frma /advanced treatment solutions
273 Weymouth Street • Rockland, MA 02370
Tel. 781-982-9300 • Fax. 781-982-1056 • www.amphidrome.com

August 4, 2014

Leasue Meyers, EIT
Missouri Department of Natural Resources
Engineering Section
Water Protection Program

Dear Ms. Meyers

This is intended to provide public comment on potential revisions to **10 CSR 20-8** (Biological Treatment. Specifically to proposed changes in section **10 CSR 20-8.14 (5) (B)** and comments on of Attached Growth Treatment Technologies

. Introduction

1. Our company supplies a Biological Active Filter (BAF) technology for BOD, ammonia and TN reduction. Being a New England Company we started under the guidance of TR-16. This document was updated in 2011 and includes a section on BAF's. I would offer TR-16 Section 6.2 as input on design guidance for this technology that could be incorporated into or referred to in an updated 10 CSR 20.
2. As you probably are aware, the state of NY is a member state to both the Ten State Standards and TR-16 and does refer to the document in their design guidance. In fact they have just come out with NY Design Standards for Intermediate Size Treatment Facilities in March 2014. The complete document can be downloaded at http://www.dec.ny.gov/permits/95768.html.

In their forward they state:

Numerous references to the GLUMRB's *Recommended Standards for Wastewater Facilities, (Ten States Standards), 2004* and NEIWPCC's *Guides for the Design of Wastewater Treatment Works -Technical Report-16, 2011 (TR-16)*, appear in this manual. *Ten States Standards* has been adopted by NYSDEC as New York State's official standards for municipal wastewater treatment and collection facilities according to 6 NYCRR Part 750-2.10.g.1. *Ten States Standards* may be viewed at: http://10statesstandards.com, and is available in print from Health Education Service, Inc., P.O. Box 7126, Albany, New York 12224, 518-439-7286. Health Education Services (HES) may be accessed online at http://www.healthresearch.org. *TR-16* is also an acceptable design standard for municipal systems of any size, or any nonmunicipal, intermediate sized systems that treat only sanitary wastewater. *TR-16* addresses standards for alternative collection systems such as vacuum sewers, low pressure/grinder pump sewers, septic tank effluent (pump) and septic tank effluent (gravity) sewers (STEP/STEG).

Appended are excerpts from both TR-16 and the NY Design Standards for Intermediate Size Treatment Facilities for your review and reference.

Specific Comments:

1. **10 CSR 20-8.14 (5) (B)**

   I have been made aware of and reviewed proposed changes and find them totally appropriate and have no additional comments.

2. Attached Growth Treatment Technologies

Recirculating Media Filters

Consider adding

Biologically Active Filters (BAF)

The descriptions in this section are largely taken from NEIWPCC's Guides for the Design of Wastewater Treatment Works, Technical Report 16, 2011 (TR-16)

In addition to the numerous processes that are refereed to recirculating media filters, there is another family of attached growth filters referred to Biologically Active Filters (BAF) and less commonly as Submerged Attached Growth Bioreactors (SAGB).

Biological filter processes have historically been referred to as biological aerated filters (BAFs) or denitrification filters. While the acronym BAF is still used, it now stands for biologically active filter, a term that encompasses both aerobic and anoxic filters. They can be static (do not require backwashing) or backwashable.

There are various types of BAFs, with most characterized by three primary criteria:
• Direction of flow (upflow or downflow)
• Media density (heavier or lighter than water)
• Biological environment (aerobic or anoxic)

Design criteria should be based manufacturer's criteria of full scale operating systems and follow guidelines set forth in **10 CSR 20-8.14 (5) (B)**.

Given the small openings associated with flow distribution and/or media retention, a high level of solids pretreatment is typically required.

Flow configuration determines many of the physical components of a BAF system.

Downflow filters generally require sunken media that are heavier than water and use countercurrent backwashing.

Upflow filters can use either sunken or floating media. Sunken media systems require flow distribution typically in the form of nozzles below the media, while floating systems use a retention system above the media that both holds the media in place and ensures that effluent is removed over the entire area of the filter.

The media used in a BAF are typically mineral media or plastic media. Mineral media are typically heavier than water, while plastic media typically have a specific gravity slightly less than that of water. The media need to be durable as they are constantly

Blowers or compressors may be used to supply air to the aerobic BAF. Diffuser systems can consist of perforated sparge piping or a nozzle arrangement in the filter underdrain system.

These filters function essentially as plug flow reactors; the dissolved oxygen at the filter surface is not necessarily representative of that in the middle of filter media depth. As head loss through the filter can change substantially during the progression from a clean to a dirty filter, blowers must be able to operate over a range of discharge pressure conditions.

With the exception of static filters, all BAFs act as both a biological treatment and physical solids separation process. Backwashing is required periodically to remove solids that accumulate due to filtration and biological growth. Backwashing is typically accomplished using a combination of compressed air and effluent water

Backwash system requirements depend on the specific system under consideration but typically include the following major components: a clearwell, backwash storage, backwash pumps, and air scour blowers.

Other than BAFs that include their own physical separation process, all fixed growth systems require some manner of physical separation of solids that are sloughed from the media.

Thank you for the opportunity to provide input. Please don't hesitate to contact us with any questions.

Very Truly Yours

F.R. Mahony & Associates

Ed Quann

Ed Quann
President

Cc: Bobby Lyerla - MEC

NEW YORK STATE

DESIGN STANDARDS FOR

INTERMEDIATE SIZED

WASTEWATER TREATMENT SYSTEMS

MARCH 5, 2014

New York State

Department of Environmental Conservation

Division of Water

625 Broadway

Albany, New York 12233-3505

Andrew M. Cuomo, Governor

Joe Martens, Commissioner

Photos on cover courtesy of: Lenning, D., T. Banathy, D. Gustafson, B.J. Lesikar, S. Wecker, D. Wright. 2005. Technology Overview Module. in (D.L. Lindbo and N.E. Deal eds.) Model Decentralized Wastewater Practitioner Curriculum. National Decentralized Water Resources Capacity Development Project. North Carolina State University, Raleigh, NC.

The technologies shown on the cover are from other States and may not conform to these Design Standards. In the case of any conflict between the apparent installation of a technology from any of the cover photos and the specifications in the figures, tables or text of these Design Standards, the Design Standards shall be used.

Foreword

The Clean Water Act (CWA) was enacted to restore and maintain the chemical, physical, and biological integrity of the nation's surface waters. This was to be done by reducing direct pollutant discharges into waterways, financing municipal wastewater treatment facilities, developing technology necessary to eliminate the discharge of pollutants, and by managing polluted runoff.

In New York State, Article 17 of the Environmental Conservation Law (ECL), "Water Pollution Control," was enacted to protect and maintain both surface and groundwater resources. It authorized the creation of the State Pollutant Discharge Elimination System (SPDES) Program to protect New York's water resources. On-site Wastewater Treatment Systems (OWTS) may discharge to either surface water or groundwater.

Pursuant to Article 17 Title 7 of the ECL all OWTSs, without the admixture of industrial or other waste, and with a groundwater discharge of 1,000 gallons per day or greater or a surface water discharge of any size, must be covered by a SPDES permit issued by the New York State Department of Environmental Conservation (NYSDEC).

Design standards for large Publicly Owned Treatment Works (POTWs) have been updated independently by the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (GLUMRB) and the New England Interstate Water Pollution Control Commission (NEIWPCC). Design standards for small individual residential systems are updated by the New York State Department of Health (NYSDOH), local county health departments, or watershed organizations. These Design Standards for Intermediate Sized Wastewater Treatment Systems (Design Standards) are being updated by NYSDEC to meet the needs not addressed by the large and small systems design standards (refer to Appendix A for the applicable technical standard). Over the last 20 years OWTS technologies have increased in the level of treatment provided and in complexity of design and operation. It is appropriate that the Design Standards are updated now to remain current with the needs of the wastewater treatment system design professionals.

Numerous references to the GLUMRB's *Recommended Standards for Wastewater Facilities, (Ten States Standards), 2004* and NEIWPCC's *Guides for the Design of Wastewater Treatment Works -Technical Report-16, 2011 (TR-16)*, appear in this manual. *Ten States Standards* has been adopted by NYSDEC as New York State's official standards for municipal wastewater treatment and collection facilities according to 6 NYCRR Part 750-2.10.g.1. *Ten States Standards* may be viewed at: http://10statesstandards.com, and is available in print from Health Education Service, Inc., P.O. Box 7126, Albany, New York 12224, 518-439-7286. Health Education Services (HES) may be accessed online at http://www.healthresearch.org. *TR-16* is also an acceptable design standard for municipal systems of any size, or any nonmunicipal, intermediate sized systems that treat only sanitary wastewater. *TR-16* addresses standards for alternative collection systems such as vacuum sewers, low pressure/grinder pump sewers, septic tank effluent (pump) and septic tank effluent (gravity) sewers (STEP/STEG).

NYSDOH regulations for residential wastewater treatment systems discharging less than 1,000 gpd are entitled *"Appendix 75-A, Wastewater Treatment Standards – Residential Onsite Systems."* Design guidance for residential onsite systems are published under the title *Residential Onsite Wastewater Treatment Systems Design Handbook*. The NYSDOH Design Handbook is available from HES, Inc. (http://www.healthresearch.org). Both documents are on the NYSDOH website.

F. Secondary Treatment

NYSDEC categorizes treatment technologies in Chapters E, F, and G of these design standards as either standard or alternative technologies. Standard technologies are systems that have been applied successfully in New York State for a long time with a good record of reliability and effectiveness. Alternative technologies are treatment systems that have not been widely used in New York State, but have been successfully applied in other parts of the country. This entire chapter consists of alternative technologies.

F.1 Introduction

Following the planning and permit application process outlined in Section A and the project evaluation process in Section B will bring the design engineer to a point of deciding on what treatment options to use to meet permit limits. This section discusses treatment methods to produce secondary treated effluent.

Preliminary and primary treatment by a septic tank or similar unit(s) is required prior to secondary treatment systems. If the preliminary and primary treatment is pre-designed into a package plant, the design engineer should demonstrate that adequate volume and dimensioning for grit removal, solids separation and solids storage is provided. Flow equalization should be provided for all treatment modes with the exception of septic tanks, single-pass sand filters, and lagoons. If flow equalization is not proposed for the system, the engineering report should specify why it is not being proposed.

Treated effluent from a secondary treatment unit should meet SPDES permit limits. Typical permit limits for surface discharge are provided in Tables B-4A and B. For systems discharging to an STS with a design flow range of 400 to 1,500 gpd, NYSDEC strongly recommends the use of filters/screens and enhanced treatment units certified by NSF International Inc.'s Standards 46 and 40, respectively, or by an equivalent certification system. For systems discharging greater than 1,500 gpd to an STS, multiple NSF-certified systems or another treatment technology chosen from these Design Standards, *Ten States Standards* or *TR-16* may be used.

The Table F-1 reprint of the 2002 EPA *Onsite Wastewater Treatment System (OWTS) Manual Table 4-1* (EPA page 4-3) presents secondary and tertiary treatment methods. The EPA website provides access to EPA's *1980 Design Manual* and *2002 OWTS Manual* (link to "Guidance, Manuals and Policies") and to other information about on-site wastewater treatment systems from federal and state environmental agencies, universities, and industry professionals.

Table F-1 Suggested Treatment Methods to Meet Treatment Objectives

(Reprinted from 2002 EPA *OWTS Manual* Table 4-1, page 4-3)

Treatment	Treatment process	Treatment methods
Suspended solids removal	Sedimentation	Septic Tank Free water surface constructed wetland Vegetated submerged bed
	Filtration	Septic tank effluent screens Packed bed media filters (incl. dosed systems): Granular (sand, gravel, glass, bottom ash), peat, textile or foam. Soil infiltration
Soluble carbonaceous BOD and ammonium removal	Aerobic suspended-growth Reactors (Activated Sludge)	Extended aeration Fixed film activated sludge Sequencing batch reactors (SBRs)
	Fixed film aerobic bioreactor	Soil infiltration Packed bed media filter (incl. dosed systems): Granular (sand, gravel, glass), peat, textile or foam Tricking filter Fixed film activated sludge Rotating biological contactors (RBCs)
	Lagoons	Facultative and aerobic lagoons Free water surface constructed wetlands
Nitrogen transformation	Biological Nitrification (N) Denitrification (D)	Activated sludge (N) Sequencing batch reactors (N) Fixed film bio-reactor (N) Recirculating media filter(N,D) Fixed film activated sludge (N) Anaerobic up-flow filter (N) Anaerobic submerged media reactor(D) Vegetated submerged bed (D) Free water surface constructed wetland (N,D)

	Ion exchange	Cation exchange (ammonium removal) Anion exchange (nitrate removal)
Phosphorus removal	Physical/Chemical	Infiltration by soil and other media Chemical flocculation and settling Iron–rich packed bed media filter
	Biological	Sequencing batch reactors (SBRs)
Pathogen removal (bacteria, viruses, parasites)	Filtration/Predation/Inactivation	Soil infiltration Packed bed media filters: Granular (sand, gravel, glass, bottom ash), peat, textile or foam
	Disinfection	Hypochlorite feed Ultraviolet light
Grease removal	Flotation	Grease interceptor Septic tank
	Adsorption	Mechanical skimmer
	Aerobic biological treatment (incidental removal will occur; overloading is possible)	Aerobic biological systems

Responsibility for the process to achieve the needed level of treatment rests with the design engineer. For some commercial wastewaters, grease removal may be required (see Section D.5) or tertiary treatment techniques, such as physical-chemical treatment (see Section G), may be more appropriate than biological secondary treatment alone. The maximum FOG concentration discharged to an STS should be controlled by effluent screens filtering for both the grease interceptor and septic tank/treatment tank effluent.

Conventional technologies that use soil for most of the treatment and have been successfully employed in New York State for many decades should be considered first. These designs have a track record of reliability with low maintenance. New and alternative technologies have potential risk and may require a higher level of oversight. The level of treatment should be determined at the pre-application meeting described in Section A.2. Most secondary treatment systems require active management (on-site visits and remote telemetry) to properly manage and maintain the treatment levels of the system.

F.2 Media Filtration and Alternative Media

F.2.a General

Sand filters and alternative media filters should be preceded by properly designed settling facilities. A septic tank with an effluent filter is usually sufficient. Aeration of septic tank effluent will extend the life of either the sand or media filter. Post filtration aeration and/or disinfection may be necessary prior to discharge to surface waters. Distribution piping for sand filters may be of a variety of materials, although perhaps the most common is PVC (ASTM D3034).

Single-pass sand filters can be buried or open. Open filters may be single-pass or re-circulating. Single-pass sand filters can be used where soil is impermeable, or where highly polished effluent is desired. Discharge is generally to surface waters but may be to a soil-based treatment system.

Refer to Appendix F for a compilation of case study data of influent levels and resultant effluent levels after treatment for BOD, TSS, TKN, TN and fecal coliform.

Sand/Gravel Filtration

Sand filtration is a well-established method of wastewater treatment. Single-pass sand filters operating by siphon dosing to gravity are preferred as being least costly and requiring the least maintenance. Where a gravity system can be used, single-pass sand filters (SPSFs) provide reduced energy costs. However, re-circulating sand filters (RSFs) that have additional operator control may cause fewer odor problems, may result in a more consistent effluent quality than single-pass filters, and will have a smaller footprint than single-pass filters. Re-circulating sand filters may require up to three pumps: to the filter, to recycle, and to the soil-based treatment system (STS).

In general, without re-circulation, smaller media sizes (d_{10}) combined with low loading rates will result in both a high-quality effluent and enhanced nitrification. A properly operated filter (i.e., not overloaded) should be able to achieve nitrification of at least 80 percent of the applied ammonia. From the 2010 *Rhode Island Sand Filter Guidance* Introduction: “Sand filters when designed, installed, and operated in accordance to this guidance will provide effluent BOD_5 and TSS levels of less than 10 mg/L. Sand filters are efficient nitrifying units, and can reduce septic tank effluent ammonia-nitrogen levels from 35 to 55 mg/L to less than 5 mg/L by passage through a single pass sand filter, providing 86 to 91 percent

removal." Additional performance data is given in the 2002 EPA *OWTS Manual* Technical Fact Sheets 10 and 11.

Liners

The sand or media filter should be evaluated for the need of a liner, curtain drain, or other appropriate measures where high groundwater levels, bedrock, and soils with fast percolation rates are present to prevent infiltration of groundwater or exfiltration of wastewater. If the natural/native soil has a percolation rate faster than 60 mpi it is strongly recommended the sand or media filter have a liner, especially where groundwater contamination is a concern.

An impermeable liner is highly recommended for sand or media filter systems with design flows over 1,000 gpd. Liners should be 30 mil per ASTM D751 (for thickness), ASTM D412 (for a tensile strength of 1,100 lb., and an elongation of less than 200 percent), ASTM D624 (for a tear resistance of 150 lb./in), and ASTM D471 (for water adsorption range of +8 to -2 percent mass). The liner should be ultraviolet resistant with a geotextile fabric or 3" of sand below it to protect the liner from puncture.

Flow Rates

In general, open filters are preferred over buried filters when the wastewater flow rate exceeds 30,000 gpd. Open filters generally can be used for wastewater flows up to 200,000 gpd.

Resting Filters

When multiple single-pass filter beds are used, a resting period of at least 60 days for every six months of operation is recommended to oxidize the clogging mat and increase the filter's lifetime. The total surface area of multiple filter beds in service should be adequate for handling the recommended design for hydraulic and organic loading even with the largest filter bed at rest. See Section F.2.b. Single Pass Sand Filters for seasonal use and resting of single-bed filters

Winter startup of filters should be avoided. Open re-circulating sand or gravel filters can be designed to avoid formation of a surface-clogging mat and the resulting required maintenance.

Filter Media Alternatives

Sand, pea gravel and graded gravel are most often used in the construction of sand/gravel filters. Using crushed stone should be avoided unless it is washed to remove all fine materials that could clog the filter. Only sand and gravel loading specifications are given in these design standards; other media require approval under Section H.

Other granular media that have been used include bottom ash, expanded clay, expanded shale, and crushed glass. These media should remove BOD and TSS similar to sand and gravel for similar effective sizes, uniformity, and grain shape. Newer commercial media, such as textile materials, open-cell foam, and peat, have had limited testing. Based on early testing data, these materials are expected to perform as well as sand and gravel. Alternative media may be contained in “pods,” tanks or containers sized by design flow or “per bedroom” for residential use. Larger containers designed to handle commercial/small municipal wastewater facilities are also available.

Any media should be evaluated based on design loading rates, durability, performance and cost. It is not feasible to provide design data for every material. The design engineer should require the manufacturer to provide sufficient documentation regarding the performance under expected on-site conditions (such as sewage strength, ambient temperature and desired effluent quality).

Sand/Gravel Media Sizing and Specification

The following subsections will focus on the use of sand or gravel media. This type of media should be durable, insoluble in water, have rounded grains, and an organic content of less than 1 percent. Only washed material should be used. Fine particles passing the U.S. No.200 sieve (less than 0.074 mm) should be limited to less than 3 percent by weight. The largest particle size should be 3/8".

A statement from a certified laboratory and/or from the source operator indicating a sample has been analyzed, and the indicated sand/gravel media is the material that will be supplied, should be provided to the design engineer prior to construction, and should also be provided for every load delivered. Sufficient media should be supplied for a minimum filter depth of 24". Ongoing monitoring of media quality during construction is strongly encouraged to assure the proper media is installed. Sample sieve size specifications are shown below.

Example Sand Media Gradation		
US Standard Sieve	*Particle Size (mm)*	*Percent Passing the Sieve*
3/8	9.5	100
4	7.8	95 to 100
8	2.4	80 to 100
16	1.2	45 to 85
30	0.60	15 to 60
50	0.30	3 to 15
100	0.15	0 to 4
200	0.075	0

Ranges of media sizes are recommended for the different types of sand/gravel filters in the discussion to follow. The effective size (ES or d_{10}) of the media refers to the sieve size in millimeters that permits 10 percent by weight to pass. The Uniformity Coefficient (UC or d_{60}/d_{10}) is the ratio between the sieve size that will pass 60 percent by weight and the effective size.

Wastewater Distribution

Gravity distribution of wastewater resulting in trickle flow to sand filters should not be allowed. System dosing, via siphons, floating outlet dosing devices, or pumps should be provided for all media filters. Provision should be made to prevent the flow of wastewater out through any vents when the system is being dosed.

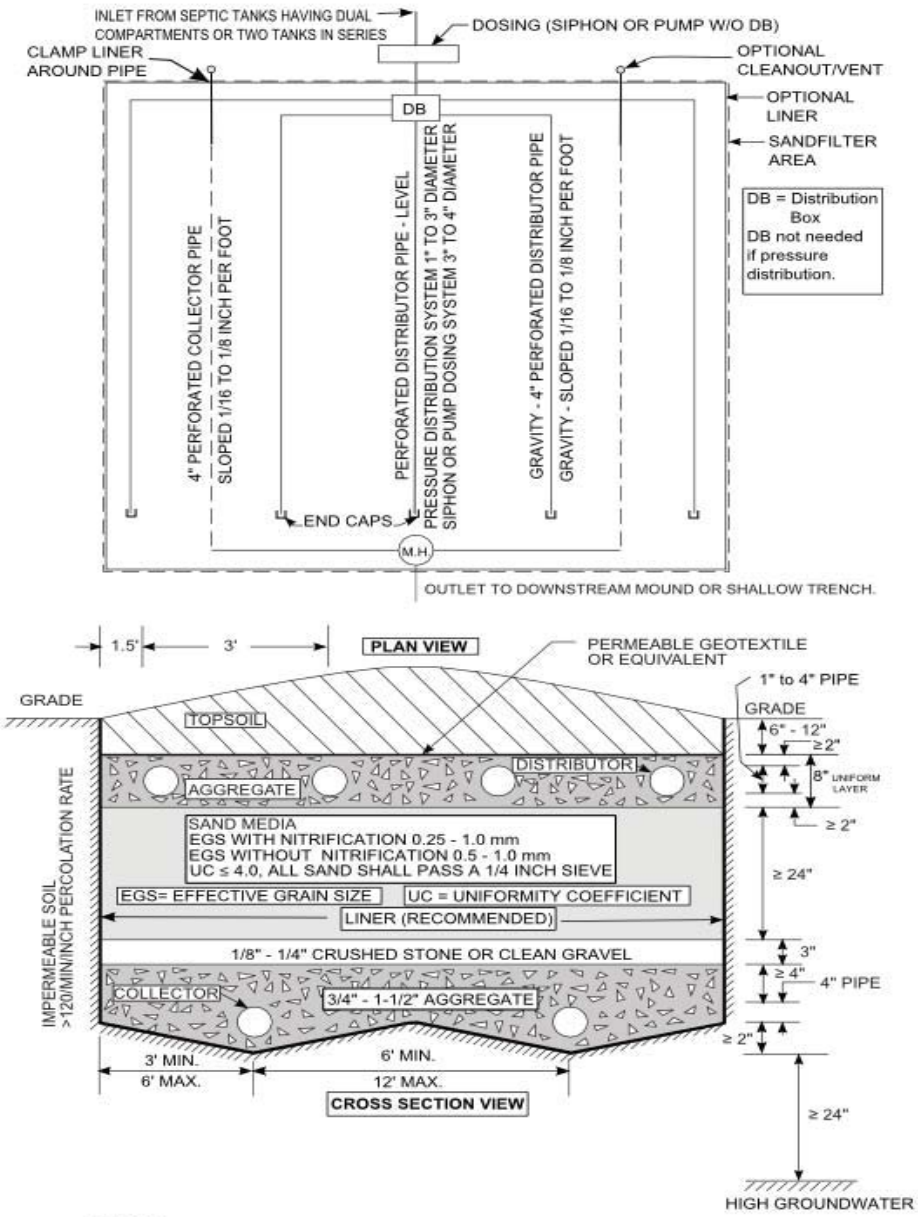
F.2.b Single-Pass Sand Filters

Single pass filters can be used as a secondary treatment method or for effluent polishing following a package plant treatment process. Single-pass sand filters typically provide insufficient treatment for intermittent stream effluent limits. Single-pass sand filters can be buried or open. Because a sand filter should be maintained by removal of biomat that forms on the filter surface from time to time, an open sand filter design would facilitate this cleaning process. Therefore, the Department encourages installation of open sand filters.

Buried single-pass sand filters are constructed below grade in a lined or unlined excavation and covered with soil material. The design limits operator access to the filter. These filters should not be used directly after package aerobic treatment plants because an upset in the aerobic unit may cause clogging of the filter. Using an effluent filter in a separate tank following the aerobic treatment unit would prevent solids carryover to the buried sand filter if properly installed, operated and maintained.

A buried sand filter should be constructed in accordance with Figure F-1. Multiple filter beds are strongly recommended when filters are of the buried type to allow for resting of beds, and redundancy. Steps should be taken to divert rainfall and runoff away from buried filters. Due to the inaccessible aspect of the buried sand filter, no preventive maintenance can be performed. Buried sand filter design is not recommended for large installations, because once the sand filter is clogged, the facility loses filtration capability until the system is replaced, which could be very costly.

Media: The recommended effective media size (ES) range is 0.25 to 1.0 mm, and the uniformity coefficient (UC) should be less than 4. If nitrification is not required, effective media size range should be 0.5 to 1.0 mm. Media with lower UCs are preferred as they are less likely to clog but more difficult to obtain or are more expensive.



NOTES:

1. A Single Center Collector may be used when the filter width does not exceed 12 Feet.
2. Collector lines to be centered between distributor lines.
3. Gravity distribution may be used to apply effluent to small filters having less than 300 lineal feet of distributor or less than 900 square feet of filter area.

Figure F-1 **Single-Pass Sand Filter- Buried Filter**

Loading: Hydraulic - The hydraulic application rate for buried filters in continuous operation should be no more than 1.0 gpd/sq. ft. of bed surface area for filters. If a bed is operated seasonally such that it will rest for an amount of time equal to or greater than its time in use (on a yearly basis), application rates up to 2.0 gpd/sq. ft. may be allowed.

Loading: Organic – Long-term organic loading should be less than 0.005 lbs. BOD/day/sq. ft. of bed surface area.

Loading: Nitrification - When nitrification is required, the hydraulic application rate should not exceed 1.0 gpd/sq. ft. of bed surface area; a lower organic loading is recommended (e.g., 0.003 lbs. BOD/day/sq. ft. of bed surface area).

Filters operating on a seasonal basis are less efficient at nitrifying wastewater, thus recirculation is recommended.

Dosing: This type of single-pass buried filter should be flooded at least twice per day, and the volume of each dose should be at least 75 percent of the volume of the distribution lines. Distribution boxes should be used to direct sewage flow. Pressurized distribution systems that provide 2' of head at the distal end of the distribution system are strongly recommended.

Base: Approximately 2" of gravel should be placed above and below the distribution lines and the underdrain of the filter. Gravel size around the under drains and distribution lines should be ¾"to 1½". Size of the crushed stone or clean gravel between the sand media layer and the base aggregate layer should be 1/8" to ¼". The ground beneath the filter should be sloped to the trenches in which the underdrains are laid.

Arrangement: Underdrain pipes should not be placed on greater than 12' centers, and at least two underdrain pipes should be provided. Underdrain pipes should be sloped to the outlet. Distribution lines should not be placed on greater than 3' centers. For installations with more than 800'of distribution lines, the filter should be constructed in two or more sections such that no section contains more than 800' of distribution lines. Dual siphons or pumps should be provided to alternate the flow to different sections. Venting of underdrains is also required.

Construction: The filter should be settled by flooding with clean water before distribution lines are placed at final grade. Before backfilling, a barrier material should be placed above the graded gravel.

Barrier material should be a synthetic drainage fabric (permeable geotextile). Untreated building paper is permitted only for SPSFs with design flows under 1,000 gpd. Backfilling should be done carefully to avoid compaction of the filter and protect distribution piping from deflection or deformation. Use of heavy machinery should be avoided.

Approximately 6" of topsoil should be mounded over the site, with a 3 to 5 percent slope to direct rainwater away from the filter.

Single-Pass Sand Filters Open Design

Open single-pass sand filters are constructed above or below grade in a lined or unlined excavation, and are accessible from the surface for maintenance and other purposes. The SPSF can be used as a secondary treatment method or for effluent polishing following secondary treatment. A typical open single-pass filter is shown in Figure F-2.

Media, organic loading, dosing, base and arrangement recommendations are the same as those listed above for the buried single-pass sand filter.

Hydraulic loading rate: Open single-pass sand filters are limited to a range of 2 to 5 gpd/sq.ft. Decreased loading rates are recommended when nitrification is required.

Distribution: Pressurized distribution is the preferred method of dosing for an open SPSF design because it provides for more even distribution of wastewater over the entire sand filter. However, pressurized distribution does require routine maintenance to maintain its efficacy such that it is better suited for open SPSF design than the buried variation. Pressurized distribution delivers a pre-determined volume of effluent to the sand filter by spraying the effluent through orifices over or into the sand filter surface area. Lower hydraulic loading rates and greater dosing frequencies allow for smaller pumps and discharge lines and require less energy to operate. Refer to Appendix E.1 for a pressurized design example.

Cover: It is often necessary to provide a cover for a filter surface because the surface of a fine medium exposed to sunlight can be fouled with algae. Also, there may be concerns about odors, cold weather impacts, precipitation, leaf and debris accumulation, and snow melt. In addition, the cover must provide ample fresh air venting. Reaeration of the filter medium primarily occurs from the filter surface.

Construction: The filter should be settled by flooding with clean water before distribution lines are placed at final grade.

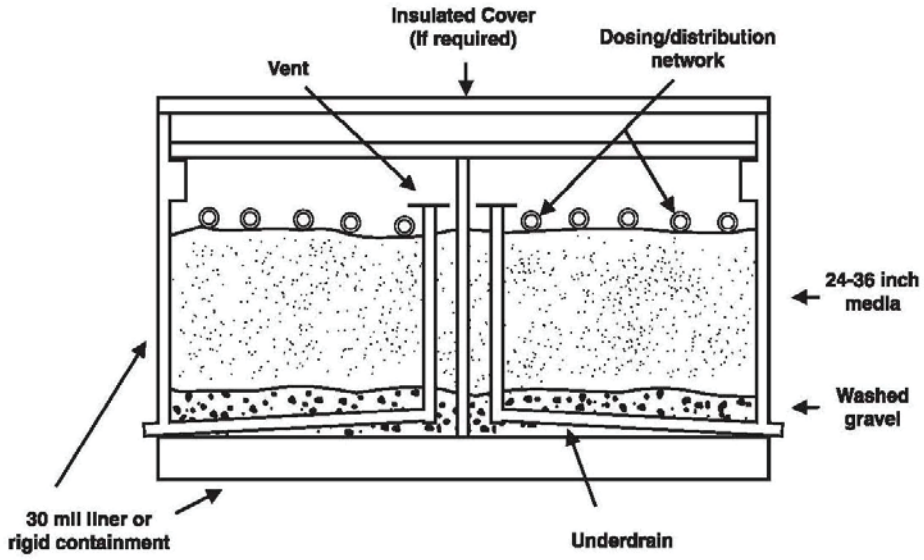


Figure F-2 Open Single-Pass Sand Filter

Walls: Provision must be made to prevent soil or stormwater from washing onto beds. Walls exposed directly to the air in cold climates should be insulated. Walls also prevent creeping weed growth from entering the filter area.

Maintenance: Winter startup in any location should be avoided. Open sand filters must be raked and weeded as needed. The distribution network should be flushed annually, and the dosing pump should be calibrated at least annually. Multiple filter beds should be provided to allow for maintenance, except for very small facilities. Regular filter bed rotation is also recommended for resting (draining and re-aerating).

F.2.c Recirculating Sand/Media Filters (RSF)

Recirculating filters can be used as a secondary treatment method or for effluent polishing following package plants. Depending on the design, an effluent filter may be required to prevent occasional solids carryover from some aerobic treatment units that may precede the sand or media filter. A typical recirculating filter is shown in Figure F-3. Note that Technology Fact Sheet 11 in EPA's 2002 *OWTS Manual* has diagrams, general design guidance, design parameter and media specification ranges,

recirculation method and component guidance, and pollutant removal performance examples.

Recirculating Sand/Media Filters - General Design Considerations

Most RSFs are constructed aboveground with an open filter surface; however, in cold climates, they can be placed in an in-ground excavation to prevent freezing. Walls preventing eroded soil or stormwater from entering the filter should be constructed. Walls should be insulated in cold climates. Pressure distribution is highly recommended for this type of design to provide equal distribution of wastewater over time onto the sand filter. It is often necessary to provide a cover for a filter surface because the surface of a fine medium exposed to sunlight can be fouled with algae. Also, there may be concerns about odors, cold weather impacts, precipitation, leaf and debris accumulation, and snow melt. In addition, the cover must provide ample fresh air venting. Reaeration of the filter medium primarily occurs from the filter surface.

Use of a weir box for recirculating is highly recommended for visual flow confirmation and determination of the quantity of recirculating flow. For systems under 1,000 gpd, a distribution box with a riser may be used for splitting flow to the STS, discharge or to the pump tank.

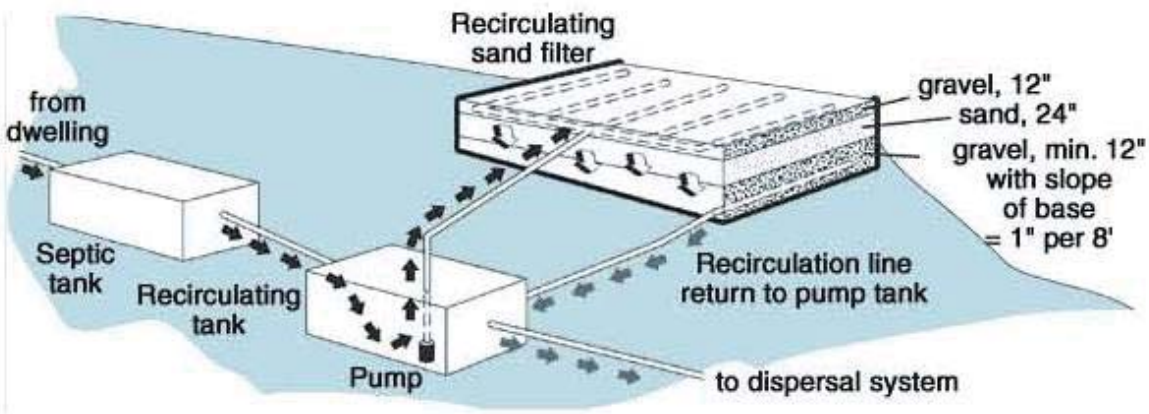


Figure F-3 Recirculating Sand/Media Filter

University of Minnesota Extension Innovative Onsite Sewage Treatment Systems - Recirculating Media Filter (http://www.extension.umn.edu/ distribution /naturalresources/dd7670.html)

Recirculation Tank Sizing

In many types of commercial systems, daily flow variations can be extreme. In such systems, the

recycling ratio necessary to achieve the desired treatment may not be maintained unless the recirculation tank is sized properly. During prolonged periods of high influent flows, the recirculation ratio can be reduced to the point that treatment performance is not maintained unless the recirculation tank is sized to provide a sufficient reservoir of recycled filtrate to mix with the influent during high-flow periods.

To size the tank appropriately for the application, assess the water balance for the recirculation tank using the following procedure:[48]

1. Select the dosing frequency based on the wastewater strength and selected media characteristics.

2. Calculate the dose volume based on the average daily flow ($Q_{average\ daily}$):

   V_{dose} = [(recycle ratio + 1) × $Q_{average\ daily}$] ÷ (doses/day)

   Q_{dose} = V_{dose} ÷ (dose period)

   where V_{dose} is the flow volume per dose, Q_{dose} is the flow rate per dose, the dose period is the time length between doses, and the recycle ratio is typically between 3:1 and 5:1. Adjust the dose volume if the calculated volume is less than the required minimum dose volume for the distribution network.

3. Estimate the volumes and duration of influent peak flows that are expected to occur from the establishment.

4. Calculate the necessary recirculation tank "working" volume by performing a water balance around the recirculation tank for the peak flow period with the greatest average flow rate during that peak period:

   Inputs = $Q_{inf} \times T + Q_{recycle} \times T = Q_{inf} \times T + (Q_{dose} - Q_{eff}) \times T = V_{inf} + V_{recycle}$

   Outputs = $V_{dose} \times$ (T ÷ dose period)

   where T is the peak flow period duration

   If the inputs are greater than the outputs, then $Q_{eff} = Q_{dose}$ and the peaks are stored in the available freeboard space of the recirculation tank. If the inputs are less than the outputs, then $Q_{eff} = Q_{inf}$.

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[48] *Onsite Wastewater Treatment Systems Manual – TFS 11 p. TFS-65* (EPA/625/R-00/008 February 2002)

To provide the necessary recycle ratio, sufficient filtrate must be available to mix with the influent septic tank effluent. The filtrate is provided by the return filtrate flow and the filtrate already in the recirculation tank.

Recycle ratio $\times Q_{inf} \times T \leq Q_{recycle} \times T$ + minimum tank working volume

Where minimum tank working volume = Recycle ratio $\times (Q_{inf} - Q_{recycle}) \times T$

5. Calculate the necessary freeboard volume for storage of peak flows when the influent volume is greater than the dosing volume during the peak flow period.

$$\text{Freeboard volume} = Q_{inf} \times T + Q_{recycle} \times T - Q_{dose} \times T$$
$$= Q_{inf} \times T(Q_{dose} - Q_{eff}) - Q_{dose} \times T$$

6. Calculate the minimum total recirculation volume.

Total tank volume = minimum tank working volume + freeboard volume

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Design Criteria for Recirculating Sand/Media Filters Using Pressure Distribution:

Recirculation: The Recirculation Ratio is the ratio of the return filtrate flow to the flow splitting device to the effluent (average design) wastewater flow or “forward flow.” Adjustable recirculation ratios covering 3:1 to 5:1 should be available to the system operator. Recirculation may be maintained by using weir boxes, flow splitter boxes, moveable gates, check valves, or the float valve arrangement. Hydraulic loading of the sand filter surface will be four to six times the forward flow because the forward flow from the pre-treatment unit combines with the filtrate recirculation volume. The storage capacity of the recirculation tank should provide enough freeboard to accommodate power outages and servicing of the system.

Dosing: Filters should be pressure dosed every 30 to 60 minutes using programmable timers. Small, regular (intermittent) doses of one to two gallons per orifice provide uniform distribution- a better environment for treatment.

Pumps should be sized to provide a minimum of 5' of head (water pressure) at the distal end of each

distribution lateral in the filter. The pump dosing the sand filter should be located in the recirculation tank that follows the septic tank and should be placed in a screened pump vault.

Flow from the septic tank to the recirculation tank is typically by gravity. All effluent should be pre-screened using an effluent filter/screen before it is dosed onto the sand filter. This screen/filter assembly helps protect the pump and sand filter surface from excessive solids.

Media: The effective size of the media should be 1.0-5.0 mm with a uniformity coefficient under 2.5. Washing is required to remove fine material (fines) from the media before installation in the sand filter. Using larger media size within the given range is preferred because it extends longevity of the filters and reduces operator maintenance time. Smaller media may provide better treatment (pathogen removal); however increasing recirculation can help address pathogen removal and treatment efficiency with larger size media. In addition, adequate resting time provides the necessary aerobic conditions for better treatment. UV disinfection may also be added to reduce pathogens.

Loading: Hydraulic - Wastewater from septic tanks is applied at loading rates of 2- 5 gpd/sq. ft. based on forward flow when sand media is used in RSFs providing secondary treatment. Where gravel media is used, hydraulic loading rates range between 10- 15 gpd/sq. ft. With a recirculation ratio of 3:1 to 5:1 at the flow-splitting device, the actual wastewater loading rate on the sand filter surface can be four to six times the forward flow from the pre-treatment unit. RSFs provide nearly complete nitrification, resulting in removal of 50 percent of the Total Nitrogen (TN). Design variations of RSFs to further reduce TN using denitrification are given in the EPA Technology Fact Sheet 9 *Enhanced Nutrient Removal – Nitrogen.*

Wastewater from package-activated sludge plants equipped with effluent filters to prevent solids carryover, or from trickling filters, may be applied at loading rates up to 10 gpd/sq. ft. when sand media filters are used as low-rate polishing filters. Refer to Section G.2 for further information on low-rate granular media filters.

Loading: Organic - Long term organic loading should be under 0.005 lbs. BOD/day/sq. ft. If nitrification is required, a lower organic loading of 0.003 lbs BOD/day/sq. ft. is recommended.

Base: Graded gravel should be placed at a depth of at least 10" around the underdrains, and should be ¾"to 1½" in size. This should be covered with at least 3" of pea gravel, which is 1/8" to 3/8" in size.

Arrangement: Multiple filter units should be provided to allow for maintenance, except for very small facilities (flow under 2,000 gpd). Rectangular beds should be considered to provide more complete coverage during dosing.

Distribution: Using large media size eliminates the option of flooding the filter. PVC pipelines with drilled orifices or spray nozzles may be used for distribution of settled sewage over the filter surface. 1" to 1½"Class 200 PVC manifolds should deliver wastewater to a distribution pipe grid of ¾"to 1" Schedule 40 PVC pipe.

Temperate climate systems typically drill upward-facing orifices, with every fifth orifice drilled at both the 6 and 12 o'clock positions. Systems in colder climates typically have all orifices pointing down, with slotted orifice shields providing free drainage. An alternative to orifice shields is to use 3" to 6" PVC or corrugated plastic foundation drainage pipe as an outer sleeve to allow free drainage and prevent filter media blockage of orifices.

Orifice spacing is determined by dosing requirements. RSFs should receive 24 to 48 equal doses of wastewater per day. Grid dimensions (created by the pipe centering and orifice spacing) should be 2' to 2½'.

The discharge pipe to the distribution system should be a 1¼" to 2" PVC (Class 200 minimum) pipe, the actual size depending upon such factors as distance, pump head, friction loss, and desired pressure at distal orifices. The discharge pipe should be drained between doses to prevent frost damage. This can be done by providing a drain line from the distribution line back to the recirculation tank, or by providing small weep holes in the discharge pipe. At least 18" of sand should be present below the weep holes. For a pumped system, the discharge pipe can be sloped back to the dosing chamber and the check valve at the pump eliminated. In this case the dosing volume should be sized to account for backflow.

Distal ends of laterals in an RSF, which are readily accessible by pushing aside a small amount of pea stone, do not need sweep elbows (turn-ups). These lateral ends should have threaded ball valves onto which a distal head measurement pipe can be attached. Lateral cleaning will occur through ball valves .

Underdrains: Four inch diameter Schedule 40 PVC slotted underdrain collection pipes should be sloped to the outlet and should not be placed on greater than 10' centers. The underdrain may lay level or on a maximum slope of 0.5 percent. Slots should be oriented upwards, sized ¼"by 2½", and spaced 4" apart.

At least two underdrains should be provided with venting. Venting should be provided by bringing the distal end of the underdrain pipe to the surface of the filter and supplied with a removable cap. In addition to venting, the pipe to the surface can be used as a cleanout and an observation port.

The underdrain pipe should leave the concrete or lined filter enclosure via a watertight, sealed penetration.

A minimum of 4" of ½"to ¾"clean washed stone should be placed between and over underdrain pipes. If a plastic liner is used, sharp, angular stone should be avoided to prevent liner punctures.

Eight inches of 3/8" clean washed pea stone should be placed carefully over underdrains and drainage stone to assure the filtering media is not washed down into the underdrain.

Walls: Provision should be made to prevent soil from washing onto beds. Walls exposed directly to the air in cold climates should be insulated. Walls also prevent creeping weed growth from entering the filter area.

Cover: For an RSF, cover the filter with 3/8" pea stone to a level of 2" to 4" over the top of the lateral (distal) end ball valve. (No topsoil cover should be placed over the pea stone.)

Maintenance: Winter startup should be avoided. Regular rotation with resting is also recommended.

F.3 Rotating Biological Contactor (RBC)

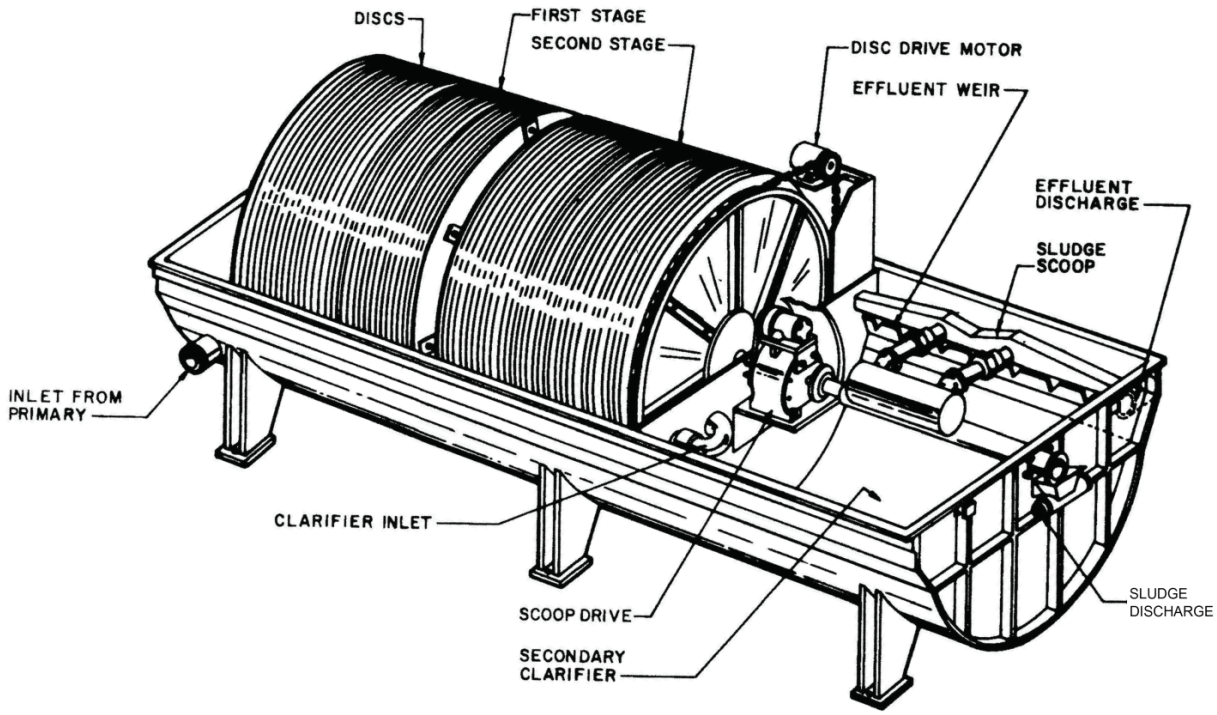

Figure F-4 Rotating Biological Contactor (RBC) Schematic

A rotating biological contactor is a biological process used in the treatment of wastewater following primary treatment. The primary treatment process removes grit and other solids through a screening process, followed by a period of settlement. The RBC process allows wastewater to come in contact with a biological medium to remove pollutants before discharge of the treated wastewater. The process involves a series of closely spaced, parallel discs mounted on a rotating shaft which is supported just above the surface of the waste water. Microorganisms grow on the surface of the discs where biological degradation of wastewater pollutants occurs. *TR-16* addresses pre-treatment requirements, media selection, unit sizing, designing for operational flexibility, and weather protection for RBC design. *TR-16* design criteria serve as New York State's standards for RBCs, as supplemented below:

1. Staging - For small installations, up to four stages can be provided on a single shaft by installing inter stage baffles in the tank, with the direction of flow parallel to the shaft.

2. Nitrification - Four or more stages are usually necessary when nitrification is desired in addition to BOD removal, because maximum nitrification rates will not be obtained until the level of

soluble BOD_5 drops to 10 mg/L or less. For design purposes, the average maximum removal rate should not exceed 0.3 lb NH_3 - N/day/1,000 sq. ft. of media. Where large and/or frequent peaks in flow or organic loading are anticipated, consideration should be given to providing either additional media or flow equalization to ensure consistently low ammonia nitrogen levels. The temperature of the system should be maintained at or above 55°F. If this is not possible, additional media should be provided to compensate for reduced removal rates. The system pH should be held between 7.1 and 8.6. If the wastewater is poorly buffered, the system should have the capacity for the addition of alkaline chemicals.

3. Pilot Plant Studies - When possible, full-scale diameter media should be used for pilot plant studies. If small diameter units are used, each stage should be loaded at or below the oxygen transfer capability of a full-size diameter unit to minimize scale-up difficulties.

4. Shaft weight monitoring - Load cells for measuring total shaft weight should be provided for the first stage of the standard-density and the high-density shafts, at a minimum. Electronic strain gauges are preferable, but hydraulic load cells may also be used. Dissolved oxygen levels should be monitored in at least the first stage of the RBC system. Supplemental air should be provided in the original design to allow operational flexibility when higher oxygen demand is required. Supplemental air helps increase DO levels, control filamentous bacteria growth, and can be used to strip excess growth from an RBC and may increase treatment efficiency.

5. Equipment - Drive systems should be variable speed and may be mechanical or air driven, although mechanical systems are preferred. In that air-driven systems are powered by diffused aeration that directs air on an array of cups peripherally attached to rotating disks, they should have positive airflow metering and control to each RBC unit. Aeration of an RBC system that is mechanically driven may increase treatment efficiency. Bearing units should be self-aligning and should be located outside media covers to allow easy access for lubrication and maintenance. Provision for auxiliary power during power outages is recommended as structural overloads of the shaft may occur when the discs do not rotate.

6. Design/Configuration - Operation and maintenance requirements (including bio-film control, drive train and radial support arm maintenance and repair, and media/shaft repair and replacement) should be considered in the design and layout of RBC treatment systems. Provision should be made for positive flow control to each stage, allowing flexibility in feeding influent and recycling or discharging RBC effluent. Tank depth/configuration should be such that solids are

not deposited in the tank. Also, provision should be made for draining the tank. Large installations with closely spaced RBC units may need a crane for shaft/media removal. System layout should account for crane reach and size. Wastewater flow perpendicular to the shaft should be encouraged to develop uniform loading over the entire length of the shaft.

7. Flexibility - Overloads generally can be avoided if flexibility is designed into the RBC system to strip excessive bio-film growth from the media or to even the organic load to all stages. Flexibility can be achieved by having variable rotational speed, the ability to reverse rotational direction, supplemental aeration, or the potential for chemical addition. The ability to increase surface area in the affected stage should also be considered. The process should include the ability to step feed, bypass and isolate individual RBC stages. If the first stage is overloaded, these provisions will allow a portion of the flow to be diverted to alternative lower density/growth stages.

8. Settling - Final settling should provide a detention time not less than 90 minutes, with maximum surface settling rate of 600 gpd/sq. ft. and weir overflow rate not greater than 5,000 gpd/linear feet. Higher surface settling and weir overflow rates may be used if the contactor is to be followed by tertiary treatment. Surface settling rates of the final clarifier(s) following the RBC process should be based on peak hourly flow rates.

F.4 Media Bio-Towers

A media bio-tower is a housing in which an attached biomass builds up over time on either redwood or plastic media. Wastewater is treated by the biological activities of the microorganisms in the attached biomass layer, using the nutrients in the wastewater as a food source. As a fixed-growth treatment unit, bio-tower media provide surface area where microorganisms grow and then eventually slough off to be recycled to the head of the treatment process, or discharged as waste sludge. Non-soluble solids should be removed by physical pre-treatment means, e.g., settling, flotation, screening.

The media bio-tower serves as a high-rate filter which provides roughing of the effluent's BOD and TSS. Roughing filters are for treating particularly strong or variable organic loads, allowing them to be treated by conventional secondary processes. Media bio-towers are designed to allow high hydraulic loading and a high level of aeration. On larger installations, air is forced through the media using blowers. *TR-16*, "Integrated Biological Treatment" contains further information on the application of bio-towers for wastewater treatment.

The media bio-tower can also be effective for secondary treatment of BOD and TSS due to biological oxidation and nitrification occurring in the bio-tower. With this aerobic oxidation and nitrification, organic solids are converted into coagulated suspended mass, which is heavier and bulkier than wastewater, and is wasted or recycled. Bio-tower effluent may be sent to a secondary clarifier or settling tank for further solids removal.

Operation of Municipal Wastewater Treatment Plants WEF Manual of Practice No. 11 Sixth Edition provides design information on bio-towers.

F.5 Activated Sludge

The activated sludge process may be used to remove suspended solids as well as carbonaceous and/or nitrogenous oxygen demand and nutrients (nitrogen and phosphorus). The chosen process will be influenced by the degree and consistency of treatment required, type of waste to be treated, proposed plant size, anticipated degree of operation and maintenance, local factors, and operating and capital costs. Designs should maximize process flexibility while maintaining design intent, process reliability, and effluent quality. The process requires competent operating supervision, including routine laboratory control and proper control of waste and return sludge.

Ten States Standards provides design criteria based on standard modes of activated sludge. *TR-16* provides guidelines for several variations of the activated sludge process that are also presented in other references, including plug flow, complete mix, step feed, contact stabilization, and extended aeration. In addition to criteria for various modes of activated sludge, *TR-16* includes the use of aerobic, anoxic and anaerobic selectors. Integrated biological treatment (IBT) processes that combine fixed-growth systems with activated sludge (suspended growth) systems are also described in *TR-16*. The design engineer may follow either of the above guidance documents based on the selected mode or use of selectors. For smaller treatment systems using extended aeration or contact stabilization modes, a few design criteria are provided below.

Pure oxygen activated sludge systems are beyond the scope of both *TR-16* and the *Ten States Standards*. These systems require site specific approval by the Reviewing Engineer using the review considerations in Section H.

Pretreatment

For all activated sludge modes, both *Ten States Standards* and *TR-16* provide pretreatment guidance, with or without the use of primary settling tanks. Without primary settling tanks, screening devices with clear openings of ¼" or less should be provided as preliminary treatment prior to discharge to activated sludge unit. Grease removal should also be provided to prevent fouling of equipment and treatment components, and creating anaerobic conditions.

When primary settling tanks are provided, bypassing is recommended by *Ten States Standards* for plant startup and initial stages of a facility's design life. If the treatment train uses only one activated sludge tank, then primary treatment/settling tanks are recommended. If denitrification is included in the treatment plant design, removal of particulate carbon should be considered in contrast to the need for supplemental carbon when denitrifying.

TR-16 also includes design provisions for floating material removal and control of foam-causing microorganisms by chlorinating foam on tank surfaces or in pumped lines.

Design Criteria

- Redundancy: *Ten States Standards* and *TR-16* both recommend two or more tanks to hold the total aeration tank volume. Exceptions to tank volume and arrangements are given below under Extended Aeration and Contact Stabilization.

- System Components: Aeration tank dimensions and design standards for diffusers, blowers, return activated sludge, wasting activated sludge, final settling, and sludge holding tanks are the same as those listed in *Ten States Standards* and *TR-16*.

- Final Settling: Final or secondary settling tank (clarifier) design criteria are given in the Settling section of *Ten States Standards*, and in the Section following Activated Sludge in *TR-16*. In *Ten States Standards*, surface overflow rates of final clarifiers are given for the various modes of activated sludge. Peak solids loading rates for the same modes are also given. *TR-16* provides information on the use of selectors in activated sludge systems. These selectors reduce the amount of sludge going to the final clarifiers.

- Sludge Handling: *Ten States Standards* provides sludge-handling design criteria in a separate chapter entitled, "Sludge Processing, Storage, and Disposal" *TR-16* provides similar information in a chapter entitled, "Residuals Treatment and Management." For smaller systems, the following guidelines for sludge storage may be used:

  Sludge Holding Tank: A sludge holding tank, preferably with supernatant decant capability, should be provided. A minimum 1,000 gallon capacity per 15,000 gallons design flow is recommended. There should be access to the sludge draw-off piping. Sludge generation and wasting is very site-specific and could be necessary every 3 to 12 months, more frequently with phosphorus removal.

  A sludge holding tank should be aerated to reduce odors, stabilize the sludge, and reduce its volume. Dispersal of waste sludge should be in accord with currently accepted practice as described in Section J.6, Residuals Hauling and Disposal (6 NYCRR Parts 364 and 360) of this document.

Extended Aeration

Ten States Standards provides some specific design criteria for the extended aeration mode of activated sludge treatment. They are supplemented below for intermediate-sized systems.

- Startup and Use Restrictions: The extended aeration process can be used where a highly nitrified effluent is required. Its use should be governed by the realization that it is a delicate biological process subject to distress caused by surge loadings, variations in organic content, and periods of low or no flow. It takes approximately three months from start-up to stabilization of effluent quality within design parameters. Therefore, it is not recommended that extended aeration facilities be used for schools or seasonal facilities.

- Flexibility of Operation: Duplicate units are not mandatory, but piping should be arranged to permit at least primary sedimentation in the event any treatment units must be taken out of operation. Additional flexibility should be built into the system to allow switching to the contact stabilization mode of operation, particularly if the wastewater flow rate or quality will have significant seasonal variations.

Ten States Standards provides some specific design criteria for the contact stabilization mode of activated sludge treatment. They are supplemented for intermediate-sized systems as follows:

- Startup and Use Restrictions: Contact stabilization should be considered only when the design flow is at least 50,000 gallons per day. Efficiency of the activated sludge process in contact stabilization mode is questionable when wastewater is either too dilute or the soluble BOD concentration is too high, or the system has significant delivery periods of non-uniform flow.

- Tank Volume: Total contact tank plus sludge re-aeration tank volume should provide not less than 1,000 cubic feet per 50 pounds of BOD_5 applied to aeration tanks on a daily basis, or a total volume equivalent to six hours of detention time based on rated design capacity, whichever results in greater value.

- The number of tanks and flow patterns should be such that two-thirds of the total volume will be available for sludge re-aeration and one-third for contact with sewage at the design rate.

- Flexibility: Tank duplication requirements will be satisfied by three tanks arranged so that any one may be dewatered for service while one remaining tank is used for sludge re-aeration and one is used for sewage contact. Additional flexibility should be built into the system to allow switching to the extended aeration mode of operation, particularly if the wastewater flow rate or quality will have significant seasonal variations.

F.6 Sequencing Batch Reactor (SBR)

Sequencing batch reactors (SBR) are activated sludge processing tanks using a fill-and-draw or batch-type mode to treat wastewater. There is no typical SBR design configuration; however, a pre-SBR flow equalization basin followed by two SBR batch-flow units with the capacity to exchange return sludge is a minimum design plan that provides redundancy and allows for flexibility of operation. This suspended growth activated sludge process provides secondary treatment in a single tank using the following steps: fill, treat, settle, decant and draw.

In the treatment step, wastewater is aerated in the tank to reduce BOD. While there are several configurations of SBRs, the basic process is similar. Minimum installation consists of at least two

identically equipped tanks with a common inlet, which can be switched between them. While one tank is in settle/decant mode, the other is in aerating and filling mode. At the inlet is a section of the tank known as the bio-selector, or selector. This selector consists of a series of walls or baffles which direct flow either from side to side of the tank or under and over consecutive baffles. This helps mix influent with returned activated sludge, beginning the biological digestion process before the liquor enters the main part of the tank.

SBRs are aerobic growth reactors that can also provide advanced treatment removals of phosphorus and nitrogenous compounds. Additional information on nutrient removal can be found in Section G "Advanced Treatment" of this document and in *TR-16*.

Design and operation of the SBR should provide treatment quality equal to that of the continuous flow-through modes of the activated sludge process. Supplemental treatment units (e.g., disinfection) may be required to meet applicable effluent limitations and reliability guidelines. *Ten State Standards* provides some specific design criteria and redundancy requirements for sequencing batch reactors. *TR-16* provides design guidance for SBR systems that includes preliminary and primary treatment requirements, SBR component processes, and downstream unit considerations.

Ten State Standards and *TR-16* both describe flow equalization requirements. SBRs may require both pre- and post-equalization tanks. Pre-equalization is important for plants that denitrify, and basins should provide sufficient volume to accommodate a single SBR batch at the peak flow expected over the duration of an SBR fill phase. The need for post-equalization of SBR discharge flows will be determined by downstream treatment units, if any. *TR-16* recommends post equalization of a minimum volume of one full SBR batch at facilities where filtration or UV disinfection is required.

Both documents should be used for intermediate-sized systems in addition to the supplemental information provided below:

- Preliminary treatment should be done with fine screening less than ¼", rather than shredding, to keep larger solids completely out of treatment units.

- More than two tanks should be provided. If a two-tank system is proposed, the engineering justification should be documented and approved by the Reviewing Engineer.

- The requirements of Ten State Standards and TR-16 for blower design should be consulted for varying the volume of air delivered in proportion to the load demand of the plant. Blowers with variable frequency drive can deliver the desired amount of air based on in-basin dissolved oxygen probes to prevent over or under aeration. Aeration equipment should also be easily adjustable in increments and should maintain solids suspension within these limits.

- Plant design should include the ability to chlorinate for filament control.

- A sludge holding tank, preferably with supernatant decant capability, should be provided. A minimum 1,000 gallons capacity per 15,000 gallons design flow is recommended. There should be access to the sludge draw-off piping. Sludge wasting from the sludge holding tank is very site-specific and may be necessary every 3 to 12 months, more frequently with phosphorus removal.

- Sludge holding tanks should be aerated to reduce odors, stabilize the sludge, and reduce the volume of settled sludge. Disposal of waste sludge should be in accord with currently accepted practice as described in Section J.6 of this document.

EPA 2002 *Onsite Wastewater Treatment Systems* Technology Fact Sheet 3 (TFS- 3) describes both Intermittent Flow (IF) SBRs (that use a true "batch treatment" scheme) and Continuous Flow (CF) SBRs. The "Performance" section of TFS-3 gives ranges of pollutant levels in effluent expected for both intermittent flow and continuous-flow SBR systems. The EPA website provides access to the 2002 *OWTS Manual* and the 1980 *OWTS Design Manual*, and other information about on-site wastewater treatment systems to state and local governments, and industry professionals.

F.7 Oxidation Ditches

An oxidation ditch is a modified activated sludge biological treatment process that uses long solids retention times to remove biodegradable organics. When operated in an extended aeration mode as a single sludge nitrogen removal system, *TR-16* recommends a 12 to 24-hour retention time.

While oxidation ditches are typically complete mix systems, they can be modified to approach plug flow conditions. (Note: As conditions approach plug flow, diffused air must be used to provide enough mixing. In addition, the system will no longer operate as an oxidation ditch). Typical oxidation ditch treatment systems consist of a single or multi-channel configuration within a ring, oval, or horseshoe-shaped basin. As a result, oxidation ditches are called "racetrack type" reactors. Horizontally or vertically mounted

aerators provide circulation, oxygen transfer, and aeration in the ditch. *Ten States Standards* provides no specific design criteria for oxidation ditches. The only applicable guidance is limited to generally applying the extended aeration mode of activated sludge treatment. The *TR-16* standard provides design guidance on using oxidation ditches for Biological Nitrogen Removal (BNR). For further design guidance, refer to EPA's *Wastewater Technology Fact Sheet: Oxidation Ditches (EPA 832-F-00-013)*. Below is a list of additional design considerations for oxidation ditches:

- Raw sewage should be comminuted or fine-screened prior to flowing into the oxidation ditch. Primary settling is not required.

- Design of the ditch or ditches should be based upon 24-hour retention of the design flow or 1,000 cubic feet per 10 pounds of BOD_5 applied to the oxidation ditch, whichever results in greater volume.

- Duplicate units are not mandatory.

- Aerators are usually of the partially submerged rotating brush type. When provided with this type of aeration, submergence should be adjustable, and at least two complete units should be provided (either located in the ditch or stocked as a spare unit). Alternative aeration schemes may be acceptable, but only upon demonstration of proper aeration and mixing capabilities by the design engineer.

- Aerators should: maintain a minimum of 2.0 mg/L of dissolved oxygen in the mixed liquor at all times throughout the aeration tank; maintain all biological solids in suspension by maintaining a velocity of at least 1.0 fps; meet maximum oxygen demand and provide for varying amounts of oxygen transferred in proportion to the load demanded; provide motors, gear housing, bearings, and grease fittings that are easily accessible; be provided with equipment replacement parts that will suffice as duplication of the unit.

- Final settling should be designed to provide a detention time of not less than four hours, a weir overflow rate not greater than 10,000 gpd/linear ft., and a surface settling rate not greater than 1,000 gpd/sq. feet.

- Pumps or airlifts may be used for return sludge. Pumps should have at least 2½"inch suction and

discharge openings. Return piping should be at least 3" in diameter. Airlifts should be at least 3" in diameter. Return sludge rates should be between 50 to 200 percent of plant design flow.

- Provisions should be made for rate regulation and measurement.

- Waste sludge storage for at least six months volume should be provided.

- A sludge holding tank, preferably with supernatant decant capability, should be provided. A minimum 1,000 gallon capacity per 15,000 gallons design flow is recommended. There should be access to the sludge draw-off piping. Sludge generation and wasting is very site- specific and could be necessary every 3 to 12 months, more frequently with phosphorus removal.

- Sludge holding tanks should be aerated to reduce odors, stabilize the sludge, and reduce its volume. Dispersal of waste sludge should be in accord with currently accepted practice as described in Section J.6, "Residuals Dispersal (Part 360)," of this document.

F.8 Lagoons (Wastewater Treatment Ponds)

Lagoons (wastewater treatment ponds) have many forms, but the facultative lagoon is the most widely used. Aerated lagoons are often preferred because of their smaller size requirements. In some areas, lagoons must be lined according to codes which further limit their application. Facultative lagoons are large, perform best when segmented into at least three cells, obtain necessary oxygen for treatment by surface re-aeration from the atmosphere, combine sedimentation of particulates with biological degradation, and produce large quantities of algae, which limits the utility of their effluent without further treatment. Aerated lagoons use mechanical equipment to enhance and intensify the biodegradation rate. They do not produce the intense algal load on downstream processes and have smaller areal requirements than facultative systems.

Ten States Standards provides specific design criteria for three types of wastewater treatment ponds. *TR-16* standards provide similar design criteria for the same three types: aerated- facultative, flow-through, and controlled discharge from wastewater treatment pond systems, and their components. Lagoons should be designed and constructed in accordance with standard engineering practice, and should have an engineered overflow structure to provide for controlled release during wet weather events. Guidance regarding controlled releases is in Section I.3.d.Both design standards may be used for intermediate-size systems as supplemented below:

- A comminutor or bar screen should be provided upstream from the influent line conveying raw sewage or waste into an aerated pond system. Primary treatment is not required.

- Minimum separation from habitation or other occupied area for an aerated pond should be 1,000 feet. Also, see Table B-2 for separation distance in developing areas.

- Multiple cells design to permit both series and parallel operation are recommended for all aerated ponds. For un-aerated ponds, series operation is preferable to parallel operation.

- For very small installations, a dike top width of under 8' may be considered.

- Influent lines or interconnecting piping to secondary cells of multiple-celled ponds operated in series may consist of pipes through separating dikes.

- Use of multiple inlets/outlets, baffles, and dikes is encouraged to prevent short circuiting. Influent lines to rectangular ponds should extend no further than one-third the length of the pond if only a single inlet or outlet is provided.

- For un-aerated ponds, interconnecting piping for multiple unit installations operated in series should be valved or provided with other arrangements to regulate flow between structures and permit flexible depth control. Interconnecting pipe to the secondary cell should discharge horizontally near the lagoon bottom to minimize the need for erosion control measures and should be located as near the dividing dike as construction permits.

- Control manholes or other such flow-splitting facilities should be provided between cells of aerated ponds to provide a positive visual means of directing and controlling flow.

- Overflow structures should consist of a manhole or box so designed that flow from the pond during ice free periods could be taken from below, but near, the water surface to select for release the best quality effluent available and insure retention of floating solids.

- For un-aerated ponds, the draw-off lines or an adjustable overflow device should permit pond operation at depths of 2' to 5', with the lowest draw off 12" above the bottom to control eroding

velocities and avoid pickup of bottom deposits.

- A locking device should be provided to prevent unauthorized access to and use of the level control facilities. Wherever possible, the outlet structure should be located on the windward side to prevent short circuiting. All structures should be designed to protect against freezing and ice damage.

- Stream hydrograph controlled release lagoons (HCRs) discharge effluent according to the current assimilative capacity of the stream. Release is usually based on stream flow, but water quality and temperature also may be considered. A review of site specific stream information and predicted effluent quality is necessary to determine at what stream flow rates a discharge will be allowed.

- In a multiple-cell facility with a diffused air aeration system and submerged air headers, consideration should be given to arranging the overflow structure and piping to allow for independent drainage of each cell down to or below the level of the air header.

- Surface runoff should be diverted around ponds to protect pond embankments from erosion.

G. Tertiary Treatment

NYSDEC categorizes treatment technologies in Chapters E, F, and G of these design standards as either standard or alternative technologies. Standard technologies are systems that have been applied successfully in New York State for a long time with a good record of reliability and effectiveness. Alternative technologies are treatment systems that have not been widely used in New York State, but have been successfully applied in other parts of the country. This entire chapter consists of alternative technologies.

G.1 Introduction

Section G discusses advanced treatment methods that produce effluent of a quality greater than secondary and for wastewater constituents not addressed by secondary limits. Table F-1 listed secondary and tertiary treatment methods, or technologies, used to accomplish treatment objectives. Table F-1 may be referred to in determining tertiary treatment methods needed to accomplish necessary treatment goals. Some secondary treatment technologies can be used to achieve advanced or tertiary treatment levels and some are required as pre-treatment prior to tertiary treatment. Most tertiary treatment systems require active management (e.g., on-site visits and remote telemetry) to properly manage and maintain treatment levels of the system.

Table G-1 Per Capita Mass Loading of Nitrogen and Phosphorus

Typical Data on the Unit Loading Factors and Expected Wastewater Contaminant Loads from Individual Residences (from WI state regulations *Section A-83.43 (7) Commercial Facilities*, Comm 83 Appendix)

Contaminant	Unit Loading Factor lb/capita per day	Value		
		Unit	Range	Typical
BOD_5	0.180	mg/L	216 - 540	392
SS	0.200	mg/L	240 - 600	436
NH3 as N	0.007	mg/L	7 - 20	14
Organic N as N	0.020	mg/L	24 - 60	43
TKN as N	0.027	mg/L	31 - 80	57
Organic P as P	0.003	mg/L	4 - 10	7
Inorganic P as P	0.006	mg/L	6 - 17	12
Grease		mg/L	45 - 100	70

Tertiary treatment technologies may be considered for attaining more stringent water quality limits, or maintaining current water quality effluent standards on a smaller facility footprint (i.e., plant treatment capacity increase without physical footprint increase). Tertiary treatment may include suspended solids

(colloid) and nutrient removal. Nitrogen removal can be accomplished with variations of secondary treatment (Sections F and G.4) - primarily activated sludge processes, recirculating media filters, and other fixed film unit processes. Phosphorus removal can be accomplished both biologically and physically/chemically.

The Water Environment Federation (WEF) has developed a table that lists various advanced technologies for nutrient removal in *WEF Manual of Practice No. 8 – Vol. 2 – Fourth Edition – 1998 (Table 15.1).* Below is the table (Table G-2), adapted from the manual. Consult the footnotes to Table G-2 for help in creating a conceptual design of an advanced treatment system for nutrient removal.

Section F.1 also discusses guidance on third party certification of certain technologies and additional management and maintenance required for secondary and tertiary treatment systems. NSF International Inc.'s standards development for tertiary systems is currently limited to NSF/ANSI Standard 245: *Wastewater Treatment Systems - Nitrogen Reduction*. NSF/ANSI Standard 245 applies to design flows of residential strength between 400 and 1,500 gpd. For systems discharging greater than 1,500 gpd to an STS, multiple NSF-approved systems, or another treatment technology chosen from these Design Standards, *Ten States Standards* or *TR-16* may be used.

Ten States Standards tertiary treatment technology selection provides information on "Phosphorus Removal by Chemical Treatment and High Rate Effluent Filtration." *TR-16* devotes an entire chapter on "Physical and Chemical Processes for Advanced Treatment," covering the following topics:

- Granular, media, disc and membrane filtration
- Chemical treatment
- Effluent reoxygenation
- Total organic carbon removal

These two standards together provide design guidance for advanced treatment systems. These Design Standards provide additional considerations that should also be referred to. Any conflicts between standards will be reviewed at the discretion of the Reviewing Engineer. Proprietary technologies will be approved according to the procedure in Section H.

Additional references include the Water Environment Federation's *1992 Manual of Practice No. 8*, and the *2002 EPA Onsite Wastewater Treatment Systems Manual*. The *OWTS Manual*, Technology Fact Sheet 8 "Enhanced Nutrient Removal of Phosphorus," and Technology Fact Sheet 9 "Enhanced Nutrient Removal of Nitrogen" describe available technologies, design, operation, maintenance, and management/ cost considerations for nutrient removal systems.

Table G-2 **Conceptual Process Selection for Nutrient Removal**

Process	**Effluent Quality**[49]								
	Reference Documents[50]	Secondary[51]	5 mg/L BOD	5 mg/L TSS[52]	Nitrification 20 mg/L Nitrate Nitrogen	10 mg/L Nitrate Nitrogen (BNR)	3 mg/L Total Nitrogen[52,53]	1.0 mg/L Total Phosphorus[52]	0.5 mg/L Total Phosphorus[52]
Activated Sludge	8, 10, 34, TR	X	M	X	M				
Extended Aeration (e.g., oxidation ditch)	8, 10, 34, WQML, TR	X	M	X	X	M			
A/O™	8, 34, WQML, TR	X	M	X	M			M	
Modified Ludzack-Ettinger (MLE)	8, 34,TR	X	M	X	X	X			
PhoStrip™	8, 34, EPA-P	X	M	X	M	M		X	X
Trickling Filters	8,10, TR	X			M				
Bardenpho™	8, 34,TR, WWE	X	M	X	X		M		
Sequencing Batch Reactors	8, 10, TR, EPA-SBR	X	M	X	M	X	M	M	
Chemical Addition (alum, lime, or iron salts)	8, 34, TR, EPA-P							X	X

[49] 'X' denotes process capable of producing effluent meeting indicated standard.

'M' denotes process should be capable of meeting indicated standard with proper design, acceptable influent characteristics, and/or tertiary filtration.

[50] '10' denotes *10 State Standard*; 'TR' denotes *TR-16* ; '8' denotes *WEF MOP No. 8 - 2010;* 'EPA-SBR' denotes *EPA 832 R-92-002 "Sequencing Batch Reactors for Nutrification and Nutrient Removal"*; 'EPA-P' denotes *EPA 625 1-87-001 "Design Manual-Phosphorus Removal";* '34' denotes *WEF MOP No. 34*; 'WWE' denotes *"Cut P and N without Chemicals"(Water & Wastes Engineering* –July and August 1974 – Barnard, J.L.); 'WQML' denotes *Water Quality Management Library "Design and Retrofit of Wastewater Treatment Plants for Biological Nutrient Removal- Vol. 5" – Randall, Barnard and Stensel (1992)*

[51] 20-30 mg/L effluent BOD_5 and total suspended solids (TSS)

[52] Filtration is recommended to meet the indicated standard.

[53] Limit of Technology

G.2 Granular Media Filters: High-Rate or Low-Rate Secondary Effluent Filtration

Granular media filters may be used for secondary treatment or as a tertiary/advanced treatment device for removal of residual suspended solids, nutrients and pathogens from secondary effluents. For example, granular media filters should be considered where final effluent concentrations of less than 20 mg/L of suspended solids and/or 1.0 mg/L of phosphorus are required by permit, or to obtain adequate turbidity reduction for urban water reuse.

A pre-treatment process such as chemical coagulation and sedimentation or other acceptable process should precede filter units where: (1) final effluent suspended solids requirements are less than 10 mg/L, (2) secondary effluent quality can be expected to fluctuate significantly, or (3) filters follow a treatment process that generates significant amounts of algae. *TR-16* has additional information on pre-treatment options specifically for post-secondary suspended solids removal.

Low-Rate Granular Media Filters

Design requirements for intermittently loaded low-rate granular media filters, e.g., intermittent sand filters, are discussed under secondary treatment methods (Section F.2 in these Design Standards) but can also be used for tertiary treatment of secondary effluent from trickling filters or activated sludge processes to achieve nutrient and/or pathogen removal. Intermittently loaded low-rate granular media filters may also use recirculation to improve final effluent quality. When used in this situation, re-circulating sand filters may have secondary effluent applied at loading rates up to 10 gpd/sq. feet. One operational advantage of low-rate granular media filters is that they do not require backwashing, as high-rate granular media filters do.

High-Rate Granular Media Filters

Both *TR-16* and *Ten States Standards* distinguish between high-rate “gravity filters” and high-rate “pressure filters” and provide design requirements for both. Design guidance for pressure filters (micro-filtration and ultra-filtration) is much more extensive in *TR-16*.

For high-rate granular media filtration processes, *TR-16* and *Ten States Standards* include design guidance for deep-bed stratified granular media units using single-, dual- , or multi-media filters with down flow regimes. Other high-rate filter units may be used if the design engineer has sufficient documented experience or performance data to provide a sound basis for using them.

Because operation and maintenance requirements may be significant, high-rate filters should not be allowed for intermediate sized treatment facilities except where it can be demonstrated that required supervision will be provided.

The designer is responsible for selection of media to meet specific conditions and treatment requirements of the project under consideration. However, Table G-3 provides a list of typical media sizes and minimum media depths for intermittently backwashed, high-rate gravity filters.

Table G-3 Typical Media Sizes and Minimum Depths

	Single Media		**Dual Media**		**Multi-Media**	
	Size (mm)	**Depth (inch)**	**Size (mm)**	**Depth (inch)**	**Size (mm)**	**Depth (inch)**
Anthracite	**-**	**-**	**1.0 to 2.0**	**20**	**1.0 to 2.0**	**20**
Sand	**1.0 to 4.0**	**48**	**0.5 to 1.0**	**12**	**0.6 to 0.8**	**10**
Garnet or Similar	-	-	-	-	0.3 to 0.6	2

Note: For design considerations for High-Rate Granular Media Filters, refer to *10 State Standards* and *TR-16*.

G.3 Physical-Chemical Unit Processes

A physical-chemical process is a unit operation that uses chemical reaction and/or physical separation to remove pollutants from wastewater, typically for nutrient removal. Physical-chemical processes are more effective in removing phosphorus than nitrogen. *TR-16* addresses "Physical-Chemical Phosphorus Removal and Chemical Precipitation for Phosphorus Removal." Biological nutrient removal is covered in Section G.4 of these Design Standards, in *TR-16*; and in *Ten States Standards*.

G.3.a Colloid (Suspended Solids) Removal

Systems employing the physical-chemical mode of treatment in lieu of, or to compliment, biological treatment may include a combination of coagulation, settling, and filtration. Colloid removal using coagulation and settling may be used to remove phosphorus, suspended solids, or organic materials. *TR-16* provides additional guidance on both phosphorus and total organic carbon removal from wastewater.

1. Chemicals: Coagulation of solids may be accomplished through use of lime or aluminum or iron compounds (usually alum or ferric chloride). In the use of lime, neutralization of high pH may be required prior to discharge.

   Polyelectrolytes (polymers) may be used alone as coagulants or as aids to other coagulants. Coagulant aids may be used to optimize floc growth and hasten settling and may allow the dosage of primary coagulant to be decreased. When polymer use is anticipated, potential solids generation and handling should be considered during design. Treatment systems should have flexibility to allow the use of polymer as a coagulant aid if necessary in the future.

   The use of a liquid supply of metal salt instead of a dry form should be considered at small plants because handling requirements would be decreased, although transportation costs may be higher.

   Safety equipment appropriate for the chemical type and form should be provided. This may include dust masks, respirators, goggles, face shields, and protective clothing for operators. If dry chemicals are used, it may be necessary to install dust collectors in storage and handling areas. Optimum chemical type and dosage should be determined by jar testing, preferably followed by pilot plant work. Dosage equipment should be sized to cover a range up to twice the recommended dosage and should be constructed of materials that will resist the caustic or corrosive nature of the chosen chemical.

   Provision for a complete mix of the chemical with the sewage, as quickly as possible, should be included. Following complete mixing, gentle agitation should be provided for a period necessary to allow floc to form.

2. Settling: Detention time in the settling facilities after chemical coagulation should be long enough to allow floc to settle. Facilities should be designed to achieve a surface settling rate no greater than 800 gpd/sq. feet. Sludge withdrawal mechanisms should be designed to prevent disruption to or loss of the floc blanket. Inlets and outlets should be designed to dissipate velocity, to distribute and receive flow equally, and to prevent short circuiting. A baffle should be provided at the outlet end to retain oils, greases, and other floatable material.

3. Filtration: Filtration may be of either the high-rate or low-rate type. Filter criteria are presented in Section G.2 of this publication. Filter dosage may be up to 5 gallons per minute/sq. ft. for high-rate filters (Section G.2) and 10 gpd /sq. ft. for the open low-rate type (see Section F.2).

G.3.b Physical-Chemical Phosphorus Removal

1. Chemicals: Aluminum compounds (salts), iron compounds (salts) or lime react with orthophosphate to form insoluble phosphate colloids. Alum is generally preferred as lime may generate excessive sludge and high pH, and iron compounds may result in iron leakage into the effluent (see safety concerns noted above).

2. Dosing: Chemical addition may occur prior to primary clarifiers (including septic tanks), secondary treatment tanks, or final clarifiers either in a separate mixing basin or in a turbulent portion of the system. *TR-16* recommends the addition of metal salts to both primary and secondary treatment facilities as the most cost-effective means of phosphorus removal by chemical precipitation. Ferrous salts may also be added prior to, or in, the secondary treatment (aeration) tank. Ferrous salt should be oxidized to the ferric state before it will precipitate out iron phosphate in the clarifier. Avoid adding ferrous chemicals to the final clarifier, as this will result in increased chlorine demand, increased suspended solids resulting in ineffective UV disinfection, and higher TSS and color in the plant effluent.

   If nitrification is desired during biological treatment, dosing should occur prior to primary settling, to reduce BOD load on the biological system. If a high percentage of the total phosphorus is present as polyphosphate or organic phosphate, dosing should occur after biological conversion to orthophosphate. When high levels of detergents (polyphosphate) are present, dosing with aluminum or iron compounds should occur after biological treatment to avoid competing side reactions of the detergent with the metal ion.

   TR-16 provides additional information on chemical application points, where adequate turbulence will ensure complete mixing of the metal salt with wastewater. If there is an internal recycling stream in the treatment plant such as recycles from sludge treatment facilities, the application point should be downstream of the plant's internal recycle streams.

   Jar tests for dosage estimation should simulate treatment plant conditions. Mixing speed should be adjusted to match the hydraulic regime in the plant, but the duration of mixing should be the same as it is in the plant. To approximate settling conditions, the

mechanism should not be motionless but should turn very slowly. If possible, jar tests should be followed by 30-day pilot plant or full scale tests.

Phosphorus levels show significant diurnal variations, so it is recommended the dosage be adjusted regularly (normally three to five changes in dose rate per day during initial phases of application). Flow equalization may be provided to reduce the number of necessary dosage adjustments.

Overdosing will prevent floc growth and settling, and can dangerously reduce the pH through formation of hydroxide salts. The addition of lime or sodium hydroxide may be needed to prevent this, especially if aeration is not provided in the aeration tank to oxidize ferrous chemicals to the ferric state.

3. Optimization: To maintain effluent quality, pH adjustment is necessary. Addition of metal salts or lime can be followed by addition of polyelectrolyte to improve settling. Multi-media filtration is recommended if consistently low phosphorus levels (below 1 mg/L) are necessary.

4. Sludge: During design, consideration should be given to the generation and disposal of additional sludge from chemical treatment.

TR-16 recommends the use of chemical precipitation for phosphorus removal process be based on:

- Chemical analysis of influent wastewater
- Objective effluent criteria
- Capability of alternative wastewater treatment processes such as biological nitrogen and phosphorus removal processes

  AND

- Overall economies of alternative processes

TR-16 also provides recommendations for economic evaluation, discussion of the various forms of phosphorus in wastewater, a comment on the declining use of lime in comparison to metal salts, and the need to provide adequate alkalinity. *TR-16* gives recommendations for chemical storage and feed facilities as well.

Ten States Standards provides both duplicative and complementary design guidance for phosphorus removal by chemical treatment (but not for biological removal). Design guidance and specifications from both *TR-16* and *Ten States Standards* should be followed.

G.3.c Membrane Processes and Membrane Bio-Reactors (MBRs)

A Membrane Bio-Reactor (MBR) incorporates a membrane to replace the secondary clarifier in the activated sludge process and generates an effluent similar to that described in Table G-4. More guidance on MBRs can be found in *TR-16.*

Table G-4 MBR Typical Performance Data[54]

Effluent BOD	mg/L	<5
Effluent TSS	mg/L	<0.5
Effluent NH_3	mg/L	<1
Effluent TN	mg/L	<10
Effluent turbidity	NTU	<1

TR-16 provides filtration design guidance for advanced suspended solids removal, chemical phosphorus removal, and total organic carbon removal. *TR-16* also has guidance on four categories of filtration for removal of suspended or dissolved particles:

- Microfiltration: 0.1 to 10 microns (most bacteria, protozoans including cryptosporidium and giardia, some viruses)
- Ultrafiltration: 0.01 to 0.1 microns (most all viruses)
- Nanofiltration: 0.001 to 0.01 microns (metals, personal care product and pesticide constituents, charged organics including nitrates)
- Reverse osmosis: Less than 0.001 microns (water softening, water reuse as drinking water, pure water production for food beverage processing)

Note: The various ranges of particle sizes provided above are typical for the particular categories of filtration.

[54] Metcalf and Eddy, Fourth Edition 2003, pp. 1127, 1128

G.4 Biological Nutrient Removal

Biological Nutrient Removal is the biological removal of nitrogen and phosphorus from wastewater through assimilation into the biomass during oxidation of organic compounds in the treatment process. For on-site wastewater treatment facilities discharging to Soil- based Treatment Systems (STS), biological nutrient removal can be accomplished using shallow soil absorption systems for nutrient uptake by the system's cover vegetation.

Treatment Plant Unit Processes

For treatment plant unit processes, several types of treatment processes are available for biological removal of nitrogen and phosphorus from wastewater, including biological nitrogen removal processes, biological phosphorus removal processes, and biological processes for simultaneous removal of nitrogen and phosphorus. *Ten States Standards* does not discuss any tertiary biological treatment systems for either N or P. *TR-16* provides general guidance on design considerations, features, performance capabilities, and operating requirements. The biological nutrient removal systems in *TR-16* include four treatment systems that remove both nitrogen and phosphorus. When designing new plants, plant expansions, and retrofits of existing plants for nitrogen and phosphorus biological removal, the use of process simulators, EPA's 2010 *Nutrient Control Design Manual*, and other available information is recommended. The EPA's *Design Manua*l also includes two tables that provide an excellent starting point for engineers and reviewers evaluating a biological nutrient removal (total nitrogen and phosphorus) design.

In selecting a process or combination of processes, the design engineer should consider the following criteria:

- Influent wastewater characteristics, including five-day Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Alkalinity, and Temperature
- Seasonal variations in influent wastewater characteristics caused by institutional contributors, population changes, septage, and other factors where applicable
- Discharge limitations
- Existing treatment facilities at the plant site
- Cost

G.4.a Biological Nitrogen Removal

In the first step of the two-step nitrification-denitrification process, ammonia and organic nitrogen present in the wastewater are oxidized to nitrite and then to nitrate by autotrophic nitrifying bacteria (Nitrosomonas and Nitrobacter) under aerobic conditions. In the second step, nitrates are reduced to nitrogen gas by heterotrophic bacteria under anoxic conditions. Nitrogen gas produced from the denitrification process escapes into the atmosphere, removing total nitrogen (TN) from the wastewater.

In suspended growth activated sludge systems, microbial growth occurs in mixed liquor kept in suspension by turbulence created by aeration or mechanical mixing devices. Suspended growth systems use selectors that can be anaerobic, anoxic, or aerobic.

Some suspended growth processes commonly used for biological nitrogen removal are single- sludge processes. The following are described in *TR-16*:

- Modified Ludzack-Ettinger (MLE) process
- Bardenpho process
- Cyclical aeration process
- Oxidation ditch process

In attached growth (fixed-film) systems, microbial growth occurs on fixed surfaces.
Fixed-growth systems can be configured using a number of stages, with more stages warranted as treatment requirements become more stringent.

Moving bed biofilm reactors use media supporting a biofilm growth that can be either aerobic (for carbonaceous removal and nitrification) or anoxic (for denitrification).

Biological filter processes include biologically active filters (BAF) that encompass both aerobic (nitrification) and anoxic (denitrification) filters.

Rotating biological contactor systems can be configured to accomplish total nitrogen removal, if sufficient aerobic and anoxic solids retention times are provided.

Sequencing batch reactors can provide a moderately high level of nitrogen removal by controlling overall cycle time and duration of steps in the SBR sequence of operation.

Integrated fixed film/activated sludge systems can incorporate media configured to work in an aerobic or anoxic environment, but the designer should understand the balance and synergy between the attached and suspended-growth biomass components. *TR-16* provides design information and details regarding anoxic and aerobic reactor design for nutrient removal. There is also design information on solids removal processes that may also be beneficial in achieving low TSS and nutrient limits.

Design guidance for secondary clarification is given in both *TR-16*, and in *Ten States Standards*. Either may be used for intermediate-sized systems.

G.4.b Biological Phosphorus Removal (BPR)

Biological phosphorus removal (BPR) or enhanced biological phosphorus removal (EBPR) is discussed in *TR-16*. EBPR is achieved by wasting sludge from a treatment system with an excess amount of phosphorus stored in the bacterial cells. The two most commonly used EBPR processes are:

- PhoStrip™ process (proprietary)
- A/O (Phoredox) process (*TR-16*)

The Phostrip™ process uses the return sludge flow for phosphorus removal. In the A/O (Phoredox) process, phosphorus removal reactions occur as wastewater passes through units of the treatment system. The *Handbook of Biological Wastewater Treatment: Design and Optimisation of Activated Sludge Systems*[55] provides greater detail on biological phosphorus removal processes.

G.5 Constructed Wetlands

A constructed wetland is a treatment process typically used to remove nutrients, suspended solids, and organic matter. Designing a constructed wetland is complicated and should be done only by a licensed professional engineer experienced in their design. The services of qualified soil scientists and wetland biologists may also be necessary.

Table F-1 lists Vegetated Submerged Beds and Free Water Surface Constructed Wetlands as means for suspended solids removal by sedimentation. However, for carbonaceous BOD and ammonium removal

[55]Adrianus C. van Haandel, J. G. M. van der Lubbe IWA Publishing, 2012

and biological nitrification-denitrification, only Free Water Surface Constructed Wetlands are recommended. Vegetated Submerged Beds are recommended for biological denitrification only, following another unit process that provides nitrification.

The primary design reference for constructed wetlands is *Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment - Design Manual.* [56] *TR-16* may be consulted for additional guidance on the use or selection of constructed wetlands.

The 2002 EPA Onsite Wastewater Treatment Systems Manual, Technology Fact Sheet (TFS) 5 describes vegetated submerged beds and other high specific surface anaerobic reactors, but no design standards are given. Vegetated submerged beds and subsurface flow constructed wetlands are equivalent. The 2002 EPA TFS-7 describes stabilization ponds, free water surface constructed wetlands, and other aquatic systems.

WEF's *Manual of Practice No.8, Design of Municipal Wastewater Treatment Plants* (1998) contains some information on the three most generally recognized types of constructed wetlands: free water surface, subsurface flow, and vertical flow. The vertical flow wetlands are only described briefly, and their construction is generally similar to either an intermittent sand filter (European) or a vegetated recirculating gravel filter (North American).

The EPA 1993 Report, *Subsurface Flow Constructed Wetlands for Wastewater Treatment: A Technology Assessment*[57], evaluates only the subsurface flow (SF) systems.

WEF's *Manual of Practice No.8, Design of Municipal Wastewater Treatment Plants* (1998) and *TR-16* both discuss reed beds as a sludge dewatering method, not as a constructed wetland for secondary treatment.

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[56] *Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment Design Manual*, U.S. Environmental Protection Agency, Office of Research and Development, Center for Environmental Research Information, Cincinnati, OH, 45268, EPA/625/1 88/022, September 1988.

[57] EPA, *Subsurface Flow Constructed Wetlands for Wastewater Treatment: A Technology Assessment*, EPA 832 R 93 008. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. 1993.

TR-16

GUIDES FOR THE DESIGN OF WASTEWATER TREATMENT WORKS

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650 Suffolk Street • Suite 410 • Lowell, MA 01854

Tel: 978-323-7929 • Fax: 978-323-7919

mail@neiwpcc.org • www.neiwpcc.org

Ronald F. Poltak, *Executive Director*

Compact Member States

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Advisory Board

Thomas Bienkiewicz, Massachusetts Department of Environmental Protection
Robert Bowker, P.E., Bowker & Associates, Inc.
Richard Darling, Maine Department of Environmental Protection
Rowland Denny, Connecticut Department of Energy & Environmental Protection
Paul A. Dombrowski, P.E., BCEE, Woodard & Curran, Inc.
Marc R. Drainville, P.E., BCEE, LEED AP, GHD
Joseph M. Ducharme, Jr., P.E., BCEE, CMA Engineers, Inc.
David Ferris, Massachusetts Department of Environmental Protection
David Formato, P.E., Onsite Engineering, Inc.
Fred R. Gaines, P.E., BCEE
Tom Joslin, P.E., Vermont Department of Environmental Conservation
William McConnell, P.E., BCEE, CDM, Inc.
William Patenaude, P.E., Rhode Island Department of Environmental Management
Wesley Ripple, New Hampshire Department of Environmental Services
Alan Slater, Massachusetts Department of Environmental Protection
Jason Turgeon, United States Environmental Protection Agency, Region 1
Thomas Walsh, Upper Blackstone Water Pollution Abatement District
Margaret Webber, Massachusetts Department of Environmental Protection
Robert Wither, New York State Department of Environmental Conservation

Writing Group Chairs

Joseph M. Boccadoro, P.E., AECOM, Inc.
Robert Bowker, P.E., Bowker & Associates, Inc.
Paul A. Dombrowski, P.E., BCEE, Woodard & Curran, Inc.
Joseph M. Ducharme, Jr., P.E., BCEE, CMA Engineers, Inc.
Fred R. Gaines, P.E., BCEE
Michael Jennings, New England Interstate Water Pollution Control Commission
Leroy Kendricks, P.E., Woodard & Curran, Inc.
William McConnell, P.E., BCEE, CDM, Inc.
Benjamin Mosher, P.E., BCEE, CDM, Inc.
Kelly Saikkonen, P.E., CDM, Inc.
Daniel P. Saulnier, P.E., Kleinfelder/SEA Consultants, Inc.
D. Craig Wagner, P.E., BCEE, CDM, Inc.

Contributing writers are listed at the beginning of each chapter. Reviewers are listed at the end of the document.

Project Officer/Editor:
John J. Murphy, NEIWPCC

Assistant Editor/Copy Editor:
Stephen Hochbrunn, NEIWPCC

Design and Production:
Ricki Pappo, Enosis

INTRODUCTION

The New England states and New York State are renowned for their lakes, streams, rivers, and coastal waters. These water resources are vital to the region's economy and are precious to its citizens. Effective wastewater treatment is absolutely fundamental to protecting these invaluable assets and to protecting public health. Thus, the proper design, construction, maintenance, and operation of wastewater treatment facilities is crucial. The region is fortunate to have many dedicated professionals who are committed to this effort and have been instrumental in the great successes that have been achieved.

For many years, these professionals have turned to the New England Interstate Water Pollution Control Commission's *Guides for the Design of Wastewater Treatment Works* as a helpful resource. Commonly known as TR-16 (short for Technical Report #16), this document provides guidance of value to engineers who are responsible for designing wastewater treatment plants, state regulators who are responsible for reviewing and approving the designs, and municipalities that may need assistance with the solicitation of professional design services for a wastewater facility. TR-16 is intended for use in conjunction with other available technical manuals, such as those produced by the Water Environment Federation (WEF).

The first edition of TR-16 was developed in 1962 in an effort to standardize wastewater treatment plants and to ensure consistency of design among the facilities in New England. Rapid advances in treatment technology necessitated the publication of an updated edition in 1980, and in 1998, amid the continued technological progress, NEIWPCC published the third edition of TR-16, which was developed with the assistance of a NEIWPCC workgroup formed specifically for the task.

In 2009, NEIWPCC's Executive Committee saw a need to revise the 1998 edition to incorporate advances in technology and eliminate out-of-date material. With guidance from the Executive Committee, NEIWPCC staff formed an advisory board made up of regional wastewater experts. The advisory board identified the changes needed in existing chapters and the new concepts that needed to be incorporated, such as new technologies, energy efficiency, and climate change implications. The board drafted an outline for the revised document, then recruited volunteers from the private and public sector to create the content. For each of the thirteen chapters, a writing group was formed, with one person taking on the key role of group chair. Under the supervision of NEIWPCC's project officer, the process of writing, reviewing, editing, and graphic design began, which ultimately resulted in the publication of this, the 2011 edition of TR-16.

The immense effort involved in creating this resource is justified when you consider what is at stake. Most wastewater treatment infrastructure is owned and operated by local municipalities and directly supported by taxpayers. This infrastructure is one of the largest assets of most communities. It is essential that it be designed to operate effectively and in a cost-effective manner. To achieve this goal, it is imperative that any design guidelines be as up-to-date as possible. Advances in wastewater treatment technology and energy efficiency, new approaches based on the need for sustainability—all must be incorporated, and all have been in this new edition. Note that the absence in this guide of design criteria for any specific process does not imply that the process is unacceptable.

This 2011 edition of TR-16 is the culmination of three years of writing, reviewing, editing, formatting, and coordinating. Its purpose, however, remains the same as in 1962, 1980, and 1998—to provide guidance in the design and preparation of plans and specifications for wastewater treatment works. As a guide, it is not to be construed as superseding the requirements, regulations, policies, and standards of the appropriate state water pollution control agencies. Users of this guide should be aware of all applicable regulations, and local and state regulators should always be contacted before starting facility planning. Users should also be familiar with federal requirements that apply to the development of engineering reports, plans, and specifications.

As is noted within this document, anticipated changes in weather patterns as a result of climate change and sea level rise should be factored into design. More precise predictions about these impacts are being developed and will change as more information is available; it is important to stay abreast of the latest thinking on this critical topic. Also, while this document focuses on traditional, centralized wastewater infrastructure, there is no denying that decentralized treatment systems can be a sound alternative. The New England states and New York State have developed separate guidance for decentralized systems, as well as for green infrastructure, stormwater, and other subjects of growing importance. To the extent possible, all these materials should be considered by municipalities seeking the best solutions for a clean environment.

Lastly, let us never forget that clean water is a finite resource that needs to be protected for future generations. Successful project designs should always have one priority above all others—the long-term protection of the precious water in our lakes, rivers, and streams.

Contents

Acknowledgments ii
Introduction iii

Chapter 1: Procurement of Design and Construction Services

1.1 Procurement of Engineering Services 1-2
1.2 Engineering Report 1-8
1.3 Contract Drawings/Plans 1-20
1.4 Technical Specifications 1-27
1.5 Field Engineering 1-28

Chapter 2: Sanitary Sewers/Wastewater Collection Systems

2.1 Design of Sanitary Sewers 2-1
2.2 Design Capacity and Design Flow 2-1
2.3 Details of Sewer Design and Construction 2-2
2.4 Manholes 2-9
2.5 Inverted Siphons (Depressed Sewers) 2-11
2.6 Aerial Crossings 2-11
2.7 Protection of Water Resources 2-12
2.8 Protection of Water Supplies 2-13
2.9 Alternative Collection Systems 2-14
2.10 Sewer System Investigation and Rehabilitation Techniques 2-18
2.11 Safety 2-20

Chapter 3: Wastewater Pumping Stations

3.1 General 3-1
3.2 Design 3-2
3.3 Ventilation 3-7
3.4 Flow Measurement 3-8
3.5 Water Supply 3-8
3.6 Electrical 3-8
3.7 Force Mains 3-9
3.8 Operation During a Power Failure 3-10
3.9 Safety 3-11
3.10 Overflows and Bypasses 3-12

Chapter 4: Wastewater Treatment Works

4.1 Plant Location 4-1
4.2 Treatment Goals and Effluent Quality 4-2
4.3 Design 4-2
4.4 Plant Details 4-10
4.5 Chemical Feed Systems 4-12
4.6 Essential Facilities in Wastewater Treatment Plants 4-18
4.7 Wastewater Flow Measurement 4-19

4.8 Plant Outfalls....4-20
4.9 Protection of Plant Staff and Visitors....4-21
4.10 Sampling....4-21
4.11 Laboratory Equipment and Needs....4-22
4.12 Personnel and Administrative Facilities....4-25

Chapter 5: Preliminary and Primary Treatment

5.1 Pretreatment....5-1
5.2 Primary Treatment....5-13
5.3 Chemically Assisted Primary Treatment....5-15
5.4 Wet Weather Treatment....5-16
5.5 Flow Equalization....5-17

Chapter 6: Biological Treatment Processes

6.1 General Concepts....6-1
6.2 Fixed Growth Systems....6-2
6.3 Suspended Growth Systems (Activated Sludge)....6-17
6.4 Integrated Biological Treatment Systems....6-45
6.5 Wastewater Treatment Ponds....6-49
6.6 Other Biological Systems....6-57

Chapter 7: Physical and Chemical Processes for Advanced Treatment

7.1 General Concepts....7-1
7.2 Filtration....7-2
7.3 Membrane Filtration....7-6
7.4 Chemical Treatment....7-9
7.5 Effluent Reoxygenation....7-16
7.6 Total Organic Carbon Removal....7-17

Chapter 8: Disinfection

8.1 General....8-1
8.2 General Requirements....8-1
8.3 Disinfection Methods....8-2
8.4 Dechlorination....8-13

Chapter 9: Land Treatment, Treated Effluent Disposal, and Treated Effluent Reuse

9.1 General....9-1
9.2 Planning Considerations....9-2
9.3 Hydrogeological Site Analysis....9-4
9.4 Design Guidelines for Land Treatment....9-9
9.5 Effluent Reuse Considerations....9-21
9.6 NEIWPCC Compact Member States Regulatory Summary....9-25

Chapter 10: Odor and VOC Control

10.1 General....10-1
10.2 Basis for Selection and Design of Odor/VOC Control Systems....10-1

10.3 Chemical Addition for Odor and Corrosion Control....10-2
10.4 Covers and Enclosures....10-6
10.5 Ventilation of Enclosed Spaces....10-8
10.6 Wet Scrubbers....10-10
10.7 Activated Carbon Adsorbers....10-13
10.8 Biofiltration....10-17
10.9 Biotrickling Filters....10-20
10.10 Activated Sludge Diffusion....10-23
10.11 Thermal Oxidation Systems....10-24
10.12 Dilution and Dispersion....10-29

Chapter 11: Residuals Treatment and Management

11.1 General....11-1
11.2 Pumping and Conveying....11-4
11.3 Thickening....11-6
11.4 Anaerobic Digestion....11-8
11.5 Aerobic Digestion....11-14
11.6 Alkaline Stabilization....11-16
11.7 Other Stabilization Methods....11-19
11.8 Chemical Feed Systems....11-20
11.9 Dewatering....11-20
11.10 Composting....11-27
11.11 Thermal Drying....11-28
11.12 Use and Disposal of Residuals....11-29
11.13 Incineration....11-36

Chapter 12: Receiving Hauled Wastes

12.1 General....12-1
12.2 Materials Received by Truck or Rail....12-1
12.3 Receiving Station Design Considerations....12-3
12.4 Elements of a Hauled Waste Management Program....12-8
12.5 Operational Considerations....12-12
12.6 Independent Septage Treatment....12-12
12.7 Land Application of Septage....12-16

Chapter 13: Instrumentation, Controls, and Reporting

13.1 General....13-1
13.2 Instrumentation and Sensors....13-3
13.3 Controls and Communications....13-13
13.4 Operator Interface Hardware and Software....13-15
13.5 Wastewater Pumping Stations and Flow Monitoring....13-17
13.6 Wastewater Treatment Facilities....13-24

Appendices

Appendix 1: TR-16: 2011 List of Reviewers....A-1
Appendix 2: TR-16: 1998 Project Team....A-2

6.2.6 Biological Filter Processes

6.2.6.1 General

Biological filter processes have historically been referred to as biological aerated filters (BAFs) or denitrification filters. While the acronym BAF is still used, it now stands for biologically active filter, a term that encompasses both aerobic and anoxic filters.

There are various types of BAFs, with most characterized by three primary criteria:

- Direction of flow (upflow or downflow)
- Media density (heavier or lighter than water)
- Biological environment (aerobic or anoxic)

BAFs can also be configured as continuously backwashed filters or static filters that do not require backwashing. However, these configurations have seen limited application in New England. Design criteria for continuously backwashed filters should be based on the manufacturer's criteria, and pilot testing may be warranted. With the exception of static filters, all BAFs act as both a biological treatment and physical solids separation process. Backwashing is required periodically to remove solids that accumulate due to filtration and biological growth.

6.2.6.2 Flow Configuration

Flow configuration determines many of the physical components of a BAF system. Described below are the alternatives and their differences.

Downflow filters generally require sunken media that are heavier than water and use countercurrent backwashing. Backwashing is typically accomplished using a combination of compressed air and effluent water. Larger solids are predominately captured on the surface, and no significant pretreatment beyond that for conventional filtration is required. Due to challenges associated with countercurrent aeration and liquid flow, downflow BAFs are used predominately for denitrification. Because denitrification produces nitrogen gas bubbles that can become trapped in the sunken media, periodic "bumping" (a brief backpulse of flow) is required to free nitrogen bubbles from the media.

Upflow filters can use either sunken or floating media. Sunken media systems require flow distribution typically in the form of nozzles below the media, while floating systems use a retention system above the media that both holds the media in place and ensures that effluent is removed over the entire area of the filter. With both types of media, backwashing is accomplished using both air and water. Systems with floating media often employ periodic backwash pulses to maintain hydraulic capacity. Upflow BAFs can be used for both aerobic and anoxic operations, depending on process requirements. These systems are commonly placed in series to achieve sequential treatment steps. Given the small openings associated with flow distribution and/or media retention, a high level of solids pretreatment is typically required.

6.2.6.3 Media

The media used in a BAF are typically mineral media or plastic media. Mineral media are typically heavier than water, while plastic media typically have a specific gravity slightly less than that of water. The media need to be durable as they are constantly cycling between states of supporting a biofilm and of being scoured to remove the biofilm. Media occupy only a portion of the filter depth and have a bulk specific surface area ranging from 70 to 500 ft^2/ft^3.

6.2.6.4 Aeration Systems

Blowers or compressors may be used to supply air to the aerobic BAF. Diffuser systems can consist of perforated sparge piping or a nozzle arrangement in the filter underdrain system. Oxygen transfer through the air distribution system is greatly enhanced to the intimate contact with the biomass and the circuitous route taken by air through the filter media. These filters function essentially as plug flow reactors; the dissolved oxygen at the filter surface is not necessarily representative of that in the middle of filter media depth. As head loss through the filter can change substantially during the progression from a clean to a dirty filter, blowers must be able to operate over a range of discharge pressure conditions. It should be noted that oxygen uptake rates are typically higher in a BAF than those observed in activated sludge systems. This is due to the two mechanisms of oxygen transfer at work in a BAF. In addition to the transfer of oxygen into water, air bubbles are in direct contact with the biofilm.

6.2.6.5 Backwashing Facilities

Backwash system requirements depend on the specific system under consideration but typically include the following major components: a clearwell, a mudwell, backwash pumps, and air scour blowers. With regard to clearwell and mudwell sizing as well as equipment redundancy, backwash systems for BAFs should meet the requirements for "Rapid Rate, Automatically Backwashed Sand Filters" in Section 7.2.10.2 of this document.

Continuously backwashed filters utilize compressors for their backwash cycles and do not necessarily require dedicated clearwells and mudwells.

Large backwash tanks may require mixers to maintain solids in suspension when returning flow to the plant. These solids are typically returned to primary clarifiers to enhance BOD removal and to help improve primary sludge characteristics for pumping. However, in some BNR configurations, backwash solids may be returned to biological reactors to augment a system's biomass.

Very large facilities (greater than 25 mgd) may find separate treatment of backwash to be advantageous. Processes such as dissolved air flotation thickeners and ballasted flocculation may be appropriate for sidestream treatment of filter backwash water.

The designer should be aware of two additional considerations relative to BAF backwash:

- Many systems require that effluent flow stops during the backwash cycle, and this condition should be accommodated in the upstream and downstream processes.
- Backwash from the filter must be accounted for in the hydraulic and pollutant loadings of a plant's recycle streams.

6.2.6.6 Other Design Considerations

When designing a BAF system, the designer should consider a number of other factors:

- *Preliminary Treatment:* Fine screening should be provided upstream of BAF systems. Dedicated automatic screens should be provided if the facility runs the risk of leaves being present in influent to the BAF or if the facility has some unscreened or poorly screened sidestreams. Consideration should be given to omitting fine screens for downflow BAFs in situations where the upstream treatment components provide protection from large solids particles.

- *Redundancy:* Redundancy requirements for BAF systems depend on the type of filter and many other site specific conditions, especially effluent requirements. Redundancy should be provided consistent with the filter redundancy requirements noted in Section 7.2.10.
- *Supplemental Carbon Addition:* Denitrification using BAFs requires the addition of a supplemental carbon source such as methanol, ethanol, acetic acid, or other blended proprietary product. Supplemental carbon addition is a key element for successful denitrification and must be done with precision; underdosing will limit nitrogen removal and overdosing can result in high effluent BOD. An integrated process control system with on-line analyzer is required with denitrification filters. Many forms of automated control are available, but a system with both feed-forward and feedback capability should be considered, especially in systems with total nitrogen limits less than 5 mg/L.
- *Low Effluent P Limits:* With regard to systems that must also meet low effluent total phosphorus limits, care should be taken to provide adequate soluble, reactive phosphorus in the MBBR so as to not limit the denitrification rate.

6.2.6.7 Process Design

General: BAFs can be incorporated into nearly all levels of biological treatment and can be configured for BOD_5 removal, nitrification, denitrification, or any combination of these processes. Given the nature of the BAF process, which includes filtering with biological treatment, the process is typically most cost-effective in tertiary treatment configurations.

Due to the physical characteristics and interactions between particles, BAFs are sized based on pollutant removals per volume of media provided. Although BAF models have been developed, they are not in widespread use, and sizing criteria is mostly empirical based on specific characteristics of the media.

Loading: Biologically active filter design should consider peak organic load conditions, including the oxygen demands that occur because of sidestream flows from sludge processing and handling. Short-duration, high strength loads should be dampened via equalization or other methods. The volume of media should be based upon the design maximum month loading of the parameter(s) of concern to meet monthly discharge limits and should also consider peak loadings that correlate to weekly and peak daily limits, if applicable. Nitrogen loadings should take into account assimilation of ammonia into biomass and ammonification of organic nitrogen present.

Carbonaceous Removal: Characteristics of different BAF design criteria are presented in Table 6-5.

Nitrification: Designers of systems providing either combined carbon-nitrogen oxidation or nitrification alone must consider a number of factors inherent with any fixed film process including the following:

- Nitrification in BAFs will only occur substantially if the soluble carbonaceous matter (BOD_5) is very low (BOD_5<125 lb/1,000 cf of media per day).
- With BAFs that provide sequential steps of treatment, it is important to carefully account for organic loading and dissolved oxygen carry-over from the upstream process.

Denitrification: Because hydraulic detention time in BAFs is limited, supplemental carbon addition must be closely matched to nitrate loading and removal.

BAFs have a wide range of types of filters and thus a range of loadings and performance. Tables 6-5 – 6-8 provide typical design criteria for BAFs used for secondary treatment, nitrification, and denitrification:

Table 6-5 **BAF Design Criteria for BOD_5 Removal**

Type	Volumetric Loading (lb/d/1,000 cu ft) (at 20°C)	Hydraulic Loading (gpm/cu ft)	Removal Efficiency
Upflow sunken or floating media, backwashing	BOD: 94–370 TSS: 50–220	1.2–6.6	BOD: 65–90% TSS: 65–90%
Submerged, non-backwashing	BOD: 50–94 (at 20°C)	0.8–5	BOD: 85–95%

Table 6-6 **BAF Design Criteria for Nitrification**

Type	Volumetric Loading (lb/d/1,000 cu ft) (at 20°C)	Hydraulic Loading (gpm/cu ft)	Removal Efficiency
Upflow sunken or floating media, backwashing (following primary treatment)	BOD: <94–188 TSS: <62–100 NH_3-N: <62–100 (20 C)	1.2–5	BOD: 70–90% TSS: 65–85% NH_3-N: 65–75%
Upflow sunken or floating media, backwashing (following secondary treatment)	BOD: <62–125 TSS: <62–100 NH_3-N: <62–100 (20 C)	1.2–8.2	BOD: 40–75% TSS: 40–75% NH_3-N: 75–95%
Submerged, non-backwashing (following secondary treatment)	NH_3-N: 12–56 (20 C)	0.8–5	NH_3-N: 85–95%

Table 6-7 **BAF Design Criteria for Pre-Denitrification**

Type	Volumetric Loading (lb/d/1,000 cu ft) (at 20°C)	Hydraulic Loading (gpm/cu ft)	Removal Efficiency
Upflow sunken or floating media, separate BAF stages (pre-denitrification + nitrification)	NO_3-N: 62–75	4–12	NO_3-N: 75–85%
Upflow, floating media combined anoxic/aerated BAF stage	NO_3-N: 62–75	4.9–8.8	NO_3-N: 70% (w/ supplemental carbon), 85% (w/o supplemental carbon)

Table 6-8 **BAF Design Criteria for Post-Denitrification**

Type	Volumetric Loading (lb/d/1,000 cu ft) (at 20°C)	Hydraulic Loading (gpm/cu ft)	Removal Efficiency
Downflow, sunken media	NO_3-N: 20–200	2–3.5 (avg) 5–7.5 (peak)	NO_3-N: 75–95%
Upflow, sunken media	NO_3-N: 50–300	4–14	NO_3-N: 75–95%
Moving bed, continuous backwash	NO_3-N: 20–120	2–4 (avg) 6 (peak)	NO_3-N: 75–95%

6.2.7 Solids Separation For Fixed Growth Systems

Other than BAFs that include their own physical separation process, all fixed growth systems require some manner of physical separation of solids that are sloughed from the media. It is important to note the inherent physical differences between solids formed in a fixed growth system and those in a suspended growth system; fixed growth system solids generally are much lower in concentration and do not have the same flocculation tendencies as activated sludge. This often results in substantial challenges to fixed growth system performance relative to effluent solids, colloidal material, and turbidity that may impact downstream processes such as disinfection. It has also been documented that clarifier depth has a correlation with performance of fixed growth system solids separation.

Solids separation is accomplished in a number of ways for fixed growth systems including clarification, floatation, or direct filtration. Clarification is most commonly used and may consist of traditional clarifiers as well as systems augmented with inclined plates or tubes. Where fixed growth systems are employed at facilities that must also meet stringent phosphorus removal requirements, ballasted flocculation/sedimentation can serve as the solids removal step.

Design of traditional secondary clarifiers for fixed growth systems, including trickling filters, RBCs, and MBBRs, should be based on the following minimum criteria:

- A minimum of two units are required.
- Clarifiers must have a minimum side water depth of 12 feet. The following overflow rate sizing criteria is based on a side water depth of 12 feet. Should a shallower depth be present in existing units, hydraulic capacity should be downrated.
- Clarifiers must be sized to provide an average overflow rate (at maximum month flow) of 600 gpd/sf(12 feet deep units).
- Clarifiers shall be sized to provide a peak hourly overflow rate of 1,200 gpd/sf (12 feet deep units).
- Clarifiers for fixed growth systems should be provided with flocculation facilities as part of the clarifier or immediately upstream, with provisions for chemical addition to improve settling.

6.3 Suspended Growth Systems (Activated Sludge)

6.3.1 Overall Considerations

Suspended growth biological treatment or activated sludge is a treatment process used in a wide variety of configurations where wastewater is amenable to biological treatment. Biological reactors, clarification, and solids return are all components of the process, which must be designed as an integrated system. The design and operation of each component has a direct impact on the size