Wastewater Treatment Plant Operator Certification Training

Module 21: Rotating Biological Contactors

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Unit 1 – General Overview

Learning Objectives

- Describe the principles of an attached growth biological treatment system and describe how a Rotating Biological Contactor operates.
- Identify the five major components of an RBC and explain their functions.
- Discuss the advantages and disadvantages of using an RBC for wastewater treatment.
- Describe the concept of staging and how it relates to efficient RBC operation.
- Calculate the treatment removal efficiencies for an RBC.

During the 1960's, Rotating Biological Contactors (RBCs) gained popularity as a biological treatment process alternative to Trickling Filters. New developments in plastic media material, as well as smaller energy requirements compared to activated sludge processes, led to the construction of numerous RBC plants during the 1970s.

Process Description

A **Rotating Biolgoical Contactor (RBC),** is a **secondary biological treatment process** which utilizes a rotating shaft surrounded by plastic media discs.

RBCs utilize a fixed film media system similar to a trickling filter. The microbial growth is passed through the wastewater, however, while the wastewater is passed through the microbial growth in a trickling filter. Biological growth attaches to the media discs and form a slime layer over the discs. This slime layer of bacteria and microorganisms is also known as zoogleal film.

- The rotation of the shaft alternately exposes the biomass with the wastewater and then with the oxygen in the atmosphere.
- RBCs are typically preceded by preliminary treatment processes such as screening and grit removal as well as primary treatment such as primary settling.
- RBCs are typically followed by secondary settling tanks and disinfection.
- Sludge from the secondary/final settling tanks should be pumped back to the primary clarifier or to a sludge thickener for further treatment.

Figure 1.1 Rotating Biological Contactors[1]

Physical Description

Media

Biological Slime Growth/Zoogleal Film

A biological slime or 'zoogleal film' grows on the media which contains the bacteria and microorganisms which supply treatment of the wastewater.

- This process is very similar to a trickling filter. The biological slime growth develops from the bacteria and microorganisms present in the wastewater.

- Typically, a layer 1/16 to 1/8 inch of biological slime grows attached to media discs. Media is composed of high density plastic circular discs or sheets usually 12 feet in diameter. Spacing between sheets provides space for distribution of wastewater and air. Corrugations increase the available surface area and enhance structural stability.

Rotation of Media

- The media is rotated on a shaft into the wastewater, then into the atmosphere to provide oxygen.

- Together, the media and the shaft are referred to as the drum. The drum rotates about 1.5 revolutions per minute (rpm) by either a mechanical or compressed air drive. Approximately 40% of media surface is immersed in the wastewater at any given moment.

Appearance of Media

- A gray, shaggy appearing biological slime is indicative of a system designed strictly for BOD removal. A brown, thinner, less shaggy biological slime is indicative of a nitrifying system.

- A significantly white appearing zoogleal film is indicative of high organic loading. A black appearing biomass may also be indicative of high organic loading but is usually accompanied by odors and low DO in the plant effluent.

Sloughing

Sloughing is the term used to refer to the process in which excess microbrial growth separates from the media and is washed to the secondary clarifiers with the treated wastewater.

- The excess slime will settle out in the secondary clarifiers and be removed from the system.

- Natural biological sloughing will occur from any fixed film reactor. It is a normal consequence of media growth.

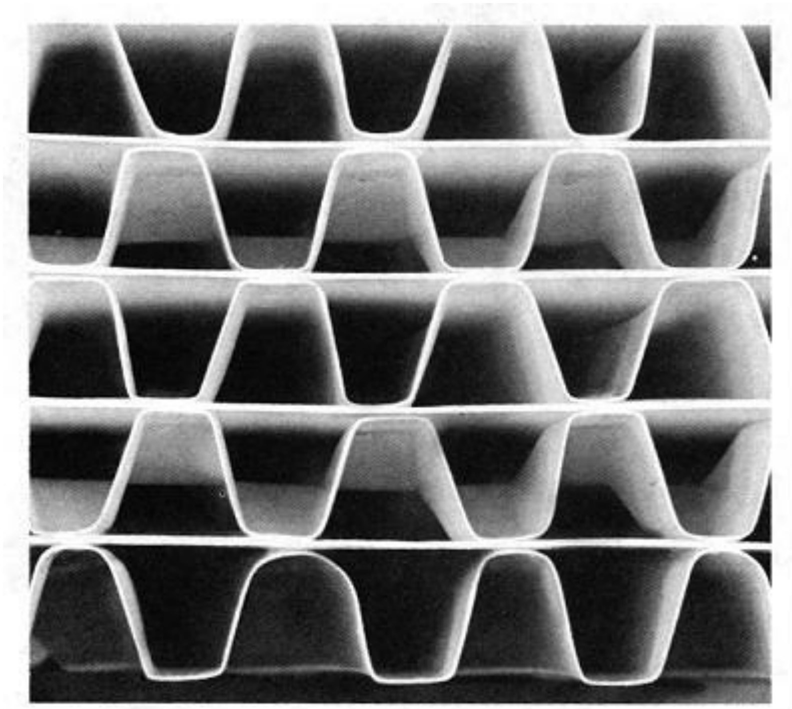

Figure 1.2 Media Cross Section[2]

Figure 1.3 Media Through the Door of the RBC Cover[3]

Shaft

- The shaft supports and rotates the media when mechanical drives are utilized for rotation of the "drum." It simply supports the media when air drives are utilized for rotation of the "drum."

- The typical maximum length is 27 feet long with a maximum of 25 feet occupied by media.

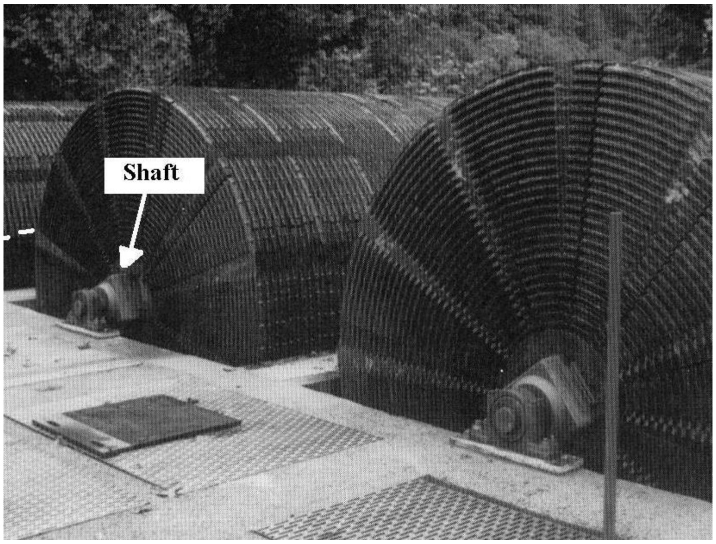

Figure 1.4 The Shaft[4]

Drive Assembly

There are two types of drive assemblies: mechanical drives and air drives.

- ♦ A mechanical drive is attached directly to the shaft and is the type of drive that is used most often.
- ♦ An air drive consists of deep plastic cups attached to the perimeter of the media, an air header located beneath the media and an air compressor. The release of air into the cups creates a buoyant force that causes the shaft to turn.

Typically, variable rotational speeds should be provided to control media growth. Rotation is important for several reasons:

- ♦ Consistent rotational speed must be maintained to achieve uniform media growth.
- ♦ Uneven media growth can lead to an unbalanced RBC, which increases torque loads on the shaft and drive of mechanical drives and results in uneven shaft rotation of air drives. This uneven shaft rotation is referred to as loping.
- ♦ Rotation affects oxygen transfer and maintains an aerobic environment for the biomass on the media.
- ♦ Rotation is used as a means of removing excess solids by shearing forces (hydraulically scoured).

Reactor Basin

- ♦ The reactor basin is the physical tank that contains the media, shaft and drive assembly (covered by a cover), through which the wastewater flows.

Cover

- Covers are made of fiberglass for durability and lightweight handling. Typically, they conform to the general shape of the media and provide appropriate ventilation or removal during warm weather operation.
- An RBC is generally covered because of climate condition reasons. The cover protects the slime from freezing and it also prevents rain from washing the slime away from the media.
- The cover prevents exposure to sunlight, which prevents growth and buildup of algae and deterioration of the plastic media due to ultraviolet light.
- The cover also provides protection for operators from sun, rain, snow and wind while performing maintenance.

Figure 1.5 An RBC Cover[5]

Rotating Biological Contactors offer several advantages over trickling filters. These advantages include:

- The elimination of the rotating distributor. Since there are less mechanical components, less money and time is required for proper upkeep.

- The elimination of ponding on the media. Increased flows do not create a ponding bottleneck as happens in tricking filters. The flow passes through the media.

Ponding is the term used to describe what happens when water collects and accumulates on a surface to the point where it creates large puddles, or ponds.

- More uniform rotation of the media. Drives offer better control of rotation as compared to the hydraulic push of a trickling filter.

- Lack of anaerobic conditions. Since the media biofilm is constantly exposed to atmospheric air during the rotation of the drum, anaerobic conditions are typically not a concern.

- Saves space within a wastewater treatment plant. Due to the rectangular configuration of RBC basins, one unit can be located close to or possibly against another RBC unit. This may not be possible for circular shaped trickling filters.

- Reduces the problem with nuisance filter fly populations through the use of a cover. The cover also minimizes the loss of heat in the winter.

- A trickling filter requires either in-plant pumping or a steep hydraulic grade line so the wastewater can pass through each treatment unit; however, a RBC may not require inter-unit pumping for the forward flow. This can be important if a wastewater treatment plant is being upgraded and minimal head loss is required.

There are a few limitations are associated with operating a Rotating Biological Contactor:

Lack of Flexibility

- Lack of flexibility becomes a problem because of the absence of provisions for recirculation. Recirculation of secondary clarifier effluent is necessary to maintain constant flow through the RBC to keep the biofilm submerged for a sufficient period of time.

Sensitivity to Industrial Wastes

- Since all microorganisms used for stabilizing the waste, known as the biomass, are attached to the media in the RBC, incoming wastewater that contains a toxic substance can potentially wipe out the entire biological population when it enters the RBC.

- Other treatment processes, such as the activated sludge process, constantly re-circulate the biomass into the contact tank. Since only a portion of the total biomass is ever in contact with the incoming waste stream at any given time, a toxic substance would only affect a portion of the biomass population.

Possible Low Dissolved Oxygen

Possible low dissolved oxygen due to high organic loadings.

- Dissolved oxygen is provided to the micro-organisms in the media when the media is rotated out of the waste stream and into the atmosphere.

- Dissolved oxygen transfer efficiency thorough this type of system is not especially efficient.

- If needed due to high organic loadings, additional dissolved oxygen can not easily be provided to the microorganisms.

Orientation

Rotating Biological Contactors can be oriented in two ways: series or parallel.

Series contain two or more basins (also called cells) that are connected, with one directly following the next.

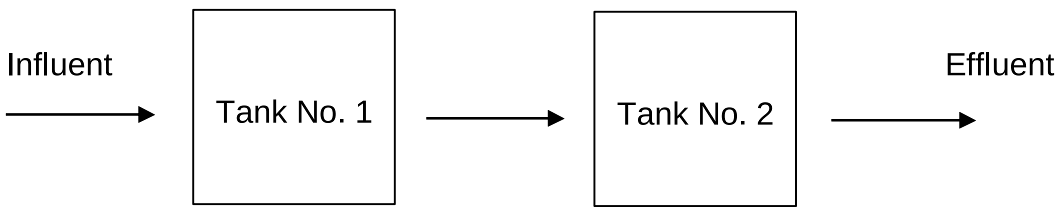

Figure 1.6 Series Orientation of Tanks

Parallel contain two or more basins (also called cells) that are operated side by side. One basin can be removed from service without disruption of treatment in the other basin(s).

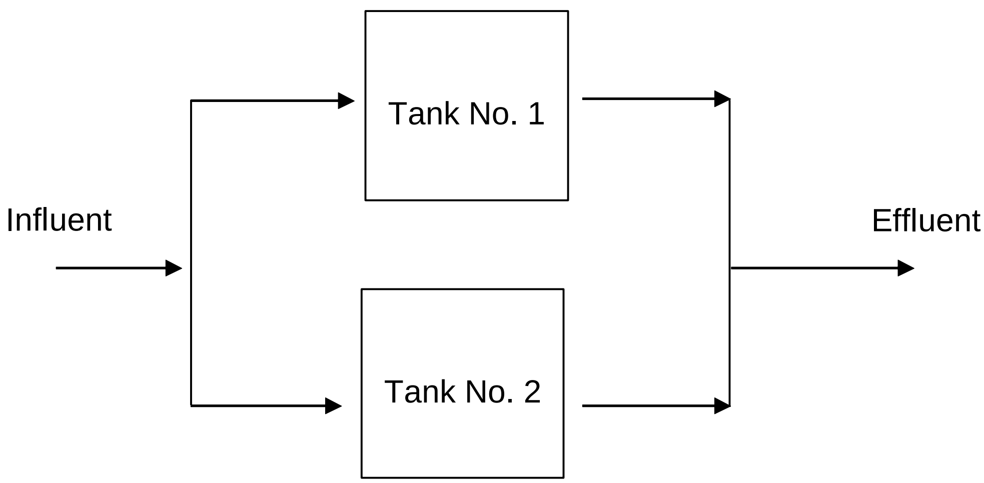

Figure 1.7 Parallel Orientations of Tanks

- For the most efficient operation, the Department of Environmental Protection (DEP) *Facilities Manual* recommends that an optimal system should contain at least three cells and should be designed to operate in both series and parallel. It is more efficient to operate with three or four stages or cells rather than two. Designing the cells to operate in series or parallel provides the Treatment Plant Operator with more flexible operating options.

Staging

- ♦ Dividing the total treatment area into distinct tanks helps maximize BOD and ammonia removals.

- ♦ The RBC process is typically divided into four separate stages.
  - Each stage is composed of a separate section of media.
  - Each stage can either have independent shafts or a common shared shaft. Plants with four or more stages are typically run with independent shafts with the flow perpendicular to shafts. Plants with less than four stages are typically run with one common shaft with the flow parallel to the shaft.
  - Stages are separated by either a baffle or a wall.
  - Each stage acts as an independent complete mix chamber.

- ♦ Staging maximizes the effectiveness of the media surface area.

- ♦ Design organic loading should be less than 6.4 lbs total BOD per 1,000 sq ft per stage.

- ♦ Typically, BOD removal efficiency is highest in the first stage and decreases through the remaining stages.

- ♦ As BOD concentrations decrease through the stages, nitrification begins.

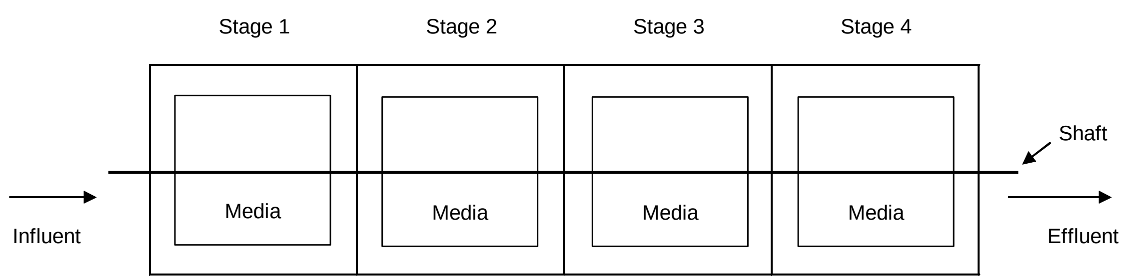

Figure 1.8 Four Stages with One Shaft and Flow Parallel to the Shaft

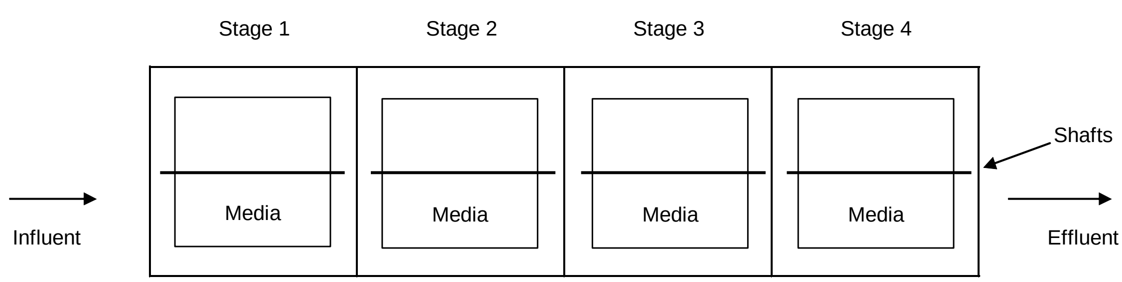

Figure 1.9 Four Stages with Four Shafts and Flow Parallel to the Shaft

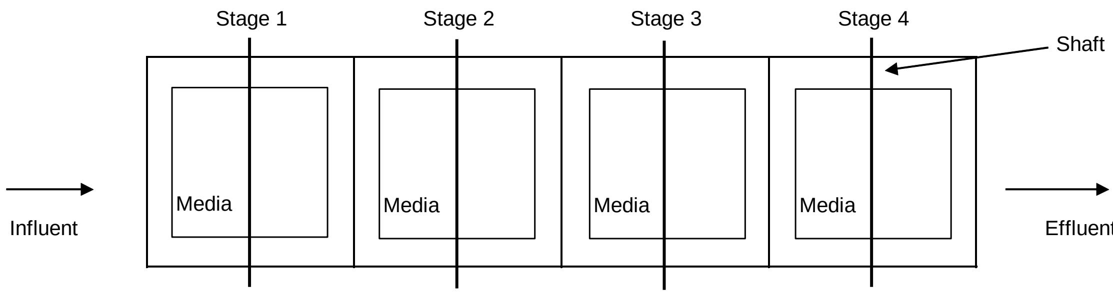

Figure 1.10 Four Stages with Four Shafts and Flow Perpendicular to Shaft

Typical Treatment Efficiencies

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is the rate at which micro-organisms use the dissolved oxygen in the wastewater while stabilizing, or breaking down, decomposable organic matter. In decomposition, the organic matter serves as food for the bacteria. BOD measurements are used as a measure of the organic strength of wastes in the water. Wastewater treatment plants are designed to remove BOD from wastewater.

- Systems are typically designed to reduce total BOD to approximately 15 to 30 mg/L.

Total Suspended Solids (TSS)

The **total solids (TS)** are the particulate matter, or solids, found in wastewater and is composed of Total Suspended Solids and Total Dissolved Solids.

Total Disolved Solids (TDS) are smaller particles which can not be removed through filtration.

Total Suspended Solids (TSS) are the larger particles which are either suspended in solution or slowly settle to the bottom. Wastewater treatment plants are designed to remove TSS from wastewater. After all, a major component of wastewater is fecal matter.

- Systems are typically designed to reduce TSS to approximately 20 to 40 mg/L.

Ammonia Nitrogen (NH_3-N)

Ammonia nitrogen is a form of nitrogen, which is a nutrient necessary for both plant and animal life. The Nitrogen Cycle is the natural conversion of nitrogen from one form to another through various biological processes.

- Large concentrations of ammonia create a large oxygen demand due to the conversion of ammonia to nitrate (NO_3) by nitrifying bacteria. Wastewater treatment plants are designed to remove NH_3 from wastewater.
- Nitrification possible if sufficient detention time is created.
- It is possible to achieve ammonia reduction to > 2 mg/L.

Percent Removal Calculations

BOD, TSS, and NH_3 are all pollutants which are present in large concentrations in the influent wastewater coming into a treatment plant. Through the treatment process, the concentrations of BOD, TSS and NH_3 are reduced.

The **Percent Removal Calculation (aka treatment efficiency)** is used to determine the percentage of the incoming concentration of a particular pollutant (BOD, TSS or NH_3) which was removed through the treatment process. It is calculated as follows:

$$\text{Percent Removal (\%)} = \frac{\text{(Influent Concentration, mg/L)} - \text{(Effluent Concentration, mg/L)}}{\text{(Influent Concentration, mg/L)}} \times 100$$

Example

Influent Total Nitrogen = 25 mg/L
Effluent Total Nitrogen = 5 mg/L

$$\text{Percent Removal (\%)} = \frac{\text{(Influent Concentration, mg/L)} - \text{(Effluent Concentration, mg/L)}}{\text{(Influent Concentration, mg/L)}} \times 100$$

$$\text{Percent Removal (\%)} = \frac{(25\text{ mg/L}) - (5\text{ mg/L})}{25\text{ mg/L}} \times 100$$

Percent Removal (%) = **80%**

Key Points for Unit 1 – General Overview

- A Rotating Biolgoical Contactor (RBC), is a secondary biological treatment process which utilizes a fixed film media system similar to a trickling filter.
- Together, the media and the shaft are referred to as the drum. The drum rotates about 1.5 revolutions per minute (rpm) by either a mechanical or compressed air drive. Approximately 40% of media surface is immersed in the wastewater at any given moment.
- A gray, shaggy appearing biological slime is indicative of a system designed strictly for BOD removal. A brown, thinner, less shaggy biological slime is indicative of a nitrifying system.
- A significantly white appearing zoogleal film is indicative of high organic loading.
- Sloughing is the term used to refer to the process in which excess microbial growth separates from the media and is washed to the secondary clarifiers with the treated wastewater
- There are two types of drive assemblies: mechanical drives and air drives.
- An RBC is generally covered because of climate condition reasons.
- Disadvantages of RBC's include lack of flexibility, sensitivity to industrial waste and possible low DO.
- Rotating Biological Contactors can be oriented in two ways: series or parallel and typically preceded by preliminary treatment processes such as screening and grit removal as well as primary treatment such as primary settling and are usually followed by sedimentation and disinfection.
- Dividing the total treatment area into distinct tanks helps maximize BOD and ammonia removals and therefore the RBC process is typically divided into four separate stages.
- RBC systems are typically designed to reduce total BOD to approximately 15 to 30 mg/L., TSS to approximately 20 to 40 mg/L and to achieve ammonia reduction to > 2 mg/L.

Exercise for Unit 1.

1. Given the following information, calculate the percent removal:
   Influent Total Suspended Solids = 200 mg/L
   Effluent Total Suspended Solids = 19 mg/L.

2. The two types of RBC drive mechanisms are _______________ and __________ drives.

3. In a RBC, the drum rotates at approximately _________ RPM and about __________ % of the media surface is immersed in the wastewater.

4. ____________ is the term used to describe uneven shaft rotation.

5. RBCs are typically designed to reduce total BOD to about _______ to _______ mg/L.

6. A Rotating Biolgoical Contactor (RBC) is a __________ __________ treatment process which utilizes a rotating shaft surrounded by plastic media discs.

7. RBCs utilize a fixed film media system similar to a _________ ______.

8. _________ is the term used to refer to the process in which excess microbial growth separates from the media and is washed to the secondary clarifiers with the treated wastewater

[1] Richard Wick, "Rotating Biological Contactors," in *Operation of Wastewater Treatment Plants*, Vol. I, (Sacramento, CA: California State University, Sacramento Foundation, 2001), p. 216.

[2] Wick, p. 218.

[3] Courtesy of Arrowhead Sewer Company, Inc., Arrowhead Lake, PA.

[4] Wick, p. 216.

[5] Courtesy of Arrowhead Sewer Company, Inc., Arrowhead Lake, PA.

Unit 2 – General Operation and Maintenance

Learning Objectives

- List the three types of general factors affecting RBC operation and list two examples of each.
- Calculate the organic loading rate of an RBC.
- Discuss the cause and significance of *Beggiattoa* as it relates to the RBC media biomass.
- Describe how media rotation, speed and media imbalance affects RBC operation.
- Explain the importance of evaluating analysis results for efficient RBC operation.

The primary factors affecting performance of a RBC can be divided into three categories: physical, biochemical and microbiological factors.

Physical Factors

Hydraulic Loading

Hydraulic loading is defined as the flow, in gallons per day, of wastewater introduced into a RBC per square foot of surface area (gpd/ft^2).

- Increased influent flows lead to increased hydraulic loading which decreases detention time. Sufficient detention time is required in any biological treatment system.

- When the annual average to peak daily flow ratio is 2.5 or greater, flow equalization basins should be used to balance flow fluctuations.

- For a system designed strictly for BOD removal, a hydraulic loading rate of 1.5 to 6.0 gallons per day (gpd)/ft^2 of media is recommended.

- For a system designed for both BOD removal and ammonia nitrogen removal, a hydraulic loading rate of 1.5 to 1.8 gpd/ft^2 of media is recommended.

- Hydraulic loading is calculated as follows:

$$\text{Hydraulic Loading (gpd/ft}^2\text{)} = \frac{\text{Influent Flow, gpd}}{\text{(\# of stages) (area per stage, ft}^2\text{)}}$$

Example

Calculate the hydraulic loading of a RBC system with the following data:

4 Stage System
Surface Area (per Stage) = 35,000 ft^2
Influent Flow = 255,000 gpd

$$\text{Hydraulic Loading (gpd/ft}^2\text{)} = \frac{\text{Influent Flow, gpd}}{\text{(\# of stages) (area per stage, ft}^2\text{)}}$$

$$\text{Hydraulic Loading} = \frac{(255{,}000 \text{ gpd})}{(4)\ (35{,}000 \text{ ft}^2\text{/Stage})}$$

Hydraulic Loading = **1.8 gpd/ft^2**

Calculation

1. Calculate the hydraulic loading of a RBC system with the following data:

   8 Stage System
   RBC Width (Per Stage) = 50 ft
   RBC Length (Per Stage) = 200 ft
   Influent Flow = 0.275 mgd

Detention Time

The length of detention will determine which processes occur:

- ♦ A minimum hydraulic retention time of 0.7 to 1.5 hours is necessary for BOD removal to occur; however, longer hydraulic retention times (1.5 hours to 4.0 hours) are necessary for both BOD removal and nitrification.

- ♦ A general rule is that as treatment levels increase, the detention time will also increase. For example, if an RBC Wastewater Treatment Plant has multiple units, the first units being used for BOD treatment will have a detention time that is shorter than the later RBC units, which would be designed for nitrification.

- Detention time of a RBC basin is calculated as follows:

$$\text{Detention Time (days)} = \frac{\text{Basin Volume (gallons)}}{\text{Influent Flow (gallons/day)}}$$

Example

What is the detention time of a 5,000,000 gallon basin with an influent flow rate of 0.125 million gallons per day (mgd)?

$$\text{Detention Time (days)} = \frac{\text{Basin Volume (gallons)}}{\text{Influent Flow (gallons/day)}}$$

$$\text{Detention Time (days)} = \frac{\text{5,000,000 gallons}}{\text{125,000 gallons/day}}$$

$$\text{Detention Time (days)} = \textbf{40.0 days}$$

Calculation

1. What is the detention time of a 7,250,000 gallon RBC basin with an influent flow rate of 110,000 gallons per day?

Short circuiting is a condition that occurs when there is no water movement in a portion of a basin. It leads to the creation of a dead spot or dead zone and is caused by the poor design of inlet and outlet piping arrangement, un-level bottoms and the shape of the basin.

Temperature

- Organic removal efficiency decreases at wastewater temperatures below 55 °F.

- Water will hold more dissolved oxygen at colder temperatures as compared to warmer temperatures. Water in the winter can hold almost twice as much Dissolved Oxygen (DO) as in the summer.

- Biological activity decreases, however, as temperature decreases. A 10 °C drop in temperature will reduce microbial activity by ½.

- Covers on RBCs provide limited protection from decreased influent temperatures but will protect equipment and media from freezing during winter months.

- The highest removal efficiencies occur in warmer weather.

Biochemical Factors

Organic Loading

- Organic loading is defined as the pounds of Biochemical Oxygen Demand (BOD) introduced into the RBC basin per 1,000 square feet of media surface area per day. The design of the media optimizes its available surface area with the use of ridges and void spaces. Consequently, the media surface area can not be accurately calculated by an operator and will be provided by the manufacturer.

- Typical organic loading of a RBC is 2.5 to 4 lbs BOD/day/1,000 ft^2. Loadings can be significantly increased if supplemental aeration (i.e., diffused air system) is utilized to increase dissolved oxygen.

- Increased organic loadings lead to increased biological slime thickness where dissolved oxygen becomes depleted. With higher organic loadings (> 6 lb BOD/day/1,000 ft^2), sulfur reducing filamentous bacteria (*Beggiatoa*) become abundant due to DO deficient conditions. This phenomenon is indicated by a white/gray colored biomass.

- Organic Load is calculated as follows:

$$\text{Organic Load (lb BOD/day/1,000 ft}^2\text{)} = \frac{(\text{BOD, mg/L}) \times (\text{Flow, mgd}) \times (8.34 \text{ lb/gallon}) \times (1{,}000)}{(\text{Area, ft}^2)}$$

Example

Calculate the organic loading of a RBC with the following data:

Media Surface Area = 175,000 ft^2
Influent Flow = 275,000 gpd
Influent BOD = 240 mg/L

$$\text{Organic Load} = \frac{(240 \text{ mg/L}) \times (0.275 \text{ mgd}) \times (8.34 \text{ lb/gallon}) \times (1{,}000)}{(175{,}000 \text{ ft}^2)}$$

Organic Load = **3.1 lb BOD/day/1,000 ft^2**

Calculation

1. Calculate the organic loading of a RBC with the following data:

   Media Surface Area = 108,000 ft^2
   Influent Flow = 100,000 gpd
   Influent BOD = 325 mg/L

pH

♦ As with all biological treatment processes, there is an optimum pH range of between 6 and 8 standard units (s.u.).

♦ The microbiological organisms begin to become stressed at higher and lower pH which in turn results in lower treatment efficiencies.

Dissolved Oxygen

♦ A minimum DO concentration of 2 mg/L is generally necessary for proper aerobic treatment systems.

♦ Oxygen demand is the amount of DO required by bacteria and microorganisms to oxidize the influent organic waste. It is directly proportional to the organic strength of the influent waste. Therefore, oxygen requirements are dependent on BOD loading as well as the degree of treatment.

♦ The strength of the waste can be indirectly measured by the Biochemical Oxygen Demand (BOD) test. This test measures the amount of DO used by bacteria in a controlled environment over 5 days.

♦ Dissolved Oxygen deficiency is typically a concern during the warmer summer months due to increasing temperatures and decreased oxygen transfer.

Means of Increasing DO Levels

- Variable-Speed Drive – This will control the rotation of the shaft and the media growth and it controls the exposure of the biomass to the atmospheric oxygen.

- Supplemental Aeration – A diffused aeration system can be installed in the reactor basin. Air from a blower system is discharged into the wastewater. Diffusers break the air stream into fine bubbles and the smaller, or finer, the bubbles are, the greater the oxygen transfer.

- Secondary Effluent Recirculation - Pumping treated secondary clarifier effluent back into the RBC units introduces DO.

- Step Feeding of Influent Flow - The influent flow into the RBC unit can be split and a portion introduced into individual stages. The organic loading, and therefore the oxygen demand, of the influent is divided between tanks.

- Removable Baffles - Baffles which divide reactor basins into separate stages can be removed, if possible. This allows for increased DO uptake.

Alkalinity

Alkalinity is an indication of the acid neutralizing capacity of the wastewater. It is a measure of wastewater's resistance to changes in pH. The major components of alkalinity are carbonate (CO_3) and bicarbonate (HCO_3) species.

General trends relating to alkalinity in wastewater treatment are as follows:

Aerobic Processes Decrease Alkalinity

- BOD removal causes a slight decrease in alkalinity.

- Ammonia (NH_3) removal, also known as nitrification, causes a significant decrease in alkalinity. During nitrification, NH_3 converted to NO_3. Theoretically, 7.14 lb of alkalinity is consumed during the oxidation of 1 lb of NH_3.

Anaerobic Processes Increase Alkalinity

- When DO is not available, nitrate (NO_3) is used as an oxygen source. NO_3 removal, also known as denitrification, causes a slight increase in alkalinity. NO_3 is converted to N_2 gas. Theoretically, 3.57 lb of alkalinity is created during the reduction of NO_3.

- When DO and NO_3 are not available, sulfate (SO_4) is used as an oxygen source. Organic nitrogen is used as a food source, which causes a significant increase in alkalinity. This leads to the generation of ammonia (NH_3).

Table 2.1 Typical Design Parameters

	Treatment Level	
Parameter	**BOD Removal Only**	**BOD and NH_3-N Removal**
Hydraulic Loading, gal/ft^2/day	2.0 – 4.0	0.75 – 2.0
Organic Loading, lb SBOD/1,000 ft^2/day	0.75 – 2.0	0.5 – 1.5
Organic Loading, lb/BOD/1,000 ft^2/day	2.0 – 3.5	1.5 – 3.0
NH_3-N Loading, lb/1,000 ft^2/day	---	0.15 – 0.3
Hydraulic Retention Time, hours	0.7 – 1.5	1.5 – 4.0
Effluent BOD, mg/l	15 - 30	7 - 15
Effluent NH_3-N, mg/l	---	< 2

Microbiological Factors

The treatment efficiency of a rotating biological contactor is the result of the metabolizing actions of bacteria and micro-organisms present in the biological slime layer that develops on the media. The presence of the biological slime which is attached to the media is the limited amount of biology you need to know for operation of a RBC. Control of the bio-mass is neither as critical nor the same as an activated sludge system. Most of the wastewater stabilization process in a RBC plant involves the slime layer, which consists of plant forms such as algae. The following provides an overview of conventional wastewater treatment.

Bacteria

Bacteria are divided into two general categories: aerobic and anaerobic. Bacteria are simple, single-celled organisms which feed on the organic waste in the waste stream. Their general form is typically spherical, cylindrical or helical.

Under a microscope, bacterial colonies would appear similar to this:

Figure 2.1 Bacterial Colonies

Aerobic Bacteria

- Aerobic bacteria require dissolved oxygen for respiration.
- Aerobic bacteria break down and stabilize organic substances into soluble matter which is converted into energy.
- Waste products include carbon dioxide (CO_2), ammonia and phosphates.

Anaerobic Bacteria

- Anaerobic bacteria do not require dissolved oxygen for respiration.
- Anaerobic bacteria can utilize nitrate (NO_3) or sulfate (SO_4) as alternative oxygen sources.
- When DO is not available, nitrate (NO_3) is used as oxygen source. NO_3 removal, also known as denitrification, causes a slight increase in alkalinity. NO_3 is converted to N_2 gas. Theoretically, 3.57 lb of alkalinity is created during the reduction of NO_3.
- When DO and NO_3 are not available, sulfate (SO_4) is used as oxygen source. Organic nitrogen is used as food source, which causes a significant increase in alkalinity. This leads to the generation of ammonia (NH_3).

Microorganisms

In addition to bacteria, the microbiology of a RBC includes more complex single- and multi-celled organisms. These organisms feed upon organic matter and bacteria. We will examine three different types of micro-organisms: protozoa, rotifers and crustaceans.

These organisms are all aerobic, meaning that they require dissolved oxygen for survival.

Protozoa

Protozoa are typically single-celled animals with complex digestive systems that consume both solid organic matter and bacteria as energy sources. They are the next level up on the food chain after the bacteria. Two types of protozoa include *Flagellates* and *Ciliates*.

Flagellates

- Flagellates utilize long hair-like strands, known as flagella, for mobility.

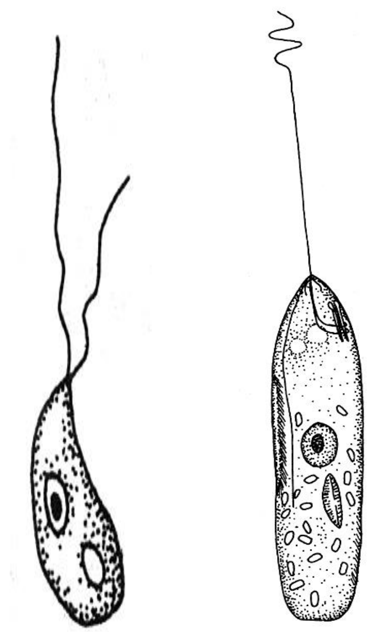

Figure 2.2 *Dinomonas Flagellate and Peranema Flagellate*[1]

Ciliates

There are two different types of ciliates: free-swimming and stalked.

- Free-swimming ciliates utilize cilia for mobility to swim quickly in the water and to ingest organic matter.
- Stalked ciliates are anchored onto suspended particles and utilize cilia for filtering organic waste.

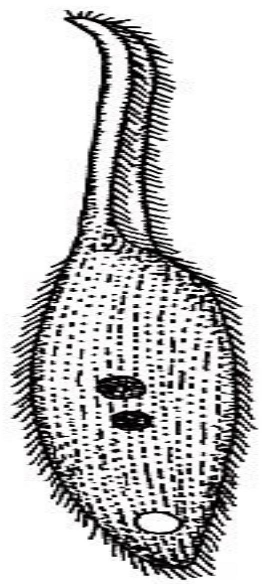

Figure 2.3 *Lionotus Ciliate*[2]

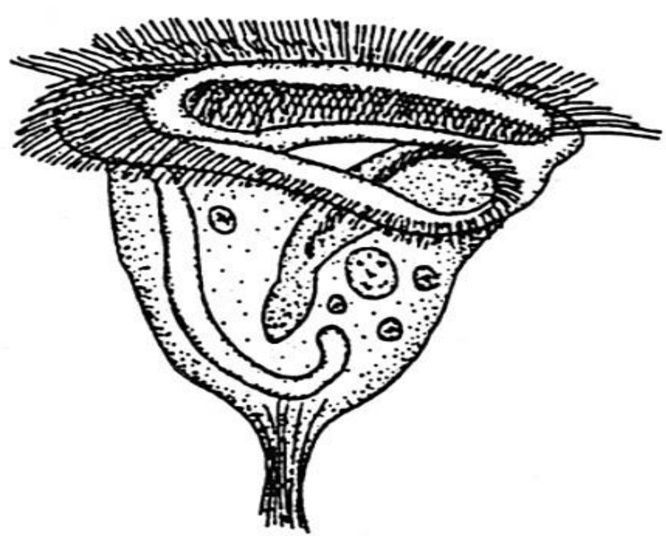

Figure 2.4 *Vorticella Cilate*[3]

Rotifers

Rotifers are multi-celled organisms. They utilize cilia around their heads for filtering organic waste and bacteria to be metabolized as food. Their presence is an indication of a very efficient biological treatment process.

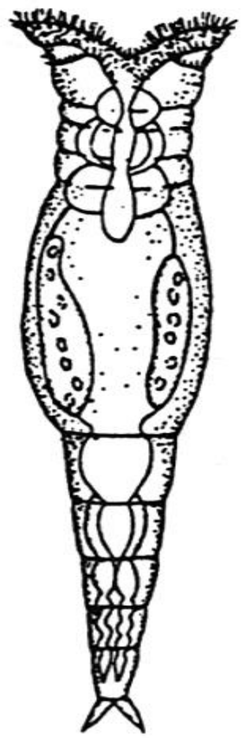

Figure 2.5 *Philodina Rotifer*[4]

Crustaceans

Crustaceans, like the *Diaphanosoma* example below, are multi-celled organisms with a shell-like covering. They typically have swimming feet or other appendages. They feed mostly upon algae.

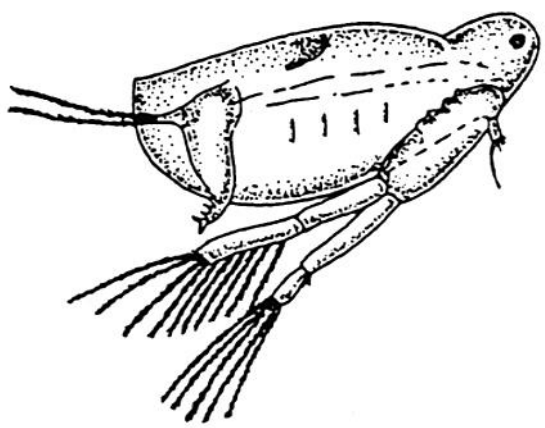

Figure 2.6 *Diaphanosoma Crustacean*[5]

Routine maintenance is necessary to ensure the proper functioning of a rotating biological contactor. This section of the training session will focus on the six RBC structures: media, shaft, reactor basin, drive assembly system, orifice/weir, lines and valves and underdrains.

Media

Description

- Generally, low-density media are used in initial stages to reduce clogging due to higher organic loadings, with approximately 9,300 m^2 of surface area on a 8.2 m shaft length.

- High-density polyethylene (HDPE) is typically utilized in final stages, offering up to 16,700 m^2 of surface area for the same shaft length.

Maintenance

- Important to maintain upstream treatment process such as mechanical cleaned bar screens and primary clarifiers, so that large objects are not flushed down into the RBC.

- Inspect for excessive growth, clogged areas or locations with limited growth.

- Inspect for damaged media sections.

- Flush excess biomass with either pressured hose or increase shaft speed.

- Use a submerged pipe to introduce air into bottom of basin. This can assist in slough off of excessive growth. Beware that introduction of air on one side can lead to high torque loading since rising air tends to rotate the media and shaft.

- If biomass growth is greater than another section, check for equal flow.

- If biomass is less than other sections, check for equal flow or determine if solids deposition is scouring growth off the ends of media disks.

- Observe for frozen sections during the winter, which indicates poor flow pattern through the basin.

- Cover the media to reduce thermal loss during winter operation. Conversely, in summer, by opening the cover inspection hatches, airflow through the media is enhanced.

Safety

- Slippery conditions around the media area may exist.

- The weight of the biomass on the media is a safety concern.

Shaft

Description

- The shaft supports and rotates the media when mechanical drives are utilized. When air drivers are utilized, the shaft simply supports the media.

- Typical maximum length of a shaft is 27 feet long with a maximum of 25 feet occupied by media.

Maintenance

- Maintenance of the shaft should be performed according to the manufacturer's specifications and intervals.

- Be sure to monitor shaft alignment.

- Check for signs of excessive shaft deflection. If observed, determine if there is excessive growth on the media.

Pillow block bearing consists of a pedestal used to provide support for a rotating shaft with the help of compatible bearings and other various accessories. Housing material for a pillow block is typically made of cast iron or cast steel.

- Excessive growth on the media may lead to failure of the pillow block bearings due to the increased weight.

- Observe for uniform and continuous rotation of the shaft. If surges are observed, this can lead to high and sudden loading to the shaft, resulting in shaft failure.

Safety

- Never try to physically stop the rotation of the shaft with your body or any object.
- Always shut down the drive assembly first and allow the shaft to come to a complete stop before attempting any maintenance activities.
- Do not crawl under shaft unless auxiliary support is provided.

Drive Assembly

Description

- There are two types of drives: mechanical drives and air drives.
- Typically, variable rotational speeds should be provided to control media growth.
- Consistent rotational speed must be maintained to achieve uniform media growth. Uneven media growth can lead to an unbalanced RBC, which will increase torque load on the shaft and drive of mechanical drives and cause loping of air drives.

Maintenance

- Monitor the amperage draw on the motor to determine if it is excessive.
- Monitor torque loading, if so equipped.
- Be sure to lubricate the bearings and maintain them properly. This is critical.
- Cover the RBC disks to reduce airflow around the bearings. This may increase some corrosive effects.

Safety

- Be sure to lock out/tag out whenever working on the drive.
- Watch for rotation or back rotation if disconnecting the drive assembly from the shaft.

Reactor Basin

Description

- The reactor basin is where the media contacts the wastewater.

Maintenance

- Periodically inspect for excessive deposits in the basin. Use either a small dipper while the RBC disks are shut off or use a small pump to extract a sample from the bottom.
- If the basin is of carbon steel construction, monitor for signs of excessive rusting.
- If supplemental submerged aeration is provided in a reactor basin to minimize solids deposition, a minor increase in treatment might be observed.

Safety

- Typically, surfaces near the basin may have a biological growth on them which will result in slippery conditions.

Orifice/Weir

Description

- The weir can be a level straight section where uniform distribution is insured as wastewater passes into and out of the reactor basin.
- The orifice may also be used to equally distribute flow through the basin.

Maintenance

- Observe for any clogged weirs or orifice areas which can inhibit equal distribution of flow.
- Use recirculation to increase hydraulic loading on the unit and reduce clogging weir/orifice problems. Recirculation must be kept within design limits.

Safety

- Depending upon hydraulic head conditions, such as if the flow is backed up in the liquid treatment train, clearing of an orifice or weir may release a sudden flow of wastewater into the RBC unit.

Lines and Valves

Inlet Structure

- The inlet valve should be kept free of biological growth which could clog it. The inlet valve should not be allowed to freeze.

- A submerged inlet pipe minimizes the amount of floating material and introduces warm wastewater into the depths of the pond, thereby helping to conserve the heat of the pond.

- If the Wastewater Treatment Plant has a parallel flow pattern, the inlet structure should be used to provide for an equal distribution of flow through liquid treatment rains.

Outlet Structure

- The outlet structure will typically permit control of the RBC depth. It is also capable of controlling the rate of discharge. Adjustment of the outlet structure should be used to maintain a uniform depth in all basins, if there are multiple basins being operated in a parallel flow pattern.

- The surface outlet is a simple baffle that will keep floating material out of the effluent. If odor or foam problems exist, a submerged outfall might need to be constructed.

Sampling and Testing Considerations

NPDES Permit testing and monitoring requirements will usually dictate the minimum testing requirements. Additional testing, above the minimum established in the NPDES Permit, is typically dependent on the equipment and staff available at the plant. All testing and monitoring, performed in addition to the minimum required by permit, must be reported to the appropriate regulating agency.

Suggested Testing Parameters

There are a number of parameters and analyses which should be tested and tracked, beyond those required by the NPDES Permit.

Biochemical Oxygen Demand (BOD) and Total Suspended Solids (TSS)

- It is recommended that BOD, CBOD and TSS be tested a minimum of once per week on plant influent, primary effluent and final effluent.
- Sampling and testing primary effluent provides information on loading to the RBC, as well as primary clarifier and RBC performance (treatment efficiency).

pH

- It is recommended that pH be tested daily on plant influent and final effluent.
- This is valuable to verify that treatment processes are the optimum pH for the micro-organisms present in the RBC media.
- pH can also useful to determine if toxic discharges are present in the plant influent, if the pH drastically increases or decreases out of the normal range.

Dissolved Oxygen (DO)

- It is recommended that DO be tested daily on final effluent.

Ammonia Nitrogen (NH_3-N)

- If the plant has ammonia nitrogen discharge limitations in its NPDES Permit, it is recommended that ammonia be tested daily, or at least once per week, on plant influent and final effluent.

- If the plant is not designed for nitrification (ammonia nitrogen removal), it is still good practice to track ammonia to establish historic concentrations. This could be useful for future plant upgrades which include nitrification treatment or to establish future applicable industrial user discharge limits.

Recordkeeping

A written record of all operation statuses and changes should be maintained for process control and to meet regulatory requirements. In addition to meeting the requirements of a facility's NPDES Permit for testing frequency and parameters, this data will allow an operator to better understand the unique operation of a particular RBC.

- All data, whether required by the NPDES Permit or necessary for process control, should be clearly recorded and carefully logged.

- Data should be maintained on-site and made available for easy reference.

Uses of Data

Process Loading Rates

- Data can be used to calculate the loading rates, both hydraulic and organic, to the RBC. This data can then be used to maintain proper loadings to the units.

Treatment Efficiency

- BOD, TSS and NH_3-N are all pollutants which are present in significant concentrations in the incoming (influent) wastewater coming into a treatment plant. Through the treatment process, the concentrations of BOD, TSS and NH_3-N are reduced.

Graphing

- Graphs can be used to detect trends in data.

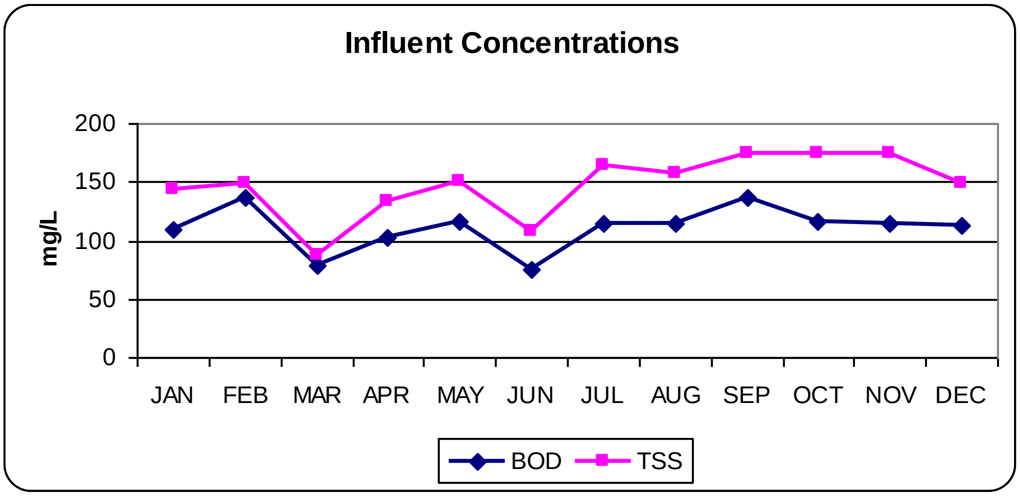

Figure 2.7 An Example of a Graph

- Graphs also allow for the identification of very unusual results.

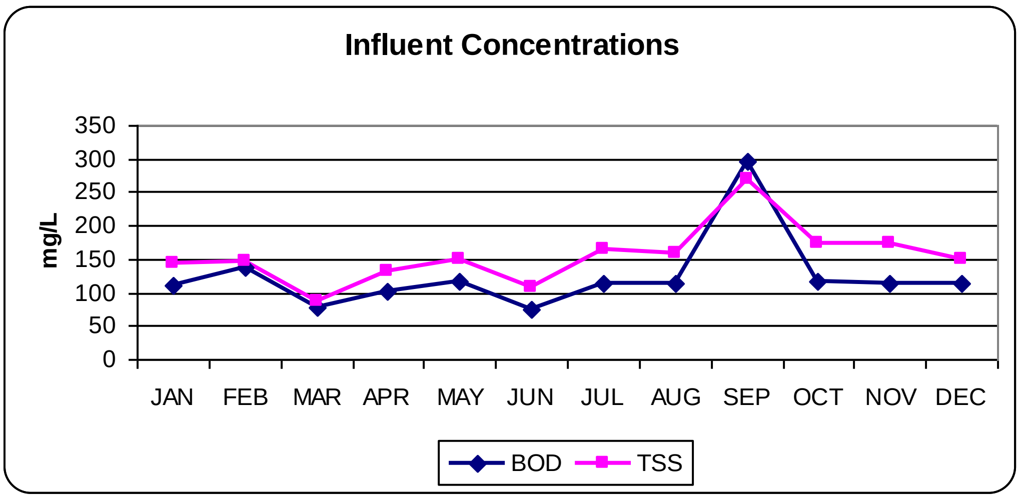

Figure 2.8 An Example of a Graph

- Long-term plots tend to be more useful than short-time spans. The more data used to create the graph, the more representative the graph will be of the treatment process. For instance, one week of data should not be used to interpolate the treatment plant performance over the course of a year.

Key Points for Unit 2 – General Operation and Maintenance

- The primary factors affecting performance of a RBC can be divided into three categories: physical, biochemical and microbiological factors.
- Hydraulic loading is defined as the flow, in gallons per day, of wastewater introduced into a RBC per square foot (ft^2) of surface area.
- A minimum hydraulic retention time of 0.7 to 1.5 hours is necessary for BOD removal to occur; however, longer hydraulic retention times (1.5 hours to 4.0 hours) are necessary for both BOD removal and nitrification.
- Biological activity decreases, however, as temperature decreases. A 10 °C drop in temperature will reduce microbial activity by ½.
- Organic loading is defined as the pounds of Biochemical Oxygen Demand (BOD) introduced into the RBC basin per 1,000 square feet of media surface area per day.
- As with all biological treatment processes, there is an optimum pH range of between 6 and 8 standard units (s.u.).
- A minimum DO concentration of 2 mg/L is generally necessary for proper aerobic treatment systems.
- Alkalinity is an indication of the acid neutralizing capacity of the wastewater. It is a measure of wastewater's resistance to changes in pH. The major components of alkalinity are carbonate (CO_3) and bicarbonate (HCO_3) species.
- The treatment efficiency of a rotating biological contactor is the result of the metabolizing actions of bacteria and micro-organisms present in the biological slime layer that develops on the media.
- Routine maintenance of in particular six RBC structures: media, shaft, reactor basin, drive assembly system, orifice/weir, lines and valves and underdrains is necessary to ensure the proper functioning of a rotating biological contactor.
- Sampling and testing provides information on loading to the RBC, as well as primary clarifier and RBC performance (treatment efficiency).

☑ Exercise for Unit 2 – General Operation and Maintenance

1. The length of detention time is a critical factor in determining which processes such as BOD and nitrification will occur in a RBC.
   a. True b. False

2. Increased influent flows lead to __________ hydraulic loading which _________detention time.

3. The highest removal efficiencies in an RBC will occur in:
   a. cold weather
   b. warm weather
   c. temperature has no effect
   d. none of the above

4. When oxygen is not available, anaerobic bacteria can use nitrate (NO_3) or sulfate (SO_4) as alternative oxygen sources.
   a. True False

5. Bacteria in SBRs are generally grouped in two broad categories called ________________ which require DO and ________________ which do not require DO for respiration.

6. List the six main RBC structures that were discussed in this unit:
   a. ________________
   b. ________________
   c. ________________
   d. ________________
   e. ________________
   f. ________________

7. In addition to testing required by your NPDES Permit, it may be important to periodically test for other parameters. Give two examples of additional tests, how often they should be sampled and where the sample should be obtained (such as influent, primary clarifier, effluent, etc...)

   a. ____

      ____

   b. ____

      ____

      ____

[1] Lenore S. Clesceri, Arnold E. Greenberg and Andrew D. Eaton, Eds., *Standard Methods for Examination of Water and Wastewater,* 20th Edition, (Washington, D.C., American Public Health Association, 1998), p. 10-123.

[2] Clesceri, p. 10-123.

[3] Clesceri, p. 10-124.

[4] Clesceri, p. 10-126.

[5] Clesceri, p. 10-129.

Additional Resources Used

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Odor Control in Wastewater Treatment Plants, Manual of Practice No. 22, (Water Environment Federation, 1995), pg. 56 and pp. 155-156.

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Unit 3 – Typical Operating Problems

Learning Objectives

- Identify four potential causes of poor quality effluent in an RBC.
- Discuss the causes of excessive biomass sloughing and how it contributes to poor quality effluent.
- Discuss the laboratory testing used to investigate a possible organic overload.
- Explain the consequences of cold weather operation on an RBC.
- Describe how the appearance of the media can indicate potential operational problems.

Problems and Solutions Associated with Poor Effluent Quality

Problem	Things to Monitor	Possible Solutions
Low Temperatures • Cold weather operating temperatures will cause a decrease in microbiological growth. • Temperatures below 55° F begin to affect biomass, which will lead to decreased treatment efficiency.	• Influent temperature.	• Cover RBC units to conserve heat.
Organic Overload • Excessive organic loading to a RBC can not be properly treated to sufficiently remove pollutants to acceptable levels.	• Influent BOD. • Influent TSS. • Influent DO. • Influent pH. • Influent temperature.	• Install equalization tanks prior to RBC to dilute high strength wastes and provide pre-aeration to RBC. • Place added treatment units in service, if available. • Install supplemental aeration equipment to handle higher DO demands. • Recirculate secondary clarifier effluent to dilute influent flow, if possible.
Hydraulic Overload • Excessive high flows result in short detention times and will lead to reduced treatment efficiencies. • **The microbiological growth may be substantially or even completely sheared from the media.**	• Influent flow.	• Install equalization tanks prior to RBC to balance highly fluctuating flows.

Problem	Things to Monitor	Possible Solutions
Short Circuiting • Condition occurs when there is no water movement in a portion of the basin. • Short circuiting results in dead zones with little or no dissolved oxygen. Dead zones will lead to reduced treatment efficiencies.	• Monitor basin surface for visibly stagnant sections of the pond or dead zones (no water movement or heavy collection of surface scum).	• Install manifolds or diffusers on inlets and outlets. • Provide multiple inlets and outlets for more equal hydraulic distribution. • Change location of inlets and outlets. • Keep inlets and outlets as far apart as possible. • Eliminate dead zones.
Toxic Influent Material • When a toxic substance is discharged into a collection system, the biological processes occurring in the treatment pond can be upset, which could lead to stressing of the organisms or the complete destruction of the biological treatment population.	• Influent pH. • Influent DO. • Influent temperature. • Influent Chemical Oxygen Demand (COD).	• Sample the collection system to identify the cause or source of toxicity. • Develop and implement sewer use ordinances to establish prohibitions and limitations of substance discharge and criminal fines if discharges occur. • Install equalization tanks prior to RBC to dilute high strength wastes and provide pre-aeration to the RBC. • Install supplemental aeration equipment to handle higher DO demands. • Recirculate secondary clarifier effluent to dilute influent flow, if possible.

Problems and Solutions Associated with Excessive Sloughing

Problem	Things to Monitor	Possible Solutions
Toxic Influent • Influent wastewater containing toxic or inhibitory substances will stress the microorganisms on the media. • **The microbiological growth could even be completely killed off if the toxicity is severe.**	• Influent BOD. • Influent Chemical Oxygen Demand (COD).	• Sample the collection system to identify the cause or source of toxicity. • Develop and implement sewer-use ordinances to establish prohibitions and limitations of substance discharge and criminal fines if discharges occur. • Install equalization tanks prior to RBC to dilute high strength wastes and provide pre-aeration to RBC.
Excessive pH Variations • pH values below 5 s.u. or above 10 s.u. can cause increased sloughing.	• Influent pH.	• Sample the collection system to identify the cause or source of pH variations. • Develop and implement sewer-use ordinances to establish prohibitions and limitations of substance discharge and criminal fines if discharges occur. • If the influent pH is too low, add sodium bicarbonate or lime. It the pH is too high, add acetic acid.
Unusual Variation in Flow and/or Organic Loading • Excessive flow or loading variations will lead to reduced treatment efficiencies.	• Influent flow. • Influent BOD.	• Install equalization tanks prior to RBC to dilute high strength wastes and provide pre-aeration to RBC and to balance highly fluctuating flows. • Place added treatment units in service, if available.

Problems and Solutions Associated with Odors

Problem	Things to Monitor	Possible Solutions
Anaerobic Conditions • Influent wastewater containing toxic or inhibitory substances will stress the microorganisms on the media. • The microbiological growth could even be completely killed off if the toxicity is severe.	• DO levels. • Biological growth will turn white in color. • Wastewater temperature.	• **Divert all or a portion of the flow to lessen organic loading**, if possible. • Recirculate the secondary clarifier effluent to increase DO, if possible. • Pre-chlorinate the influent flow to oxidize the offending material. • If during the summer, open hatches in the cover to increase air flow through the unit.
Short Circuiting • pH values below 5 s.u. or above 10 s.u. can cause increased sloughing.	• Monitor basin surface for visibly stagnant sections of the pond or dead zones (no water movement or heavy collection of surface scum).	• Install manifolds or diffusers on inlets and outlets. • Provide multiple inlets and outlets for more equal hydraulic distribution. • Change the location of inlets and outlets. • Keep the inlets and outlets as far apart as possible. • Eliminate dead zones.

Problems and Solutions Associated with Equipment Malfunction

Problem	Things to Monitor	Possible Solutions
Excessive Snail Shells • Snail shells may clog pipes and pumps. This problem generally occurs at plants providing nitrogen removal.	• Visually inspect for an abundance of snails and shells.	• Ensure adequate mixing in all basins to minimize snail shell deposits. • Chlorination to kill the snails. • Increasing pH to 10 s.u for a brief period will kill snails with no harm to microbiological growth.
Shaft • Shaft bearings runs hot or fails due to inadequate maintenance practices. • Uneven biomass buildup on the media can result in loping of the shaft. • Water can seep into the bearings.	• Follow established or suggested maintenance schedules.	• Lubricate bearings per manufacturer's instructions.
Motor • Motor runs hot or fails due to inadequate maintenance practices. • The chain drive alignment is improper.	• Follow establish or suggested maintenance schedules. • Check alignment.	• Lubricate motor per manufacturer's instructions. • Align properly.

Key Points for Unit 3 – Typical Operating Problems

- Poor effluent quality can be caused by low temperatures, organic overload, hydraulic overload, short circuiting and/or a toxic influent.
- Excessive sloughing can be caused by toxic influents, excessive pH variations, and unusual variations in flow and organic loading.
- Odors can be caused by anaerobic conditions and short circuiting.
- Equipment malfunctions can be caused by snail shells clogging pumps and pipes, uneven biomass buildup causing loping of the shaft, failure to follow regular maintenance procedures for the bearings or the motor, or the chain drive alignment is improper.

Exercise

1. List three problems associated with poor effluent quality and the solution(s) for each.

2 Under what conditions can pH increase sloughing?

3 Explain how anaerobic conditions cause odor problems.

4 Explain how the problem of excessive snail shells can be resolved.