CHAPTER 80
BIOLOGICAL TREATMENT

81. TRICKLING FILTERS

81.1 General

___ Trickling filters shall be preceded by effective settling tanks equipped with scum and grease collecting devices, or other suitable pretreatment facilities.

81.2 Hydraulics

81.2.1 Distribution

81.2.1.1 Uniformity

___ The sewage may be distributed over the filter by rotary distributors or other suitable devices that will ensure uniform distribution to the surface area.

81.2.1.2 Head Requirements

___ For reaction type distributors, a minimum head of 24 inches (61 cm) between low water level in the siphon chamber and center of the arms is required. Similar allowance in design shall be provided for added pumping head requirements where pumping to the reaction type distributor is used.

81.2.1.3 Clearance

___ A minimum clearance of 6 inches (15 cm) between media and distributor arms shall be provided. Greater clearance is essential where icing may occur.

81.2.2 Dosing

___ 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 the sewage shall be practically continuous. The piping system shall be designed for recirculation.

81.2.3 Loading Rates

___ Hydraulic loading rates for trickling filters shall range from 25-100 gpd/ft^2 for low-rate filters, 100-1000 gpd/ft^2 for high-rate filters, and 700-3000 gpd/ft^2 for roughing filters.

___ Organic (BOD_5) loading rates shall range from 5-25 lb/d/1000 ft^3 for low- rate filters, 25-100 lb/d/1000 ft^3 for high-rate filters, and may exceed 100 lbs/day/1000 ft^3 for roughing filters.

81.2.4 Piping System

___ The piping system, including dosing equipment and distributor, shall be designed to provide capacity for the peak hourly flow rate, including recirculation required under Section 81.5.5.

81.3 Media

81.3.1 Quality

___ The media may be crushed rock, slag, or specially manufactured material. The media shall be durable, resistant to spalling or flaking and relatively insoluble in sewage. The top 18 inches (46 cm) should have a loss by the 20-cycle, sodium sulfate soundness test of not more than 10%, as prescribed by ASCE Manual of Engineering Practice, Number 13. The balance should pass a 10-cycle test using the same criteria. Slag media shall be free from iron. Manufactured media shall be resistant to ultraviolet degradation, disintegration, erosion, aging, all common acids and alkalies, organic compounds, and fungus and biological attack. Such media shall be structurally capable of supporting a man's weight or a suitable access walkway shall be provided to allow for distributor maintenance.

81.3.2 Depth

___ Rock and/or slag filter media shall have a minimum depth of 5 feet (1.5 m) above the underdrains. Manufactured filter media should have a minimum depth of 10 feet (3 m) to provide adequate contact time with the wastewater. Rock and/or slag filter media depths shall not exceed 10 feet (3 m) and manufactured filter media depths shall not exceed 30 feet (9.1 m) except where special construction is justified through extensive pilot studies.

81.3.3 Size and Grading of Media

81.3.3.1 Rock, Slag and Similar Media

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

Passing 4 2 inch (11.4 cm) screen - 100% by weight
Retained on 3 inch (7.6 cm) screen - 95-100% by weight
Passing 2 inch (5.1 cm) screen - 0-2% by weight
Passing 1 inch (2.5 cm) screen - 0-1% by weight

81.3.3.2 Manufactured Media

___ Suitability will be evaluated on the basis of experience with installations handling similar wastes and loadings in accordance with Section 43.2.

81.3.3.3 Handling and Placing of Media

___ Material delivered to the filter site shall be stored on wood-planked or other approved clean, hard-surfaced areas. All material shall be rehandled at the filter site and not material shall be dumped directly into the filter. Crushed rock, slag and similar media shall be placed by hand to a depth of 12 inches (30 cm) above the title underdrains. The remainder of material may be placed by means of belt conveyors or equally effective methods approved by the engineer. All material shall be carefully placed so as not to damage the underdrains. Manufactured media shall be handled and placed as approved by the manufacturer. Trucks, tractors, and other heavy equipment shall not be driven over the filter during or after construction.

81.4 Underdrainage System

81.4.1 Arrangement

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

81.4.2 Hydraulic Capacity and Ventilation

___ The underdrains shall have a minimum slope of 1%. Effluent channels shall be designed to produce a minimum velocity of 2 fps (0.61 m/s) at average daily rates of application to the filter including recirculated flows.

___ 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% of their cross-sectional area will be submerged under the design peak hydraulic loading, including proposed or possible future recirculated flows. Consideration shall be given to the use of forced ventilation, particularly for covered filters and deep manufactured media filters.

81.4.3 Flushing

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

81.5 Special Features

81.5.1 Flooding

___ Appropriate valves, sluice gates, or other structures shall be provided to enable flooding of filters comprised of rock or slag media for filter fly control.

81.5.2 Freeboard

___ A freeboard of 4 feet (1.2 m) or more should be provided for tall, manufactured media filters to maximize the containment of windblown spray. Otherwise, the freeboard shall be at least 18 inches (46 cm). In all cases, the freeboard should rise above the top of the distribution arms.

81.5.3 Maintenance

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

81.5.4 Winter Protection

___ Adequate protection such as covers (in severe climate) or windbreaks (in moderate climate) shall be provided to maintain operation and treatment efficiencies when climatic conditions are expected to result in problems due to cold temperatures.

81.5.5 Recirculation

___ The piping system shall be designed for recirculation as required to achieve the design efficiency. The recirculation rate shall be variable and subject to plant operator control. The recirculation ratio (R/Q) should be between 0.4 and 4.0. At least two (2) recirculation pumps shall be provided.

81.5.6 Recirculation Measurement

___ Devices shall be provided to permit measurement of the recirculation rate. Time lapse meters and pump head recording devices are acceptable for facilities treating less than 1 MGD (3785 m^3/d).

81.6 Rotary Distributor Seals

___ Mercury seals shall not be used. Ease of seal replacement shall be considered in the design to ensure continuity of operation.

81.7 Multi-Stage Filters

___ The foregoing standards also apply to multi-stage filters.

81.8 Unit Sizing

___ Required volumes of media filters shall be based upon pilot testing in accordance with Section 43.2 with the particular wastewater and media or any of the various empirical design equations that have been verified through actual full scale experience.

81.9 Design Safety Factors

___ Trickling filters are affected by diurnal load conditions. The volume of media determined from either pilot plant studies or use of acceptable design equations shall be based upon the design peak hourly organic loading rate rather than the average rate. An alternative is flow equalization.

82. ACTIVATED SLUDGE

82.1 Flexibility

___ All designs shall provide for flexibility in operation. Plants over 1 MGD (3785 m^3/d) shall be designed to facilitate easy conversion to various operation modes.

82.2 Pretreatment

___ Where primary settling tanks are not used, effective removal or exclusion of grit, debris, excessive oil or grease, and grinding/shredding or screening of solids should be accomplished prior to the activated sludge process. Grit removal and grinding/shredding are not required with SDG or STEP collection systems.

___ Where primary settling is used, provision shall be made for discharging raw sewage directly to the aeration tanks to facilitate plant start-up and operation during the initial stages of the plant's design life.

82.3 Aeration

82.3.1 Capacities and Permissible Loadings

___ Calculations should be submitted to justify the basis for design of aeration tank capacity. Calculations using values differing substantially from those in the accompanying table should reference actual operational plants. Mixed liquor suspended solids levels greater than 5000 mg/1 may be allowed, providing adequate data is submitted showing the aeration and clarification system capable of supporting such levels.

___ When process design calculations are not submitted, the aeration tank capacities and permissible loadings for the several adaptations of the processes shown in the following table shall be used; alternatively, the ranges given in Metcalf and Eddy or WPCF MOP 8 may be used. These values apply to plants receiving peak to average diurnal load ratios ranging from about 2:1 to 4:1. Thus, the utilization of flow equalization facilities to reduce the diurnal peak organic load may be considered as justification to approve organic loading rates that exceed those specified in the table.

Permissible Aeration Tank Capacities and Loadings

Process	Aeration Tank Organic Loading – lb. BOD_5/day per 1000 ft^3	F/M Ratio lb. BOD_5/day per lb. MLVSS	MLSS+ mg/liter
Conventional Step Aeration Complete Mix	40	0.2-0.5	1000-3000
Contact Stabilization	50++	0.2-0.6	1000-3000
Extended Aeration Oxidation Ditch	15	0.05-0.1	3000-5000

+MLSS values are dependent upon the surface area provided for sedimentation and the rate of sludge return as well as the aeration process.

++Total aeration capacity, includes both contact and reaeration capacities. Normally the contact zone equals 30% to 35% of the total aeration capacity.

82.3.2 Arrangement of Aeration Tanks

82.3.2.1 General Tank Configuration

a. Dimensions

___ The dimensions of each independent mixed liquor aeration tank or return sludge reaeration tank shall be such as to maintain effective mixing and utilization of air. Ordinarily, liquid depths should not be less than 10 feet (3 m) or more than 30 feet (9 m) except in special design cases.

b. Short-circuiting

___ The shape of the tank and the installation of aeration equipment should provide for positive control of short-circuiting through the tank.

82.3.2.2 Number of Units

___ Total aeration tank volume should be divided among two or more units, capable of independent operation.

82.3.2.3 Inlets and Outlets

a. Controls

___ Inlets and outlets for each aeration tank unit shall be suitably equipped with valves, gates, stop plates, weirs, or other devices to permit flow control to any unit and to maintain a reasonably constant liquid level. The hydraulic properties of the system shall permit the maximum instantaneous hydraulic load to be carried with any single aeration tank unit out of service.

b. Conduits

___ Channels and pipes carrying liquids with solids in suspension shall be designed to maintain self-cleansing velocities or shall be agitated to keep such solids in suspension at all rates of flow within the design limits. Adequate provisions should be made to drain segments of channels that are not being used due to alternate flow patterns.

82.3.2.4 Freeboard

___ All aeration tanks shall have a freeboard of not less than 18 inches (46 cm). Additional freeboard or windbreak may be necessary to protect against freezing or windblown spray.

82.3.3 Aeration Equipment

82.3.3.1 General

___ Aeration equipment shall be capable of maintaining a minimum of 2.0 mg/1 of dissolved oxygen in the mixed liquor at all times and providing thorough mixing of the mixed liquor. In the absence of experimentally determined values, the design oxygen requirements for all activated sludge processes should be at least 1.1 lb O_2/lb. peak BOD_5 applied to the aeration tanks (1.1kg O_2/kg peak BOD_5), with the exception of the extended aeration process, for which the value should be at least 1.5.

___ In the case of nitrification, the oxygen requirement for oxidizing ammonia must be added to the above requirement for carbonaceous BOD removal. The nitrogen oxygen demand (NOD) should be taken as 4.6 times the diurnal peak TKN content of the influent. Also, the oxygen demands due to recycle flows - heat treatment supernatant, vacuum filtrate, elutriates, etc. - must be considered due to high concentrations of BOD and TKN associated with such flows.

___ Unless flow equalization is provided, the aeration system should be designed to match the diurnal organic load variation while economizing on power input.

82.3.3.2 Diffused Air Systems

The design of diffused air system to provide the oxygen requirements shall be done by either of the two methods described below in (a) and (b), augmented as required by consideration of items (c) through (k):

___ a. Having determined the oxygen requirements per Section 82.3.3.1, air requirements for a diffused air system shall be determined by use of any of the well known equations incorporating such factors as:

1. Tank depth;
2. Alpha factor of waste;
3. Beta factor of waste;
4. Certified aeration device transfer efficiency;
5. Minimum aeration tank dissolved oxygen concentrations;
6. Critical wastewater temperature; and
7. Altitude of plant.

In the absence of experimentally determined alpha and beta factors, wastewater transfer efficiency shall be assumed to be 50% of clean water efficiency for plants treating primarily (90% or greater) domestic sewage. Treatment plants where the waste contains higher percentages of industrial wastes shall use a correspondingly lower percentage of clean water efficiency and shall have calculations submitted to justify such a percentage.

___ b. Normal air requirements for all activated sludge processes except extended aeration (assuming equipment capable of transmitting to the mixed liquor the amount of oxygen required in Section 82.3.3.1) shall be considered to be 1500 ft^3/lb BOD_5 peak aeration tank loading (93.5 m^3/kg BOD_5). For the extended aeration process the value shall be 2050 ft^3 (125 m^3).

___ c. To the air requirements calculated above shall be added air required for channels, pumps, aerobic digesters, or other air-use demand.

___ d. The specified capacity of blowers or air compressors, particularly centrifugal blowers, should take into account that the air intake temperature may reach 40EC (104EF) or higher and the pressure may be less than normal. The specified capacity of the motor drive should also take into account that the intake air may be -18EC (0EF) or less and may require oversizing of the motor or a means of reducing the rate of air delivery to prevent overheating or damage to the motor.

___ e. The blowers shall be provided in multiple units, so arranged and in such capacities as to meet the maximum air demand with the single largest unit out of service. The design shall also provide for varying the volume of air delivered in proportion to the load demand of the plant. Aeration equipment shall be easily adjustable in increments and shall maintain solids suspension within these limits.

___ f. Diffuser systems shall be capable of providing for the diurnal peak oxygen demand of 200% of the design average oxygen demand, whichever is larger. The air diffusion piping and diffuser system should be capable of delivering normal air requirements with minimal friction losses.

___ g. Air piping systems should be designed such that total head loss from blower outlet (or silencer outlet where used) to the diffuser inlet does not exceed 0.5 psi (0.04 kgf/cm^2) at average operating conditions.

___ h. The spacing of diffusers should be in accordance with the oxygen requirements through the length of the channel or tank, and should be designed to facilitate adjustment of their spacing without major revision to air header piping.

___ i. All plants employing fewer than four independent aeration tanks shall be designed to incorporate removable diffusers that can be serviced and/or replaced without dewatering the tank.

___ j. Individual assembly units of diffusers shall be equipped with control valves, preferably with indicator markings for throttling, or for complete shutoff. Diffusers in any single assembly shall have substantially uniform pressure loss.

___ k. Air filters shall be provided in numbers, arrangements, and capacities to furnish at all times an air supply sufficiently free from dust to prevent damage to blowers and clogging of the diffuser system used.

82.3.3.3 Mechanical Aeration Systems

a. Oxygen Transfer Performance

___ The mechanism and drive unit shall be designed for the expected conditions in the aeration tank in terms of power. Certified testing shall verify mechanical aerator performance.

b. Design Requirements

The design requirements of a mechanical aeration system shall accomplish the following:

___ 1. Maintain a minimum of 2.0 mg/1 of dissolved oxygen in the mixed liquor at all times throughout the tank or basin;

___ 2. Maintain all biological solid in suspension;

___ 3. Meet maximum oxygen demand and maintain process performance with the largest unit out of service; and

___ 4. Provide for varying the amount of oxygen transferred in proportion to the load demand on the plant.

82.4 Return Sludge Equipment

82.4.1 Return Sludge Rate

___ The rate of sludge return expressed as a percentage of the design average flow of sewage should generally be variable between the limits set forth as follows:

	% DAF	
	Minimum	Maximum
Standard Rate	15	75
Carbonaceous Stage of Separate Stage Nitrification	15	75
Step Aeration	15	75
Contact Stabilization	50	150
Extended Aeration	50	150
Nitrification Stage of Separate Stage Nitrification	50	200

___ The rate of sludge return shall be variable to pump sludge at the above rates.

82.4.2 Return Sludge Pumps

___ If motor driven return sludge pumps are used, the maximum return sludge capacity shall be obtained with the largest pump out of service. A positive head should be provided on pump suctions. Pumps should have at least 3 inch suction and discharge openings.

___ If air lifts are used for returning sludge from each settling tank hopper, no standby unit will be required provided the design of the air lifts are such to facilitate their rapid and easy cleaning and provided other suitable standby measures are provided. Air lifts should be at least 3 inches (7.6 cm) in diameter.

82.4.3 Return Sludge Piping

___ Discharge piping should be at least 6 inches (15.2 cm) in diameter and should be designed to maintain a velocity of not less than 2 fps (0.61 m/s) when return sludge facilities are operating at normal return sludge rates. Suitable devices for observing, measuring, sampling and controlling return activated sludge flow from each settling tank hopper shall be provided, as outlined in Section 63.2.3.

82.4.4 Waste Sludge Facilities

__ Waste sludge control facilities should have a maximum capacity of not less than 25% of the average rate of sewage flow and function satisfactorily at rates of 0.5% of average sewage flow or a minimum of 10 gpm (0.63 1/s), whichever is larger. Means for observing, measuring, sampling, and controlling waste activated sludge flow shall be provided. Waste sludge may be discharged to the concentration or thickening tank, primary settling tank, sludge digestion tank, vacuum filters, or any practical combination of these units.

83. ROTATING BIOLOGICAL CONTACTORS

83.1 General

__ Design standards, operating data and experience for the Rotating Biological Contactor (RBC) process are not well established. Therefore, expected performance of RBCs shall be based upon experience at similar full scale installations or thoroughly documented pilot testing with the particular wastewater.

83.2 Required Pretreatment

__ RBCs must be preceded by effective settling tanks equipped with scum and grease collecting devices unless substantial justification is submitted for other pretreatment devices that provide for effective removal of grit, debris, and excessive oil or grease prior to the RBC units. Bar screening/grinding/shredding are not suitable as the sole means of pretreatment.

83.3 Unit Sizing

__ Unit sizing shall be based on experience at similar full-scale installations or thoroughly documented pilot testing with the particular wastewater. In determining design loading rates, expressed in units of volume per day per unit area of media covered by biological growth, the following parameters must be considered:

a. Design flow rate and influent waste strength;

b. Percentage of BOD to be removed;

c. Media arrangement, including number of stages and unit area in each stage;

d. Rotational velocity of the media;

e. Retention time within the tank containing the media;

f. Wastewater temperature; and

g. Percentage of influent BOD that is soluble.

In addition to the above parameters, loading rates for nitrification will depend upon influent total kjeldahl nitrogen (TKN), pH, and the allowable effluent ammonia nitrogen concentration.

83.4 Design Safety Factor

Effluent concentrations of ammonia nitrogen from the RBC process designed for nitrification are affected by diurnal load variations. Therefore, it may be necessary to increase the design surface area proportional to the ammonia nitrogen diurnal peaking rates to meet effluent limitations. An alternative is to provide flow equalization sufficient to insure process performance within the required effluent limitations.