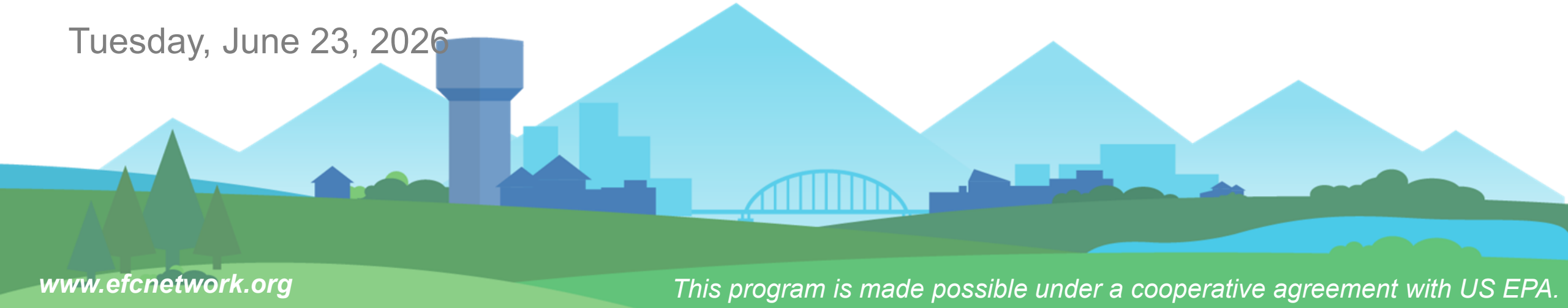
US Territories Wastewater Operator Training Series

Secondary Treatment Part 2- Fixed-Film Media

Tuesday, June 23, 2026



This program is made possible under a cooperative agreement with US EPA.

A.J. Barney

Research Engineer

ajbarney1@unm.edu

SOUTHWEST
ENVIRONMENTAL
FINANCE CENTER

SOUTHWEST
ENVIRONMENTAL
FINANCE CENTER

SCHOOL OF
ENGINEERING

This training series is funded by the EPA

Who we are

SOUTHWEST ENVIRONMENTAL FINANCE CENTER

SCHOOL OF ENGINEERING

Fixed Film Media

What is Fixed-Film Media?

Biological/ Secondary wastewater treatment process that removes nutrients and pollutants from wastewater utilizing microorganisms that grow as a film fixed onto a stationary surface or media

Zoogleal Film

History of Fixed Film Media Treatment in Wastewater

Technology to use microorganisms in wastewater treatment was established in 1890

First U.S. installation was in Madison, Wisconsin in 1901

Trickling filters became the dominant secondary treatment process in the U.S. in the 1950s

Activated sludge replaced trickling filters as the dominant technology in the 1970s

Fixed-Film media still utilized in novel technology and has seen a recent resurgence due to increase efficiency

EFCN
environmental finance center network

Trickling Filters: 1890

Important Fixed Film Terms

Aerobic bacteria- Bacteria that live and reproduce only in an environment containing oxygen

Facultative bacteria- Bacteria that uses dissolved oxygen or oxygen from other sources such as nitrates or sulphates for respiration

Anaerobic- Conditions that are absent of free oxygen

Sloughing- Breaking off of biological or biomass material from fixed film media

Why do we use biological treatment?


To protect receiving waters


Removing O_2 depleting organics
and excessive nutrients

Removing solids

Secondary/ biological treatment removes 90% or more of suspended solids and BOD

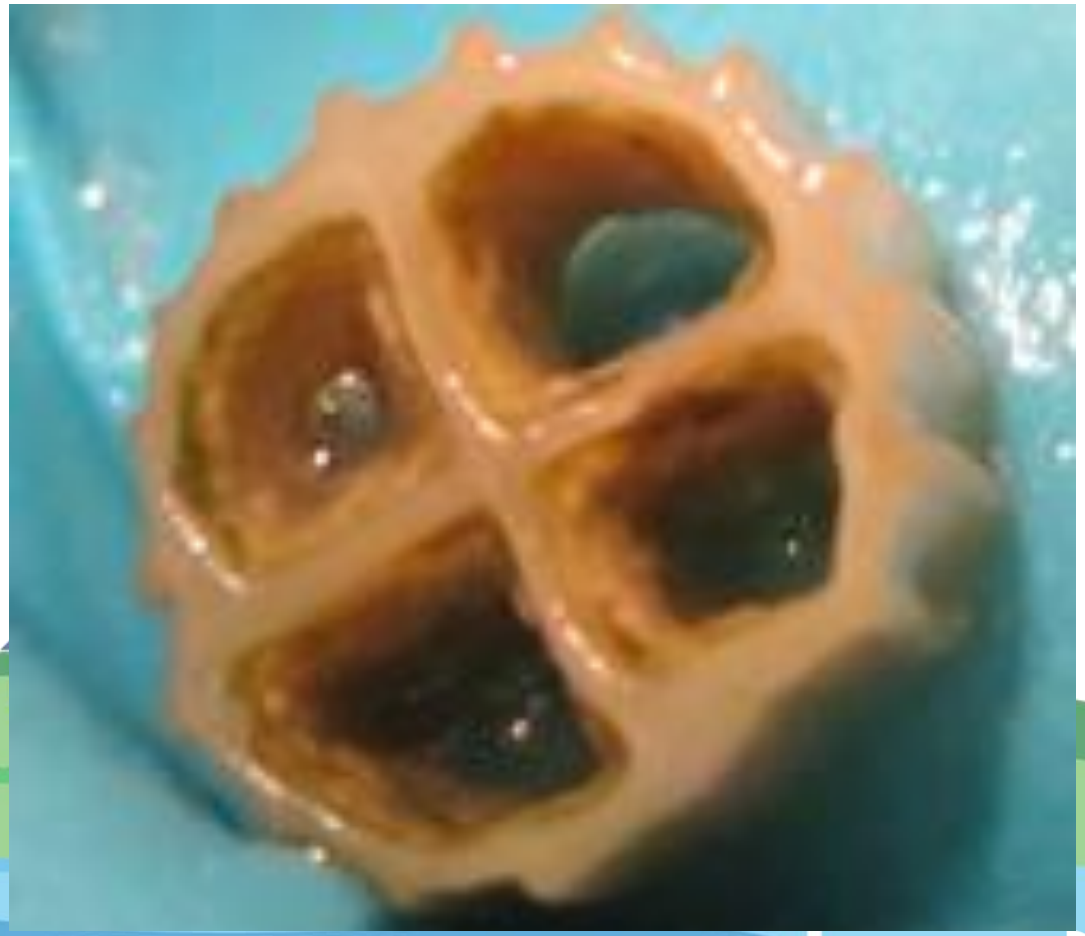
Reducing pathogens

Types of Fixed Film Media

Trickling Filters

Rotating Biological Contactors

Integrated Fixed-Film Activated Sludge



Trickling Filters

Trickling Filter Process

Preceded by screening and sedimentation

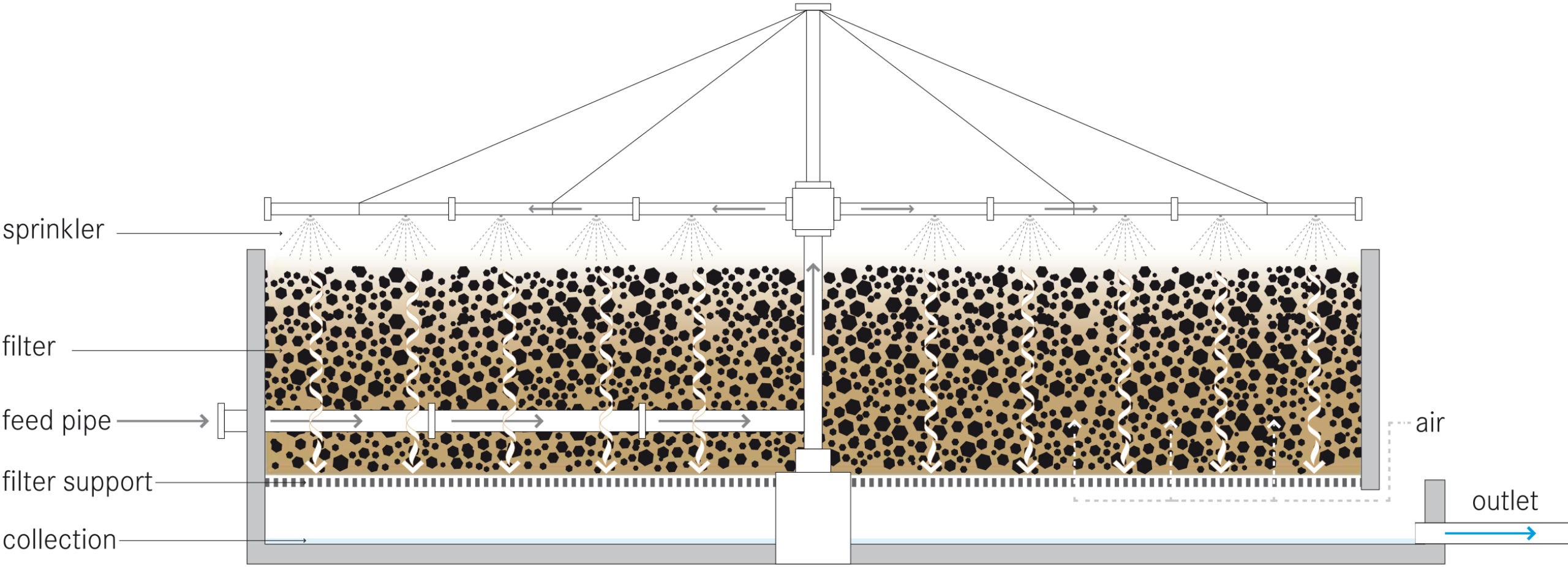
Wastewater is applied to the media using a distribution arm or sprinkler

Microorganisms consume nutrients in the wastewater

Sloughing occurs as microorganism film thickens

Treated wastewater drains and passes on to secondary clarifiers

Trickling Filter Components




City of Stockton Regional Wastewater Control Facility (RWCF) Modifications Project Construction
April 2020

Distribution Systems

Fixed Spray Heads:

- Similar to lawn sprinklers arranged in a pattern
- Not as common in the US
- Extensive piping requirements
- Pumping system for even distribution
- Difficult access for maintenance and repair

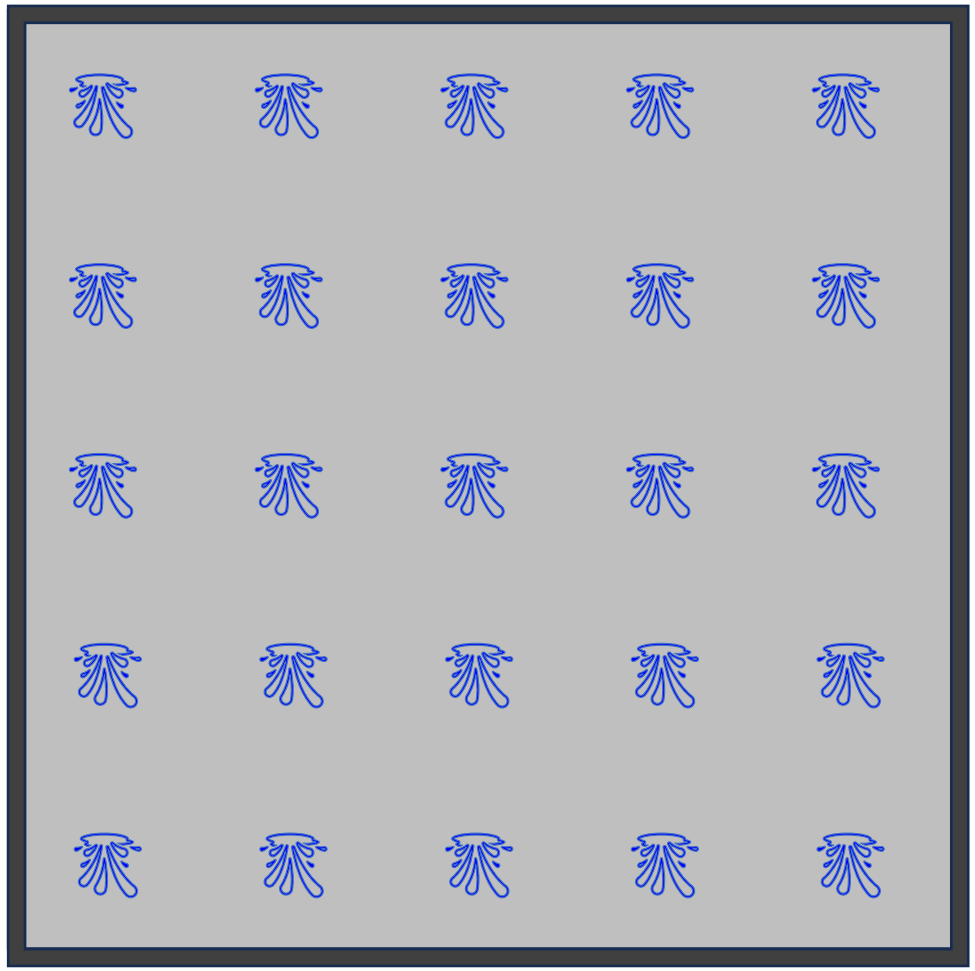
Rotating Arm:

- 2 or more rotating horizontal pipe “distributor arms”
- Water distributed through orifices on one side of pipes
- Typically move using force of wastewater flowing out
- Can be motorized to control rotational speed

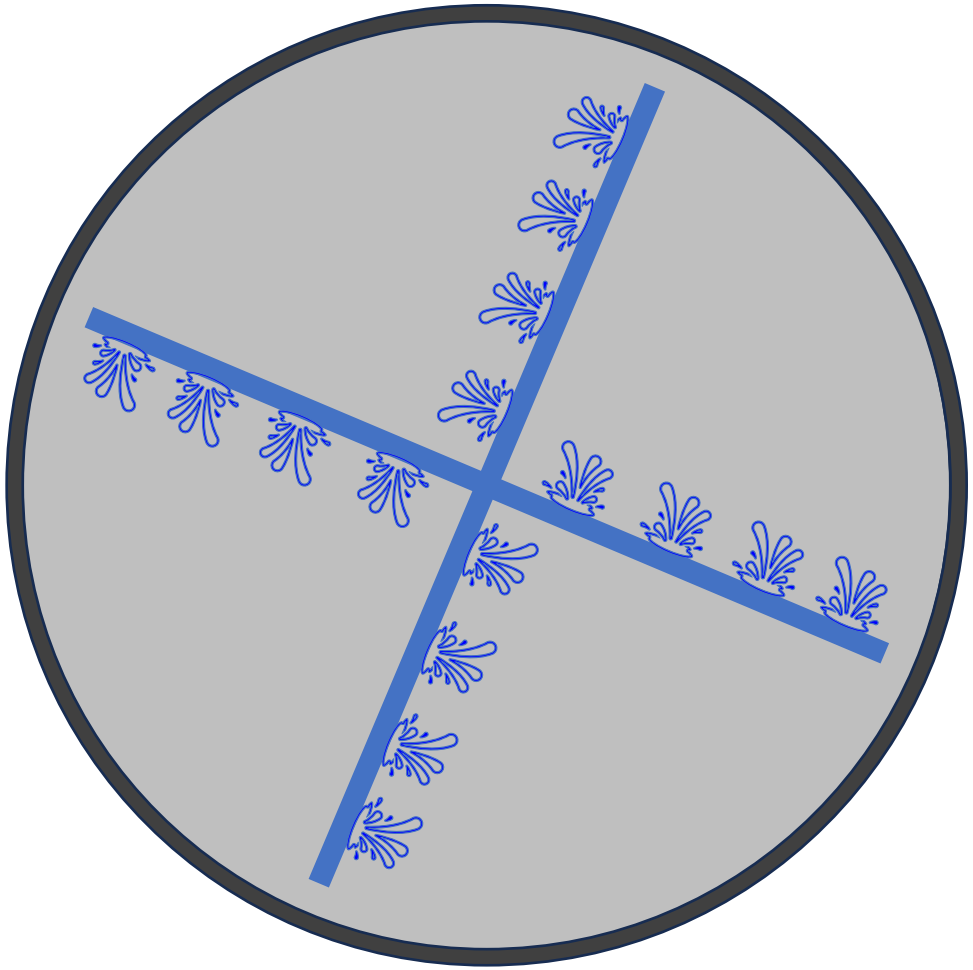
Either way, the goal is uniform hydraulic load per area for optimum efficiency.

Distribution Systems

Fixed Nozzle Distribution



Rotary Type Distribution



Filter Media

Trickling Filter Media

Typically natural rock or plastic

Three key parameters used to determine construction, operation, maintenance, and performance

- Surface Area
- Void Ratio
- Dry Weight

Ideal material has a large surface area, a high void ratio and a light weight

Rock Media

Synthetic Filter Media

Figure 1.10 Plastic Random Dump Trickling Filter Media [7]

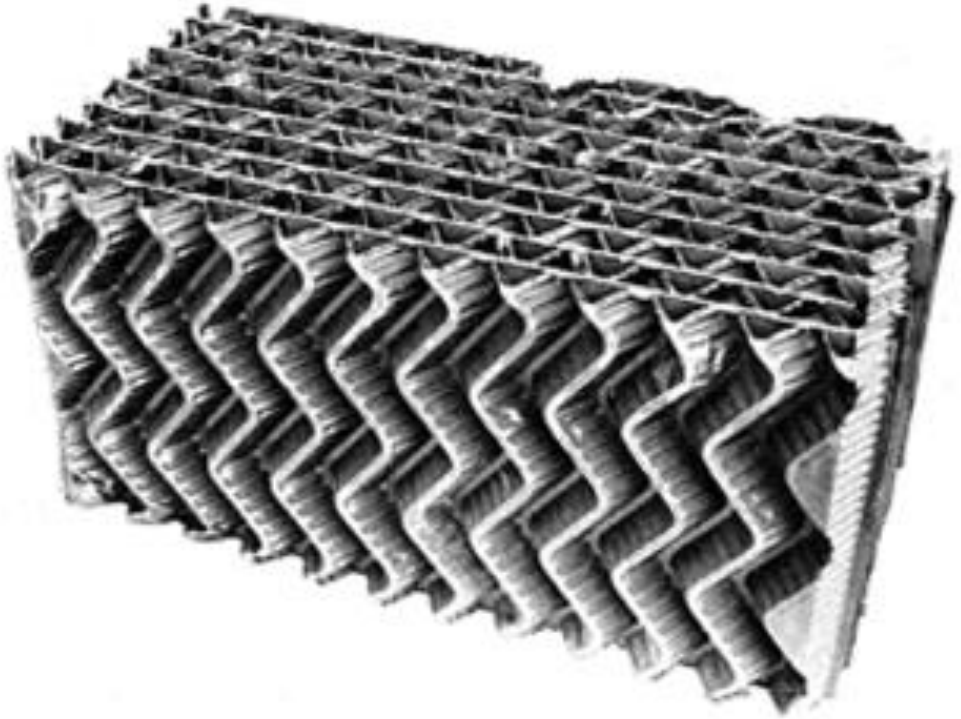


Figure 1.9 Plastic Cross Flow Trickling Filter Media [6]

Media Size

Rock media be about 2.5-6” across

- Size is not the most critical, but media should be uniformly sized for ventilation

Media depth:

Rock = 5-7 feet (35-50% void space)

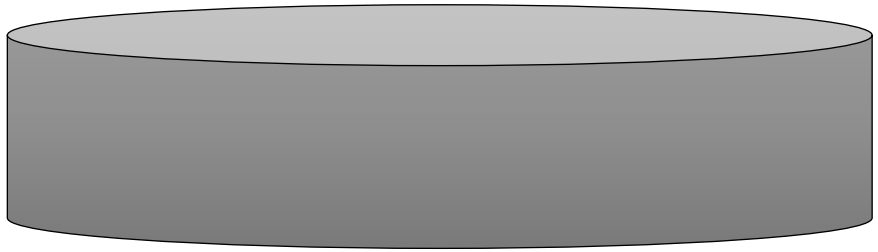
Synthetic media = up to 40 feet (95%)

Media Characteristics

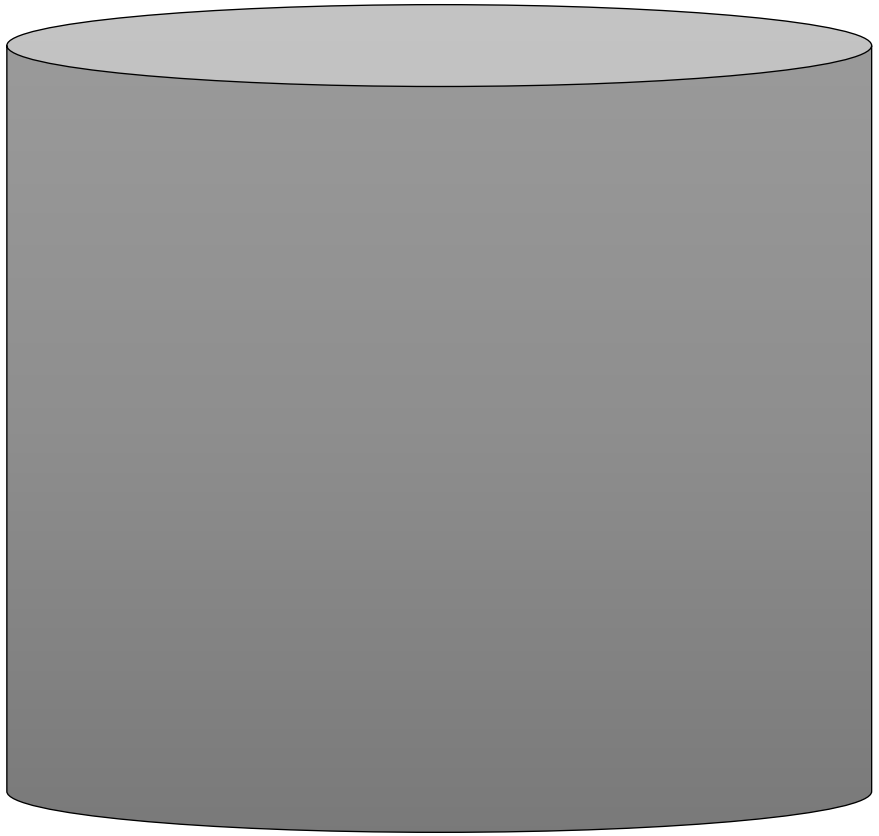
Media Type	Nominal Size (ft)	Surface Area (ft^2 of surface / ft^3 of media	Void Ratio (Volume of void/vol of media) x 100	Dry Weight (lb/ft^3)
River Rock	0.08 - 0.25	15 - 19	35 - 50	80 - 90
Slag Rock	0.25 – 0.42	14	100	60
Random	varies	30 - 32	92 - 95	1.7 - 3
Vertical Flow	2' x 2' x 4'	27 - 40	92 - 95	1.5 – 2.8
Cross Flow	2' x 2' x 2'	30 - 68	95	1.5 – 2.8

Adapted from Table 6.1 Operation of Wastewater Treatment Plants, Vol 1, 8th edition, Sacramento State 2019

Containment Structures



Rock Media: Shorter (typically less than 10 feet, sides of concrete or brick



Cross and Vertical Flow Media: Can be very tall (up to 40+ feet), media is self supporting, sides may be steel or fiberglass

Trickling filter operations

Wastewater filters through media resulting in growth of microbial mass (film)

Organics in the wastewater are used as food to grow the mass and is oxidized to carbon dioxide and water

Partially decomposed organics and dead film periodically shed

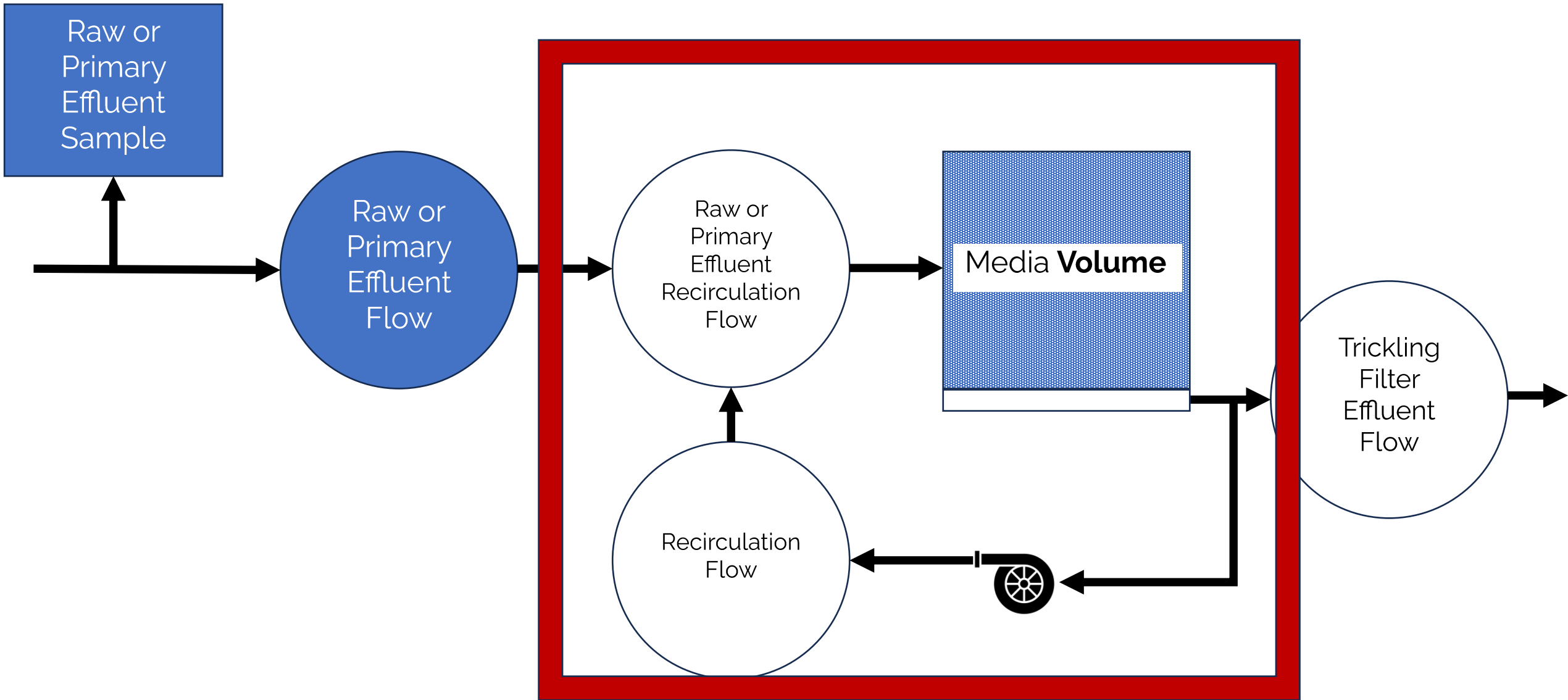
Dissolved oxygen (DO) is continuously absorbed from the surrounding air through the filter voids

Recirculation is the most common method to make adjustments to trickling filters

- Filter effluent recycled back through the process

Speed controlled by flow through distribution orfices

Recirculation



Recirculation

Increasing contact time of water in the filter

- Reseeds the filter with microbes

Increased flow rate results in continuous and uniform sloughing

- Producing hydraulic sheer to slough solids
- Reduces ponding
- Improves ventilation by returning DO to the top of the filter
- Increased hydraulic loading reduces flies, snails and other nuisances

Dilute wastewater to lower BOD concentrations

- Reduces thickness of film

Dilute toxic wastes that might be received

Preventing the filters from drying out and freezing

Recirculation Ratio

$$TF\ recirculation\ ratio = \frac{Q_r\ [\frac{gal}{day}]}{Q_{in}\ [\frac{gal}{day}]}$$

Q_r = Recirculation flow rate
Q_{in} = Influent flow rate

Underdrain

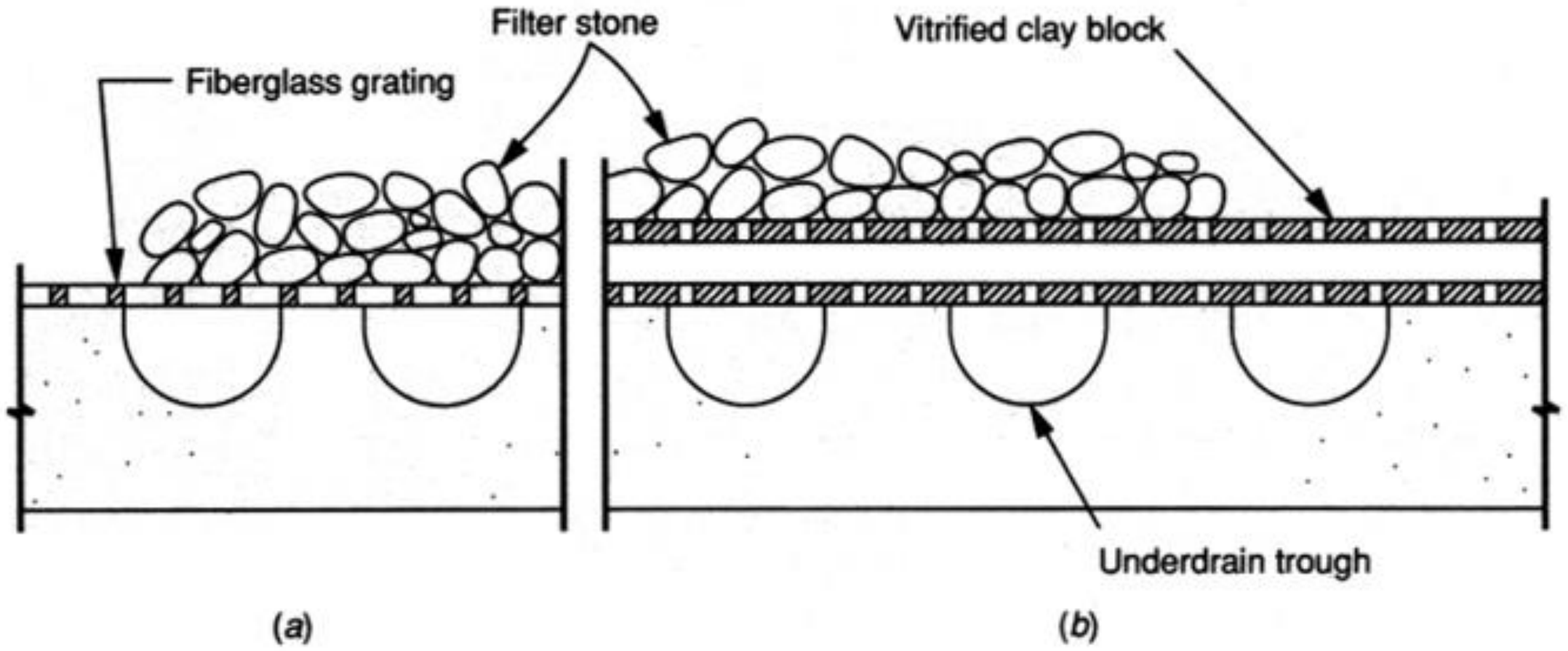
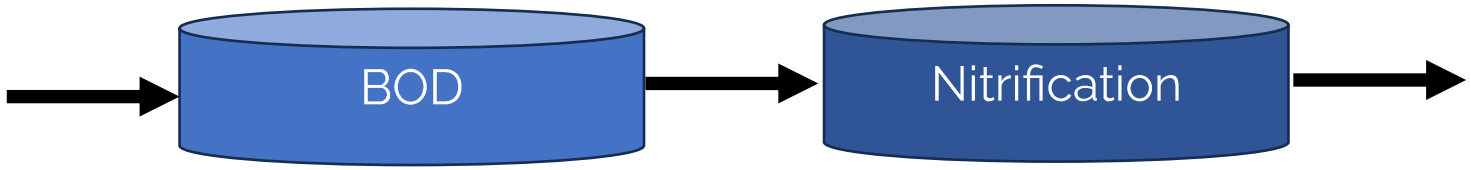


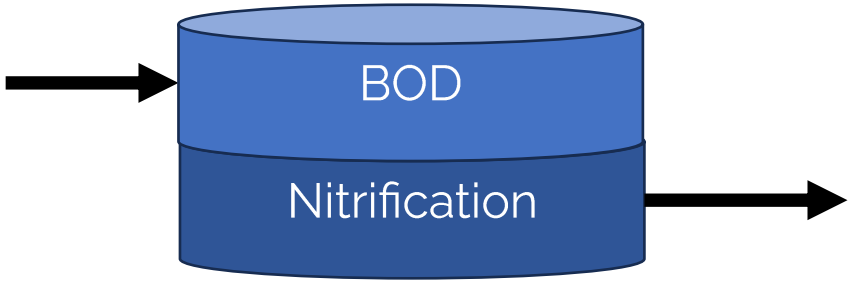
Figure 1.11 Trickling Filter Underdrain System [8]

Operation

Two Stage Operation:

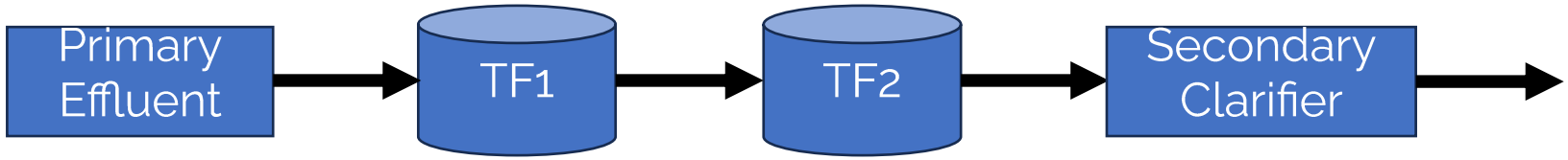


Single Stage Operation:

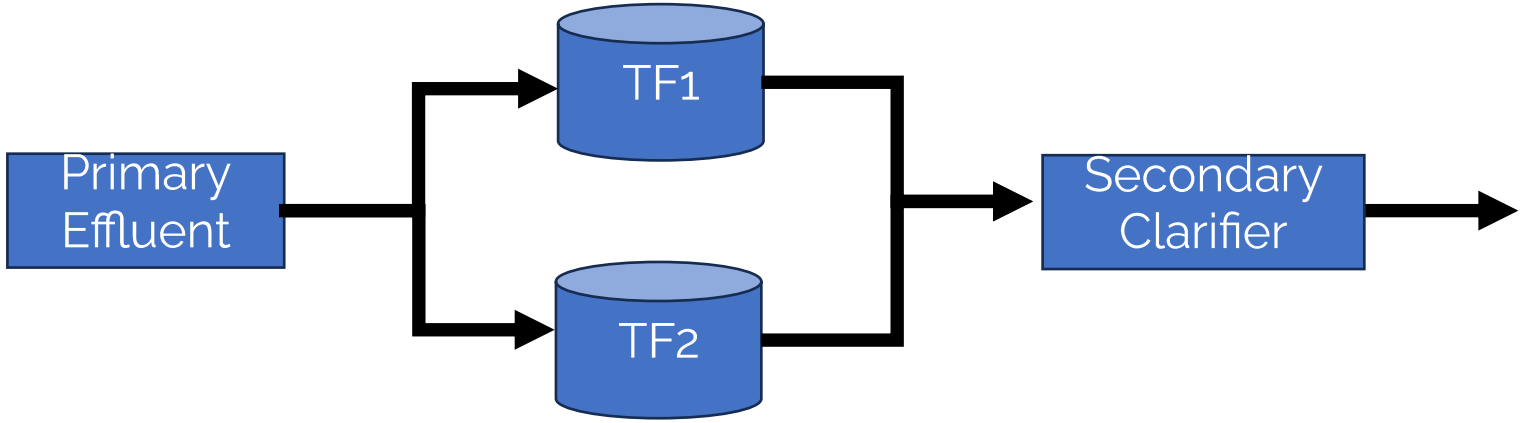


Operation

Series Operation:



Parallel Operation:



Trickling Filter Classification

Standard Rate:

Hydraulic loading
= 25-100 gpd/ft^2

BOD loading
= 5-25 lbs/day/1000 ft^3

Depth = 6-8ft (rock)

Effluent BOD
= 20-25 mg/l

High-Rate:

Hydraulic loading
= 100-1000 gpd/ft^2 or 350-2100 gpd/ft^2 for synthetic

BOD loading
= 25-100 lbs/day/1000 ft^3 or 50-300 lbs/day/1000 ft^3 for synthetic

Depth = 3-5ft (rock)

Effluent BOD
= 20-25 mg/l

Roughing

High-rate filter with a high organic loading

BOD loading
= 100-300 lbs/day/1000 ft^3

Used with biological process

Used in plants that receive strong organic wastes

EFCN
environmental finance center network

Sampling Requirements

Parameter	Sampling Frequency	Location(s)	Typical Ranges
TSS	Daily or Weekly	Influent Primary effluent Final Effluent	150 – 400 mg/L 60 – 150 mg/L 15 - 40 mg/L
BOD5	Weekly	Influent Primary effluent Final Effluent	150 – 400 mg/L 100 – 380 mg/L 15 - 40 mg/L
COD	Daily or Weekly	Influent Primary effluent Final Effluent	300 – 800 mg/L 200 – 380 mg/L 60 - 120 mg/L
DO	Daily or Continuously	Filter underflow Filter effluent	3.0 – 8.0 mg/L 1.5 – 2.0 mg/L
pH	Daily or Continuously	Influent Effluent	6.8 – 8.0 7.0 – 8.5
Temperature	Daily or Continuously	Influent	Seasonal
Chlorine residual before dechlorination	Daily	Secondary Effluent	0.5 – 2.0 mg/L
Coliform bacteria or *E. coli* after dechlorination	Weekly	Final Effluent	50-700 MPN/100mL

Operation & Maintenance

Sample Tasks (not an exhaustive list)	Frequency
Check that rotary distribution system is running smoothly	Daily
Check bearing oil levels	Weekly
Clean distribution arm orifices	Weekly
Time rotational speed	Monthly
Flush distributor arms	Weekly
Adjust distributor arm levels	Seasonally
Conduct pan tests to test distribution of wastewater over filter surface	As needed

Maintenance Specifics

Distribution arm flushed by opening the end dump gate on each arm

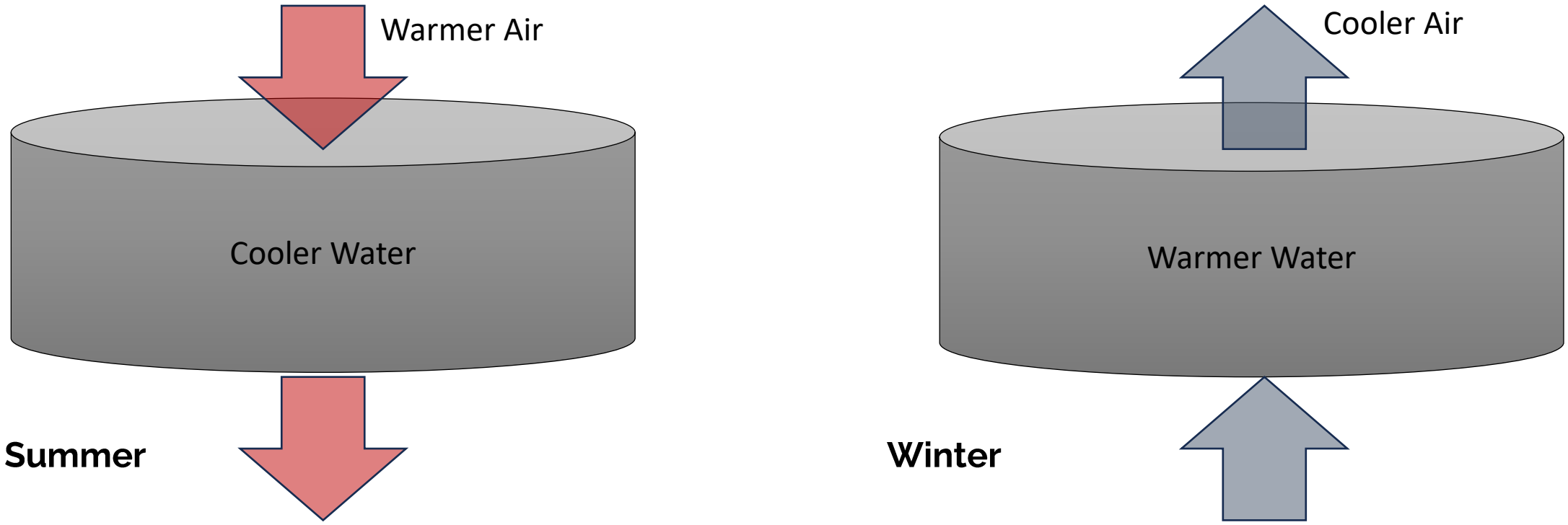
Monitor arm for jumping, vibration, and slowing which may indicate bearing or track is damaged and in need of replacement

Large distributors should rotate at ~1 RPM

Trickling Filter Troubleshooting

Abnormal Condition	Possible Solution
Odor	Bring additional trickling filter online, increase recirculation, increasing oxygen flow
Ponding	Increase recirculation, spray off growth and clogging material, chlorine dosing
Psychoda/ Fly larvae	Increase recirculation, chlorine dosing, flooding
Freezing	Decrease recirculation
Debris Accumulation	Raking debris from media, nearby landscaping maintenance

Seasonal Air Flow Changes

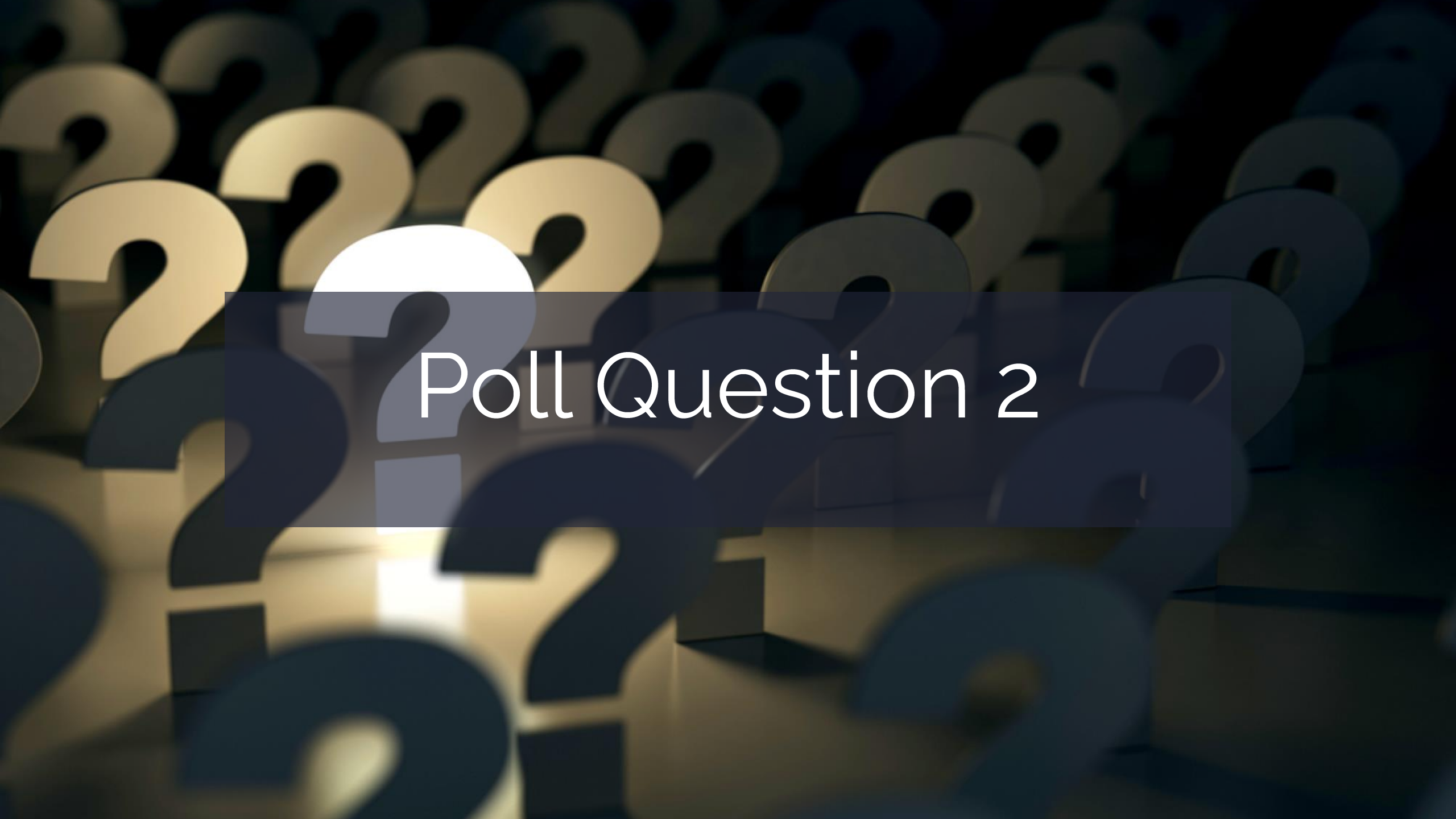


Advantages & Disadvantages

- Low energy requirements
- Low maintenance requirements
- Ability to treat variable organic loads & toxic substances

- Can generate odors
- Can have issues with macrofauna (insects, flies, snails)
- Temperature sensitivity
- Icing in cold weather
- Low flows can immobilize distributor arms in unmotorized systems


Poll Question 1


Poll Question 2

Rotating Biological Contactor (RBC)

RBC Process

Wastewater flow through a reactor containing the rotating media

The rotating drum is made up of a series of closely spaced, parallel discs designed to collect wastewater

Operate under the same fixed media principle as a trickling filter

- Zoogleal film grows on the surface of the discs

As these modules rotate the biofilm absorbs air and microorganism use the oxygen to consume biological material

Water flow out of the drums and passes through the channel along with sloughed material

RBC Process

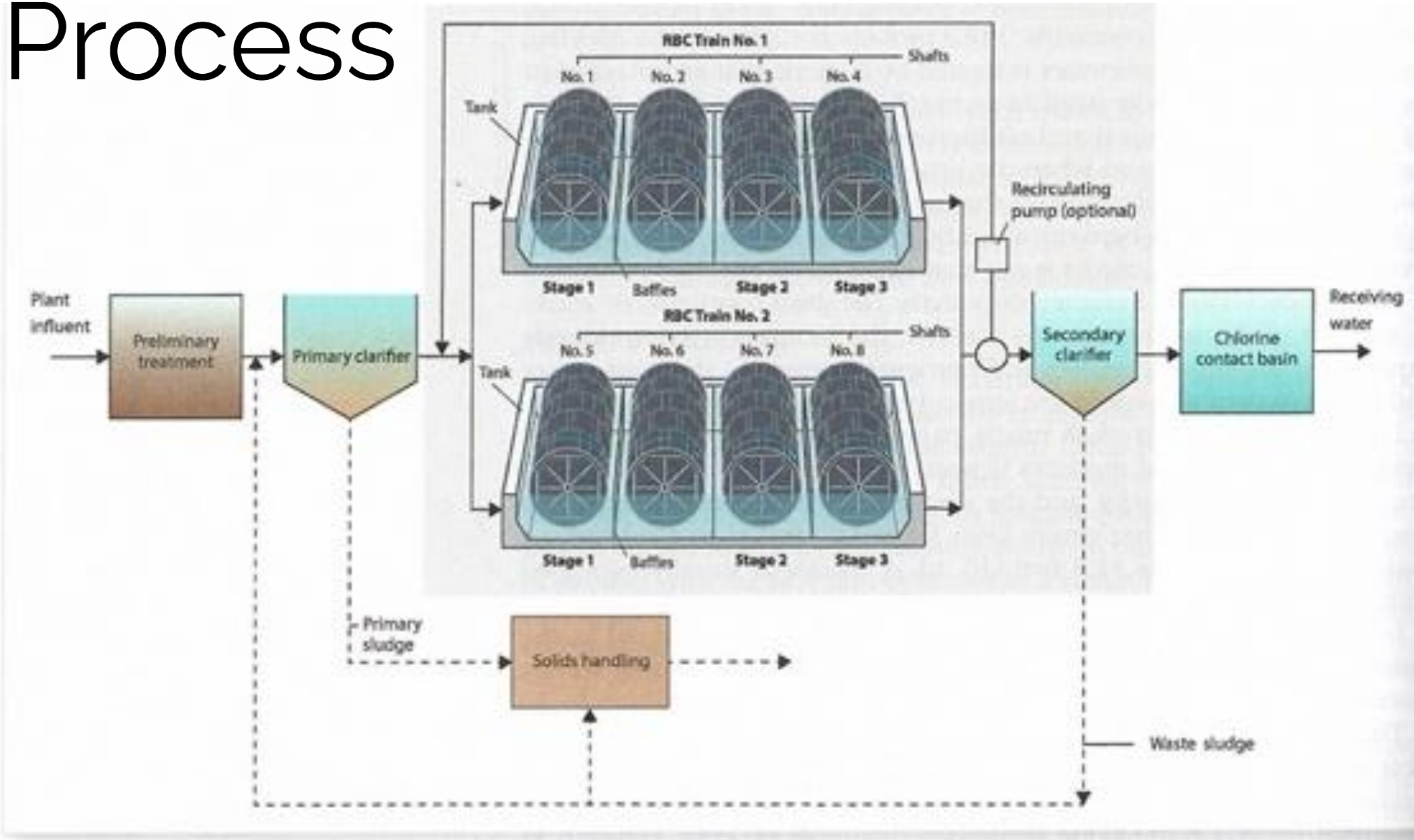
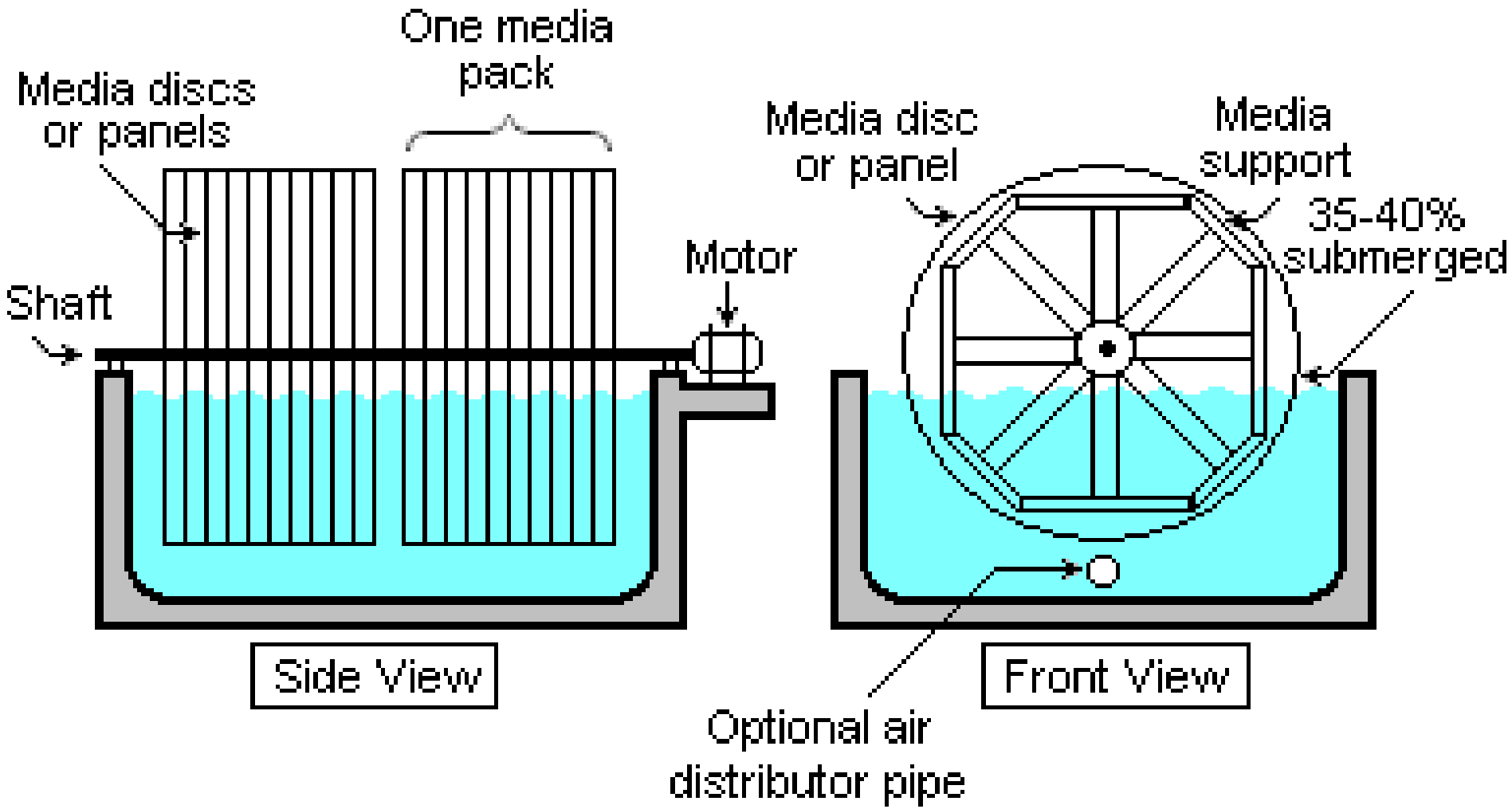


Figure 6.34 Typical rotating biological contactor (reactor) treatment facility

RBC Schematic



https://upload.wikimedia.org/wikipedia/commons/3/3c/Rotating_Biological_Contactor.png

RBC Operations

Several plastic drums sit in steel tank in the shape of the media

- Leads to odors and septic conditions

Media drum rotates ~ 1.5 rpm with 40% of the media submerged

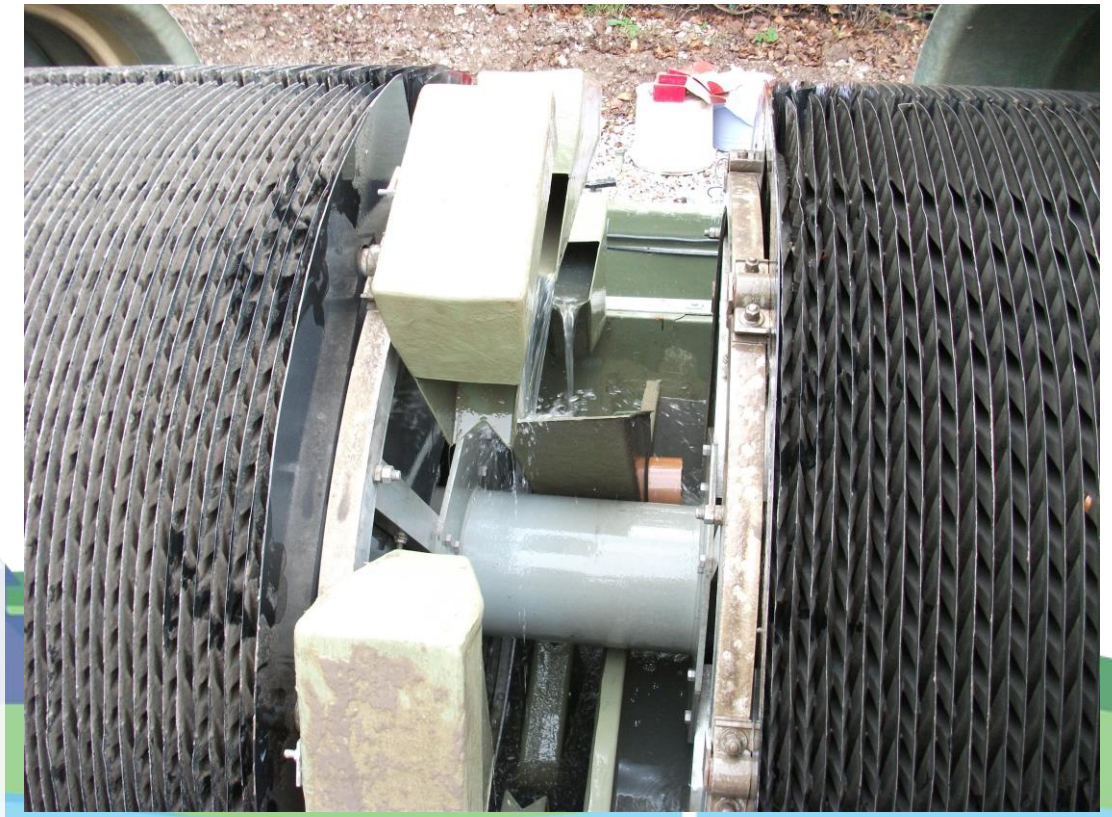
- Greater submergence (70-90%) needed for nitrification. Decrease load on shaft.

Rotation creates contact with wastewater and absorbs dissolved oxygen from the air

Film sloughs as it is submerged into the wastewater

Velocity must be at least 1 fps to scour sloughed material

- Aeration can be used to keep organics suspended



RBC Operations Cont'd

RBS biomass is less than trickling filters

- Plants combine activate sludge with RBCs to increase available biomass

RBC systems are a plug flow process

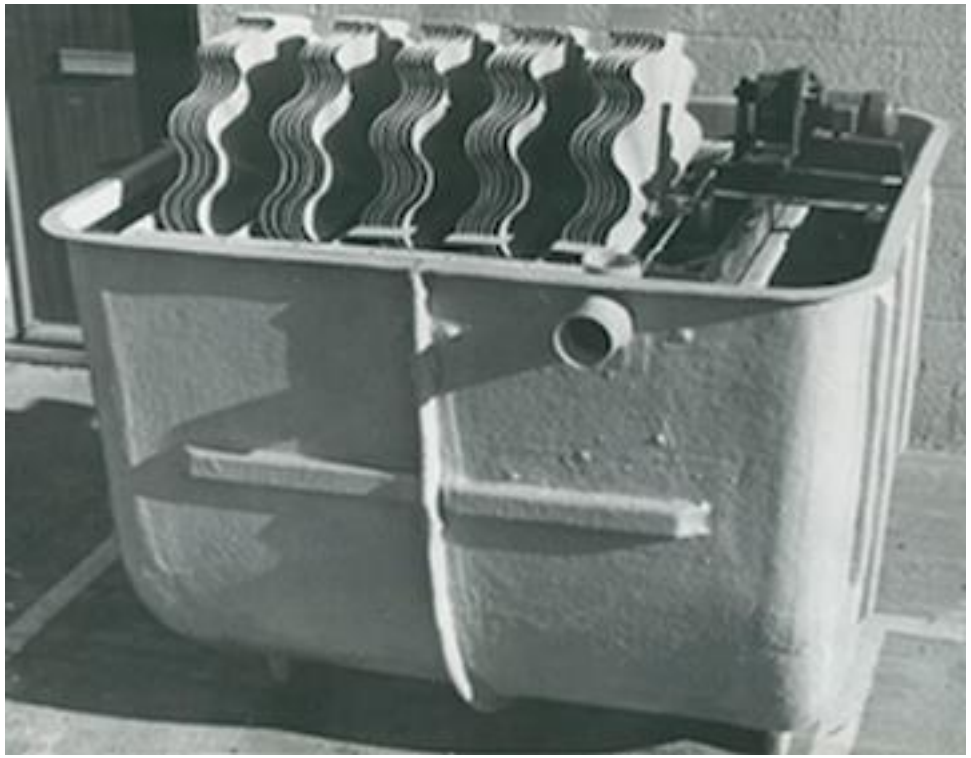
Located in the same position as a trickling filter or activated sludge basin

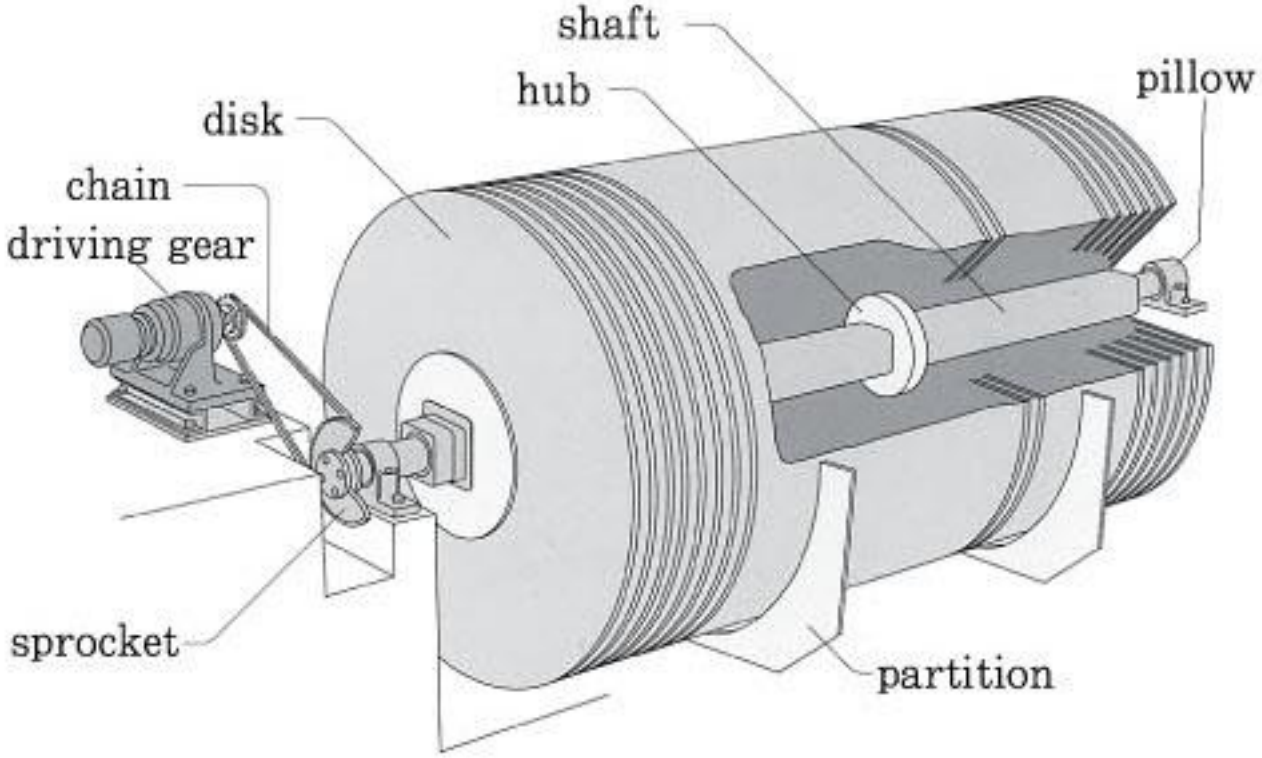
- Once-through operation, often without recirculation

Divided into four stages- a removable baffle, concrete wall, or bulk-head and effluent orifice

Staging maximizes the effectiveness of RBCs

RCB's in 1955





http://www.igreenion.com/rotating-biological-contactor.html

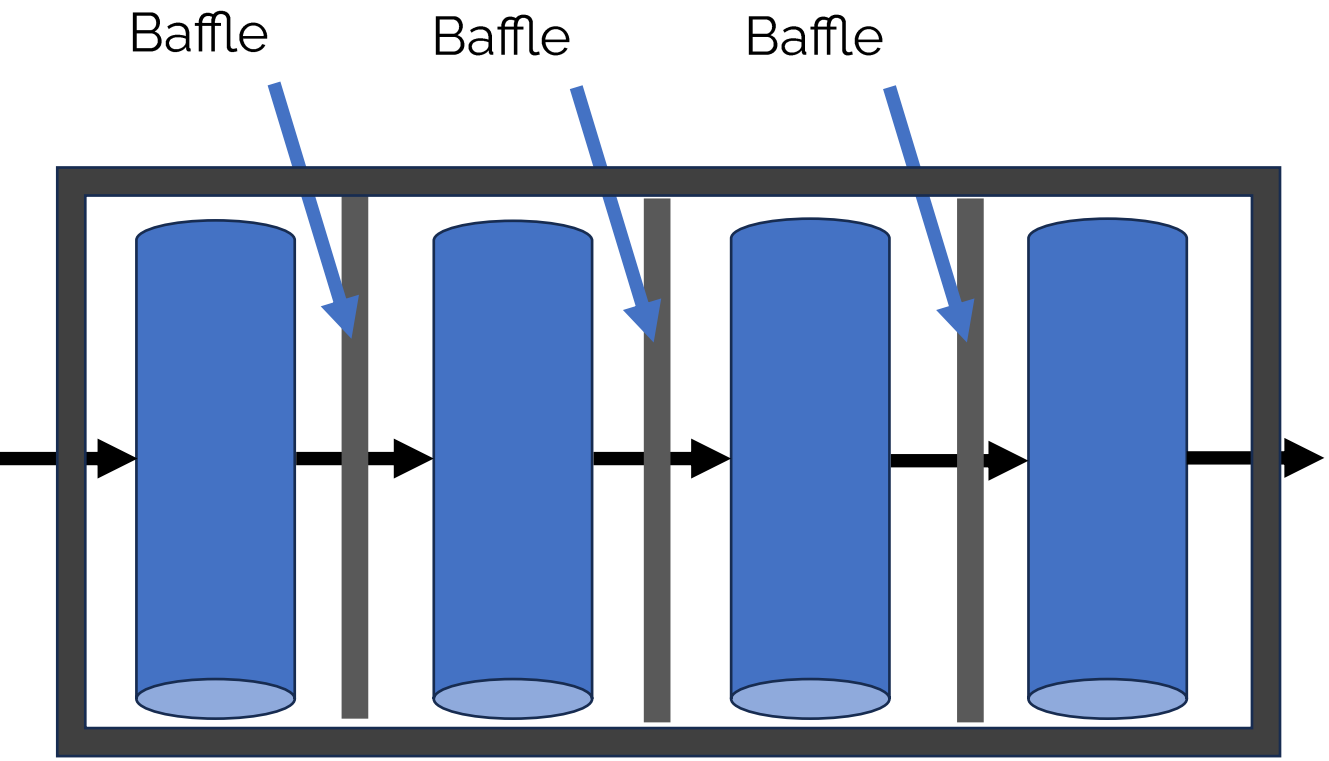
RBC Media Characteristics

Characteristic	Standard Density	High Density
Surface Area	90,000 - 110,000 ft^2/shaft	120,000 - 165,000 ft^2/shaft
Common use	BOD Removal	Nitrification
Optimal Biofilm Thickness	0.04 – 0.06 in	0.015 - .03 in
Percent of Weight Occupied by biofilm	60 – 80%	60 – 80%

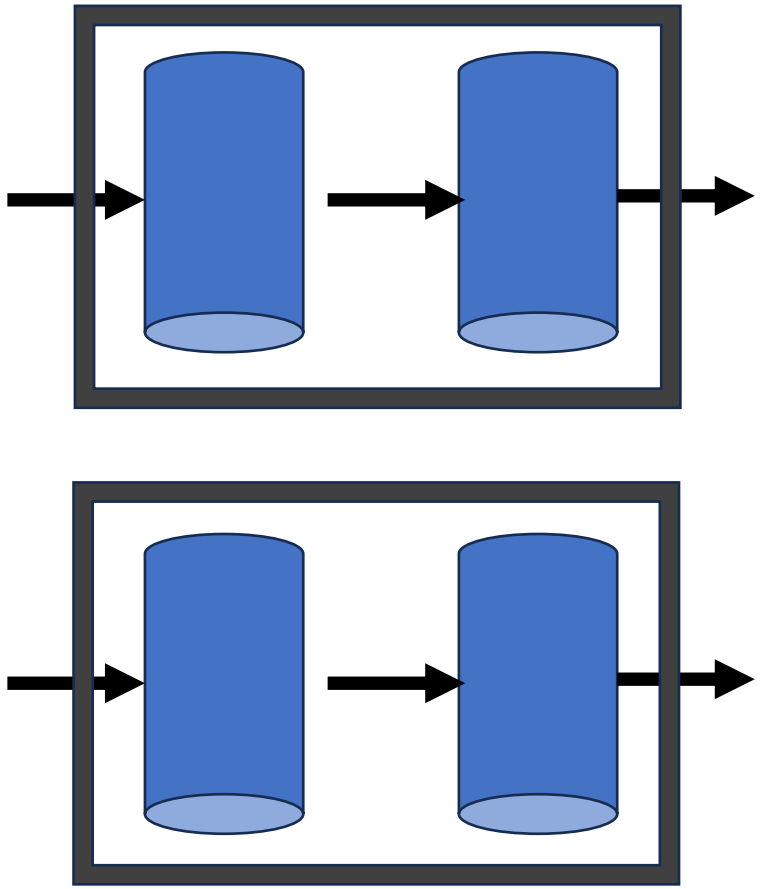
RBC Parameters

Parameter	BOD Removal Only	BOD Removal and Nitrification	Nitrification Only
Wastewater Source	Primary Effluent	Primary Effluent	Secondary Effluent
Media type	Standard Density (100,000 ft^2/shaft)	Standard Density (100,000 ft^2/shaft)	High Density (150,000 ft^2/shaft)
Surface Area	36 ft^2/ft^3	36 ft^2/ft^3	55 ft^2/ft^3
Organic Load Rate to Overall Reactor (lb/BOD/d/1000ft^3)	3-4	3-4	< 0.5
Organic Load Rate to First Stage (lb/BOD/d/1000ft^3)	4-6	3-4	

Trains

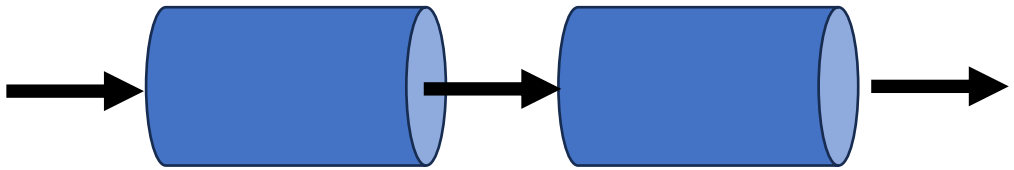


4 RBCs in a single train

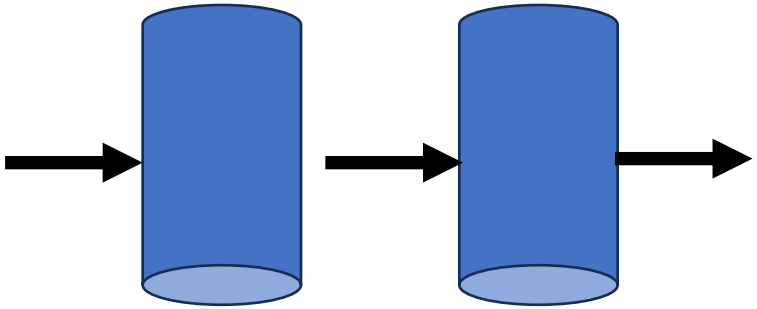


4 RBCs in two trains

Direction of Flow

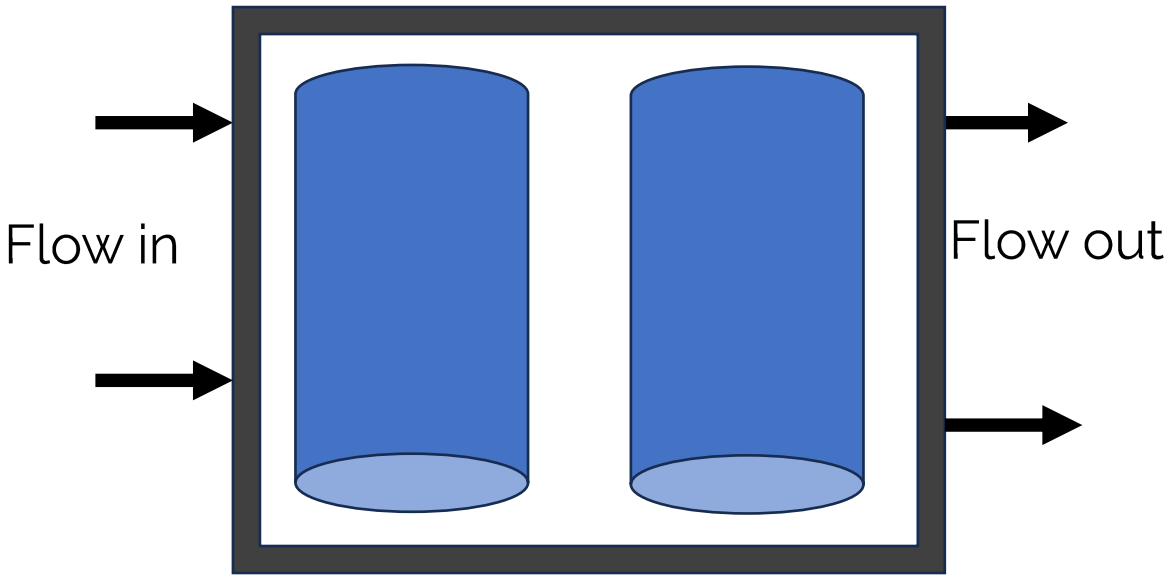


Flow parallel to the shaft

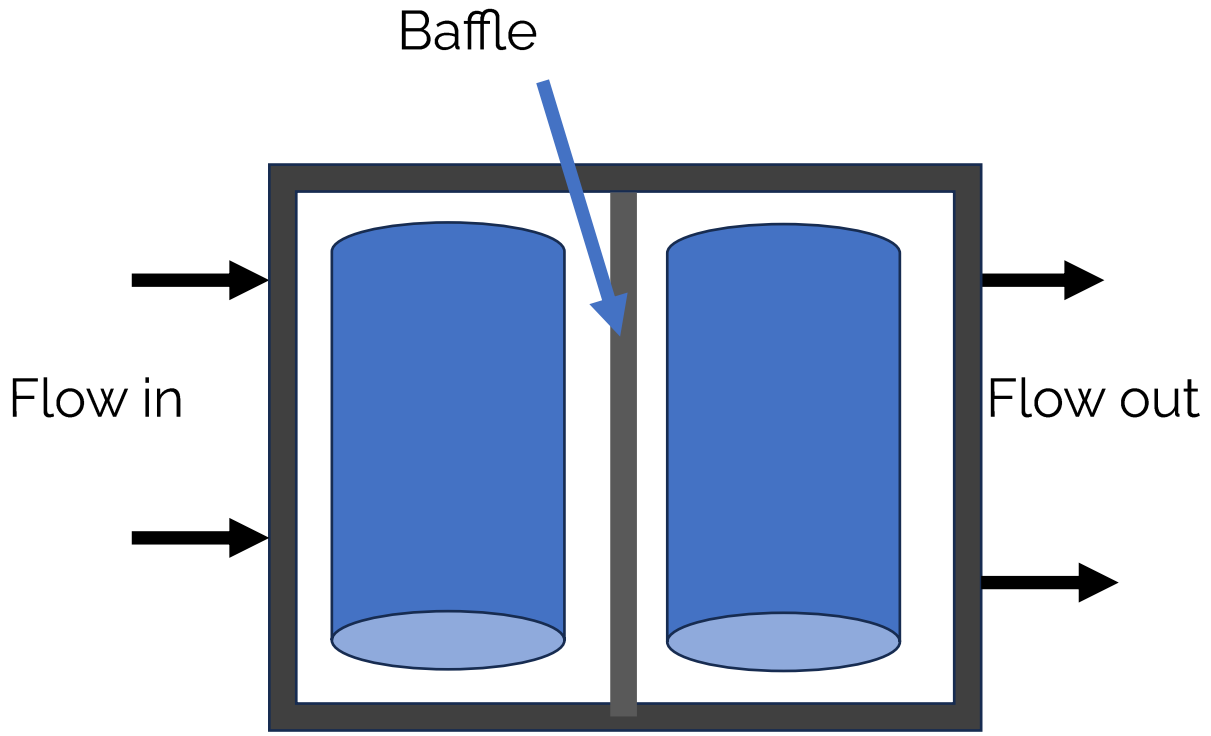


Flow perpendicular to the shaft

Modes



2 RBCs one stage



2 RBCs in two stages

RBC Covers

Protect bio slime from freezing

Keep intense rains from washing off some bio slime

Keep direct sunlight off media to prevent algae growth

Block sunlight exposure which makes media brittle

Provide protection for personnel and equipment

Operation & Maintenance

Sample Tasks (not an exhaustive list)	Frequency
Check for hot shafts and bearings; listen for unusual noises in shaft and bearings	Daily
Grease mainshaft and drive bearings	Weekly
Inspect chain drives, mainshaft bearings and drive bearings	Monthly
Change oil in speed reducer and inspect belt drives	Every 3 months
Clean magnetic drains in speed reducers	Every 6 months
Grease motor bearings	Annually

RBC Troubleshooting

Abnormal Condition	Possible Solution
Excessive Bio Growth	Increase rotational speed, aerate, remove baffles
Odor	Chemical treatment
Black biofilm appearance	Place an additional unit in service
White biofilm appearance	Addition of aeration before biological treatment
Excessive Sloughing	Removal of toxic substances, reduce loading, dilution/ increase recirculation

RBC Staging

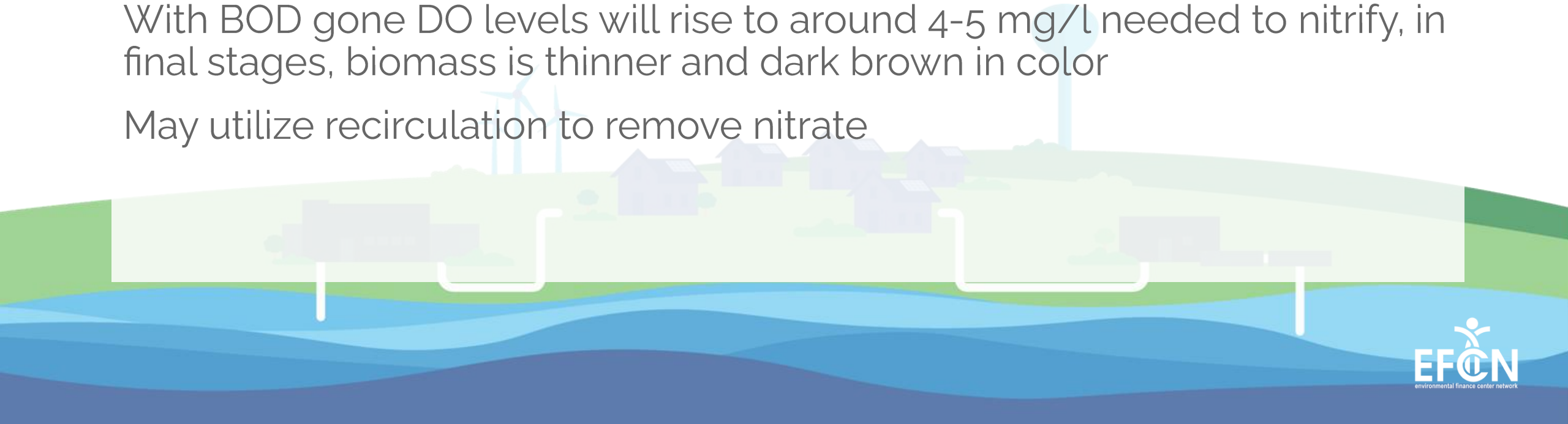
Designed because they accommodate nitrification

DO levels in first stage are lower (1 mg/l)

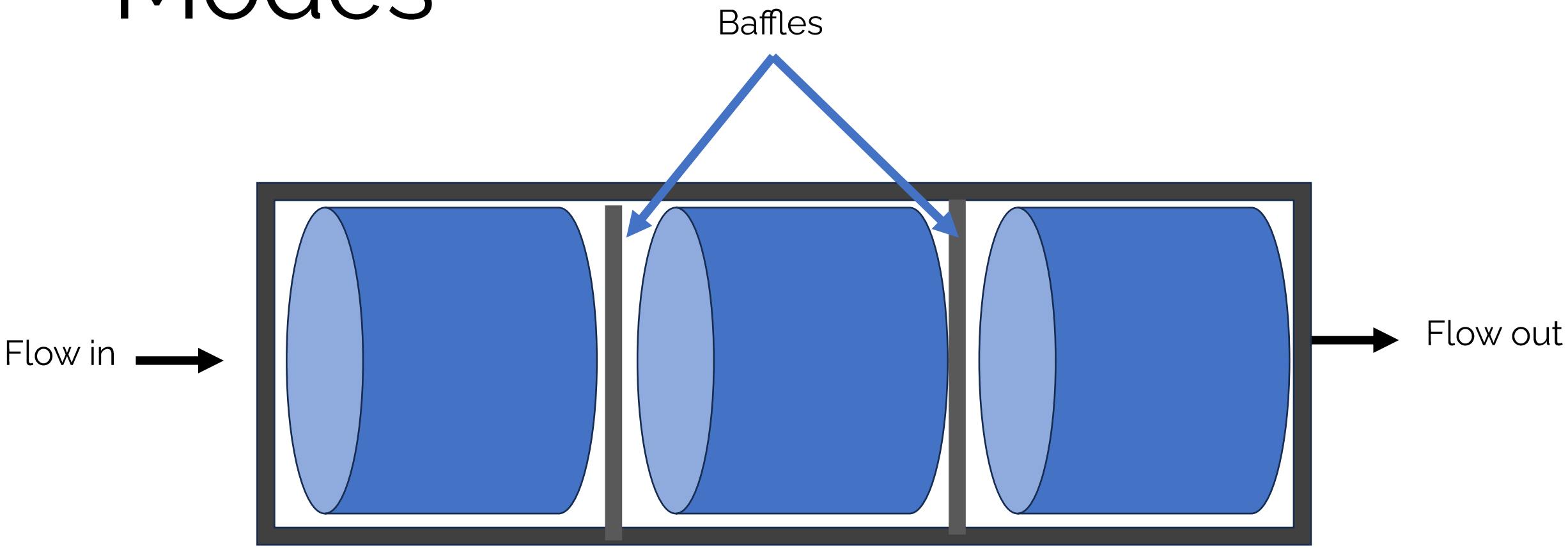
- Remove primary BOD, gray shaggy mass

With BOD gone DO levels will rise to around 4-5 mg/l needed to nitrify, in final stages, biomass is thinner and dark brown in color

May utilize recirculation to remove nitrate



Modes



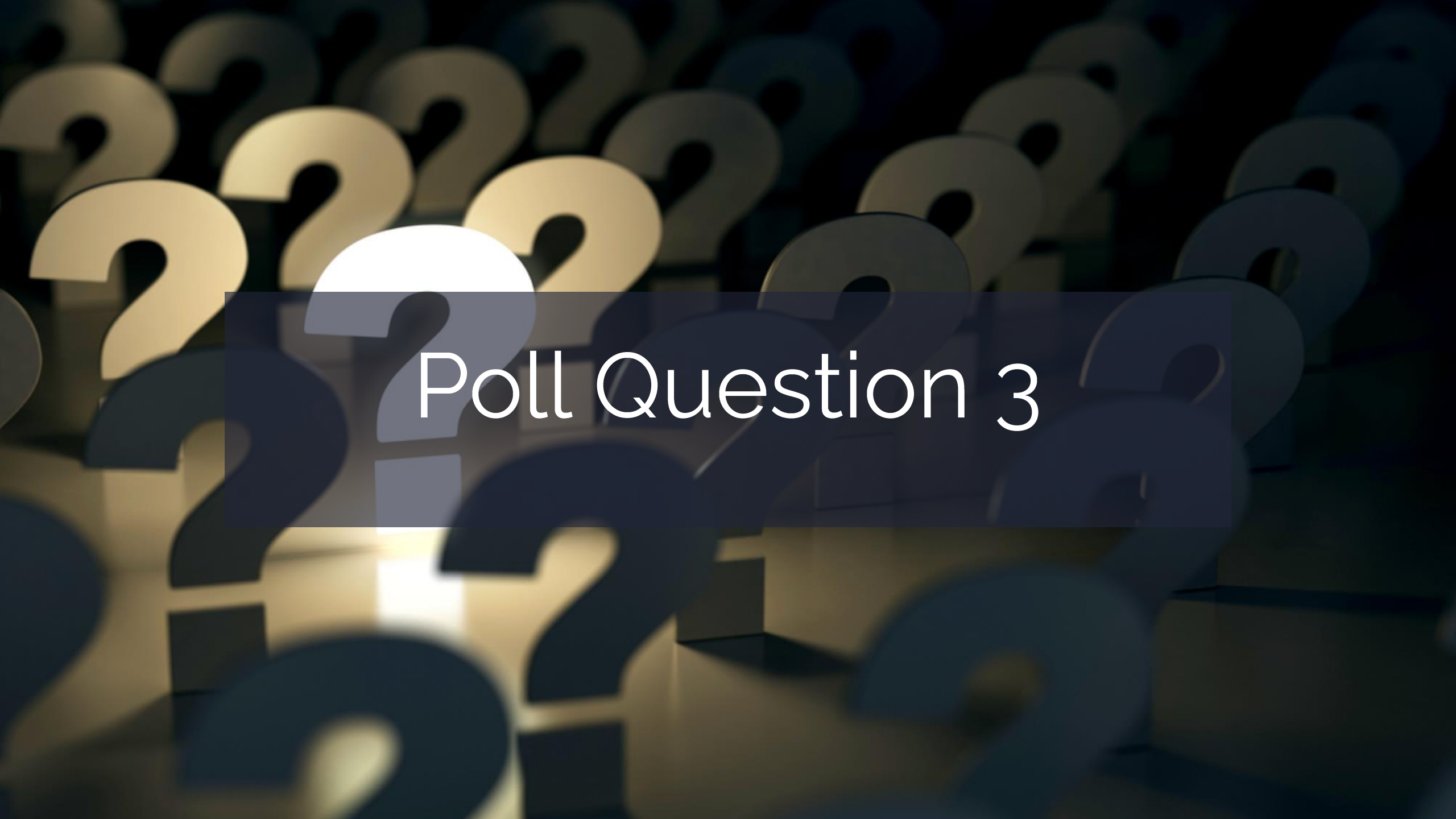
1 RBCs with 3 stages and perpendicular floiw

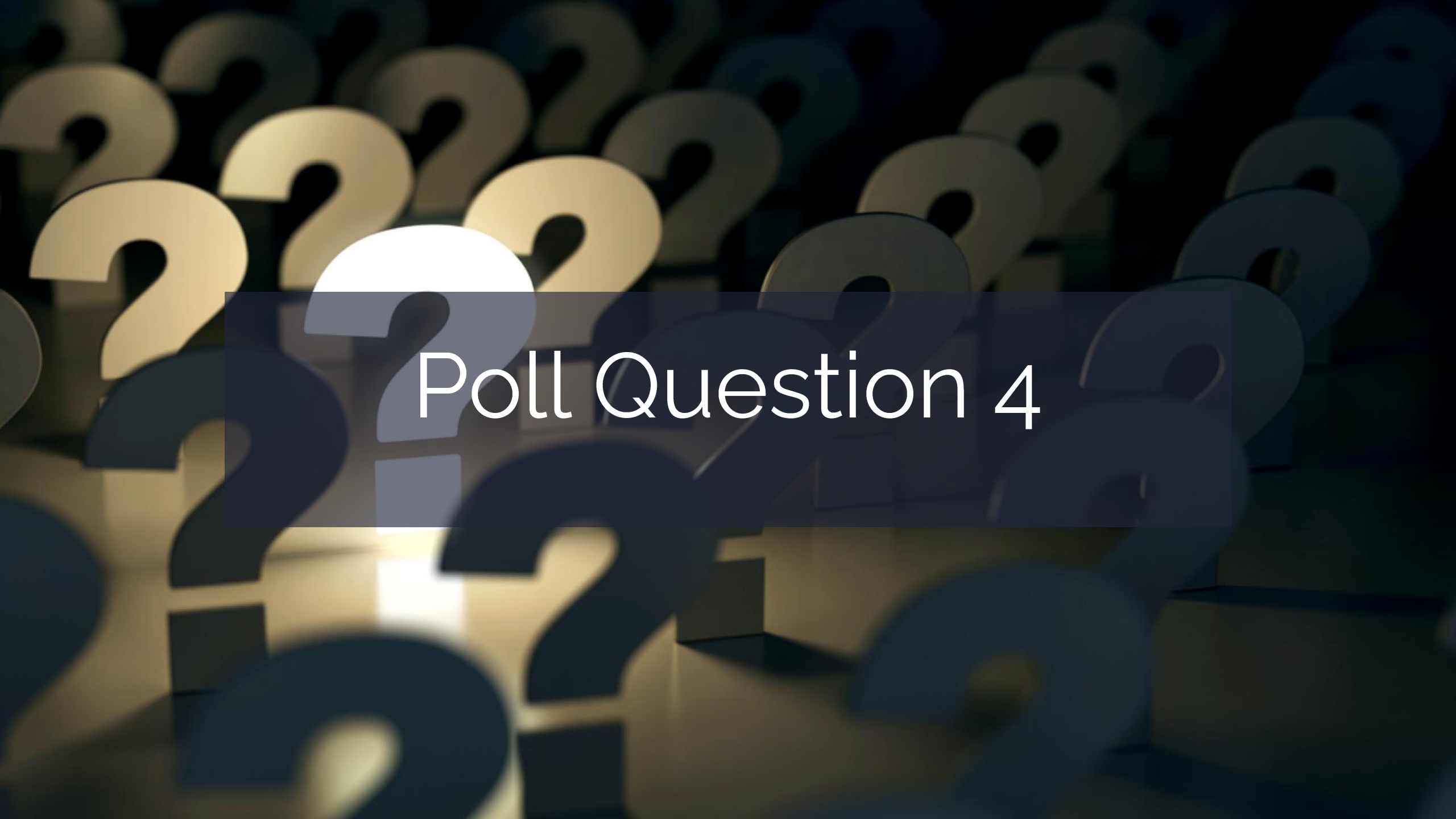
RBC Parameters

Parameter	BOD Removal Only	BOD Removal and Nitrification	Nitrification Only
Hydraulic Loading Rate (gpd/ft^2)	1-3	1-3	1-2.5
Hydraulic Retention Time (hr)	0.7-1.5	1.5-4	1.2-3
Effluent BOD	15-30	7-15	7-15
Effluent NH4-N		<2	1-2

Some Limitations

- RBCs typically require lower organic loading rates than trickling filters
- They don’t provide as much flexibility as trickling filters when it comes to operating over a wide range of organic loading
- They can’t be used as roughing filters or as high-rate reactors


Poll Question 3


Poll Question 4

Questions?

CONTACT INFORMATION

SOUTHWEST ENVIRONMENTAL FINANCE CENTER

A.J. Barney
ajbarney1@unm.edu

Department of Civil Engineering MSC01 1070
1 University of New Mexico
Albuquerque, NM 87131
505-277-0644
swefc@unm.edu
http://swefc.unm.edu

EFCN
environmental finance center network