Wastewater Treatment Plant Operator Certification Training

Module 20: Trickling Filters

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Unit 1 – Process Description and Classifications of Trickling Filters

Learning Objectives

- Name the three components of a trickling filter.
- Name the two general types of trickling filters based on method of distribution.
- Describe the process and operation of a trickling filter.
- Identify the three classifications of trickling filters based on hydraulic and organic loading rates.
- Calculate hydraulic loading rates for trickling filters.
- Calculate organic loading rates for trickling filters.

Overview

Trickling Filters are a unique type of fixed film biological treatment. In a trickling filter, the micro-organisms used to treat the wastewater are attached, or fixed, to a medium as they contact the wastewater. These micro-organisms form a slime growth on the medium known as zoogleal film.

- Wastewater applied to a trickling filter has already passed through a mechanical bar screen and/or primary clarifiers where the majority of settleable and floatable solids are removed.
- Wastewater is distributed over the top of the medium and slowly trickles through it. The biological growth is attached to the media.
- This is in contrast to “suspended growth” biological treatment, where the micro-organisms float freely in the wastewater.
- Trickling filter effluent always passes through a secondary clarifier or sand filter to allow for capture of solids generated as a result of treating the wastewater.
- The sludge (solids) from a final clarifier should be pumped back to the primary clarifier or to a sludge thickener for further treatment.

Although these units are referred to as “Trickling Filters,” no physical filtration actually occurs. Instead, contaminants are removed by biological processes in an aerobic environment.

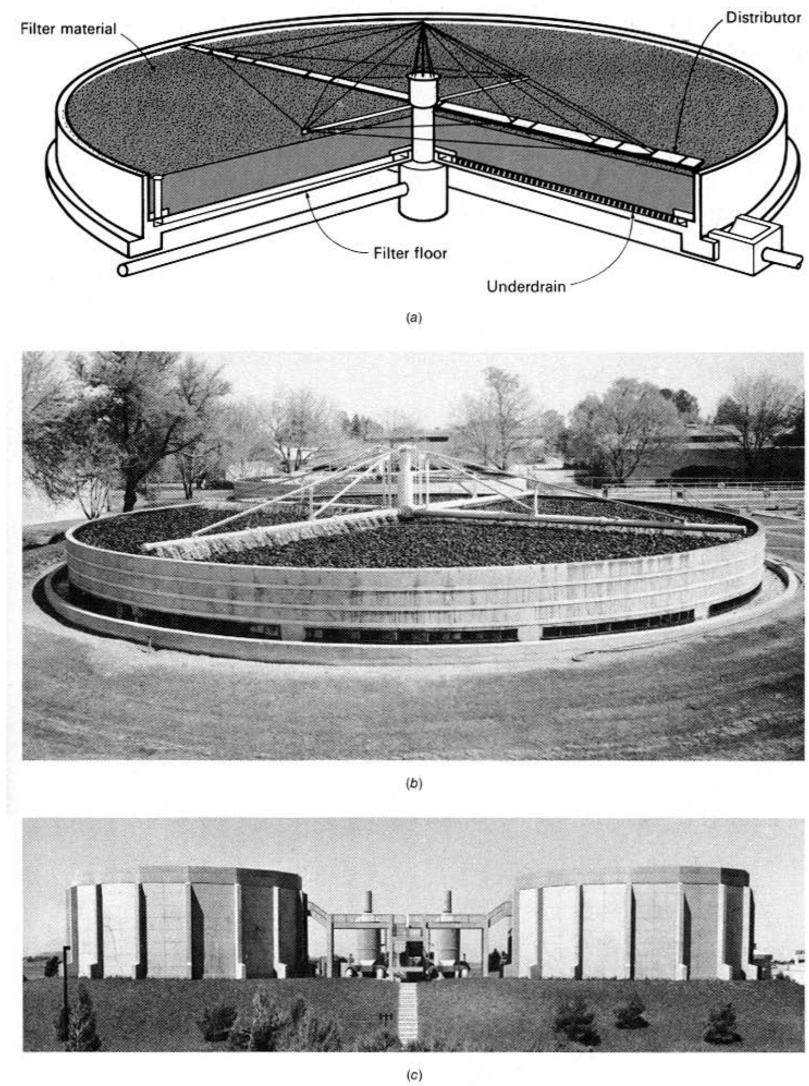

Figure 1.1 Trickling Filter Overview [1]

History

Trickling filters were the most widely used form of wastewater treatment in the first half of the twentieth century. The first trickling filter used for a large public treatment system was installed in Madison, Wisconsin, in 1912.

By the middle of the twentieth century, suspended growth activated sludge systems started becoming more common.

- Effluent quality achieved with the new activated sludge systems was often better than those achieved with trickling filters.

The invention of lightweight, synthetic media increased the treatment capability of trickling filters.

Trickling filters are still considered a viable treatment alternative due to their low energy and maintenance requirements and their ability to treat variable organic loads and toxic substances.

Physical Description

Trickling filters may be circular with a rotary distributor or stationary with a dosing chamber and a spray field. Trickling filters are composed of three basic components:

- Distribution System
- Filter Media
- Underdrain System

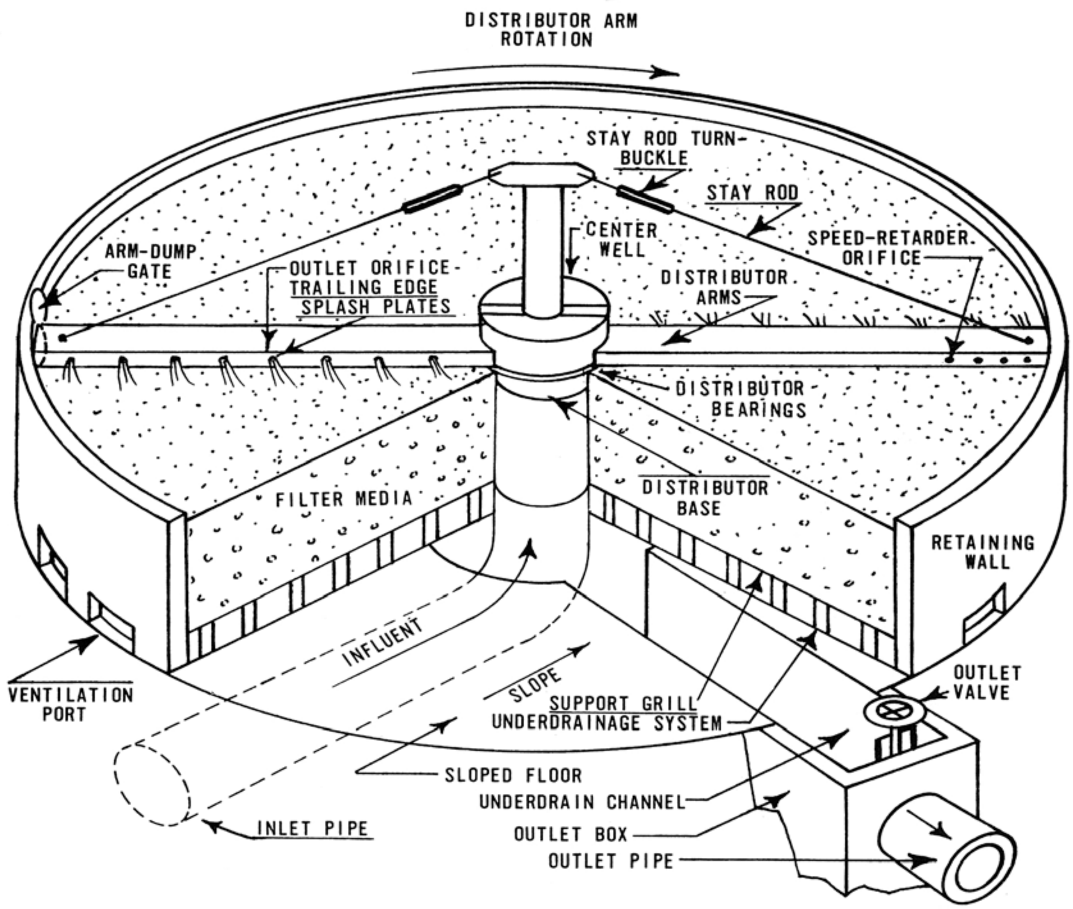

Figure 1.2 Circular Trickling Filter Diagram [2]


Figure 1.3 Stationary Trickling Filter with Fixed Individual Spray Heads


Figure 1.4 Dosing Chamber for Stationary Trickling Filters

Distribution System

The Distribution System distributes wastewater over the media surface. For optimum treatment efficiency, a uniform hydraulic load per unit area is required.

Circular trickling filters use rotary arms to distribute wastewater. Stationary trickling filters use fixed spray heads to distribute wastewater.

Circular Trickling Filter with Rotary Arms

- Rotary arms consist of two or more horizontal pipes suspended above the filter media.
  - The horizontal pipes are also known as "distributor arms."
- Wastewater is distributed over the media through orifices located along one side of the pipes.
  - They are typically set in motion by the force of the wastewater flowing out of nozzles on one end of the arm.
  - They can also be motor-driven to control the rotational speed.

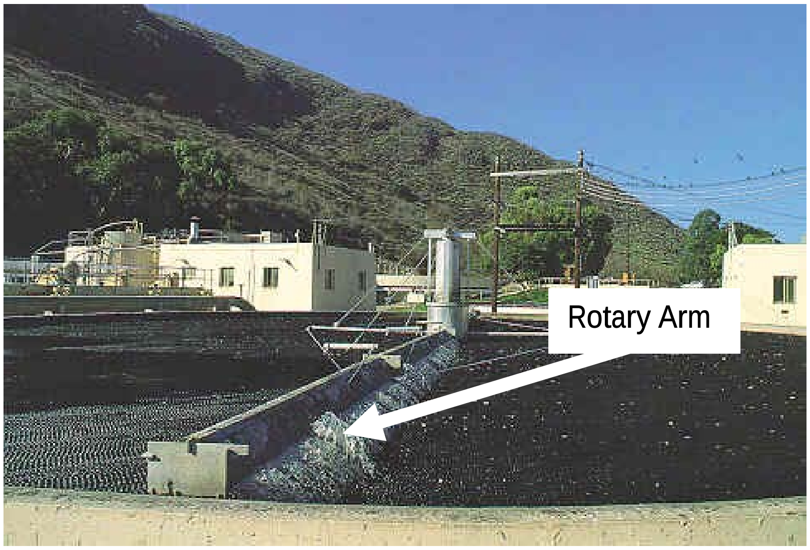

Figure 1.5 Trickling Filter Rotary Arm [3]

Stationary Trickling Filter with Fixed Spray Heads

- Spray heads are arranged in a fixed pattern near the surface of the media.
- They are similar to lawn sprinklers in appearance and function.
- Spray heads are supplied by a piping network maintained below the surface of the media.
- Fixed-nozzle distribution systems are not as common as rotary arms due to:
  - An extensive piping and pumping system to provide even flow distribution; and
  - Difficult access for maintenance and repair.

Figure 1.6 Spray Head for a Stationary Trickling Filter

Filter Medium

The **Filter Medium** provides a surface for the biological slime layer or zoogleal film to attach and grow. This layer consists of bacteria and micro-organisms, such as protozoa.

The filter media needs to be durable, insoluble, and resistant to chemicals. There are generally three types of filter media:

- Rock (or slag)
- Redwood
- Synthetic Materials

Rock (or slag)

Rock is the original media used in trickling filters. It is generally field stone, slag, or crushed stone. Typically, the rocks are approximately 2 to 4 inches in diameter.

- The actual size is not too critical; however, it is important that the media is uniform to allow sufficient ventilation through the void space.
- The biggest disadvantage of rock or slag is that the stone will occupy the majority of the volume of the filter bed:
    - This reduces the void spaces necessary for the passage of air, which limits the surface area per unit volume for biological growth.
    - There is typically only 35% void space between rock media.

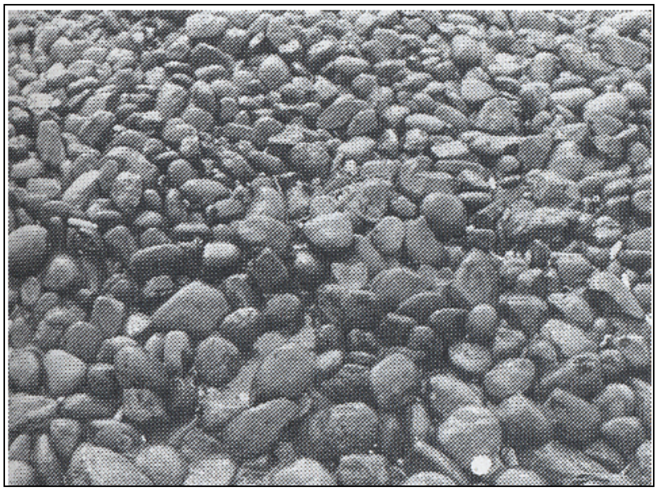

Figure 1.7 Rock Trickling Filter Media [4]

Redwood

Redwood lumber can be used to support the biological slime layer. However, the use of redwood lumber has decreased, and very few if any new trickling filters use redwood media.

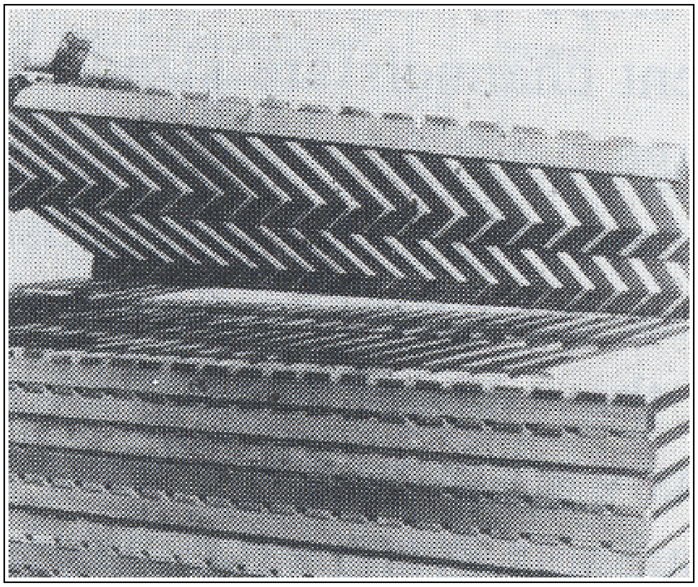

Figure 1.8 Redwood Trickling Filter Media [5]

Synthetic Material

Synthetic materials used as filter media are lightweight materials, typically plastics, originally developed in the 1950's. Synthetic materials provide approximately 95% void space between the media. The advantages to synthetic material are:

- More surface area for microbial growth
- More void space to promote air flow
- Uniform media allows even loading distribution
- The lightweight design allows:
  - Ease of installation and handling of material
  - Construction of deeper beds

The two general classifications of synthetic media are:

- Cross Flow
- Random Dump

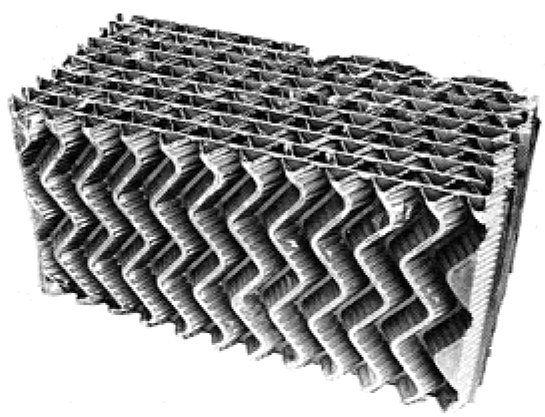

Figure 1.9 Plastic Cross Flow Trickling Filter Media [6]

Figure 1.10 Plastic Random Dump Trickling Filter Media [7]

Underdrain System

The underdrain system collects treated wastewater and solids discharged from the filter media and conveys them to a sedimentation tank. The system is located below, or underneath, the filter media and operates by gravity flow.

- It has a sloped bottom which directs flow to a center channel
- It provides support for the filter media, which sits on top of the underdrain system
- It allows air circulation through the media
  - The requirement for free passage of air controls the size of openings in the underdrain

The underdrain system is typically composed of either:

- Vitrified clay blocks
- Fiberglass grating over collection troughs

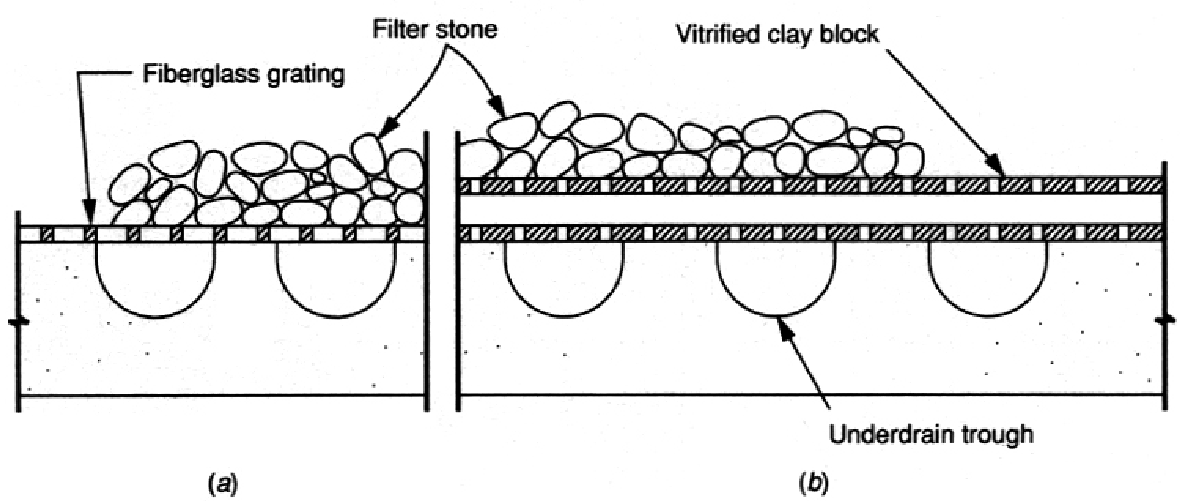

Figure 1.11 Trickling Filter Underdrain System [8]

Figure 1.12 Side View of the Underdrain System for a Stationary Trickling Filter

Process Description

The trickling filter treatment process occurs through the biological degradation of organic material by bacteria and micro-organisms contained in the zoogleal film on the filter media. These micro-organisms primarily reduce the carbonaceous biochemical oxygen demand (cBOD) of the wastewater; however, they can also be utilized to reduce ammonia nitrogen (NH_3-N) through the process of "nitrification."

Process Biology

The treatment efficiency of a trickling filter is the result of the metabolizing actions of bacteria and micro-organisms present in the zoogleal film that develops on the filter media.

Controlling the biological populations on a trickling filter is not the same or as critical as controlling the biological populations in an activated sludge system. Most of the wastewater stabilization process in a trickling filter involves the zoogleal film which consists of plant forms such as algae.

This section provides a brief overview of the process biology for conventional wastewater treatment.

Bacteria

Bacteria are divided into two general categories: those that require oxygen for respiration (aerobic bacteria) and those that do not (anaerobic bacteria). 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 appear similar to this:

- Aerobic Bacteria
  - Require dissolved oxygen for respiration
  - 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
  - Do not require dissolved oxygen for respiration
  - Can utilize nitrate (NO_3) or sulfate (SO_4) as alternative oxygen sources
  - When dissolved oxygen 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)

Micro-organisms

In addition to bacteria, the microbiology of a trickling filter 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
- Crustaceans
- Nematodes

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

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

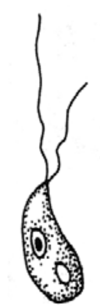

Figure 1.13 *Dinomonas Flagellate* [9]

Figure 1.14 *Peranema Flagellate* [10]

- **Ciliates** are grouped into two categories: *Free-Swimming* and *Stalked*. Free-Swimming Ciliates, like the *Lionotus Ciliate*, utilize cilia for mobility to swim quickly in the water and to ingest organic matter. Stalked Ciliates, like the *Vorticella Cilate*, are anchored onto suspended particles and utilize cilia for filtering organic waste.

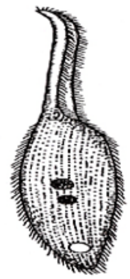

Figure 1.15 *Lionotus Ciliate* [11]

Figure 1.16 *Vorticella Cilate* [12]

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.

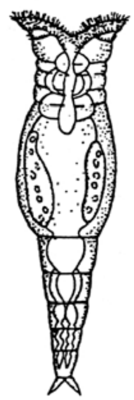

Figure 1.17 *Philodina Rotifer* [13]

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

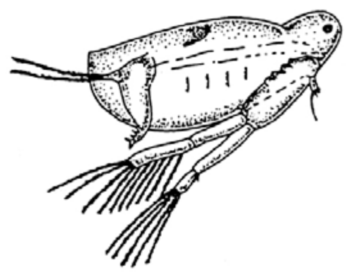

Figure 1.18 *Diaphanosoma Crustacean* [14]

Nematodes are a more advanced life form present in attached growth media systems. Depending upon the species, the organism may be visible with the naked eye. Nematodes feed on the smaller, simpler micro-organisms which are found in the slime layer, such as bacteria and protozoan.

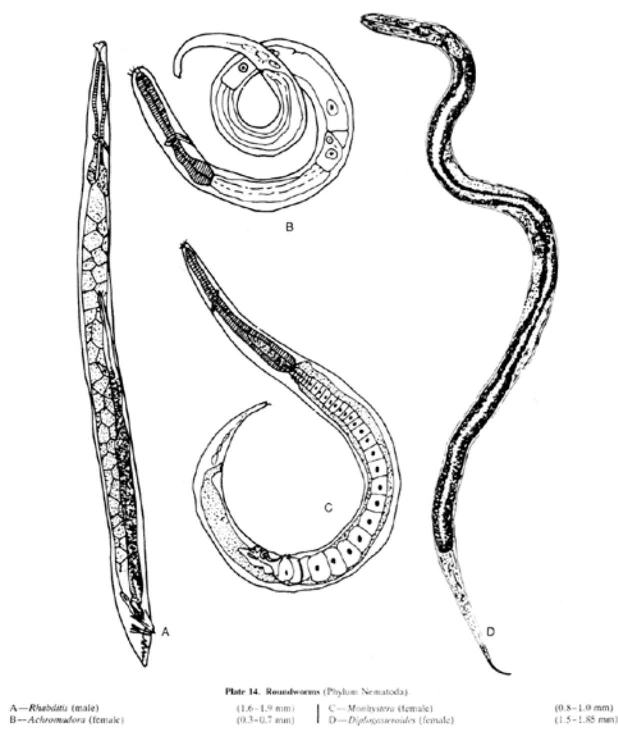

Figure 1.19 Nematodes [15]

Nitrification

In addition to the reduction of biochemical oxygen demand (BOD), trickling filters can be utilized for nitrification. Nitrification is the biological reduction of nitrogen from one form, ammonia (NH_3-N), to another form, nitrate nitrogen (NO_3-N).

Inorganic nitrogen is an essential nutrient for plant and algae growth. Certain forms of inorganic nitrogen can also be toxic to fish.

Ammonium and Ammonia

- Ammonium has the chemical formula NH_4^+ and ammonia has the chemical formula NH_3. These two forms of nitrogen are related by the following equilibrium relationship:

$$NH_4^+ \leftrightarrow NH_3 + H^+$$

- A given total amount of ammonia nitrogen in a water sample will consist of a fraction of ammonia and ammonium. The fractions of each depend on the pH.
- Most of the ammonia nitrogen in raw domestic wastewater (or any water in the neutral pH range) will be in the form of ammonium, NH_4^+.
- The primary sources of ammonia nitrogen in domestic wastewaters are urea and proteinaceous matter, which are readily converted by bacteria to ammonia. Ammonia nitrogen in domestic wastewater typically ranges in concentration from 12 to 50 mg/L as nitrogen, or "N."

Nitrite

- The chemical formula for nitrite is NO_2^-.
- Nitrite is formed from the oxidation of ammonia. *Nitrosomonas* bacteria oxidize ammonia to nitrite in biological wastewater treatment systems.

Nitrate

- The chemical formula for nitrate is NO_3^-.
- Nitrate is formed from the oxidation of nitrite. *Nitrobacter* bacteria oxidize nitrite to nitrate in biological wastewater treatment systems. Nitrite and nitrates are not typically found in raw domestic wastewater.

Organic-Nitrogen

- Organic-Nitrogen in domestic wastewaters comes primarily from urea and proteinaceous matter. The organic nitrogen concentration in domestic wastewater ranges from 8 to 35 mg/L as N.

Total Kjeldahl Nitrogen (TKN)

TKN is the sum of organic nitrogen and ammonia nitrogen. The concentration of TKN in typical domestic wastewater ranges from 20 to 85 mg/L as N.

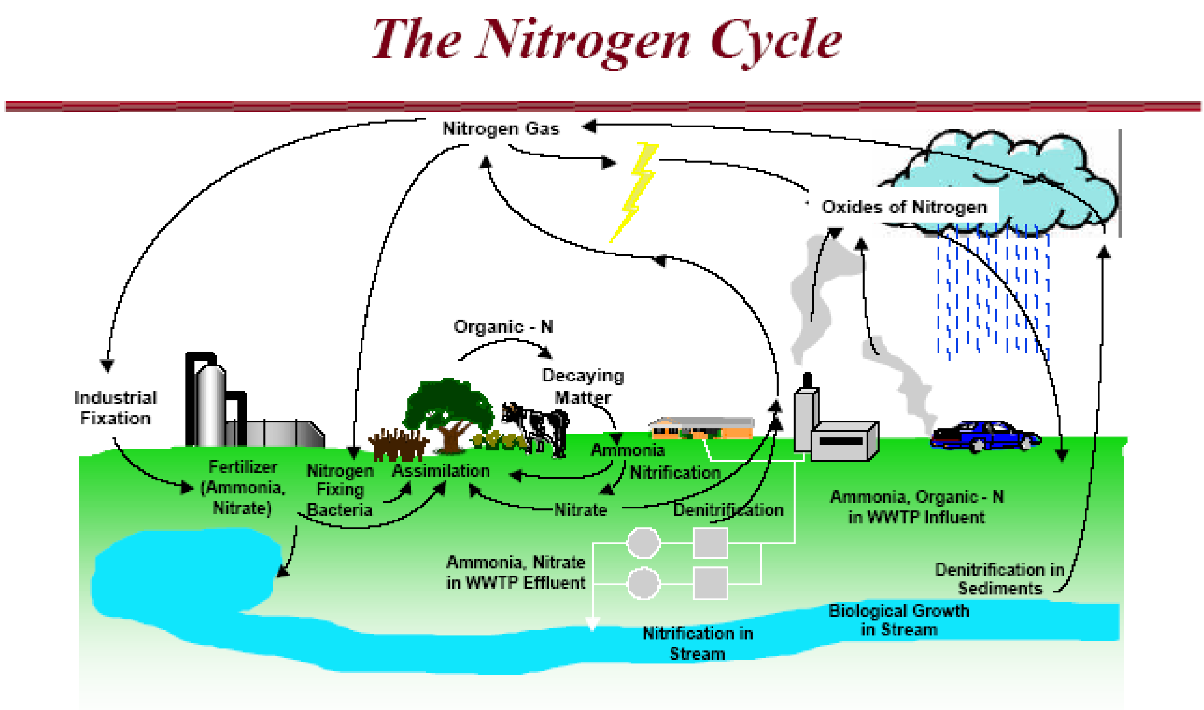

Figure 1.20 The Nitrogen Cycle [16]

Nitrogen's Effect on Receiving Waters

- Nitrogen is an essential nutrient for the growth of protista (protozoa, algae, and fungi) and plants; however, excessive quantities of nitrogen and certain forms of nitrogen discharged from wastewater treatment plants can adversely affect receiving waters and aquatic species.

Ammonia Toxicity

- Ammonia concentrations of about 3 mg/L are toxic to fish. Ammonia also imparts an oxygen demand in natural water systems because nitrifying bacteria will consume dissolved oxygen (DO) while oxidizing ammonia to nitrite and nitrate. This can result in low DO conditions that are harmful to fish and other aquatic species.

Oxygen Depletion After Algae/Plant Die-off

- Excessive nitrogen discharged from a wastewater treatment plant can result in the proliferation of algae (called algal blooms) and certain aquatic plants. This proliferation results in an increase in the mass of dead algae and plant matter, which become a food source for bacteria. As the bacteria feed on the dead matter, the DO level drops to levels that can no longer support certain species of fish. This process is called eutrophication.

Nitrate in Groundwater

- Nitrate in excess of 10 mg/L as N in drinking water can cause methemoglobinemia, a condition which impairs the blood's ability to carry oxygen. Nitrates are a concern if a wastewater treatment plant discharges to a stream or lake that recharges groundwater used as a drinking water supply.

Biological Nitrification

Biological nitrification is the process in which *Nitrosomonas* bacteria oxidize ammonia to nitrite and *Nitrobacter* bacteria oxidize nitrite to nitrate.

$$NH_4^+ \xrightarrow{\text{Nitrosomonas}} NO_2 \xrightarrow{\text{Nitrobacter}} NO_3$$

ammonia → nitrite → nitrate

- This process results in the overall conversion of ammonia to nitrate. These microorganisms are autotrophic, which means they derive their carbon source from inorganic carbon, such as carbon dioxide and bicarbonate. Most other types of organisms in the trickling filter are heterotrophic, which means they derive their carbon source from the organic matter in the wastewater.

- The overall result of nitrification is:

$$NH_4 + 2O_2 \rightarrow NO_3 + 2H^+ + 2H_2O$$

- Several factors influence the nitrification process through a trickling filter:
  - **Organic Loading**: Nitrification efficiency is greatly affected by the organic loading of the filter. Optimum nitrification is achieved at the following Biochemical Oxygen Demand (BOD) loadings:

    Rock Media → 3 – 8 lb BOD/day/1,000 ft^3

    Plastic Media → 12 – 181 lb BOD/day/1,000 ft^3

  - **Hydraulic Loading**: Sufficient hydraulic loading of the filter is necessary to maintain complete media wetting. Increased recirculation rates will also dilute the organic concentration of the filter influent, thus providing a more competitive environment for nitrifying bacteria.
  - **Temperature**: The nitrification process is extremely temperature dependent. The optimum range for nitrifying bacteria is between 4º to 45º C (39º to 113º F).
  - **pH:** The optimum pH range of nitrifying bacteria is between 7.8 and 8.2 s.u. The amount of alkalinity in the wastewater can have a significant impact on the pH level.
  - **Alkalinity:** Effluent alkalinity should be monitored daily to ensure that a minimum of 50 mg/L alkalinity (as $CaCO_3$) is maintained. An alkalinity concentration below 50 mg/L may result in pH levels below 7.0, which will adversely affect nitrification and decrease the ammonia removal efficiency. The bacteria consume 7.14 mg/L (or pounds) of alkalinity (as $CaCO_3$) for every mg/L (or pounds) of ammonia-nitrogen (NH_4^+-N) oxidized.
  - **Dissolved Oxygen**: Sufficient dissolved oxygen (DO) is required to drive the nitrification process. Typically, DO between 2.0 and 2.5 mg/L is considered the optimum range for a maximum nitrifying growth rate. Generally, maintaining a DO of at least 1.0 mg/L through the filter is necessary to achieve proper nitrification.
  - **Filter Media**: Generally, the larger the surface area of the filter media, the higher the nitrification ability. Since the filter media provides area for bacteria growth, larger surface areas will contain greater microbial populations and therefore will function more efficiently. For this reason, plastic filter media, which typically has a larger surface area than rock media, is better suited for nitrification.

Calculation

Example: Township WWTF, which processes 1.0 MGD, is required to nitrify to meet the 2.0 mg/L ammonia discharge limit stated in their NPDES permit. A table reflecting average daily influent alkalinity and ammonia concentrations and the average daily ammonia removal requirement is presented in the table below. Using the equation provided, determine how many pounds of alkalinity are available for nitrification.

	Alkalinity	Ammonia
	mg/L	mg/L
Influent	**210**	**50.0**
Final Effluent Requirement	**50**	**2.0**
Available for Nitrification	**160**	**---**
Removal Requirement	**---**	**48.0**

Flow (MG) x concentration (mg/L) x 8.34 = lbs

1.0 MG x 160 mg/L alkalinity x 8.34 = 1,334 lbs alkalinity

Now, determine how many pounds of alkalinity are required for nitrification. Hint: Approx. 7.2 lbs of alkalinity is required for every pound of ammonia-nitrogen oxidized.

	Alkalinity		Ammonia	
	mg/L	lbs	mg/L	lbs
Influent	**210**	**---**	**50.0**	**---**
Final Effluent Requirement	**50**	**---**	**2.0**	**---**
Available for Nitrification	**160**	**1,334**	**---**	**---**
Removal Requirement	**---**	**--**	**48.0**	**400**

400 lbs ammonia removed x 7.2 lbs alkalinity = 2,880 lbs of alkalinity are required.

Based on this information, will the addition of alkalinity be required in order to achieve complete nitrification and if so how much?

2,880 lbs alkalinity required – 1,334 lbs alkalinity available = 1,546 lbs alkalinity needed.

Answer: Yes. **At least 1,546 lbs of alkalinity will need to be added.**

Calculation

Capital City WWTF, which processes 2.0 MGD, is required to nitrify to meet the 2.0 mg/L ammonia discharge limit stated in their NPDES permit. A table reflecting average daily influent alkalinity and ammonia concentrations and the average daily ammonia removal requirement is presented in the table below.

	Alkalinity	Ammonia
	mg/L	mg/L
Influent	**415**	**52.0**
Final Effluent Requirement	**50**	**2.0**
Available for Nitrification	**365**	**---**
Removal Requirement	**---**	**50.0**

Using the equation provided, determine how many pounds of alkalinity are available for nitrification, the pounds of ammonia removed and the pounds of alkalinity required for nitrification. Based on this information, will the addition of alkalinity be required in order to achieve complete nitrification and if so how much?

Flow (MG) x concentration (mg/L) x 8.34 = lbs

Biological Denitrification

Biological denitrification is the process in which micro-organisms reduce nitrate to nitrite and nitrite to nitrogen gas.

- Heterotrophic bacteria normally present in trickling filters perform this conversion when there is no molecular oxygen or dissolved oxygen, and there is sufficient organic matter. The bacteria derive their oxygen from the oxygen contained in the nitrate. The nitrogen gas produced is in the form of nitric oxide (NO), nitrous oxide (N_2O), or nitrogen gas (N_2).

- The net removal of nitrogen is accomplished by stripping the nitrogen gas formed during denitrification out of the wastewater in a subsequent aeration process.

- Denitrification does not occur within the trickling filter.

Advantages of a Trickling Filter

1. Low Energy Requirements: Trickling filters do not typically require additional energy-consuming equipment such as aeration blowers.

2. Waste Sludge Easy to Dewater: Sludge and solids from a trickling filter are primarily composed of the sloughed off biological slime layer.
   - This type of sludge tends to settle and dewater easier than waste activated sludge from conventional activated sludge plants.

3. Low Maintenance Requirements: Since there are a limited number of moving parts, trickling filters typically require minimum maintenance.

4. Consistent Effluent Quality: Trickling filters perform extremely reliably at low or consistent loadings.
   - Trickling filter technology is a simple, reliable process.

5. Resistant to Toxins and Shock Loads: Trickling filters have the ability to handle and recover from shock loads since they are not a complete mix system.
   - A toxic "slug" will only effect the portion of the filter that it is sprayed on, thus allowing the remainder of the filter to continue to operate normally.
   - Recirculation of filter effluent back through the filter acts to dilute any shock loads which are introduced to the unit.

6. Ease of Operation: Trickling filters do not require a high level of sophisticated operation in order to provide a reasonable effluent.

Disadvantages of a Trickling Filter

1. Odors and Nuisance Organisms: Excessive organic loading or inadequate ventilation can lead to anaerobic decomposition in the filter media which can cause objectionable odors. For covered filters, a forced-air ventilation system and odor control of the exhaust is usually provided. Operators should always check for atmospheric hazards before entering.
   - Filter flies (*Psychoda*) and other insects can flourish around trickling filters if housekeeping is not maintained or if the filter media moisture is not adequate.

2. Potential for Clogged Media: Excessive sloughing off of the media slime layer can cause portions of the filter media to become clogged, resulting in inefficient treatment removal and poor effluent quality. Seasonal sloughing will be apparent from the increase in secondary sludge production.

3. Cold Weather Can Cause Freezing: Icing of the distributor arm orifices or spray nozzles is a common problem during winter months due to the low hydraulic loading onto the filters.

4. Lack of Adjustment: Trickling filters do not have features which allow them to be quickly adjusted for a rapid increase in loading. In addition, trickling filters can not be fine-tuned to achieve a high level of treatment.

5. Pumping Costs: It may be necessary to pump the wastewater to a higher elevation so the flow can go out through the distributor. Additionally, recirculation of wastewater may be necessary to achieve sufficient wetting of the media.

Trickling filters can be classified into three general categories according to their design hydraulic and organic loading rates. These categories are:

- Standard Rate Filters
- High Rate Filters
- Roughing Filters

Standard Rate Filters

Design Loading

- Hydraulic Loading Rate
  - 25 – 100 gallons per day per square foot (gpd/ft^2)

- Organic Loading Rate
  - 5 – 25 pounds of BOD per day per 1,000 cubic feet (lb BOD/day/1,000 ft^3)

Media

- Typically a rock media
- Generally 6 – 8 feet in depth

Effluent Quality

- Achieves a 50% to 70% BOD reduction

Recirculation Capabilities

- Can be recirculated at a rate between 0.0 to 1.0 times the average forward flow through the plant (i.e., the influent flow rate into the plant)

Seasonal Sloughing

- Seasonal sloughing will occur particularly in the fall and winter months.

Problems

- Lack of recirculation may increase filter flies

- Seasonal variations yield variable treatment efficiency. As with most biological systems, peak performance and treatment efficiencies typically occur during the warmer summer months.

High Rate Filters

Design Loading

- Hydraulic Loading Rate
  - Rock media → 100 – 1,000 gpd/ft^2
  - Synthetic media → 350 – 2,100 gpd/ft^2

- Organic Loading Rate
  - Rock media → 25 – 100 lb BOD/day/1,000 ft^3
  - Synthetic media → 50 – 300 lb BOD/day/1,000 ft^3

Media Depth

- Rock media → 3 – 5 feet
- Synthetic media → 15 – 30 feet

Effluent Quality

- 65% to 95% BOD reduction
- May also be used for nitrification

Recirculation Capabilities

- Most high-rate trickling filters have the capability to re-circulate at a rate between 1.0 and 2.0 of the average forward flow of the plant.

Roughing Filters

Design Loading

- Roughing filters are unique trickling filters which are capable of handling extremely high organic loading rates.
- Organic loading rate → 100 – 300 lb BOD/day/1,000 ft^3

Uses

- Used to reduce organic loading to subsequent oxidation processes.
- A "pre-treatment" for high strength wastewater prior to another biological treatment process.
- Roughing filters are also used in applications where the discharge criteria is not very stringent, such as in pre-treatment of high strength industrial wastewater that is discharged to the sanitary sewer system for further treatment.

Hydraulic Loading Rate

Hydraulic loading rate is the flow of wastewater applied to the trickling filter per unit of surface area. Generally, hydraulic loading is expressed in gals/day/ft^2.

- o In other words, it is the volume of wastewater that passes over a 1 foot by 1 foot section of the filter during a 24-hour period.

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

Calculation

$$\text{Hydraulic Loading (gpd/ft}^2\text{)} = \frac{\text{Influent Flow, gpd}}{\text{(Surface Area, ft}^2\text{)}}$$

Example: Calculate the hydraulic loading of a Trickling Filter with the following data:

Diameter of TF = 60 ft
Influent Flow = 755,000 gpd

Surface Area = (π) x (radius)^2 = (3.14) x (30)^2 = 2,826 ft^2

$$\text{Hydraulic Loading} = \frac{\text{(755,000 gpd)}}{\text{(2,826 ft}^2\text{)}} = \mathbf{271\ gpd/ft^2}$$

Exercise: Calculate the hydraulic loading of a Trickling Filter with the following data:

Diameter of TF = 40 ft
Influent Flow = 2.0 mgd

Organic Loading Rate

Organic loading rate is defined as the pounds of Biochemical Oxygen Demand applied to the trickling filter per 1,000 ft^3 of volume of media per day.

- o *Biochemical Oxygen Demand* is the rate at which organisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria and energy results from its oxidation.

♦ Generally, organic loading is expressed in lb BOD/day/1,000 ft^3.

- o In other words, it is the amount of organic loading, in pounds of BOD that is applied over a 10 foot wide by 10 foot long by 10 foot deep section of the filter during a 24-hour period.

♦ Increased organic loadings lead to increased biological activity, where dissolved oxygen becomes depleted.

Calculation

$$\text{Organic Load (lb BOD/day/1,000 ft}^3) = \frac{(\text{BOD, mg/L}) \times (\text{Flow, mgd}) \times (8.34\ \text{lb/gallon}) \times (1{,}000\ \text{ft}^3)}{(\text{Volume, ft}^3)}$$

Example: Calculate the organic loading of a Trickling Filter with the following data:

Diameter of TF	=	50 feet
Depth of Media	=	20 feet
Influent Flow	=	1.0 mgd
Influent BOD	=	240 mg/L

$$\text{Media Volume (ft}^3) = (\pi) \times (\text{radius})^2 \times (\text{depth}) = (3.14) \times (25\ \text{feet})^2 \times (20\ \text{feet}) = 39{,}250\ \text{ft}^3$$

$$\text{Organic Load} = \frac{(240\ \text{mg/L}) \times (1.0\ \text{mgd}) \times (8.34\ \text{lb/gallon}) \times (1{,}000\ \text{ft}^3)}{(39{,}250\ \text{ft}^3)} = \mathbf{51\ lb\ BOD/day/1{,}000\ ft^3}$$

Exercise: Calculate the organic loading of a Trickling Filter with the following data:

Diameter of TF	=	60 feet
Depth of Media	=	6 feet
Influent Flow	=	100,000 gpd
Influent BOD	=	200 mg/L

Basic Treatment Unit Arrangement

Trickling filters are generally preceded by primary clarifiers and followed by final clarifiers. There are, however, several different variations of this theme. Two or more filters can be operated in unison and intermediate clarifiers can be incorporated between filters. Treatment unit arrangements can be classified into the following two categories:

- Single-Stage
- Two-Stage

Single-Stage Arrangement

The simplest arrangement of a trickling filter plant involves a primary clarifier followed by a trickling filter followed by a final clarifier.

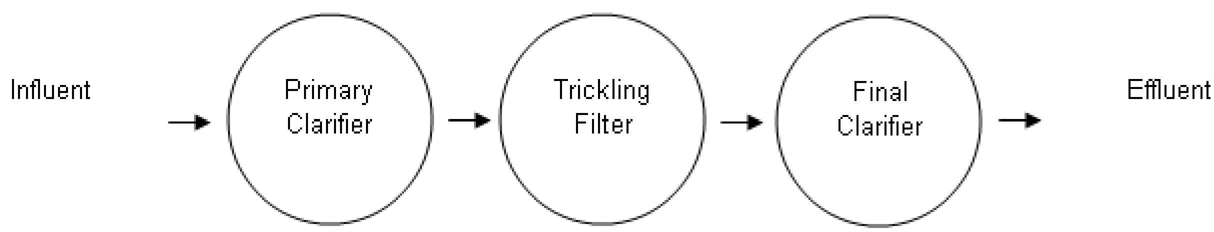

Figure 1.21 Single-Stage Trickling Filter Arrangement

Two-Stage Arrangement

Two-stage trickling filter systems typically have two filters, one flowing into the other. The first stage is primarily used for cBOD removal and the second state is typically used for nitrification. Two-stage filters are used when:

- A high-quality effluent is required; the first stage is primarily used for BOD removal and the second stage is typically used for nitrification.
- High strength wastewater is treated; or
- Cold weather operation is required.

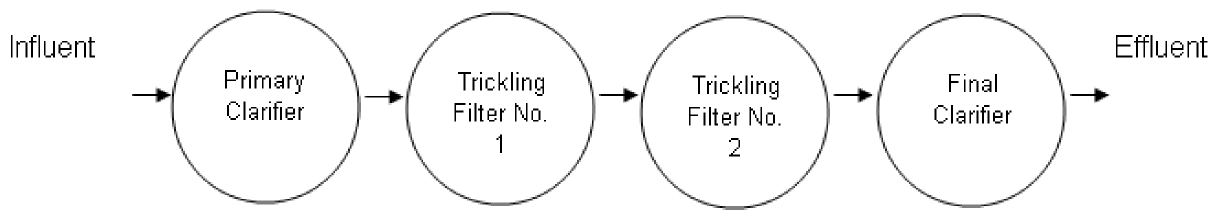

Figure 1.22 Two-Stage Trickling Filter Arrangement

Use of Intermediate Clarification

Often, two-stage trickling filter systems utilize an intermediate clarifier between the first and second filters. The intermediate clarifier is used to remove solids, including sloughed slime layers, from the first filter. Removal of these solids minimizes clogging of the second filter.

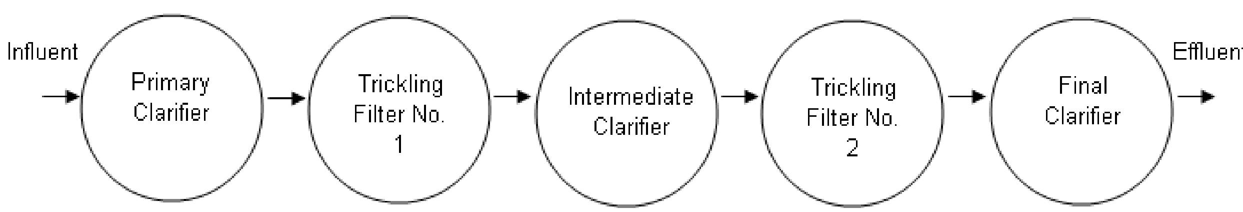

Figure 1.23 Two-Stage Trickling Filter Arrangement with Intermediate Clarification

Orientation of Trickling Filters

Trickling Filters can be oriented in one of the following ways:

- Series
- Parallel

Series Orientation

"Series" orientation contains two or more trickling filters that are connected, with one directly following the next.

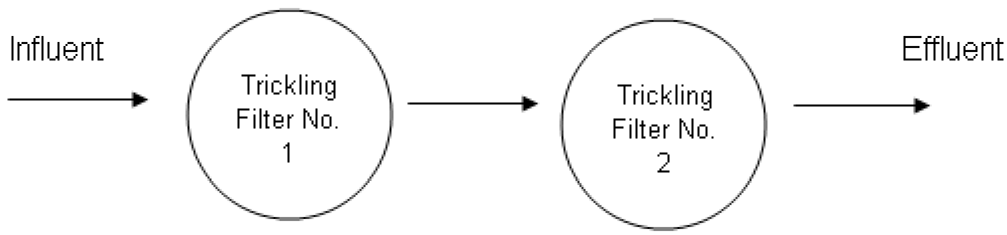

Figure 1.24 Series Orientation of Trickling Filters

Parallel Orientation

"Parallel" orientation contains two or more trickling filters that are operated side by side. One filter can be removed from service without disruption of treatment in the other filters(s).

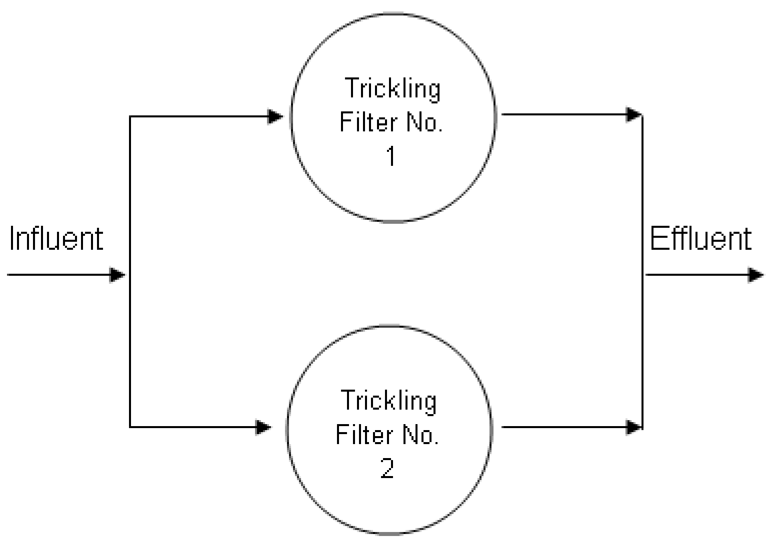

Figure 1.25 Parallel Orientation of Trickling Filters

For the most efficient operation, the DEP's *Facilities Manual* recommends that an optimal system should contain at least three cells and should be designed to operate in series *and* parallel.

Table 1.1 Design Information for Trickling Filters [17]

Item	**Low or Standard-rate**	**Intermediate rate**	**High-rate**	**High rate**	**Roughing**	**Two-stage**
Filter medium	Rock, slag	Rock, slag	Rock	Plastic	Plastic	Rock, plastic
Hydraulic loading ,gpd/ft2	25-100	100-500	100-1000	350-1200	1400-5600	100-1000
BOD5 loading, lb/1,000 ft3/day	5-25	15-30	25-100	50-300	100-500	60-120
Depth, ft	6-8	6-8	3-5	15-30	15-40	6-8
Recirculation ratio	0-1:1	0-1:1	1-2:1	1-2:1	1-4:1	0.5-2:1
Filter flies	Many	Some	Few	Few or none	Few or none	Few or none
Sloughing	Intermediate	Intermediate	Continuous	Continuous	Continuous	Continuous
BOD5 removal efficiency (%)	50-70	80-90	65-95	65-95	40-65	85-95
Effluent	Well-nitrified	Partially nitrified	Little nitrification	Little nitrification	No nitrification	Well-nitrified
Adapted in part from WEF (2000) AND METCALF & EDDY (1997)						

Benefits of Recirculation

Recirculation is the practice of recycling a portion of the trickling filter effluent back through the filter. The recycled wastewater can be pumped from several different locations, such as a trickling filter effluent, intermediate clarifier effluent, or secondary clarifier effluent. There are several primary reasons to re-circulate trickling filter effluent.

Keeping the Filter Wet

- The filter media must remain wet in order to sustain the biological slime layer necessary for proper treatment.
- The bacteria and micro-organisms living in the slime layer will die off if the media becomes dry.
- Synthetic media does not tend to retain moisture as well as rock media.
- Synthetic media has a higher void space. This allows more efficient air movement which may tend to dehydrate the bio-growth on the media.

Diluting Toxic Influent Flow

- Recirculation acts as a buffer for toxic, or shock, loads by diluting the influent flow.
- Recycled wastewater minimizes loading variations applied to the filter.

Improving Treatment Efficiency

- Recycled wastewater contacts the active biological slime layer on the filter media more than once. This allows for increased treatment efficiency and helps to “seed” the filter with micro-organisms, depending on the recirculation arrangement.
- Recycled filter effluent minimizes loading variations applied to the filter by diluting higher strength wastewater and supplementing weaker strength wastewater, depending on the recirculation arrangement.
- Recirculation keeps wastewater fresh and reduces the potential creation of septic conditions. It also helps to reduce scum formation.
- Recirculation improves distribution over the surface of the filters and reduces clogging through the filter.

Controlling Excess Biomass

- Recirculation increases the hydraulic loading applied to the trickling filters and can aid in the normal sloughing process to control media slime layer biomass.
- The recycled flow will help "shear" off excessive biomass accumulations to maintain a more optimum and uniform slime growth.
  - This creates a more uniform and continuous sloughing of the slime layer.
  - Sloughing prevents clogging and ponding of wastewater and increases voids for ventilation.

Recirculation Arrangements

There are many different recirculation arrangements, or patterns, used for trickling filters. The incorporation of recycled wastewater can be divided into two categories:

- Single-Stage Recirculation Patterns
- Two-Stage Recirculation Patterns

Single-Stage Recirculation Patterns

1. Trickling filter effluent can be re-circulated directly back to the trickling filter influent:

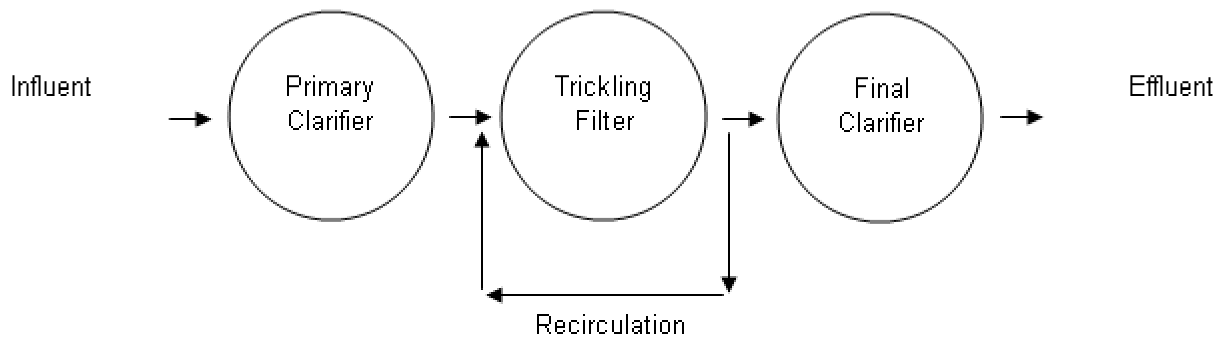

Figure 1.26 Single Stage Trickling Filter with Filter Effluent Recirculation

2. Final clarifier effluent can be re-circulated to the trickling filter influent:

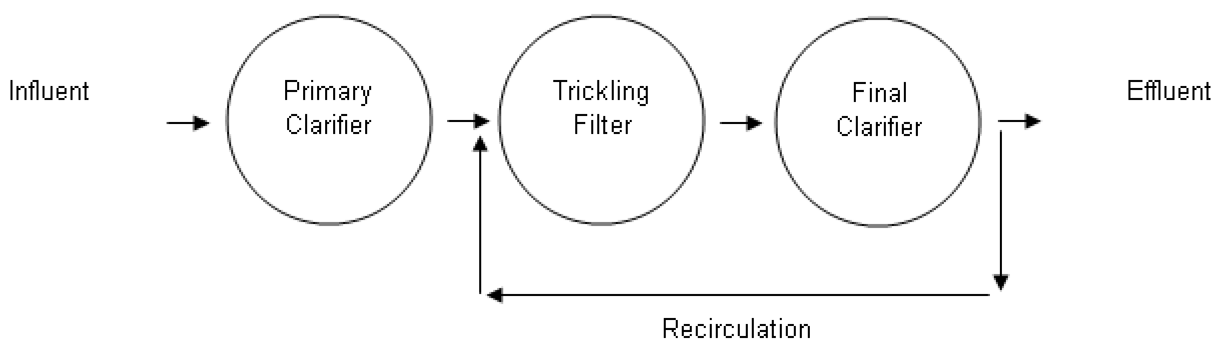

Figure 1.27 Single Stage Trickling Filter with Final Clarifier Effluent Recirculation

Two-Stage Recirculation Patterns

- Two-stage plants can have many different recirculation patterns.

Description of Common Two Stage Patterns

- Recycle will be directly around one or two filters.
- Filter effluent will pass through a clarifier prior to passing back through a second filter.

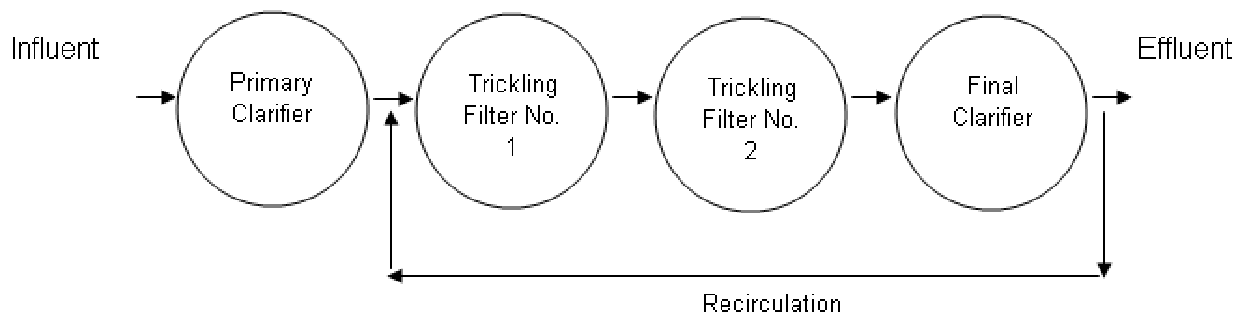

Figure 1.28 Two Stage Trickling Filter Arrangement with Final Clarifier Recirculation

Recirculation of Clarified Wastewater

It is often preferred to recirculate wastewater that has already passed through a clarifier.

- This reduces the chances of solids clogging the filter media.
- Most solids in the trickling filter effluent will have settled in the clarifier.
- A drawback, however, can be hydraulically overloading the clarifier.

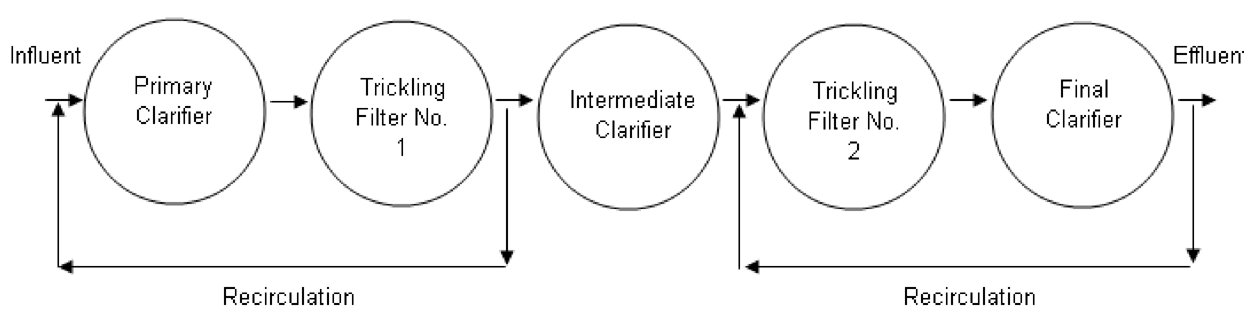

Figure 1.29 Two Stage Trickling Filter Arrangement with Intermediate Clarification and Recirculation

Notes Regarding Recirculation

Recirculation should not be confused with the return of settled solids from the final clarifier to the primary clarifier for wasting to the sludge handling system.

- Wasting secondary sludge to the primary clarifier may occur through the same piping.
- The intent of wasting sludge to the primary clarifier is not to return sludge solids to the trickling filter.

Recirculation flows should always be taken into account when calculating hydraulic loading. Excessive recirculation may cause a hydraulic overload of the system.

- Ventilation is crucial because nitrifying bacteria require adequate oxygen to survive (i.e., 4.2 mg oxygen per mg ammonia oxidized). The trickling filter is either vented naturally or through the use of blowers (forced ventilation). Blowers are usually placed at the bottom of the tank to force air up through the media.

Key Points for Unit 1 – Process Description and Classifications of Trickling Filters

- Trickling filters are a type of fixed film biological treatment. The micro-organisms used to treat the wastewater are attached, or fixed, to a medium as they contact the wastewater. These micro-organisms primarily reduce the cBOD of the wastewater; however, they can also be utilized to reduce ammonia nitrogen through the process of nitrification.

- Trickling filters are a viable treatment alternative due to their low energy and maintenance requirements and their ability to treat variable organic loads and toxic substances.

- Trickling filters are composed of a distribution system, filter media and underdrain system.

- The filter medium provides a surface for the zoogleal film to attach and grow. There are generally two types of filter media: rock (or slag) and synthetic material.

- The underdrain system collects treated wastewater and the solids discharged from the filter media. The waste is conveyed to a sedimentation tank by gravity flow.

- Bacteria are divided into two general categories: those that require oxygen for respiration (aerobic bacteria) and those that do not (anaerobic bacteria).

- Trickling filters can be classified into three general categories according to their design hydraulic and organic loading rates and include standard rate, high rate and roughing filters.

- Seasonal variations yield variable treatment efficiency. As with most biological systems, peak performance and treatment efficiencies typically occur during the warmer summer months.

- Seasonal sloughing will be apparent from the increase in secondary sludge production.

- Hydraulic loading rate is the flow of wastewater applied to the trickling filter per unit of surface area. Generally, hydraulic loading is expressed in gals/day/ft^2.

- Organic loading rate is defined as the pounds of Biochemical Oxygen Demand applied to the trickling filter per 1,000 ft^3 of volume of media per day.

- Treatment unit arrangements can be classified into single stage and two-stage and be arranged either in series or in parallel.

- Recirculation is the practice of recycling a portion of the trickling filter effluent back through the filter. Excessive recirculation may cause a hydraulic overload of the system.

Unit 1 Exercise

1. Name the three components of a trickling filter.

   a. ______________________________

   b. ______________________________

   c. ______________________________

2. List the three functions of the underdrain system.

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. The slime layer or growth attached to the filter media is also known as ________ ________.

4. The primary function of the bacteria and micro-organisms contained in the zoogleal film is __________

   ____.

5. Biological nitrification is the process in which __________organisms convert ammonia into nitrate. ____________bacteria oxidize ammonia to nitrite and __________bacteria oxidize nitrite to nitrate.

6. Name the two general types of trickling filters based on method of distribution.

   a. ______________________________

   b. ______________________________

7. Describe the process and operation of a trickling filter.

8. Identify the three classifications of trickling filters based on hydraulic and organic loading rates.

   a. ____

   b. ____

   c. ____

9. Sludge from the final clarifier should be pumped back to the ________ ________ or to a _______ __________for further treatment.

10. Calculate the hydraulic loading rate of a trickling filter, given a diameter of 55 feet and an influent flow of 1.25 mgd.

11. Calculate the organic loading rate of the trickling filter in the above question, given a media depth of 20 feet and an influent BOD of 235 mg/L.

[1] L. Metcalf and H. Eddy, *Wastewater Engineering Treatment Disposal Reuse*, 3rd edition, (New York, NY: McGraw-Hill Book Co., Inc., 1991), p 45.

[2] Larry Bristow, "Chapter 6: Trickling Filters," *Operators of Wastewater Treatment Plants,* Volume I, (Sacramento, CA: California State University, Sacramento Foundation, 1998), p 172.

[3] US Filter, *Rotary Distributors*, http://www.usfilter.com/water/ProductDescription.asp?WID=25&PID=158&EU=14&TE=3&PATH=EU-TE, June 2, 2004.

[4] L. Metcalf and H. Eddy, *Wastewater Engineering Treatment Disposal Reuse*, 3rd edition, (New York, NY: McGraw-Hill Book Co., Inc., 1991), p 621.

[5] ibid.

[6] ibid., p 406.

[7] Hi-Tech Environmental, Inc., *Hi-Tech Poly-Pak Trickling Filter Media*, http://www.hi-techenv.com/FilterMedia.htm, June 16, 2004.

[8] L. Metcalf and H. Eddy, *Wastewater Engineering Treatment Disposal Reuse*, 3rd edition, (New York, NY: McGraw-Hill Book Co., Inc., 1991), p 622.

[9] Lenore S. Clesceri, Arnold E. Greenberg, Andrew D. Eaton, Eds. *Standard Methods for Examination of Water and Wastewater*, 20th Edition, (Washington DC: American Public Health Association, 1998), p 10-121.

[10] ibid., p 10-123.

[11] ibid., p 10-124.

[12] ibid.

[13] ibid., p 10-129.

[14] ibid., p 10-129.

[15] Lenore S. Clesceri, Arnold E. Greenberg, Andrew D. Eaton, Eds., *Standard Methods for the Examination of Water and Wastewater*, 18th Edition, (Washington DC: American Public Health Association, 1992), p. 10-99.

[16] PA DEP, *Design and Operation of Biological Nutrient Removal for Municipal Wastewater Facilities*, http://www.dep.state.pa.us/dep/deputate/watermgt/wsm/wsm_tao/innovtechforum/innovtechforum-ib-copi_01-20.pdf, June 21, 2004.

[17] L. Metcalf and H. Eddy, *Wastewater Engineering Treatment Disposal Reuse*, 3rd edition, (New York, NY: McGraw-Hill Book Co., Inc., 1991), p 615.

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Unit 2 – Trickling Filter Operation Strategies

Learning Objectives

- Identify five daily operations inspections appropriate for trickling filters.
- List three abnormal operating conditions typically encountered in a trickling filter facility and explain what steps can be taken to correct each problem.
- Give one example of an operation modification that may be required due to sampling results.

Physical Inspections

Trickling Filters should be inspected on a daily basis for signs of:

- Ponding
- Uneven Distribution of Flow
- Clogging
- Roughness or Vibration
- Leakage
- Filter Flies
- Unusual Odors

These problems will be discussed later in this unit.

Sampling and Recordkeeping

Developing a Sampling Plan

1. Review NPDES Permit parameters. Include all mandatory analysis at the specified frequencies.

2. Review the types of discharges to the collection system (i.e., residential, commercial, or industrial).

3. Review any regulations which require loading information to the wastewater treatment plant. One example is PA Code 25, Chapter 94 (Pennsylvania Municipal Wasteload Management Report).

4. Determine if any process upsets have occurred in the past.

5. Review solids handling and disposal procedures.

Importance of a Sampling Plan

- It is important for an operator to understand the normal operating ranges of the plant in order to determine when the plant is not performing correctly.

- Test results can often indicate which part of the treatment process may be causing the problem.

Factors to Consider

- 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.

Suggested Testing Parameters

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

Influent Flow and Recirculation Rates

- Useful for determining whether hydraulic over- or under-loading may be contributing to poor performance.
- A plant is operating efficiently when enough recirculation occurs to promote good biological growth and efficient treatment, but is not so much that unnecessary amounts of energy are consumed in pumping the recirculation flow.

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

- It is recommended that BOD, Carbonaceous Biochemical Oxygen Demand (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 trickling filter, as well as primary clarifier performance.

pH

- It is recommended that pH be tested daily on plant influent and final effluent.

Dissolved Oxygen (DO)

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

Settleable Solids or Suspended Solids

- It is recommended that settleable solids be tested daily or at least once a week.
- Many wastewater treatment plants are replacing the settleable solids test with the suspended solids test.

Recordkeeping

A written record of all operation statuses and changes should be maintained for process control and to meet regulatory requirements. Besides 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 trickling filter.

- 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 available for easy reference.

Uses of Data

- There are many uses of trickling filter operational data. Properly collected, analyzed, and recorded data is invaluable for calculating process loading rates and treatment efficiencies, as well as developing trends through the use of graphs.

Process Loading Rates

- Data can be used to calculate the loading rates, both hydraulic and organic, to the trickling filter. 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.

Calculation

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

Example: Calculate the BOD removal efficiency of a Trickling Filter with the following data:

Influent BOD = 175 mg/L
Effluent BOD = 20 mg/L

Percent Removal = [(175-20) / 175] x 100 = 88.6%

Exercise: Calculate the Ammonia Nitrogen removal efficiency of a Trickling Filter with the following data:

Influent NH_3-N = 10 mg/L
Effluent NH_3-N = 2.5 mg/L

Graphing

- Graphs can be used to detect trends in data.

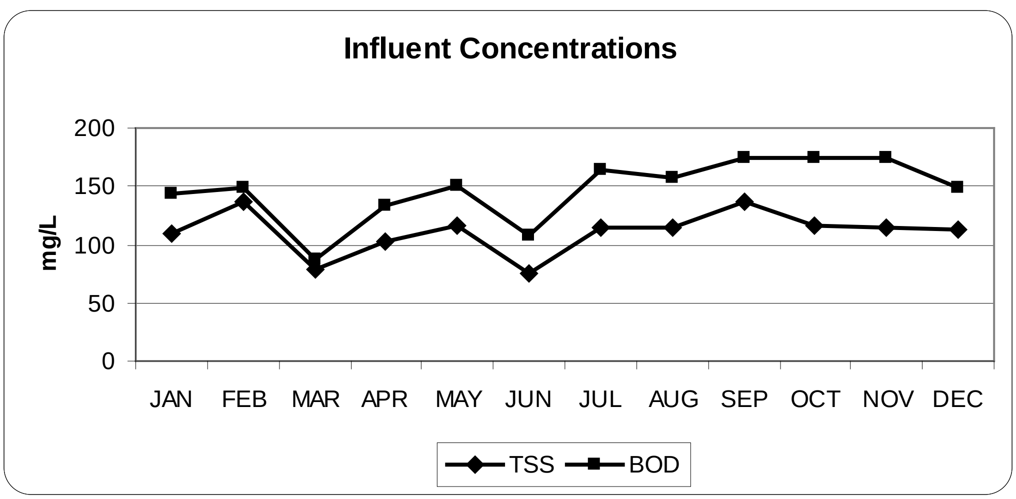

Figure 2.1 Graph of Influent Concentrations Showing Trends

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

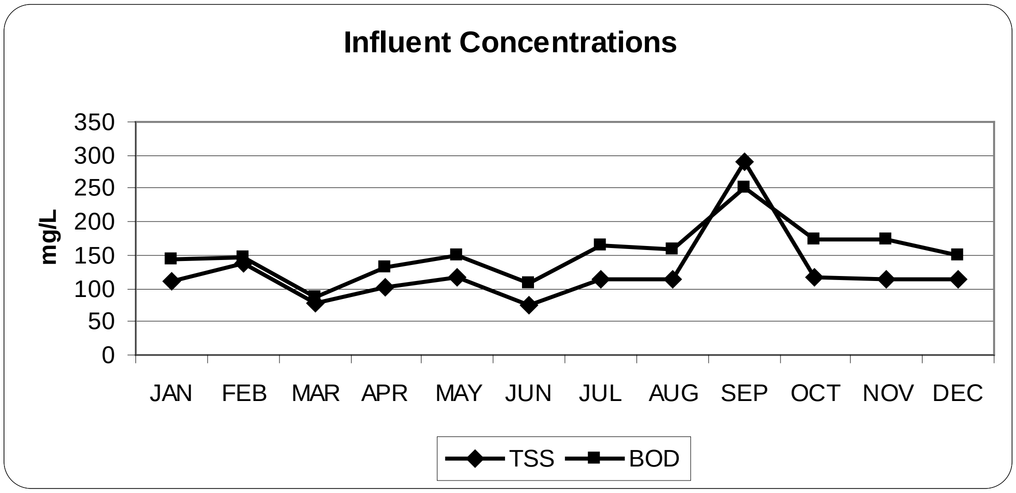

Figure 2.2 Graph of Influent Concentrations Showing Unusual Results

- Long-term plots tend to be more useful than short time periods. 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.

High Total Suspended Solids

Causes and Effects

- Elevated total suspended solids (TSS) may be caused by:
  - *Excessive sloughing of biomass, or*
  - Hydraulic overloading of the final clarifier.

Responses

- Calculate the hydraulic loading rate of the wastewater treatment plant if total suspended solids are high.

High Biochemical Oxygen Demand

Causes and Effects

- Excessive biochemical oxygen demand (BOD) may be caused by:
  - Increased influent organic loading can lead to excessive organic loads to a trickling filter which can not be properly treated to sufficiently remove pollutants to acceptable levels. This results in decreased treatment efficiency.

Responses

- Sample the collection system to identify the cause or source of increased loading.
- Develop and implement sewer-use ordinances to establish limitations on organic loading discharge and criminal fines if discharges occur.

High Settleable Solids

Causes and Effects

- High loading to the wastewater treatment plant flushes material out of the primary clarifier.
- Insufficient hydraulic loading to the trickling filter causes the biological growth to die and slough off.
- Excessive hydraulic loading to the trickling filter causes the biological growth to be stripped off the media.
- Clogging of the trickling filter void spaces causes the biological growth to be unable to maintain an aerobic environment and the biological growth will slough off the media.

Responses

- Check hydraulic loadings and adjust as necessary.

Low Dissolved Oxygen

Causes and Effects

- Low dissolved oxygen might result from clogged void spaces around the media which causes inadequate air flow through the filter.

Responses

- Observe the media growth to see if it is excessive.
- Check for clogging of the media or if the media growth is starting to fall apart.
- Check to see if any atmospheric conditions might cause a decreased air flow through the filter.

High Chlorine Demand

Causes and Effects

- Might be caused by industrial waste being discharged. This will cause an inability to achieve downstream disinfection.
- Excessive total suspended solids in the effluent, caused by sloughing of the filter media, will also exert a high chlorine demand.

Responses

- Conduct a survey of the sewer system customers to determine if non-domestic type wastewater is being discharged.
- Calculate the hydraulic loading rate of the trickling filters and adjust if necessary.
  - Place multiple trickling filters in “parallel” operation to reduce excessive hydraulic loading, which will minimize excessive sloughing.

Poor Clarity

Causes and Effects

- Excessive suspended solids in the effluent can result in poor clarity and be caused by sloughing of the filter media.
  - Excessive hydraulic loading of the filter causes sloughing, or shearing of the slime layer.
- Excessive suspended solids in the effluent can also be caused by improper operation of the downstream clarifier. Maintaining too much sludge in the clarifier will lead to the flushing out of solids with the effluent.

Responses

- Calculate the hydraulic loading rate of the trickling filters and adjust if necessary.
  - Place multiple trickling filters in “parallel” operation to reduce excessive hydraulic loading, which will minimize excessive sloughing.
- The timely removal of settled sludge from the final clarifiers will eliminate flushing of solids in the final clarifier effluent.

Low or High pH

Causes and Effects

- Septic conditions typically cause wastewater pH to decrease.
- The biological process of nitrification will naturally result in a slightly decreased pH.
- Industrial wastewater discharges can lead to either increased or decreased pH, depending on the source of the discharge.

Responses

- For septic conditions, the pH of the wastewater will need to be increased. This may be the result of too high a load or too small media. Septic conditions mean sulfates are being broken down and H_2S is being formed. The odor and reduced treatment will be a problem long before pH.
- For nitrified wastewater, the pH will need to be increased. Nitrification consumes alkalinity which may cause pH to fall. Adding alkalinity will stop the decrease and may cause it to increase. This is desired since the best pH for nitrification is 7.8 to 8.2, which is higher than most plants are normally.
- The pH of industrial discharges will need to be adjusted accordingly.
- Correct the problems that allowed the anaerobic conditions to develop.

High Fecal Coliform

Causes and Effects

- High solids in the clarifier effluent will hinder proper disinfection and result in high fecal coliform counts.

Responses

- By properly removing settled solids from the final clarifier, excessive solids will not be washed out in the effluent. Increasing solids removal from the treatment process will help to eliminate this problem.

Nutrient Imbalance

Causes and Effects

- Bacteria and micro-organisms living in the filter media slime layer require a sufficient supply of nutrients, such as nitrogen and phosphorus, to grow and reproduce.
- Typically, normal domestic wastewater contains adequate nutrients for this purpose; however, certain industrial wastewaters are nutrient deficient.

Responses

- The influent wastewater should be analyzed to establish that the proper nutrient loadings are available for the filter media biomass.
  - A general rule of thumb is that five (5) pounds of ammonia nitrogen and one (1) pound of orthophosphate are required for every one hundred (100) pounds of biochemical oxygen demand.
- If the influent wastewater is nutrient deficient, nutrients must be added to attain optimum treatment efficiencies.

Ponding

Causes and Effects

- Ponding is caused when biological solids build-up in the filter media and block passage of air and water through portions of the trickling filter.

- Solids may accumulate because the media is improperly sized or because the hydraulic loading is too low to sheer the slime layer.

- Accumulated solids can cause surface ponding that is visible to the operator, but sometimes the accumulation of solids is not made visible by ponding.

- To determine if a ponding problem is the result of biomass buildup:
  - The distributor arm can be stopped in one position for a period of time.
  - The hydraulic load to that portion of the filter will increase and should result in increased hydraulic sheering.
  - The effluent total suspended solids (TSS) should be monitored.
    - If there is an initial increase in TSS which tapers off, the ponding problem is likely a result of biomass accumulation.

Responses

- Increasing the recirculation rate to the trickling filter may sheer the accumulated biomass and open plugged void spaces in the media.

- If the filter has a rotary distribution arm, slowing the rate of revolution of the arm can also act to flush excess solids.
  - Slowing the revolution of the arm increases the instantaneous hydraulic load to each section of the media and can work to flush biomass.

- If additional flushing is required, low doses of chlorine can also be applied to the filter media to kill excess biomass

Odors

Causes and Effects

- Septic wastewater is one of the main sources of odors.
- Odors can be emitted when wastewater is sprayed or distributed over the filter media.
- They can also occur as a result of excess biomass accumulation in the media.
- May indicate that an area within the filter is not properly aerated or that the biomass is dying off.

Responses

- If the odor is caused by substances in the wastewater, pre-aerating the wastewater can eliminate the problem.
  - It might become necessary, however, to collect and treat the off-gas as well.
- If the odor is caused by biomass accumulation in the media, increasing the recirculation rate and checking for vent obstructions can eliminate the problem.
- Check for clogged nozzles which may not be allowing for equal distribution of flow.

Filter Flies

Filter flies, *Psychoda*, are tiny, gnat-size insects which are a common nuisance found around trickling filters.

Causes and Effects

- Uneven or intermittent wetting (poor distribution of the wastewater over the media) of the filter media provides a breeding ground for filter flies.
- Filter flies thrive on filters which alternate between wet and dry conditions.

Responses

Filter fly populations can be reduced or eliminated by:

- Increasing the recirculation rates to flush the filter.
- Periodically flooding the filter.
- Using natural techniques such as the installation of bird houses or bat boxes.

If filter fly populations continue to be a problem, more aggressive chemical alternatives might be necessary:

- Application of an insecticide on the filter media.
- Pre-chlorinating the trickling filter influent.

Sloughing

Sloughing refers to the slime layer falling off the trickling filter media.

Causes and Effects

- Sloughing is a normal consequence of filter operation.
- The slime layer will continue to increase in thickness until organic matter can no longer permeate it.
  - Micro-organisms nearest the media will not receive enough organic matter to sustain growth and reproduction and they will begin to die. Sections of the slime layer will then slough-off the media.
  - These solids will be collected in the underdrain collection system and flow to the final clarifier to settle out.
- This may occur due to plugged distributor nozzles or low flow conditions.
  - Treatment efficiency will be lost until the slime layer receives enough organic material and/or moisture to support re-growth.
- Abnormal sloughing may also occur when the hydraulic loading rate through the filter is too high.
  - The slime layer will slough off due to the sheering force of the wastewater.
  - Viable micro-organisms will be lost and treatment can become less efficient.

Responses

- If excessive sloughing is caused by low organic loading:
  - Unplug the trickling filter's distributor arm orifices or spray nozzles.
  - Increase re-circulation flow to the trickling filter.
- If excessive sloughing is caused by high hydraulic loading:
  - Divert a portion of the flow to additional treatment units or an equalization tank, if possible.
  - Decrease the re-circulation flow to the trickling filter, if possible.

Weather Concerns

Causes and Effects

- Cold weather generally slows biological reaction rates of the treatment process, however, the real danger is icing of the filter media.
  - Icing can also cause structural damage to the media.

Responses

- Decrease the recirculation rate to maintain a warmer temperature since the recirculation flow is generally cooler than the influent wastewater flow.

- To prevent heat loss and increase treatment efficiency, it may be necessary to restrict or close the ventilation systems.

- Keep wastewater from spraying out of the distributor arm by removing orifices and end plates to create streams of wastewater rather than sprays.

- If icing does occur:
  - Break up any ice that forms on the surface of the media.
  - Flood the filter to help melt the ice, if necessary.
    - Prior to flooding the filter, be sure the filter walls were designed to sustain the weight of a flooded filter.

Shock Loads

Causes and Effects

- Storm events
  - Excessive inflow and infiltration (I/I) resulting from storm events can lead to increased hydraulic loading to the plant.
  - The sheering force of the increased hydraulic loading has the potential to slough off the filter media slime layer.
- Industrial discharges
  - When a toxic substance is discharged to a treatment plant, the biological processes occurring in the trickling filter can be upset.
  - This could lead to stressing of the organisms or the complete destruction of the biological treatment population.
  - Industrial discharges can result in either increased organic loading or toxic loading.
    - Increased organic loading can result in dissolved oxygen depletion and micro-organism die-off or excessive slime growth, clogged media, and ponding.
    - Influent toxic loads have the potential to wipe out the microbial populations on the filter media.

Responses

- High hydraulic loading coupled with low organic loading
  - Operating trickling filters in parallel can reduce the hydraulic load to each filter by dividing the influent flow.
    - This can reduce the amount of sloughing that can occur when hydraulic loading peaks.
- High organic loading
  - Treatment efficiency may be improved by placing additional filter units on-line to distribute the organic load.
  - Increasing the recirculation flow may also dilute the organic loading.

- Toxic influent loading
  - If the toxic influent can not be neutralized prior to reaching the filter, the filters should be operated in series.
  - Biomass in the first filter may be damaged by the toxic load, but the toxin may be treated or diluted sufficiently so as not to effect subsequent filters.
  - Increasing the re-circulation rate can also dilute the influent toxic substance concentration.
  - 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.

Impacts of Other Processes

The operational performance of both upstream and downstream treatment units will have a direct effect on the performance of a trickling filter.

Screening

- Mechanically cleaned bar screens are preferred over grinding mechanisms, such as comminutors, to ensure that objects that might clog the filter nozzles are removed from the wastewater.
- Bar screens and comminutors help to minimize clogging of the trickling filter distribution orifices or spray heads.
- Screening equipment failure can lead to plugged orifices which will require increased flushing of the distributor arms.

De-gritting

- Grit and heavy, settleable materials are typically not a concern for a trickling filter because they are removed in the primary clarifier. However, the presence of grit will increase the wear on the primary clarifier and the sludge equipment.

Primary Clarification

- Primary clarification is necessary to remove solids that would clog nozzles in the distribution arms.

Secondary Clarification

- Secondary clarification is necessary to capture the sloughed-off solids generated as a result of treating the wastewater.

Chlorination

- Chlorination is normally the preferred method of disinfection. The use of ultra-violet light for disinfection might be hindered by the turbid nature of wastewater.

Distributor Arm

Never attempt to stop the distributor arm by standing in front of it or reaching out with your hand.

- This is very dangerous and can result in serious injury or death.
- The distributor arm is extremely heavy and has a powerful momentum while it is in motion.
- If the speed of the distributor arm needs to be reduced, open the speed-retarder orifices located on the side opposite of the normal direction of flow (see Figure 1.2 Circular Trickling Filter Diagram on page 1-5).

To stop the distributor arm:

- Shut off all flow to the trickling filter.
- Allow the distributor arm to come to a stop itself.
- Use a strong rope to secure the arm to a large stationary object to prevent movement of the arm.

Media

Walking across the trickling filter media can also be very dangerous. The biological growth and wet surface creates a slippery surface.

- If you must walk on the surface, it should only be attempted with heavily ridged treaded boots.
- The filter media can also be very unstable. Placing excessive weight on the surface, such as walking across it, can result in unexpected settling.

Key Points for Unit 2 – Trickling Filter Operation Strategies

- Trickling Filters should be inspected on a daily basis for signs of ponding, uneven flow distribution, clogging, vibration, leakage, filter flies and unusual odors.
- A sampling plan will assist in locating problems within the plant with the minimum parameters for the samples being influent flow, recirculation rates, BOD, TSS, pH, DO, settleable solids and suspended solids.
- The operational performance of both upstream and downstream treatment units will have a direct effect on the performance of a trickling filter.

☑ Unit 2 Exercise

1. Identify five daily operations inspections appropriate for trickling filters.

2. List three abnormal operating conditions typically encountered in a trickling filter facility and explain what steps can be taken to correct each problem.

3. Give one example of an operation modification that may be required due to sampling results.

Unit 3 – Start-Up and Maintenance of Trickling Filters

Learning Objectives

- List five items that should be inspected after new construction of a trickling filter and before start-up of the operation.
- Describe the process of putting a filter into operation with no growth on the media.
- List and describe five normal maintenance tasks required for trickling filters.

Inspection

Packing Grease

- Use a waterproof grease to lubricate grease fittings for bearings. Lubrication will vary from daily to monthly depending on the manufacturer's recommendations.

Nozzles

- Nozzles must be kept clear. Upstream processes are critical to reducing the need to clean nozzles.
- Replace damaged nozzles or splash plates. Apply an anti-seize compound onto the threads when replacing the nozzles.
- Verify that the wastewater splash zone does not extend beyond the edge of the filter. If necessary, adjust the nozzles.

Media

- Remove any objects that fall onto the media surface to prevent washing the objects into the media.
- Check for ponding.
- Check for odors.
- Flood the filters for a brief period every few months to control the growth of filter flies.
- Verify all areas are wetted uniformly. Conduct a test which collects wastewater, during one rotation, in a pan to determine surface loading rate, on a semi-annual frequency. Conduct the test at three locations from the center of the filter.
- Verify depth of media is not decreasing or settling on an annual basis. Some early types of synthetic media have been known to fail and collapse when the growth of biological slime exceeded the manufacturer's recommendations.
- Filter flies will start to accumulate at the interface between dry and wet zones. Minimize such areas so the section that is dry is re-wetted with a high volume of water on a regular basis.

Distributor Arm

- Check for level arms.
- Every month, open up and flush out ports to remove any accumulated solids.
- Check the seal on the center column to ensure that excessive wastewater is not leaking past the seal.
- Check the ease of rotation. The distributor arm should not stop during normal operations. If flows are very low, the arm should start rotating once the flows increase. Use a spring gauge to check for the amount of torque necessary to move the arm.
- Check for vibration. Vibration indicates possible problems with the main bearings.

Underdrain System

- Solids accumulation may occur but this is typically not a problem. Inspect the underdrain system quarterly to ensure the proper water flow out of the media and airflow into the media.

Painted Surfaces

- Touch up any carbon steel surfaces to prevent corrosion.

Valves

- All valves in a wastewater treatment plant should be operated at least once per year to ensure that they operate.
- Never backseat a globe or gate valve in the fully open position. If left in this position, it can stick or freeze in place.
- Use outlet gates on the trickling filter to periodically flood the filter. The release of water may flush solids out of the underdrain.

Manuals

- Review all Operation and Maintenance manuals on a periodic basis to ensure manufacturers' procedures are being followed.
- Contact the manufacturer every few years to determine if any modifications are recommended to previously issued instructions.

Start-Up

Mechanical

- Check for objects in the distributor arms.
- Check to ensure that nozzles are adjusted to the desired opening size.
- Check the rotation of the distributor arm. Generally, it should be easy for one person to move without much effort.
- Check for material in the underdrain system.
- Check that the inlet and outlet valves function.
- Check the level probes on the control system of the recirculation system.

Biological

- It will require several weeks of wastewater application to a new trickling filter before any appreciable bio-growth will be attached to the media. High rate recirculation will help to establish growth.
- Attempt to equalize flow in upstream processes so that high hydraulic peak loadings are minimized.
- Maintain a low sludge blanket level in the upstream primary clarifier so that organic loading to the trickling filter is minimized as much as possible.
- Notify regulatory agencies that effluent quality may not be in compliance with the NPDES Permit until the bio-growth is established.

Bearings and Seals

Location

- The distributor bearings are typically located in either the base of the center column or at the top.
- Both bearings should be lubricated as per the manufacturer's recommendations.

Oil

- Check the manufacture's recommendations and change accordingly.

Mercury Seals

- Replace the mercury seals as needed.

Figure 3.1 Tickling Filter with Leaking Seals

Distributor Arms

Procedure

- Use a carpenter level to check the vertical alignment of the center column and the distributor arms.
- Check for the proper tension of horizontal and vertical guy supports between the column and arms.

Adjustments

- Clean the nozzles when they become clogged.
- Flush out each distributor arm at least once a month.
- Minor variations in the distributor arm are acceptable and may occur due to seasonal temperature differences. However, major variations in vertical alignment should be corrected.

Figure 3.2 Tickling Filter with Clogged Nozzles

Fixed Nozzles

- Fixed nozzles are similar to lawn sprinklers. Each riser pipe is topped with a spray head, known as a "nozzle," which is positioned several inches above the media surface.

- These nozzles need to be observed frequently to verify the desired spray pattern and distribution.

Procedures

- Conduct a pan test annually to determine if all nozzles are providing equal flow.

Adjustments

- Flush out internal piping to prevent solids accumulation, especially at the end of the manifold nozzles.

Underdrains

Description

- Although maintenance of the underdrain is not normally required, it should be checked annually for any accumulation of solids or debris.

Maintenance

- Visually inspect underdrains using a flashlight, mirror, or robotic sewer TV camera on an annual basis.

Pumps and Level/Recirculation Control System

- Verify level control system set points on a quarterly basis.

- Test all low level and high level alarms on a quarterly basis.

- Follow any additional manufacturer's recommendations.

Key Points for Unit 3 – Start-Up and Maintenance of Trickling Filters

- Inspection of newly constructed trickling filters should include packing grease of bearings, nozzles, media, distributor arms, underdrain systems, painted structures, valves, and a working familiarity with all operation manuals.

- Start-up procedures include mechanical inspections, biological checks of systems, inspecting bearings and seals, checking the distributor arms and nozzles,

☑ Unit 3 Exercise

1. List five items that should be inspected after new construction of a trickling filter and before start-up of the operation.

    a. ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

    e. ______________________________

2. Describe the process of putting a filter into operation with no growth on the media.

3. List and describe five normal maintenance tasks required for trickling filters.

    a. ____

    ____

    b. ____

    ____

    c. ____

    ____

    d. ____

    ____

    e. ____

    ____