the ground around the tower.

#### 6.3.4.2 Maintenance Provisions

All distribution devices, underdrains, channels, and pipes should be installed so that they may be properly maintained, flushed, and drained.

#### 6.3.4.3 Flow Measurement

Devices should be provided to permit measurement of flow to the ABF towers, ABF tower recirculation, return activated sludge, and waste activated sludge flows.