Wisconsin Department of Natural Resources
Wastewater Operator Certification

Advanced Trickling Filtration and RBC's Study Guide

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Subclass B

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Preface

This operator's study guide represents the results of an ambitious program. Operators of wastewater facilities, regulators, educators and local officials, jointly prepared the objectives and exam questions for this subclass.

How to use this study guide with references

In preparation for the exams you should:

1. Read all of the key knowledges for each objective.

2. Use the resources listed at the end of the study guide for additional information.

3. Review all key knowledges until you fully understand them and know them by memory.

It is advisable that the operator take classroom or online training in this process before attempting the certification exam.

Choosing A Test Date

Before you choose a test date, consider the training opportunities available in your area. A listing of training opportunities and exam dates is available on the internet at http://dnr.wi.gov, keyword search "operator certification". It can also be found in the annual DNR "Certified Operator" or by contacting your DNR regional operator certification coordinator.

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Chapter 1 - Principle, Structure and Function

Section 1.1 - Principles of Trickling Filters and RBC's

1.1.1 Describe the appearance and types of microorganism growth on the various stages of an RBC unit.

Rotating biological contactor units are designed to work in stages. Each stage receives the effluent from the previous stage and has less food energy present than the previous stage. The population of microorganisms in each stage reflects the differing levels of food energy present. This can be observed by visual appearance of the discs as well as by microscopic examination.

On the first stage:
Normal growth has a shaggy texture with a brown to gray color. The organisms are those specialized for high energy levels (heavy eaters). Under a microscope the operator will see a great deal of motion characterized by free swimming ciliates and some stalked ciliates.

On the second stage:
Will appear to be slightly darker in color than the first stage. It will be less shaggy and have much less volume of growth. Microscopic examination will reveal less motion and many large community stalked ciliates.

On later stages (three or four):
Will appear brown to golden tan and reveal much less volume of growth due to low food energy. Stripping of the floc particles will start to occur. The organisms present will be those that have low food energy requirements, such as rotifers, nematodes, and large community stalked ciliates.

1.1.2 Describe the types of microorganism growth in a trickling filter.

The microorganisms that grow on the media of a trickling filter are primarily aerobic organisms. They are similar to the organisms found in the other biologic secondary treatment systems. The largest population on the filter media are various forms of bacteria. They are varied and use different substances to produce their cell mass. High forms of microorganisms are plentiful, feeding on bacteria, and other lower forms. Some of the higher form organisms would include free swimming ciliates, stalked ciliates, rotifers, and nematodes (worms).

1.1.3 Define nitrification/denitrification and how the following variables affect the process:

A. Temperature
B. Dissolved oxygen
C. pH
D. Detention time

Nitrification: is the biologic conversion of ammonia to nitrate; it is accomplished by nitrifying bacteria that require sufficient dissolved oxygen and detention time to complete the task; in trickling filters nitrification can normally only be expected in standard (low) rate type filters; nitrifying bacteria are normally found on later RBC stages where dissolved oxygen is higher because the carbonaceous oxygen demand has been satisfied in the early stages

Denitrification: is the biologic conversion of nitrate to free nitrogen; it is accomplished by special bacteria that operate in anaerobic conditions and strip the combined oxygen from the nitrate molecule; this process may occur in the final clarifier under anaerobic conditions

A. Temperature: nitrification is temperature dependent; higher wastewater temperatures are beneficial to the nitrifying bacteria; colder wastewater temperatures slow down the bacterial activity

B. Dissolved oxygen: the nitrifying bacteria require higher dissolved oxygen levels than other bacteria; it is essential that dissolved oxygen levels be maintained at all times to retain these organisms; organic shock loadings creating anoxic conditions will harm the nitrifiers and cause nitrification to be reduced or to cease altogether

C. pH: nitrifiers function best at a pH of 8.4 but will work adequately at all pH ranges found in normal domestic wastewater; when nitrification occurs alkalinity will be removed from the wastewater at a rate of just over 7 mg/L for each mg/L of ammonia that is converted to nitrate; if the influent alkalinity is low enough (relatively soft groundwater areas) the nitrification process can lower effluent pH values possibly causing an effluent violation; the use of chlorination, dechlorination, and phosphorus removal chemicals can also add to the lowering of effluent pH values; these chemicals often add acidity

D. Detention time: nitrification is a process that requires sufficient contact time with the bacteria to complete the process; nitrification in most cases can only be expected to be consistent in standard (low) rate trickling filters

Section 1.2 - Structure and Function

1.2.1 Discuss the density of RBC media at various stages of a system.

Where heavy growths are anticipated (early stages) low density media is used. Where less growth is expected (later stages) a high density media is used to house as many organisms as possible. High density media should not be used in the early stages because of excess weight on the shafts and bearings. A high density media would not provide enough air space for the high rates of waste stabilization of early stages causing biological growth to clog the media. High density media is usually used on the 3rd & 4th stages and is also associated with a wastewater treatment plant designed for nitrification.

1.2.2 Compare various types of media used in a trickling filtration system.

Plastic media has several advantages it is much lighter than rock requiring less supporting structure. Plastic media offers more surface area per cubic foot of volume which increases the amount of surface area exposed for biologic growth. It also has more void space which helps in air circulation. Synthetic material is more inert and less affected by change in chemical characteristics of the wastewater. The initial cost of plastic media is greater than rock media.

High organic loadings require larger media sizing to increase void spaces. Increased void spaces are necessary to prevent ponding and poor ventilation due to heavy biological growths that develop with the high organic load. Larger sized media provides less surface area.

1.2.3 Explain multi-stage (series) and parallel operation of trickling filters.

In multi-stage (series) operation, the entire flow goes through each filter in a line of trickling filters. In a parallel operation, the flow is split between two or more filters. There may or may not be a settling basin between the filters.

Chapter 2 - Operation and Maintenance

Section 2.1 - Operation

2.1.1 Outline the procedure for start-up of a trickling filter.

A. Check all mechanical equipment (pumps, valves, end gates, and nozzles, etc.) prior to introducing any wastewater flow
B. Open the end gates to flush the arms of any debris
C. Adjust the turnbuckles to level the arms
D. Close the end gates
E. Check for even flow distribution and speed of rotation
F. Check the nozzles to ensure even spray patterns
G. Adjust the recirculation rate to obtain optimum wetting of the filter

2.1.2 Describe the operational problems caused by various dissolved oxygen levels in both trickling filters and RBC's.

1. Trickling filters: the loss of higher form organisms is usually the result of low dissolved oxygen conditions or an influent containing toxic material; if low dissolved oxygen conditions exist the large varieties of filamentous organisms can be expected to replace other organisms; this is due to the filaments' ability to survive under very low dissolved oxygen conditions; in under-loaded filters snails can sometimes become a problem

2. RBC's: the dissolved oxygen levels vary with RBC stages; the lowest level is at the first shaft and the highest at the last shaft; for plants designed for BOD removal only first stage dissolved oxygen should increase from stage to stage with the last stage having a dissolved oxygen level of 1-3 mg/L; a plant designed for nitrification will have first stage dissolved oxygen of 2-3 mg/L and last stage dissolved oxygen in the range of 4-8 mg/L; low dissolved oxygen levels would normally be caused by an organic overload to the RBC discs; if additional RBC trains are available they should be placed in service to reduce the overload; if no additional RBC trains are available an operator would have to consider other options such as increasing the air flow on air driven RBC's or adding supplemental air on mechanical driven units, removing the baffle between the first and second shaft to effectively increase first stage surface area, attempt to step feed primary clarifier effluent to reduce early stage overload, and possibly using recirculation to improve dissolved oxygen; another dissolved oxygen problem could be caused by a sulfide organism known as beggiatoa which appears as a whitish growth on the discs; if the growth covers the majority of disc surface little or no BOD removal will occur causing dissolved oxygen problems; to correct this condition it is necessary to significantly reduce the source of sulfides (including

hydrogen sulfide), sulfates, and sulfur compounds (industrial sources in collection system need to be checked including photo-finishing operations)

2.1.3 List the organic loading of soluble BOD per 1,000 square feet of media for the following:

1. For first RBC stage
2. For overall RBC train
3. When using high density media on later RBC stages

1. For first RBC stage: at average design should not exceed 3.5 pounds of soluble BOD per 1,000 ft^2

2. For overall RBC train: the overall loading should not exceed 1.5 pounds of BOD per 1,000 ft^2

3. Using high density media: this should not be used in the first two shafts and if designed for BOD removal loading should not exceed 2.0 pounds BOD per 1,000 ft^2 for the first high density shaft

2.1.4 Explain the nitirification/denitrification affects on the following:

A. Final clarifier operation
B. Oxygen demand
C. Biochemical oxygen demand
D. Effluent quality

A. Final clarifier operation: denitrification may occur in the final clarifier and cause floating sludge; the free nitrogen gas attaches to the sludge making it buoyant; obvious gas bubbles in the final clarifier also indicate denitrification; frequent sludge pumping to maintain low sludge blankets will minimize this problem.

B. Oxygen demand: additional oxygen is required in order to properly nitrify.

C. Biochemical oxygen demand: effluent BOD levels are affected in the case of partial nitrification; this occurs because nitrification continues to take place in the BOD test bottle during the incubation period producing BOD levels that are higher than normal; if total nitrification has occurred there is no affect on effluent BOD.

D. Effluent quality: improved with nitrification because all or part of the ammonia has been converted to nitrate; ammonia is toxic to fish and aquatic life while nitrate is not; ammonia reacts with chlorine to form chloramines which are toxic; nitrification reduces chlorine demand; the result is less chlorine is required for disinfection and less chemical is required for dechlorination.

2.1.5 State the normal rotational speed of an RBC and describe how to alter the speed of the following:

A. Mechanical drive units
B. Air-driven units

The normal rotational speed of an RBC is 1-2 RPM.

A. Mechanical drive units: speed is altered by changing the size of pulleys and belts

B. Air-driven units: speed is altered by increasing or decreasing the air flow

Changes in the rotational speed affect the media build-up, capacity, and the shearing of the biomass growth. A faster speed allows less build-up as it has more shearing force that increases the sloughing of biomass. Lower speeds can cause uneven growth and excess build-up in some areas of the discs.

2.1.6 Discuss what determines the normal rotational speed of a trickling filter distributor arm.

The normal rotational speed of a trickling filter distributor arm is dependent on the diameter of the filter. Large diameter filters rotate slower because the tip speed increases proportional to the radius squared. This could mean rotational speeds of significantly less than one RPM for large diameter filters and up to 3-5 RPM for very small diameter filters. The importance of the rotational speed is to ensure uniform and frequent wetting of the media surface while not having a tip speed that represents a safety hazard. In most cases manufacturers will have speed limitations based on the equipment especially the size and type of bearings used.

2.1.7 List ways an operator can control the speed of the distributor arm of a trickling filter.

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

2. Change the recirculation rate: increased recirculation causes increased flow and increased arm speed; decreased recirculation results in just the opposite

3. Install speed retarder nozzles: installing nozzles on the opposite side of the distributor arms from normal flow will act as speed retarders to slow the rotation

4. Open the end gates on distributor arms: rotational speed can be reduced by partially opening the end gates on the arms; this should only be considered a temporary solution during high flows as this allows too much wastewater to be directed along the outside of the filter; this causes a reduction in treatment efficiency; a better long-term solution would be to install speed retarder nozzles

2.1.8 Describe the term "filter channeling" in trickling filtration.

Filter channeling occurs when portions of the filter plug and the wastewater flows downward in channels. This is not desirable because the entire filter volume is not being used reducing treatment efficiency. If left uncorrected it may also result in increased odors. Filter channeling may also result from the arms stopping in one place.

2.1.9 Discuss the effects that seasonal temperature changes have on the operation of a trickling filter or an RBC.

A. Trickling filters: In general, all biologic growth is temperature dependent. Colder temperatures slow down the growth of micro-organisms while warmer temperatures increase the growth. Biological activity is dependent on the warmth of the air and the wastewater temperature. Warm air will rise from the underdrain through the media in the winter. Air will filter down into the underdrain system in the summer. Trickling filter temperature problems in Wisconsin may be improved by covering the filter and applying forced air ventilation to the underdrain system. For winter operations, this means conserving as much heat as possible by closing vents on trickling filter covers and covering clarifiers. As temperatures increase, covers should be ventilated to provide additional oxygen. During warm weather, nitrification may occur. If denitrification occurs in the final clarifier, it is possible to have floating sludge. This will require frequent sludge pumping to keep sludge blankets low.

B. RBC: If the primary tank is allowed to fill with sludge there are a number of problems that will occur. If this situation occurs during warm weather, the affects of improper clarifier operation will be worse than during cold weather due to the high level of biological activity. Full treatment can be expected in warm weather in a week to 10 days, with optimum efficiency in 2 to 3 weeks. Cold weather start-up could take up to twice as long, depending on actual wastewater temperatures. Temperature affects ventilation requirements, rate of waste stabilization, and performance of the clarifiers. In winter months, growth will slow down. Operators should close windows and entry doors to prevent freezing and help to maintain heat in the system. Nitrifying organisms seem more adversely affected by cold weather. As the temperature increases, operators should increase the ventilation to avoid odor problems and accumulations of toxic hydrogen sulfide. As waste temperature continues to rise, the operator should take steps to avoid floating solids in the clarifier caused by nitrification (need to pump sludge more frequently). Colder temperatures in all biological treatment systems will cause lower efficiency as micro-organisms slow-down their activity.

The effect on the first stage of the RBC train would be:

1. An organic overload of the shaft due to rapid growth of the biomass; this causes shaft weight overloading and possible damage to the shaft, bearings, or drive units.

2. A reduction in treatment efficiency caused by plugging of the spaces between the discs with organic debris and biologic overgrowth.

3. A possible formation of white sulfide bacteria (beggiatoa) due to the presence of hydrogen sulfide. If the disc becomes overgrown with these organisms, almost no treatment will take place.

4. A lowering of pH would reduce treatment efficiency of the first stage and may inhibit nitrification on later stages.

5. Significant odor problems may occur due to the release of hydrogen sulfide.

6. Organic solids may build-up in the bottom of the RBC tank due to suspended solids carry-over from the clarifier and sloughing from the first stage disc.

2.1.10 List ways to test and improve trickling filter ventilation.

A. Ways to test ventilation:

1. Conduct a smoke test - in general air flow will be upward through the filter in the winter and downward in the summer
2. Inspect the underdrains - they can be visually inspected to ensure that there is adequate space for air flow
3. Check for odors - it may be an indication that there is insufficient ventilation

B. Ways to improve ventilation:

1. Reduce biological growth that may be slowing ventilation by additional recirculation or addition of chlorine (5 mg/L should be sufficient to kill excessive growth)
2. Install forced air ventilation - fans should be operated to circulate air in the same direction as the natural air current; this is not always practical; the most common forced air ventilation is to apply air to the underdrain system forcing the air up and through the filter
3. Remove all ice and debris from the filter surface

2.1.11 List the items to consider when establishing a sludge removal schedule for a secondary clarifier.

1. The frequency of pumping
2. The amount and concentration of sludge
3. The stability of sludge
4. The time of year and temperature
5. The design of clarifier
6. The amount of nitrification occurring in the plant
7. The process to which sludge is to be pumped (primary clarifier, thickener, and anaerobic digester, etc.)

2.1.12 Explain how to determine if secondary sludge should be pumped to a primary clarifier before pumping to a digester.

If a treatment plant does not have a sludge thickener secondary sludges may be pumped back to the primary clarifier for additional thickening. If the final clarifier can produce a reasonable thick sludge (about 3%) it can be pumped directly to the sludge handling units (aerobic or anaerobic digesters) without additional thickening. Final clarifier design rates for surface settling should be 1200 $g/d/ft^2$.

2.1.13 Describe the characteristics of secondary sludge from a trickling filter and an RBC.

A. Trickling filter:

1. Standard rate: trickling filter; black in color; stable (highly oxidized); seasonal sloughing (usually Spring & Fall)
2. High rate: trickling filter; brown in color; tendency to septicity (not fully oxidized); needs more frequent sludge pumping; continuous sloughing

B. RBC's: The sloughed biomass from the RBC discs is collected in the secondary clarifier-

1. Its color is gray-brown
2. Its shape is stringy
3. Density is about 2-3% suspended solids
4. Settleability is moderate
5. Stability is very good
6. BOD is almost completely oxidized and very stable

If mostly nitrified denitrification may occur in the final clarifier if sludge is not removed relatively soon. This could cause floating sludge in the final clarifier.

2.1.14 Discuss clarifier weir overflow rates and how they affect performance.

Weir overflow rates at average design flows would be about 10,000 GPD/ft. If the range is exceeded solids will be carried over the weir due to excessive velocity. Uneven or dirty weirs (plugged) cause short circuiting and higher flow rates over portions of the weirs. This causes solids to be carried over the weirs. Both of these situations would reduce clarifier performance by increasing effluent BOD and suspended solids.

2.1.15 Describe the common ways of recirculating flow through a trickling filter for the following situations:

A. To reduce wastewater organic strength to the filter
B. For increased hydraulic flow to increase sloughing and/or maintain flow rate over filter
C. To reduce detention time in the primary clarifier to prevent odors during low flows
D. To improve the dissolved oxygen level to filter effluent

A. To reduce wastewater organic strength to the filter: secondary clarifier effluent should be recirculated to the inlet of the filter to reduce (dilute) the primary effluent organic loading; the total pounds of BOD is not reduced but the concentration is lower due to the increased hydraulic loading from the final effluent

B. For increased hydraulic flow to increase sloughing and/or maintain flow rate over filter: since only hydraulic loading increase to the filter is needed, recirculation can be directly around the filter, final effluent to the filter inlet, or final effluent to the inlet of the primary clarifier

C. To reduce detention time in the primary clarifier to prevent odors during low flows: to reduce detention time in the primary clarifier, final effluent should be recirculated to the inlet of the primary clarifier; trickling filter effluent could also be recirculated to the inlet of the primary clarifier; this would also increase solids loading to the primary clarifier but it would reduce detention time

D. To improve the dissolved oxygen level of filter effluent: to improve the trickling filter effluent dissolved oxygen, final effluent should be recirculated to the inlet of the trickling filter; this would improve BOD removal and increase dissolved oxygen levels to the final clarifier; generally, any increase in recirculation should enhance BOD removal and increase the dissolved oxygen of the trickling filter effluent

Section 2.2 - Maintenance

2.2.1 List the daily, weekly, monthly, quarterly, and annual activities for maintenance of a trickling filter.

A. Daily:

1. Check the functioning of all operational mechanical equipment
2. Check the electric motors to ensure they are not overheating
3. Check the distributor nozzles
4. Provide filter ventilation as required
5. Check for odors
6. Check for ice formation in winter
7. Observe the filter for any signs of ponding or channeling
8. Perform scheduled maintenance

B. Weekly:

1. Flush the distributor arms
2. Clean/repair nozzles as required
3. Perform scheduled maintenance

C. Monthly:

1. Check the distributor arms to ensure they are level
2. Check the distributor bearings
3. Lubricate bearings per manufacturers specifications
4. Perform scheduled maintenance

D. Quarterly:

1. Adjust the distributor arms for levelness
2. Use protective coatings as needed
3. Perform scheduled maintenance

E. Annually:

1. Lubricate equipment per manufacturers specifications
2. Perform filter cover maintenance as needed
3. Perform general maintenance as needed

2.2.2 List the weekly, monthly, quarterly, and annual activities for maintenance of an RBC unit.

A. Weekly:

1. Check the shaft bearings to ensure they are not running hot
2. Listen for any unusual noises from any bearings
3. Check the drive motors to ensure they are not running hot
4. Check for any oil leaks in the speed reducer
5. Check oil levels per manufacturers specifications
6. Check all drive belts and chains
7. Test load cells if growth appears excessive

B. On air drives:
1. Check the compressor to ensure it is not running hot
2. Check the compressor drive motor to ensure it is not running hot
3. Observe the shaft rotational speed and for even rotation
4. Observe the aeration in all tanks

C. Monthly:
1. Lubricate the shaft bearings per manufacturer's specifications
2. Clean or change the air filters on air drive units per manufacturer's specifications

D. Quarterly:
1. Check the alignment of chain and belt drives
2. Check tightness of the chain and belt drives
3. Adjust the shaft bearings if required
4. Use protective coatings as needed

E. Annually:
1. Change oil or lubricants per manufacturer's specifications
2. Grease the electric motor bearings if appropriate

Chapter 3 - Monitoring, Troubleshooting, and Calculations

Section 3.1 - Monitoring

3.1.1 Compare the following for standard (low) rate, intermediate rate, and high rate trickling filters:

A. Hydraulic loading rates
B. Organic loading rates
C. Recirculation ratios

A. Hydraulic loading rate (MGD/acre):

1. Standard (low) rate: 1 - 4
2. Intermediate rate: 4 -10
3. High rate: 10- 40

B. Organic loading rate (lbs BOD/1,000 ft^2):

1. Standard (low) rate: 5 - 25

2. Intermediate rate: 15 - 30
3. High rate: 25 - 300

Organic loading for design of treatment for domestic wastewater (lbs BOD/1,000 ft^2):

1. Standard (low) rate: 20
2. Intermediate rate: 30
3. High rate: 60

C. Recirculation ratio:

1. Standard (low) rate: little or none
2. Intermediate rate: less than 2:1
3. High rate: 2:1 - 4:1

3.1.2 Define the following tests:

A. Carbonaceous BOD
B. Nitrogenous BOD
C. Inhibited BOD
D. Soluble BOD
E. Ultimate BOD

A. Carbonaceous BOD: a test known as "first stage BOD"; it is the BOD resulting from oxygen demand of only carbonaceous material with no effect from nitrification

B. Nitrogenous BOD: a test that measures that portion of the total BOD attributed to nitrification that has occurred in the BOD bottle during incubation; it is calculated by subtracting the BOD from an inhibited test of the same sample from the total reported BOD

C. Inhibited BOD: a test that has chemical additions to stop any nitrification from occurring during the incubation period; this measures only the carbonaceous BOD

D. Soluble BOD: a test to measure only the BOD from dissolved materials; this is accomplished by filtering the sample prior to setting-up the BOD test; this eliminates any affect on BOD from suspended solids in the sample

E. Ultimate BOD: a long term test that is incubated until almost all of the oxygen demand has been satisfied; this test is only used for special purpose applications like stream modeling where multiple sources discharge to a stream segment

3.1.3 Outline a procedure for sampling soluble BOD and explain its significance in assessing RBC performance.

A. Rinse the fiberglass filter
B. Switch to an empty vacuum flask
C. Pull the sample through the filter
D. Set-up BOD from filtrate

E. Report the 5-day BOD as soluble BOD

Soluble BOD determinations are used to determine organic loading rates for design and operations of RBC units.

3.1.4 Explain the following procedures for testing for ammonia nitrogen:

A. Selective electrode method
B. Nesslerization
C. Titrimetric method

A. Selective electrode method: an ammonia-selective electrode is used to determine ammonia concentrations; a series of standard solutions are used for calibration

B. Nesslerization: this method is a colorimetric method using a spectrophotometer, filter photometer, or nessler tubes; this method requires a preliminary distillation step

C. Titrimetric method: this method requires the preliminary distillation step; titration of the distillate with a sulfuric acid solution until the red indicator turns a pale lavender

3.1.5 Describe sample sites and tests that should be run at each site to monitor a trickling filter plant.

Normal sampling locations for permit requirements would be the plant influent and the final effluent. Tests would routinely be done for BOD, suspended solids, and pH. If ammonia is part of the permit requirements this test would also be run. The influent/effluent sampling can also be used to compute overall treatment plant removal efficiencies. Special sampling for filter efficiency would involve sampling influent and effluent to and from the filter for BOD. The influent filter BOD sample can also be used to determine the total organic loading to the trickling filter.

Section 3.2 - Troubleshooting

3.2.1 Explain the effects of the following on trickling filter and RBC operations.

A. Toxic shock loadings
B. Organic shock loadings
C. Hydraulic shock loadings

A. Toxic shock loading: the discharge of industrial wastes containing heavy metals, organics, high or low pH, chlorine, or other toxic materials could reduce the number of microorganisms in the filter or totally kill all the biologic growth on the media; this will cause a reduction in BOD removal and must be corrected

B. Organic shock loading (high BOD and suspended solids): high loadings of organic materials can cause severe limitations on the primary clarifier and secondary treatment process; high organic suspended solids can overload the primary clarifier causing odor problems and exceed the capability of the sludge handling system; high organic loadings can overload the filter causing oxygen limitations, excessive biologic growth on the media causing filter ponding, odor problems, and excessive solids loading to the final clarifier

C. Hydraulic shock loading: high hydraulic flows can reduce detention times in the clarifiers and could cause excessive sloughing from the filter media; high hydraulic flow is often caused by excessive clear water sources (cooling water, vacuum pan evaporators, and poor industrial practices, etc.) which lowers (dilutes) the influent wastewater strength; correction could be by removing clear water flows at the source and connecting them to storm drainage facilities; good water conservation practices at the industrial source can significantly reduce such flows; high hydraulic flows from inflow and infiltration will reduce the effective detention time for all treatment unit processes; on the RBC discs this will reduce the time the microorganisms have to stabilize the organic matter in the waste stream; this could reduce the biomass on the early stages and could reduce the effectiveness of the nitrifiers on the later stages

3.2.2 List the effects industrial discharge may have on RBC treatment efficiency and give corrective steps to reduce their impact.

1. Cause: organic overloads (poor overall treatment)
Correction: place more RBC tanks on line; increase or add aeration; step feed or remove baffles; flow equalization at plant or source; pretreat wastewater at the source; assess high sewer service charges for overloads

2. Cause: toxic shock loads (strips biomass from media stopping treatment)
Correction: by-pass RBC trains (need advance warning); pretreat wastewater at the source; eliminate toxic at source for separate handling; (do not allow toxics to become part of the wastewater flow)

3. Cause: hydraulic overload (clear water sources)
Correction: work within the collection system to eliminate sources of clear water (cooling water, rain water, etc) and connect them to storm sewers

4. Cause: oils and grease
Correction: pretreat at the source with oil/grease separators and traps

5. Cause: other (inorganic solids, floating materials, and pH problems, etc.)
Correction: pretreat at the source to minimize materials of this type

3.2.3 List some reasons that would cause a trickling filter four-arm distributor not to turn.

1. The flow is too low for the number of nozzles
2. The bearing has malfunctioned or failed completely
3. The arm end gates are open
4. The nozzles may be plugged with debris
5. On a motor driven unit it could be loss of electrical power or a failed electric motor

3.2.4 Explain why an RBC plant might experience a sudden increase in chlorine residual without increasing the chlorine feed.

This situation would be caused by the plant achieving complete nitrification which reduces chlorine demand and increased chlorine residual. The reason for the reduced chlorine demand is that ammonia nitrogen has a chlorine demand (forms chloramines) while nitrate nitrogen has no chlorine demand. This can occur at RBC plants designed just for BOD removal during the period they are under-loaded or at RBC plants designed for nitrification.

3.2.5 Describe the possible causes and corrective actions to be taken for the following problems in a trickling filter:

A. Poor BOD removal efficiency
B. Failure to meet ammonia limits
C. Poor suspended solids removal efficiency

A. Poor BOD removal efficiency:
Cause -
1. An organic overload to the filter clarifiers
2. Short circuiting occurring in the clarifiers
3. Toxic loadings impairing microorganisms

Correction -
1. Place more units on-line (if available); reduce overload by flow equalization, or pretreatment at the source
2. Level or clean the clarifier weirs to correct the short circuiting problem; add additional baffles if needed
3. Correct the source of toxic loadings by eliminating or pretreating flows at the source

B. Failure to meet ammonia limits:
Cause -
1. Inadequate dissolved oxygen levels
2. Temperatures are too low
3. Toxics are inhibiting nitrifying organisms

Correction -
1. Increase the dissolved oxygen levels by reducing organic loading (place more filters in service) and increase the filter ventilation
2. Take measures to conserve wastewater temperature by covering the filter and clarifiers
3. Correct the source of toxic loadings by eliminating or pretreating flows at the source

C. Poor suspended solids removal efficiency:
Cause -
1. Poor operations of the clarifier (poor sludge pumping practices, short circuiting, or broken equipment)
2. Organic overload to the treatment plant
3. Hydraulic overload to the final clarifier

Correction -
1. Correct sludge pumping practices, correct short circuiting, and repair equipment

2. Reduce the organic loading to the clarifier by placing more clarifiers on line or consider addition of chemical coagulant aids to improve settling
3. Place more clarifiers on line or reduce the recirculation ratio to increase detention time

3.2.6 Describe the possible causes and corrective actions to be taken for the following problems in an RBC unit:

A. White growth covering most of the first stage
B. Failure to meet ammonia limits
C. Excessive load weights on shafts

A. White growth covering most of first stage:

1. Cause: sulfur bacteria (beggiatoa) has taken over; this has been caused by sulfur compounds (hydrogen sulfide, sulfates, or other sulfur sources); it can also be caused by organic overload which reduces dissolved oxygen under the first shaft and this bacteria can function better in this environment than the more desirable organisms; if the entire shaft is covered almost no first stage BOD reduction will occur

Correction: possible corrections for this situation would include: adding more RBC trains (if available), increase the air to the discs (if air driven), consider supplemental air (if mechanical driven), reduce organic overload (if possible), reduce sources of sulfur compounds, pre-aerate or add chlorine in the wet well to eliminate hydrogen sulfide, chlorinate RBC influent at low concentrations, and consider removal of baffle between the first and second shafts to increase first stage surface area

B. Failure to meet ammonia limits:

1. Cause: the nitrification bacteria on the latter stages are not converting ammonia to nitrate; this could be caused by low dissolved oxygen or a reduction in detention time; the low dissolved oxygen could be caused by an organic overload and the reduced detention time could be caused by a hydraulic overload; nitrifying bacteria need adequate dissolved oxygen and sufficient time to convert the ammonia to nitrate; since nitrifiers are also temperature dependent this may be caused by a significant drop in the wastewater temperature

Correction: check dissolved oxygen levels along the entire train, determine hydraulic flows to compute the detention times, and check temperatures of the wastewater along the RBC train; depending on the causes it will be necessary to increase dissolved oxygen levels (adding additional air or reducing organic loading), increase detention times(reducing hydraulic loading rate), or increase temperature (closing ventilation doors or other energy conservation measures covering the primary clarifier to conserve heat); the hydraulic and organic overload can be reduced by placing additional RBC trains in service if they are available

C. Excessive load weights on shafts:

1. Cause: organic loading is too high; stage loading is too high; shaft speed is too low; organic solid accumulation because of inadequate pre-treatment; accumulation of mineral deposits on the media; digester supernatant is adding excessive BOD or sulfides

Correction: the first effort should be to reduce the organic overload by placing additional RBC trains in service (if available), improving primary treatment, reducing or improving sidestream quality, increase air or add supplemental air, and consider removal of baffle between the first and second shafts to effectively increase first stage surface area; the second effort would be to decrease the biomass on the shaft by increasing rotational speed to increase shearing forces and sloughing using a high pressure hose directed at the media to reduce biomass and considering chlorination at low concentrations to remove excess disc growth

3.2.7 List some reasons why a clarifier can experience a build-up of sludge even through adequate sludge pumping time is being provided.

1. Broken scrapers or inoperative sludge collection equipment
2. Coning or bridging
3. Improper design

A sludge filled primary clarifier would cause the following:

A. Anaerobic (septic) conditions would develop causing formation of hydrogen sulfide
B. High levels of suspended solids would discharge from the clarifier (including larger suspended material)
C. Much higher levels of soluble BOD would discharge from the clarifier
D. Anaerobic conditions would cause a drop in clarifier pH

Inadequate sludge removal with adequate pumping time could be caused by broken or inoperative sludge collection mechanisms. It could also be caused by the improper alignment and adjustment of the sludge collection system. It might also be caused by an improper or poorly designed clarifier. Too high a pumping rate could cause coning or bridging which would prevent adequate sludge removal.

3.2.8 Describe the potential chain of events if secondary clarifier sludge pumping rates are consistently:

A. Too low
B. Too high

A. Too low: At this pumping rate solids would tend to accumulate in the clarifier causing anaerobic conditions, gas formation, black floating sludge, and high secondary effluent BOD. If the secondary sludge is pumped back to the primary clarifier for further thickening this anaerobic material can significantly affect primary effluent and loading to the trickling filter (low or no dissolved oxygen, increased soluble BOD loading, and increased suspended solids loading). If the secondary sludge is pumped to dewatering equipment it can be expected that it will dewater poorly. The return sidestream can adversely affect loading to the primary clarifier and the trickling filter.

B. Too high: At this pumping rate the sludge will be thin (low percentage solids). If the sludge is pumped back to the primary clarifier, the excess water can cause a hydraulic overload to the primary clarifier, reducing its detention time, and performance. If the sludge is pumped to an anaerobic digester, it can cause problems of hydraulic digester overload, excessive heating costs, possible digester upset, and excessive supernatant return flows to the primary clarifier (which can affect primary treatment performance). If it is pumped to dewatering equipment, the solids handling system can be overloaded, it will require additional chemicals, and would produce excessive sidestream flows returned to the head of the treatment plant. If the pumping rate was extremely high it could also cause coning which could result in anaerobic conditions as with a low pumping rate.

3.2.9 Suggest corrective actions for the following causes of low DO in an RBC unit:

A. Influent wastewater causing an organic overload
B. In-plant sidestreams causing an organic overload
C. Primary clarifier causing an organic overload

A. Cause: influent wastewater causing organic overload

Correction: the in-plant correction would be to place additional RBC trains on line (if available); in many instances this is not a possible alternative and the source of the organic overload in the collection system must be determined and appropriate pretreatment provided; many times this is caused by an industrial source discharging high-strength organic loads that were not planned for in the original design

B. Cause: in-plant sidestreams causing organic overloads

Correction: in-plant sidestreams, such as anaerobic digester supernatant, aerobic digester decant, final filtration backwash, or sludge processing return flows can add significant organic overloads if those units are not properly operated; to correct this situation all units providing sidestream returns must be properly operated to minimize impact of these return flows; another method of reducing the impact of return sidestreams would be to provide flow equalization to spread the load out over a longer time period

C. Cause: poor operation of primary clarifier causing organic overload

Correction: this situation would normally be caused by inadequate sludge pumping that would cause anaerobic conditions in the primary clarifier, an increase loading to the RBC shafts of both BOD and solids, or no dissolved oxygen from the primary clarifier effluent; to correct this the operator needs to adequately pump sludge to prevent anaerobic conditions from developing in the clarifier

Section 3.3 - Calculations

3.3.1 Given data, calculate the percent removal of BOD and suspended solids from an RBC plant.

Given:

Influent BOD = 180 mg/L
Influent suspended solids = 200 mg/L
Final effluent BOD = 15 mg/L
Final effluent suspended solids = 20 mg/L

Formula:

percent removal = (concentration (in) - concentration (out)) ÷ concentration (in) x 100

% removal BOD = (180 - 15) ÷ 180 x 100 = 91.7%

% removal SS = (200 - 20) ÷ 200 x 100 = 90.0%

3.3.2 Given data, calculate a recirculation ratio.

Given:
Recirculation flow rate = 300 GPM
Average influent flow rate = 0.18 MGD

Formula:

recirculation ratio = recirculation flow rate ÷ influent flow rate

recirculation ratio = 300 ÷ (180,000 ÷ 1,440) = 2.4:1

3.3.3 Given data, calculate average detention time for a clarifier.

Given:
Clarifier = 50 feet in diameter
Depth = 10 feet
Flow = 1 MGD

Formula:

detention time = tank volume ÷ flow rate

tank volume = 3.14 r^2 D

tank volume = 3.14 x 25^2 x 10 = 19,625 ft^3

detention = (tank volume (ft^3) x 7.5 (gal/ft^3) x 24 hours) ÷ flow (GPD)

detention = (19,625 x 7.5 x 24) ÷ 1,000,000

= 3.53 or 3.5 hours

3.3.4 Given data, calculate the maximum loading and determine how many RBC trains should be in operation.

Given:
Four train RBC plant
Each train has four shafts
All shafts have 100,000 square feet of media
First shaft loading = 3.5 pounds of soluble BOD per 1,000 square feet (max.)
Total train loading = 1.5 pounds of soluble BOD per 1,000 square feet (max.)
Average daily plant flow = 1.5 MGD
Primary effluent soluble BOD = 80 mg/L

In order to determine the number of trains to be placed in service both the first stage loading and the total stage loading must be evaluated.

Formula:

maximum loading = (shaft loading x surface area) ÷ 1000

pounds = flow (MGD) x concentration (mg/L) x 8.34 lbs./MG x 1 L/mg

shaft/trains required = pounds to RBC unit ÷ max. pounds to shafts/trains

max. first shaft loading = (3.5 x 100,000) ÷ 1,000

= 350 pounds of soluble BOD

max. train loading = (1.5 x 100,000 x 4 (trains)) ÷ 1,000

= 600 lbs. of soluble BOD

pounds of soluble BOD to RBC unit = 1.5 x 80 x 8.34 x 1

= 1,000 lbs. soluble BOD

first shafts required = 1,000 ÷ 350

= 2.85

total trains required = 1,000 ÷ 600

= 1.67

Operate 3 of the 4 trains at the flow rate as a minimum.

3.3.5 Given data, calculate the feed rate of chlorine for an RBC in pounds per day.

The amount of chlorine required to totally strip growth from RBC shafts is dependent on the total biomass to be removed and the chlorine demand of the primary effluent. For this objective a chlorine dosage is suggested to reduce growth on the shafts.

Given:
Average daily flow = 0.40 MGD
Desired dosage of chlorine = 15 mg/L

Formula:

pounds = flow (MGD) x concentration (mg/L) x 8.34

pounds = 0.40 x 15 x 8.34

= 50 pounds per day

3.3.6 Given data, calculate the surface settling rate of a circular clarifier.

Given:
Clarifier (circular) = 50 feet in diameter
Flow rate = 1 MGD

Formula:

surface area = 3.14 x r^2

surface area = 3.14 x 25 x 25 = 1,963 ft^2

surface settling rate = flow (GPD) ÷ surface area ft^2

surface settling rate = 1,000,000 ÷ 1,963

= 509.4 GPD/ft^2

3.3.7 Given flow and weir length, calculate the weir overflow rate.

Given:
Circular clarifier = 50 feet in diameter
Flow rate = 1 MGD

Formula:

length of weir = 2 x 3.14 x r

length of weir = 2 x 3.14 x 25

= 157 feet

overflow rate = flow (GPD) ÷ weir length (ft)

overflow rate = 1,000,000 ÷ 157

= 6,370 GPD/ft.

3.3.8 Given data, calculate the organic loading rate to a trickling filter.

Given:
Primary clarifier effluent = 125 mg/L
Flow = 1.4 MGD
Filter size = 70 feet in diameter, 8 feet deep

Formula:

organic loading rate (pounds/day/1,000 ft^3) = (flow (mg) x concentration (mg/L) x 8.34) ÷ volume of the filter media

organic loading rate = (1.4 x 125 x 8.34) ÷ (35 x 35 x 3.14 x 8 ÷ 1,000)

organic loading rate = 1,459.5 ÷ (30,772 ÷ 1,000)

organic loading rate = 1,459.5 ÷ 30.772

= 47.4 pounds of BOD per day/1,000ft^3

3.3.9 Given data, calculate how much of the flow (percentage) should go to each of two trickling filters operating in parallel.

Given:
2 trickling filters, one 80 feet in diameter and one 120 feet in diameter; assume same depth

Formula: Flow rate is proportional to surface area or volume if the filters are of different depth.

area of filter = 3.14 x r^2

area of filter one = 3.14 x 40^2 = 5,024 ft^2

area of filter two = 3.14 x 60^2 = 11,304 ft^2

total area = 5,024 + 11,304 = 16,328 ft^2

percent of flow to filter one = area (filter one) ÷ total area x 100

percent of flow to filter one = 5,024 ÷ 16,328 x 100 = 30.8%

percent of flow to filter two = 11,304 ÷ 16,328 x 100 = 69.2%

3.3.10 Given data, calculate the hydraulic loading in gallons per day per square foot to a trickling filter.

Given:
Filter size = 80 feet in diameter
Flow rate = 1,000,000 GPD

Formula:

Note: This rate can be expressed in GPD/ft² or GPD/acre.

area of the filter = $3.14 \times r^2$

$= 3.14 \times 40^2$

$= 5{,}024$ ft²

hydraulic loading rate = flow (GPD) ÷ area ft²

hydraulic loading rate = 1,000,000 ÷ 5,024

= 199 GPD/ft²

3.3.11 Given data, calculate the organic pound loading of BOD and suspended solids to a trickling filter.

Given:
Gallons of wastewater = 5,000
BOD = 4,000 mg/L
Percent solids = .5%

Formula:

pounds BOD or solids = flow (mg) x concentration (mg/L) x 8.34

Or

pounds solids = (% solids x flow (mg/L) x 8.34) ÷ 100

= (.5 x 4,000 x 8.34) ÷ 100

= 167 pounds of BOD

3.3.12 Given data, calculate the pounds of BOD per day of recirculation loading.

Given:
Recirculation rate = 0.50 MGD
BOD of recirculation = 75 mg/L

Formula:

pounds per day = flow (MGD) x concentration (mg/L) x 8.34

pounds per day = 0.50 x 75 x 8.34

= 313 pounds of BOD

References and Resources

1. **CONTROLLING WASTEWATER TREATMENT PROCESSES.**

   (1984). Cortinovis, Dan. Ridgeline Press, 1136 Orchard Road, Lafayette, CA 94549.

2. **OPERATION OF MUNICIPAL WASTEWATER TREATMENT PLANTS.**

   Manual of Practice No. 11 (MOP 11), 2nd Edition (1990), Volumes I, II , and III. Water Environment Federation (Old WPCF), 601 Wythe Street, Alexandria, VA 22314-1994. Phone (800) 666-0206.

   http://www.owp.csus.edu/training/

3. **OPERATION OF WASTEWATER TREATMENT PLANTS.**

   3rd Edition (1990), Volumes 1 and 2, Kenneth D. Kerri, California State University, 6000 J Street, Sacramento, CA 95819-6025. Phone (916) 278-6142.

   http://www.owp.csus.edu/training/

4. **OPERATION OF WASTEWATER TREATMENT PLANTS.**

   Manual of Practice No. 11 (MOP 11) (1976). Water Pollution Control Federation, 601 Wythe Street, Alexandria, VA 22314-1994. Phone (800) 666-0206. (Probably Out-of-Print, See Reference Number 2)

   http://www.wef.org/