Wisconsin Department of Natural Resources
Wastewater Operator Certification

Biological Treatment - Attached-Growth Processes Study Guide

Subclass A2

February 2016 Edition
Wisconsin Department of Natural Resources
Operator Certification Program
PO Box 7921, Madison, WI 53707

http://dnr.wi.gov

Preface

The Biological Treatment – Attached Growth Study Guide is an important resource for preparing for the certification exam and is arranged by chapters and sections. Each section consists of key knowledges with important informational concepts you need to know for the certification exam. This study guide also serves as a wastewater treatment plant operations primer that can be used as a reference on the subject.

Any diagrams, pictures, or references included in this study guide are included for informational/educational purposes and do not constitute endorsement of any sources by the Wisconsin Department of Natural Resources.

In preparing for the exams:
1. Study the material! Read every key knowledge until the concept is fully understood and known to memory.

2. Learn with others! Take classes in this type of wastewater operations to improve your understanding and knowledge of the subject.

3. Learn even more! For an even greater understanding and knowledge of the subjects, read and review the references listed at the end of the study guide.

Knowledge of the study guide material will be tested using a multiple choice format. Every test question and answer comes directly from one of the key knowledges.

Choosing a test date:
Before choosing a test date, consider the time you have to thoroughly study the guides and the training opportunities available. A listing of wastewater training opportunities and exam dates is available at www.dnr.wi.gov by searching for the keywords “Operator Certification”.

Acknowledgements

The Biological Treatment – Attached Growth Processes Study Guide was the result of a collaborative effort of yearlong monthly meetings of wastewater operators, trainers, consultants, the Wisconsin Wastewater Operator Association (WWOA), and the Wisconsin Department of Natural Resources (WDNR). This study guide was developed as the result of the knowledge and collective work of following workgroup members:

Gary Hanson, Short Elliott Hendrickson, Inc, Delafield, WI
Scott Tutas, West Bend WWTP, West Bend, WI
Amy Garbe, Department of Natural Resources, Fitchburg, WI
Danielle Luke, Department of Natural Resources, Madison, WI
Jack Saltes, Department of Natural Resources, Madison, WI

Table of Contents

Chapter 1 - Theory and Principles
- Section 1.1 - Definitions pg. 1
- Section 1.2 - Microbiological Principles pg. 2
- Section 1.3 - Process Variation pg. 5

Chapter 2 - Operation and Maintenance
- Section 2.1 - Definitions pg. 7
- Section 2.2 - Equipment pg. 7
- Section 2.3 - Methods pg. 11
- Section 2.4 - Preventative Maintenance pg. 12

Chapter 3 - Monitoring, Process Control, and Troubleshooting
- Section 3.1 - Definitions pg. 14
- Section 3.2 - Sampling and Testing pg. 14
- Section 3.3 - Data Understanding and Interpretation pg. 14
- Section 3.4 - Sidestreams and Recycle Flows pg. 15
- Section 3.5 - Performance Limiting Factors pg. 17
- Section 3.6 - Corrective Actions pg. 18

Chapter 4 - Safety and Regulations
- Section 4.1 - Definitions pg. 19
- Section 4.2 - Personal Safety pg. 19
- Section 4.3 - Chemical Safety pg. 20

Chapter 5 - Calculations
- Section 5.1 - Surface Area pg. 21
- Section 5.2 - Flows and Loading pg. 21
- Section 5.3 - Recirculation Ratio pg. 23

Chapter 1 - Theory and Principles

Section 1.1 - Definitions

1.1.1 Define aerobic (oxic) [O2].

Aerobic is a condition in which free and dissolved oxygen (DO) is available in an aqueous environment.

1.1.2 Define anaerobic [Ø].

Anaerobic is a condition in which free, dissolved, and combined oxygen is unavailable in an aqueous environment.

1.1.3 Define anoxic [NO2, NO3, SO4].

Anoxic is a condition in which oxygen is only available in a combined form such as nitrate (NO3-), nitrite (NO2-), or sulfate (SO4) in an aqueous environment.

1.1.4 Define beggiatoa.

Beggiatoa is an unwanted filamentous bacteria that may appear as a white biomass on attached-growth processes.

1.1.5 Define biomass.

Biomass is the biological growth on the media that consists mostly of microorganisms.

1.1.6 Define denitrification.

Denitrification is a biological process where bacteria convert nitrate (NO3-) and nitrite (NO2-) to nitrogen gas (N2) under anoxic conditions.

1.1.7 Define nitrification.

Nitrification is a biological process where nitrifying bacteria convert nitrogen in the form of ammonia (NH3) into nitrite (NO2-) and nitrate (NO3-) under aerobic conditions.

1.1.8 Define organic loading and organic overload.

Organic loading is the amount of biodegradable material that exerts an oxygen demand on the biological treatment process. The organic strength of the wastewater is usually measured as biochemical oxygen demand (BOD) in milligrams per liter (mg/L).

An organic overload is an event which significantly increases the organic loading (BOD) to the reactor above normal primary clarifier effluent organic loading conditions.

1.1.9 Define plug flow.

Plug flow is wastewater flowing through a biological reactor (basin) as a series of distinct thin 'plugs' or columns of wastewater, each with a uniform composition, traveling in the axial direction of the reactor, with each plug or column having a different pollutant composition from the ones before and after.

1.1.10 Define secondary treatment.

Secondary treatment is the biological treatment of wastewater. It provides a high level of biodegradable organic pollutant removal to protect receiving water quality that clarification alone cannot provide. Attached growth is one type of secondary treatment.

1.1.11 Define shock or slug loads.

Shock loads are usually short-term discharges to a treatment system. These discharges can be excessive hydraulic flows, organic loads, or toxic substances that impair treatment.

1.1.12 Define treatment facility overflow (TFO).

A TFO is a release of wastewater, other than through permitted outfalls, from a wastewater facility into a water of the state or the land surface. All TFOs must be reported to the Department of Natural Resources within 24 hours of the occurrence.

Section 1.2 - Microbiological Principles

1.2.1 Describe the attached-growth processes.

Attached-growth processes (also known as fixed-film processes) are biological wastewater treatment processes with the biomass attached to some type of media. The media normally found at wastewater treatment plants are rock, ceramic, plastic materials, and slag. The growth formed on the media is a mixture of mainly aerobic microorganisms. These organisms are similar to those found in other secondary biological treatment processes. The microorganisms include free-swimming and stalked ciliates, rotifers, nematodes, and many others. As the biomass thickens, it loses its ability to adhere to the media and is sloughed. Attached-growth processes are easy to operate and resilient to shock loads, however they are less flexible for process control than activated-sludge process.

1.2.2 Describe the role microorganisms have in the attached-growth process.

The principle role microorganisms have in the attached-growth process is to convert dissolved and particulate organic matter, measured as biochemical oxygen demand (BOD), into cell mass. In a conventional attached-growth process, microorganisms use oxygen to break down organic matter (food) for their growth and survival. Over time and as wastewater moves across the media, food (BOD) decreases with a resultant increase in cell mass.

1.2.3 Discuss biofilms in attached-growth treatment processes.

Biofilm is a biological film that grows on the media of attached-growth processes. It is also referred to as fixed film.

Within the biofilm are microorganisms that are responsible for the removal of organics (BOD) and nutrients for their growth. Biofilm consists of different types of bacteria and extracellular polymeric substances, the “weak glues” in which the bacteria are embedded and attaches to the media surfaces.

A biofilm that is not too thick or not too thin, but just right will result in optimum wastewater treatment. Wet biofilms and their thicknesses can be controlled by changing the velocity of the wastewater across the media to remove excess biofilm as follows:

A. RBCs: rotational speed
B. Trickling filter/biotowers: recirculation rate (flushing)
C. MMBRs and IFAS: aeration
D. MBBRs: mechanical mixing
E. Biological aerated filters: backwashing

1.2.4 Describe the environmental factors that influence the health and growth of microorganisms.

The attached-growth process must operate under proper environmental conditions to support a healthy, growing population of microorganisms. The operator must monitor the process to ensure the right environmental conditions are being provided for efficient attached-growth performance.

A. Food
Incoming wastewater to a treatment plant provides the food the microorganisms need for growth and reproduction. This food is mostly organic material and the more soluble the organic material is, the more easily the microorganisms can use it. Since the amount and type of organic loading in the treatment plant affects the growth of the microorganisms, primary clarifier effluent total BOD and soluble BOD are measurements an operator can make to determine the amount and type of incoming food.

B. Flow
Incoming wastewater must flow through a treatment plant at a rate that allows the microorganisms sufficient time to consume the incoming food. High flows can shorten the time necessary for the full treatment of wastewater. Extremely high flows can wash the microorganisms off of the media and through to the final clarifier.

C. Oxygen
The attached-growth process is aerobic. The microorganisms need free oxygen to convert food into energy for their growth. For optimal performance, it is very important for an operator to be sure enough oxygen is being provided for the microorganisms. In trickling filters and biotowers, the oxygen is supplied through the voids in the media after the distributor arms have passed by. The microorganisms in a rotating biological contactor (RBC) are on the media discs and receive oxygen when rotated out of the wastewater.

D. Temperature
All biological and chemical reactions are affected by temperature. Microorganism growth and reaction rates are slow in cold temperatures and much faster in warmer temperatures. Most microorganisms do best under moderate temperatures (10°C to 25°C).

E. pH
Biological and chemical reactions are affected by pH. Most microorganisms do well in a pH environment of 6.0 to 9.0. Acidic (low pH) or alkaline (high pH) conditions can adversely affect microorganism growth and survival. Operators should measure influent pH to ensure proper plant pH conditions.

F. Nutrients

Microorganisms need nutrients such as nitrogen and phosphorus for their metabolism. Most incoming wastewater to a treatment plant, especially domestic sources, contains an abundance of these nutrients. The ratio of BOD to nitrogen to phosphorus should be at least 100:5:1. Primary clarifier effluent can be tested to determine this nutrient ratio.

G. Toxicity

Incoming wastewater to a treatment plant may at times contain materials or compounds that are toxic to microorganisms. Depending on the concentration of toxic material, microorganisms could be affected, thus impairing the process efficiency.

1.2.5 Describe the appearance and types of microorganism growth on the various stages of a RBC unit.

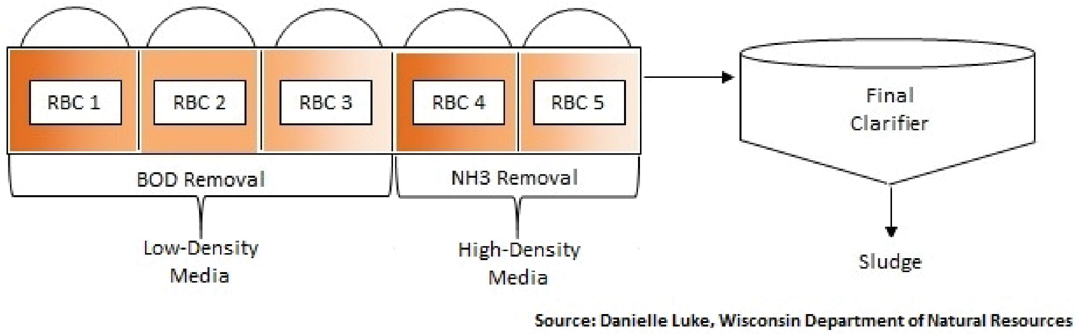
RBC units are designed to work in stages. Each stage receives effluent wastewater from the previous stage. Food (BOD) is less and less as the wastewater passes through the RBC treatment train. The population of microorganisms growing on the RBC media reflects the decreasing level of food available. This is observed by visual appearance of the disk media as well as by microscopic examination. Many of the same organisms observed under a microscope in an activated sludge treatment plant can also be observed in a RBC plant.

On the first few stages, normal healthy growth is rather dense and covers most of the media due to higher growth rates from the higher available food (BOD). The biomass growing on the media is usually tan-brown to light gray (varying with individual plants). Under the microscope, an operator will likely see a lot of motion which is characteristic of free-swimming and crawling ciliates with some stalked ciliates.

On the later stages, where food is lower, there will be less growth on the media. If food becomes very limiting, the attached-floc particle stripping can occur. Still tan-brown to light gray, growth may be splotchy. Microscopic examination will reveal less motion and more and larger numbers of stalked ciliates, rotifers, and nematodes.

Some RBC plants are designed to provide nitrification to remove ammonia in the later stages of a RBC treatment train. These stages are typically high-density media. When nitrification is occurring, media growth is very different from earlier stages by being thin, very granular (sandpaper texture), and dark brown.

Figure 1.2.5.1

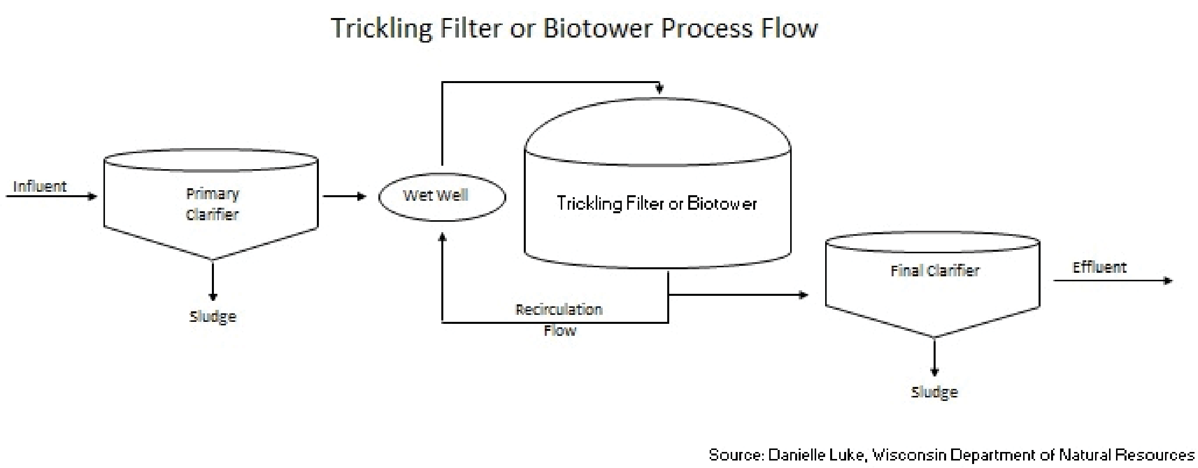


Section 1.3 - Process Variation

1.3.1 Describe the trickling filter and biotower attached-growth processes.

A trickling filter or biotower is a process in which influent and recirculated flow enters the trickling filter or biotower through distributor arms. The distributor arms circulate and evenly spread the wastewater across the top of the media. The wastewater then flows down through the media, where it is treated by the bacteria attached to the media and exits the trickling filter or biotower. The effluent is either recirculated back to the wet well or leaves to other treatment processes or directly to the final clarifier.

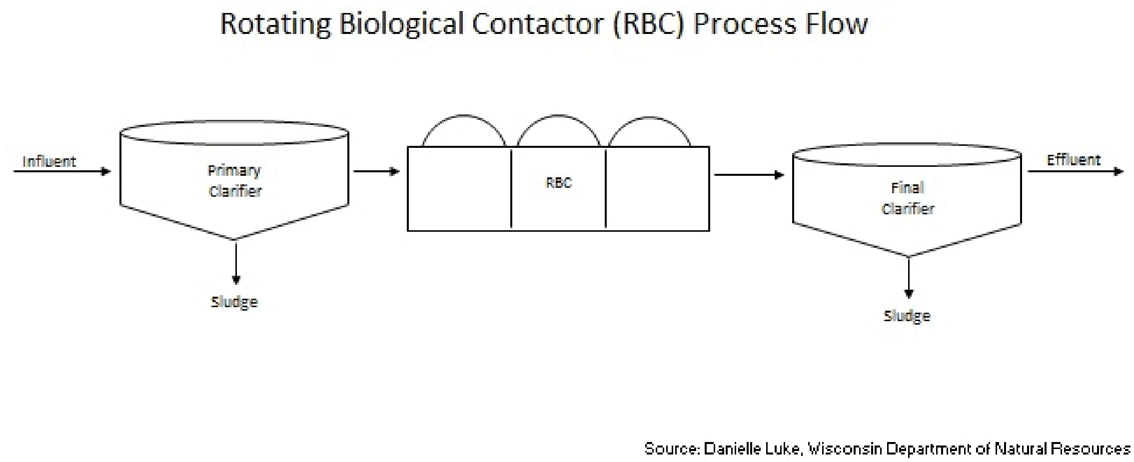
Figure 1.3.1.1



1.3.2 Describe the rotating biological contactor (RBC) process.

A RBC is a process in which influent enters the RBC basin and is treated by bacteria attached to rotating discs in stages and is divided by baffles. The wastewater exits the RBC basin and leaves as effluent to other treatment processes or directly to the final clarifier. Unlike a trickling filter or biotower, a portion of the flow is not recirculated back to the head of the process.

Figure 1.3.2.1



1.3.3 Describe hybrid (combined) attached growth processes.

A. Moving bed bio-reactors (MBBR)
The MBBR processes consist of loose media in an activated-sludge suspended-growth basin. The media remains in the individual basins as the activated sludge travels through the stages. A diffuser on the bottom provides oxygen into the system, mixes the media, and causes excess biomass to be sloughed off the media. This allows for more treatment within a smaller volume. Unlike typical suspended-growth processes, there is no recycle side flow.

B. Integrated fixed-film activated-sludge (IFAS) process
The IFAS process consists of both loose or fixed media (like a MBBR system) and typical activated-sludge solids recycling. This variance allows for more nitrification in the same tank volume.

C. Aerated submerged bio-film (ASBF) reactors
Nitrification (ammonia removal) is very difficult to achieve within pond and lagoon systems in Wisconsin because of extremely cold wastewater temperatures (6°C or less) which inhibit nitrifying bacteria from growing. ASBF reactors may be used to enhance nitrification in municipal wastewater treatment ponds and lagoons by encouraging the growth of a nitrifying bacterial biomass on a submerged-media surface. Supplying air directly to the submerged biofilms enhances the oxygen transfer to the bacteria in the bio-film, encouraging better nitrification.

D. Biological active filter (BAF)
A BAF combines biological treatment and solids removal. This allows for high loading applications using a small construction footprint without the need for clarifiers. Wastewater flows upward through a special granular media filter bed that serves for both attached-biomass growth (biological treatment) and as a filter (solids removal). An aeration system introduces air at the bottom of the filter for the co-current upward flow of wastewater and oxygen through the media bed. Treated water is always above the media bed. The beds are backwashed with water and air to maintain a thin, active biofilm on the media while removing excess solids. BAFs are patented processes.

1.3.4 Describe the solids contact process and how it can improve RBC performance.

RBC performance can be significantly improved by recirculating final clarifier settled solids back through the RBC unit with supplemental aeration. Such an operational mode creates a hybrid suspended-growth system within an attached-growth system resulting in a mixed liquor suspended solids (MLSS) in the RBC basins. Supplemental aeration maintains desired dissolved oxygen (DO) levels while also providing necessary mixing of the returned solids.

MLSS levels of 1,000 to 3,000 mg/L in the RBC basins have been shown to improve BOD, total suspended solids (TSS), and ammonia removal in RBC plants in Wisconsin modified for this operational mode. Improved settleability also results due to a mixed attached-suspended growth floc.

Chapter 2 - Operation and Maintenance

Section 2.1 - Definitions

2.1.1 Define loping in a rotating biological contractor (RBC).

Loping is the uneven shaft rotation due to unbalanced biomass on the disc media.

2.1.2 Define recirculation.

Recirculation is the portion of the attached-growth effluent returned back to the influent of the process.

2.1.3 Define recirculation ratios.

Recirculation ratios are expressed as the volume of return recirculation flows to the volume of the attached-growth process influent. Typical recirculation ratios are 1:1 to 4:1.

Section 2.2 - Equipment

2.2.1 Describe the components and equipment of a rotating biological contactor (RBC).

A. Air- and/or mechanical-drive system
Air-driven units consist of air cups, air diffusers, and air headers. Mechanical-driven units use motor, belts, chain, sprockets, and speed reducers. In figure 2.2.1.1, all of these components are inside the drive casing.

B. Media
The media is a series of large rotating discs constructed of either high- or low-density plastic-polyethylene, in which the biomass adheres. The rotating discs should never be submerged more than 40% of their diameter and never rotated at a speed greater than 1.5 rpms.

C. Baffles
The baffles may be concrete or wood planking and separate one shaft from another. Some baffles contain weirs to control the flow from one stage to the next.

D. Enclosure
Outdoor RBCs normally have covers or enclosures over the entire unit to protect the microorganisms from the weather, for odor control, and for security. An enclosure also includes the building the RBCs are housed. An enclosure is pictured on the front cover of this guide.

E. Bearings
The bearings support the shaft and allow the unit to rotate smoothly without friction.

F. Air cups
The air cups are attached across the outer surface of the media. They are angled to capture air as it rises, rotating the media discs.

G. Shafts
The shaft runs through the center of the media discs and is supported by the bearings.

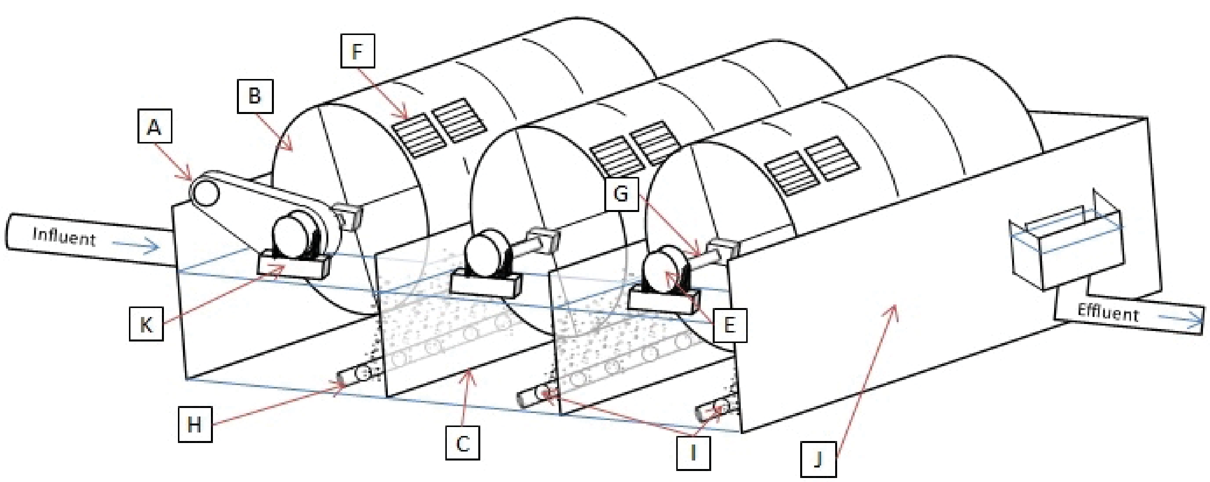
H. Air header
Light-weight air headers carry the air through the system and run the length of the media assembly. The headers are easily removable for cleaning.

I. Air diffusers
Coarse-bubble air diffusers distribute air from the header into the air cups.

J. RBC basin
The RBC basin holds the wastewater being treated and allows the wastewater to come in contact with the organisms on the discs.

K. Load cells
Load cells measure the biomass weight on the discs.

Figure 2.2.1.1

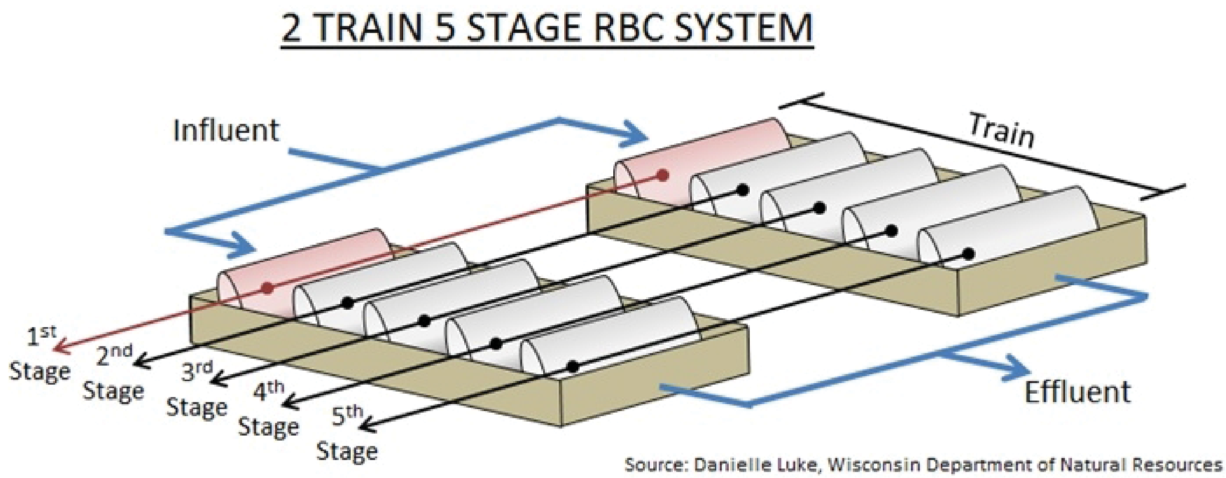


Source: Danielle Luke, Wisconsin Department of Natural Resources

2.2.2 Discuss the difference between a RBC shaft, stage, and train.

An individual RBC shaft holds and rotates the media through the wastewater. The first stage is the first shaft(s) of rotating media. A RBC train is the sequential series of shafts in the basin. When a system has more than one train, each zone in the system that receives the same loading is considered one stage.

Figure 2.2.2.1



2.2.3 Describe the components and equipment of a trickling filter process.

A. Filter media
Attached-growth filter media has a high surface area, high durability, and does not easily clog. Typical media consists of rocks or high-density plastic media over which the wastewater flows and causes a layer of microbial slime growth, covering the media.

B. Containment structure
The containment structure provides housing for the media, typically extending 4 to 5 ft above the media to prevent wind from effecting the rotation of the distributor arms.

C. Distributor arms
The main component of the distribution system, distributor arms convey the wastewater to various holes along the arm, then distributes the wastewater evenly over the filter media. Splash plates under the holes further evenly distribute the wastewater as the thrust of the wastewater spray rotates the distributor arm.

D. Speed-retarder orifices
Located on the back side of the distributor arm, these holes help to regulate the rotation speed, maintaining even wastewater distribution.

E. Distributor end gates
Located on the ends of the distributor arm, the end gates are opened to flush out accumulated debris within the distributor arm.

F. Turnbuckles and stay rods (guy wires)
Turnbuckles and stay rods allow height adjustment of the distributor arms.

G. Underdrain system

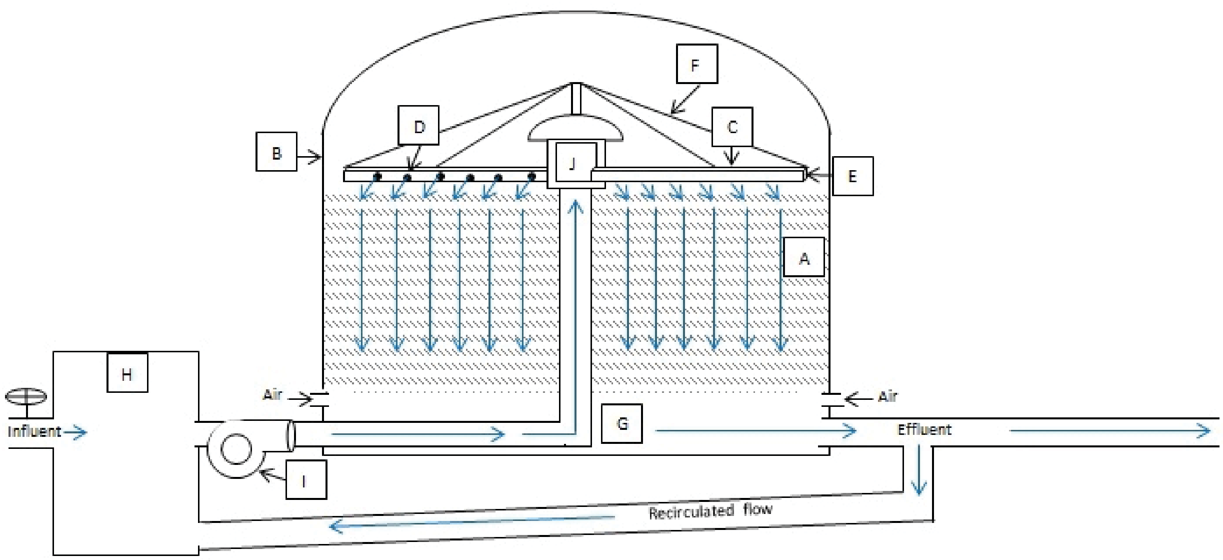
Located underneath the filter media, this system supports the filter media, allows air into the media, and collects the filter effluent then directs it to the outlet box.

H. Wet well
The wet well is the collection point for the primary clarifier effluent and the recirculated filter or biotower effluent.

I. Pumps
Pumps are used to bring wastewater to the top of the trickling filter or biotower allowing wastewater to flow past the media.

J. Motorized drives
Drives are sometimes installed to mechanically rotate distributor arms and control wastewater flow distribution.

Figure 2.2.3.1

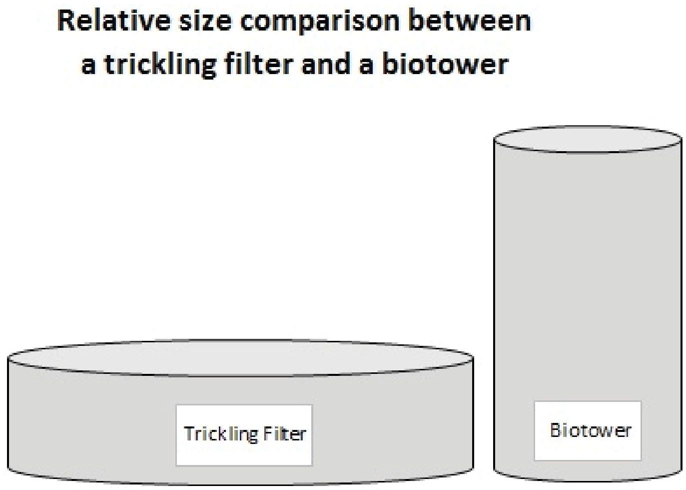


Source: Danielle Luke from the Wisconsin Department of Natural Resources

2.2.4 Describe the differences between a trickling filter and a biotower.

Trickling filters and biotowers are both attached-growth reactors. In the simplest sense, trickling filters are short and wide while biotowers are tall and thin. For example, a trickling filter may have 12 ft of media and be 100 ft wide while a biotower of similar cubic (ft^3) area would be only 15 ft in diameter but 50 ft tall. Being tall and thin, a biotower will sit on a much smaller footprint. Today, most reactors contain plastic media through which wastewater flows and biomass grows. Early design and construction of trickling filters in the 1970s contained rock media.

Figure 2.2.4.1



Section 2.3 - Methods

2.3.1 Describe the differences between low-rate, intermediate-rate, high-rate, and roughing trickling filters.

The type of trickling filter depends on the projected organic loadings. Low-rate filters can treat up to 25 lbs of biochemical oxygen demand (BOD)/1,000 ft^3 of media surface area per day; intermediate-rate filters treat up to 40 lbs of BOD/1,000 ft^3 per day; high-rate filters treat up to 100 lbs of BOD/1,000 ft^3 per day. Roughing filters are designed for BOD loadings of 100 to 300 lbs of BOD/1,000 ft^3 per day.

2.3.2 Discuss acceptable organic loading rates to rotating biological contactors (RBC).

Commonly, RBCs are 12 ft in diameter and 25 ft long. Standard media density is 100,000 ft^2 per shaft. High-density media is between 120,000 and 180,000 ft^2. Many sources all recommend 2.5 to 4.0 lbs of soluble BOD/day/1,000 ft^2. USEPA and the Department of Natural Resources recommend soluble BOD loading not exceed 2.5 lbs of soluble BOD/day/1,000 ft^2. For operators, this is especially important to know because excessive biological growth and biomass weights on rotating shafts will stress and can cause resultant shaft failure. As a result, first shafts are not installed with high-density media. Heavy growths on the first stage in a RBC train are usually indicative of high organic loadings. Load cells should be used to regularly measure the weights on the shafts (see key knowledge 2.2.1).

2.3.3 List ways an operator can control the distributor arm speed of a trickling filter or biotower.

A. Change the recirculation rate
Increased recirculation causes increased flow and increased arm speed; while decreased recirculation results in just the opposite.

B. Change the number of nozzles on the distributor arms
Less openings for a given flow would mean a higher speed (higher force) while more openings mean a slower speed (less force).

C. Install speed-retarder nozzles

Installing nozzles on the opposite side of the distributor arms from the normal flow will act as speed retarders to slow the rotation

2.3.4 Discuss the reasons why primary treatment is needed prior to attached-growth processes.

Primary treatment is necessary to remove settleable solids prior to the attached-growth process. Without proper removal, excessive solids will accumulate and clog the media causing organic overloading, anaerobic conditions, ponding, and fouling. Primary treatment reduces organic loading and removes grease.

2.3.5 List and explain the purposes for recirculation in trickling filters and biotowers.

Recirculation is the primary process control method for these attached-growth processes by which filter effluent is returned to and reapplied onto the filter. Recycling of the effluent increases the contact time of the wastewater with the microorganisms, increasing and optimizing treatment efficiency. Recirculation can be continuous or intermittent. Return pumping rates can be constant or variable. Recirculation rates range from 2:1 to 4:1.

Recirculation can serve other purposes as follows:

A. Reduce the strength of the wastewater being applied
B. Increase hydraulic detention time
C. Maintain distributor arm rotation during periods of low flow
D. Produce hydraulic shear to increase solid sloughing to prevent ponding
E. Prevent filters from drying out
F. Provide uniform flow distribution
G. Maintain the optimum biomass thickness and growth by more continuous and uniform sloughing rate
H. Prevent freezing during cold winter weather

2.3.6 Explain the importance of even-flow distribution across the media of a trickling filter or biotower.

As distributor arms turn and apply wastewater across the surface of the media, it is extremely important that constant and uniform hydraulic and organic loading rate pass by the attached biomass. The distributor arm ports should be kept unplugged, open, and flowing, and the distributor arms rotating at a constant, uniform rate. Uneven flow distribution means the media volume is not being fully utilized and reduces treatment efficiency.

Section 2.4 - Preventative Maintenance

2.4.1 List the characteristics of a well-operating rotating biological contactor (RBC).

A. Healthy biomass that is uniformly brown and distributed in a thin, even layer over the entire media
B. No unusual noises from the drive unit or shaft
C. No loping of the RBC discs

2.4.2 Discuss the characteristics of well-operating trickling filters or biotowers.

A. Healthy, thin layer of biomass with entire surface wetted
B. All orifices are open and flowing
C. Level distributor arms that rotate continuously and smoothly
D. No ponding
E. No leaking from center column seal

2.4.3 Discuss methods of reducing excessive biomass on attached-growth media.

A. Trickling filters or biotowers
1. Eliminate or reduce high-strength organic wastewater at the source
2. Reduce organic loading through the media by increasing the recirculation rate
3. Increase the hydraulic loading rate (HLR) through the filter to slough off excess growth by increasing the recirculation rate
4. Isolate the filter and add chlorine or a caustic to shock the biomass (effluent limits must be maintained during any shock treatments). An operator should consult O&M manual and/or consultant to determine the chemical dosages to apply then neutralize before discharge.

B. RBCs
1. Eliminate or reduce high-strength organic wastewater at the source
2. Reverse the rotation and speed of the shafts, if capable
3. Increase air flowrate under the RBCs to slough off excess growth, if capable
4. Isolate the RBC basin and add chlorine or a caustic to shock the biomass (effluent limits must be maintained during any shock treatments). An operator should consult their O&M manual and/or consultant to determine the chemical dosages to apply then neutralize before discharge.

2.4.4 Discuss important maintenance tasks to ensure even distribution of wastewater on trickling filter or biotower media.

Biological growth and debris buildup may plug the distributor arm orifices. Cleaning the nozzles and splash plates routinely will help prevent the orifices from plugging. Biological growth and debris may also buildup inside of the distributor arms preventing an even flow and should be routinely flushed as well. Extra stress on the center column connections and unequal loadings can be prevented by adjusting the stay rods (guy wires).

2.4.5 List the maintenance tasks to perform on RBC equipment.

A. Shafts and main bearings
B. Drive motor
C. Diffusers
D. Drive assembly units
E. Blower equipment

All maintenance and repairs should be documented. Consult the manufacture's O&M manual for specific equipment maintenance.

2.4.6 List some reasons that would cause a trickling filter or biotower distributor arms not to turn.

A. Low flow

B. Bearing failure
C. Open end gates
D. Plugged nozzles
E. Power failure
F. Broken stay rods (guy wire)

2.4.7 Discuss some important maintenance considerations for trickling filters and biotowers.

A. Monitor the oil level in the upper bearing assembly weekly. The oil level and condition is crucial to life of equipment.
B. Grease the lower bearing and seal assemble monthly. Failure to grease regularly will result in premature bearing and seal failure.
C. To maintain speed and even distribution, check for proper flow through all the orifices daily. Flush out distributor arms by opening the end gates weekly.
D. If the distributor arms are not rotating level, stay rod adjustment may be necessary.

Consult the manufacture's O&M manual for specific equipment maintenance. All maintenance and repairs should be documented.

Chapter 3 - Monitoring, Process Control, and Troubleshooting

Section 3.1 - Definitions

3.1.1 Define filter channeling in a trickling filter or biotower.

Filter channeling occurs when portions of the filter plug and the wastewater flows downward in channels, reducing treatment efficiency.

Section 3.2 - Sampling and Testing

3.2.1 Identify the sampling locations to determine attached-growth process efficiency.

Samples should be collected at the influent to the attached-growth process and after the final clarifier for overall treatment removal efficiency.

The influent sample location should be the wet well which will include: primary clarifier effluent, recirculation flow, and sidestreams.

Section 3.3 - Data Understanding and Interpretation

3.3.1 Describe the nitrification process as it occurs in a rotating biological contactor (RBC).

RBCs can be designed and operated to remove ammonia. Plug flow through RBCs promote nitrifying organism growth, additional RBC shafts/media are necessary for nitrification to occur in a RBC system. Nitrifying bacteria growth depends upon the soluble biochemical oxygen demand (BOD) in the wastewater. Soluble BOD needs to be used up before nitrifiers will grow. Typically, nitrification will occur when the soluble BOD in the wastewater is reduced to less than 20 mg/L. As wastewater moves through a RBC train, the first stages of a RBC system use carbon (BOD) as the primary food source and the BOD is reduced. When BOD gets low enough, ammonia becomes the primary food source allowing nitrifiers to grow on the latter stages and ammonia is reduced. The growth and appearance of bacteria on the RBC change as well (see key knowledge 1.2.5) with shafts that are nitrifying appearing thin, dark-brown and grainy.

Nitrification, as in any biological treatment system, is most affected by temperature. As wastewater temperatures drops to 6°C or less, nitrifying bacteria growth rates are reduced with resultant loss of nitrification. Other factors that can affect sensitive nitrifying bacteria and nitrification are variable influent flow and ammonia loadings, dissolved oxygen (DO), pH, and alkalinity. A DO range of 2.0 to 3.5 mg/L and a pH of 7.0 to 8.5 produce the best nitrification rates.

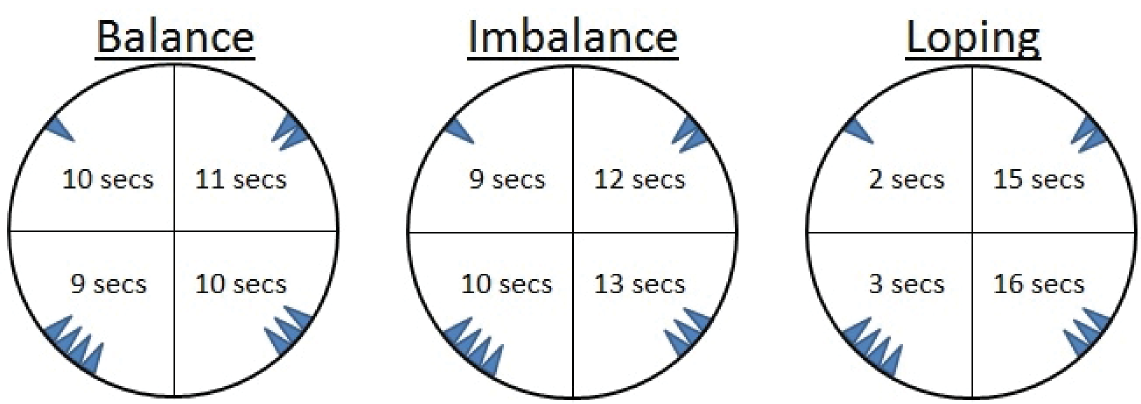
3.3.2 Discuss the effects of partial nitrification in attached-growth wastewater treatment plants.

Partial nitrification occurs when not all of the ammonia has been converted to nitrate. Higher levels of ammonia can affect the overall quality of the wastewater effluent. BOD 5-day (BOD5) test results will read higher than normal because nitrification occurs during the incubation process. In this case, a carbonaceous (cBOD5) test may be used and reported with DNR approval because the result removes the contribution from the nitrification process. Higher levels of ammonia are also more toxic to fish and aquatic life and require more chlorine for disinfection.

3.3.3 Discuss the process of checking the balanced rotation of a RBC.

RBC rotation should be checked by timing quarter rotations (at least weekly). The RBC media is marked or notched in quarters. Using a stop watch, each quarter of the RBC is timed as it rotates from one notch or mark to the next. An evenly balanced RBC shows quarter rotations with relatively similar times (see figure 3.3.3.1).

Figure 3.3.3.1



Source: Jack Saltes and Danielle Luke, Wisconsin Department of Natural Resources

Section 3.4 - Sidestreams and Recycle Flows

3.4.1 Discuss the possible impact of sidestreams or recycle flows on the attached-growth process.

Sidestreams or recycle flows usually come from solids handling treatment or dewatering processes, such as decanting digesters or sludge storage tanks. Sidestreams may be high in biochemical oxygen demand (BOD), suspended solids, ammonia, phosphorus, and sulfides or very low in temperature. It is best to return sidestreams slowly and regularly so microorganisms adjust and acclimate to this loading. If the facility's Wisconsin Discharge Pollution Elimination System (WPDES) permit limits phosphorus or ammonia, it is critical to know the loading from sidestreams. Sidestreams can upset a treatment plant or result in a pass-through of pollutants to the effluent, resulting in permit violations. If the WPDES permit limits phosphorus or ammonia, it may be necessary to separately treat the sidestream.

3.4.2 List common sidestreams within a treatment plant.

The most common sidestreams are from:

A. Thickening and dewatering processes
1. Gravity belt thickening filtrate
2. Centrifuge centrate
3. Gravity thickening supernatant
4. Dissolved air flotation (DAF) subnatant
5. Rotary drum thickening filtrate
6. Belt filter press filtrate
7. Sludge drying bed underdrain
8. Plate and frame filtrate
9. Reed bed filtrate

B. Stabilization and storage
1. Aerobic digester decant
2. Anaerobic digestion supernatant
3. Biosolids storage decant
4. Effluent filter backwash

3.4.3 Discuss the acceptance of septage and holding tank waste at an attached growth system.

By their nature, septage and holding tank wastes can be very strong in BOD, total suspended solids (TSS), ammonia, phosphorus, and sulfides. They may also be high in organic acids and fat, oils, and grease (FOG). Plants that accept these wastes should control the discharge of these wastes into the plant and know the strength, volume, and how much the plant can handle during a day or week without stressing the microorganisms. Large slug loads can impact the microorganisms that may not be accustomed to such waste. Septage or holding tank waste can also create unfavorable environmental conditions. Discharging septage or holding waste should be at a location that allows removal of grit and screenings and blending slowly into the plant influent. Some larger plants have septage receiving stations that provide preliminary treatment and regulate the flow into the plant. While receiving septage or holding tank waste at a treatment plant can be a good revenue source for a community, it must be done at a volume and flowrate as to not upset the plant and at a reasonable treatment cost. Hauled-in wastes should also be regularly sampled and monitored.

Figure 3.4.3.1

Range of Wastewater Characteristics
All units [mg/L], except for standard pH units

Parameter	Domestic Sewage[1]	Septage[2]	Holding Tank[2]
BOD	100-400	565-5,800	225-800
TSS	100-350	2,220-14,700	60-700
Ammonia	12-50	116-428	18-310
Phosphorus	4-15	24-186	8-28
pH		1.5-12.6	

1 Metcalf & Eddy (1972)
2 Madison Metro Sewage District Data (2006)

Section 3.5 - Performance Limiting Factors

3.5.1 Discuss the potential effects on biomass growth from various types of loadings.

A. Toxics
Toxic pollutants such as heavy metals, acid or caustic, chlorine, surfactants, quats, metal salts in high concentrations, and other toxic materials can kill or significantly reduce the microorganisms growing on the media causing a reduction in biochemical oxygen demand (BOD) removal. Effluent limit violations could result.

B. High organic loadings
Influent excessively high in BOD can result in excessive biological growth on the media causing plugging, channeling, ponding, odors, and high solid loadings to downstream final clarifiers, resulting in effluent limit violations.

C. High nutrient loadings (ammonia)
Excessively high influent ammonia can be toxic to microorganisms, thus impairing overall treatment. Ammonia can also pass largely untreated through the treatment process if high enough. Quaternary ammonia compounds, often used as cleaners in certain businesses or industries, can also impact the biomass and treatment. Effluent limit violations could result.

D. Excessive hydraulic flow
Excessive flow, most commonly from excessive infiltration and inflow (I/I), can effect treatment by reducing detention times necessary for the attached microorganisms to treat the pollutants. High flows, if high enough, can also hydraulically strip off the attached biomass from the media. Excess I/I from the collection system, especially in the late winter and early spring, can be very cold and thus affect the wastewater temperature for proper treatment. Effluent limit violations could result.

3.5.2 Explain the purpose of media ventilation in the operation of attached-growth processes.

A. Trickling filters and biotowers
Ventilation to the media in a trickling filter and biotower is important as air provides oxygen necessary for microorganism growth. If inadequate ventilation is occurring, there is the possibility that the aerobic organisms could become anaerobic resulting in odor problems. If it is suspected that ventilation is inadequate, perform a smoke test. If natural ventilation is

inadequate, forced air pumped through the underdrain system can be used to enhance oxygen requirements.

B. Rotating biological contactors (RBC)
RBCs rely on passive ventilation. The air spaces on the rotating media provide opportunity for air, food, and microorganisms to come together and provide a space for sloughed biomass to leave the media.

Section 3.6 - Corrective Actions

3.6.1 Describe the possible causes and corrective actions for common trickling filter problems.

Figure 3.6.1.1

Problem	Cause	Corrective Action
Ponding	Organic overload	Flush the filter by increasing the recirculation rate to strip excessive biological growth
	Deteriorated media	Replace media
	Solids from the primary clarifier	Remove more solids
Plugged orifices and media surface	Poor preliminary treatment	Upgrade screening process
Icing	Cold weather	Decrease recirculation; cover units; build wind breaks
Odor	Anaerobic conditions	Increase recirculation; increase ventilation
Filter fly nuisance	Larval buildup on walls	Better housekeeping; flush the walls

3.6.2 Describe the possible causes and corrective actions for common rotating biological contactors (RBC) problems.

Figure 3.6.2.1

Problem	Cause	Corrective Action
Excessive growth	Heavy influent organic overloading; inadequate sloughing	Reverse rotation; clean (strip) media; add supplemental air; recirculate effluent; reduce organic loadings; place additional RBCs in service (if available); evaluate sidestream loadings
Loping	Shaft imbalance due to uneven growth on media	Clean (strip) media
Biomass change (color, density)	Toxic influent conditions; change of pH	Determine source of toxins
Beggiatoa	Low dissolved oxygen (DO) and organic overloading	Increase DO (aeration); reduce organic loadings
Snail infestation	Proper environmental conditions for snail growth and reproduction	Isolate basin and add chlorine for 24 hours, then dechlorinate and drain; let media dry and manually remove snail masses
Partial Nitrification	Insufficient biomass; insufficient oxygen; low detention time; and cold water	Apply for carbonaceous biochemical oxygen demand (cBOD) limits; if chronic, upgrading may be necessary (supplemental air; additional media; recirculation ability; solids contact process)

Chapter 4 - Safety and Regulations

Section 4.1 - Definitions

4.1.1 Define personal protective equipment (PPE).

PPE is the protective clothing and other devices designed to protect an individual while in potentially hazardous areas or performing potentially hazardous operations. Examples of PPE include gloves, hard hat, steel-toed boots, safety glasses, and appropriate clothing.

4.1.2 Discuss the importance of floatation devices at a wastewater treatment plant.

Sampling from basins, channels, and other treatment processes puts an operator at risk of falling into the wastewater. Basins that are aerated can be the most dangerous because the aeration process makes it extremely difficult, if not impossible, to stay afloat in waters saturated with high concentrations of air. For this reason, an operator should never extend beyond the protection of the guardrails. The Occupational Safety and Health Administration (OSHA) highly recommends ring buoys with at least 90 ft of line be provided and readily available for emergencies and strategically placed around all process basins. OSHA also recommends any operator working over or near water where a risk of drowning is present be provided with a life jacket or buoyant work vest.

Section 4.2 - Personal Safety

4.2.1 List various safety considerations that are important when working in a wastewater treatment plant.

A. Falling into tanks where currents can pull an operator under the water surface
B. Noise
C. Exposure to waterborne and bloodborne pathogens
D. Rotating equipment
E. Electrical hazards
F. Slippery surfaces
G. Confined spaces
H. Compressed air
I. Chemicals and chemical equipment

Operators should follow all federal and state safety requirements. Safety programs and emergency procedures should be in place and followed at all times.

4.2.2 Discuss procedures for entering treatment tanks or vessels.

Owners of wastewater treatment facilities should clearly define all confined spaces. Operators should know them and follow all confined space entry procedures.

4.2.3 Describe the applicable safety program and requirements municipal wastewater treatment plants must follow.

The Wisconsin Department of Safety and Professional Services - SPS 332 Public Employee Safety and Health must be followed. Some of the important safety requirements are confined space, excavation, hearing conservation, bloodborne pathogens, CPR/First Aid, Safety Data Sheets (SDS), electrical, fall protection, hazardous materials, as well as others. Non-public entities follow the Occupational Safety & Health Administration (OSHA) CFR 29 part 1910.

4.2.4 List the additional safety precautions related to trickling filters and biotowers.

A. Distributor arm rotation
Stop the flow to the trickling filter or biotower and allow the distributor arms to come to a complete stop before entering to perform maintenance. Secure the distributor arms once stopped to prevent rotation.

B. Walking on media surfaces
Take caution while walking across the media due to the slippery and uneven surfaces.

4.2.5 List the additional safety precautions related to rotating biological contactors (RBC).

A. Shaft rotation
Stop the rotation of the RBC shaft by following manufacture's O&M manual recommendations.

B. Ventilation
Ensure proper oxygen conditions exist with RBCs located within enclosures.

Section 4.3 - Chemical Safety

4.3.1 Discuss the importance of maintaining chemical delivery, storage, and usage records.

Some chemicals used in an attached-growth treatment plant are hazardous materials and must be identified. Safety Data Sheets (SDS) for each are required to be kept onsite and readily available. In the event of a spill, the Department of Natural Resources must be contacted.

4.3.2 Discuss preventative spill measures and procedures when handling hazardous chemicals.

Storage tanks must have secondary containment that equals the volume of the storage tank. Place containment pails under potential leaks points and when uncoupling fill lines during unloading of delivery vehicles. Inspect and maintain fill lines and valves. Inspect storage tanks and hardware for integrity. Pay attention to what is being done! Provide onsite containment equipment such as absorbent booms, sandbags, etc. and seal the yard and storm drains to prevent offsite loss of chemical.

In case of a spill:

A. Any spill of a hazardous material should be reported to the Department of Natural Resources within 24 hours and the local emergency response agencies.

B. Contact CHEMTREC for further spill response and cleanup advice.

4.3.3 Discuss the proper procedure for entering a chemical storage tank.

Contract any tank inspection and repairs to trained specialists for such work. FOLLOW ALL CONFINED SPACE ENTRY PROCEDURES.

Chapter 5 - Calculations

Section 5.1 - Surface Area

5.1.1 Given data, calculate the total surface area (ft^2) of a rotating biological contactor (RBC) unit(s).

GIVEN:

Number of RBC trains = 2
RBC shafts per train = 4
Surface area of shafts 1, 2, and 3 = 100,000 ft^2
Surface area of shaft 4 = 150,000 ft^2

FORMULAS AND SOLUTION:

Total surface area per train (ft^2) = shaft 1 (ft^2) + shaft 2 (ft^2) + shaft 3 (ft^2) + shaft 4 (ft^2)
= 100,000 ft^2 + 100,000 ft^2 + 100,000 ft^2 + 150,000 ft^2
= 450,000 ft^2/train

Total surface area (ft^2) = (total surface area per train (ft^2)) × (# of trains)
= 450,000 ft^2/train × 2 trains
= 900,000 ft^2

Section 5.2 - Flows and Loading

5.2.1 Given data, calculate the influent loading of biochemical oxygen demand (BOD) (lbs/day/1,000 ft^2 of media) to a trickling filter.

GIVEN:
[MGD = million gallons per day]

Primary effluent BOD = 180 mg/L
Flow to filter = 1.8 MGD
Surface area of filter = 8,790 ft^2

FORMULAS AND SOLUTION:

BOD (lbs/day) = flow (MGD) × BOD conc. (mg/L) × 8.34
= 1.8 MGD × 180 mg/L × 8.34
= 2,702.16 lbs of BOD/day

BOD (lbs/day/1,000 ft^2) = BOD (lbs/day) ÷ [surface area (ft^2) ÷ 1,000 ft^2]
= 2,702.16 lbs/day ÷ 8.79 ft^2
= 307.41 lbs of BOD/day/1,000 ft^2

5.2.2 Given data, calculate the hydraulic loading rate (HLR) (gallons per day (gpd) per square foot) to a trickling filter.

GIVEN:

Filter diameter = 80 ft
Flowrate = 1,000,000 gpd

FORMULAS AND SOLUTION:
[NOTE: This rate can be expressed in gpd/ft^2 or gpd/acre.]

Area of the filter (ft^2) = 3.14 × [radius (ft)]^2
= 3.14 × (40 ft)^2
= 5,024 ft^2

HLR (gpd/ft^2) = flow (gpd) ÷ area (ft^2)
= 1,000,000 gpd ÷ 5,024 ft^2
= 199 gpd/ft^2

5.2.3 Given data of the Incoming BOD to a rotating biological contactor (RBC) wastewater treatment plant; media density and surface area, calculate the organic loading.

GIVEN:

Primary clarifier effluent soluble BOD (sBOD) = 200 mg/L
Primary clarifier flow = 0.250 MGD
RBC media surface area of first stage = 200,000 ft^2

Recommended loading rate = 2.5 lbs of sBOD/day/1,000ft^2

FORMULAS AND SOLUTION:

Organic loading (lbs/day) = influent flow (MGD) × incoming sBOD (mg/L) × 8.34
= 0.250 MGD × 200 mg/L × 8.34
= 417 lbs of sBOD/day

Organic loading (lbs/day/1,000 ft^2) = [organic load (lbs/day) ÷ media surface area (ft^2)] × 1,000
= [417 lbs of sBOD/day ÷ 200,000 ft^2] × 1,000
= 2.1 lbs of sBOD/day/1,000 ft^2

Section 5.3 - Recirculation Ratio

5.3.1 Given data, calculate the recirculation ratio.

GIVEN:
[gpm = gallons per minute]
[MGD = million gallons per day]

Recirculation flowrate = 270 gpm
Average influent flowrate = 0.26 MGD
1 day = 1,440 minutes

FORMULAS AND SOLUTION:

Recirculation flowrate (MGD) = [flowrate (gpm) × 1,440 min/day] ÷ 1,000,000
= [270 gpm × 1,440 min/day] ÷ 1,000,000
= 0.389 MGD

Recirculation ratio = recirculation flowrate (MGD) ÷ influent flowrate (MGD)
= 0.389 MGD ÷ 0.26 MGD
= 1.5 or 1.5:1

References and Resources

1. UW WATER LIBRARY

Most of the resources listed on this page can be borrowed through the UW Water Library as part of a partnership between the UW Water Library, the Wisconsin Wastewater Operator Association (WWOA), Central States Water Environmental Association (CSWEA), and the Wisconsin Department of Natural Resources. Instructions for borrowing materials from the UW Water Library can be found by visiting the website provided below, clicking on 'WISCONSIN RESIDENTS', and then clicking on 'HOW TO BORROW MATERIALS'.

www.aqua.wisc.edu/waterlibrary

2. OPERATION OF MUNICIPAL WASTEWATER TREATMENT PLANTS

Water Environmental Federation (WEF) (2008). Manual of Practice (MOP) No. 11 vol. I, II, III (6th ed.). New York, New York: McGraw-Hill

www.wef.org

3. OPERATION OF WASTEWATER TREATMENT PLANTS

Office of Water Programs, California State University, Sacramento (2008). Operation of Wastewater Treatment Plants (7th ed.). Sacramento, California: University Enterprises, Inc., California State University

www.owp.csus.edu/training/

4. SPS 332 PUBLIC EMPLOYEE SAFETY AND HEALTH

Wisconsin Administrative Code SPS 332 Public Employee Safety and Health (2014)

http://docs.legis.wisconsin.gov

5. OSHA CFR 29 PART 1910

Occupational Safety & Health Administration [OSHA]. (2012). Regulations (Standards-29 CFR 1910.1200)

www.osha.gov