# WASTEWATER LAGOON TRAINING
# DAY 1: WASTEWATER TREATMENT FUNDAMENTALS
# MAY 15-19, 2023

# About the Trainers

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# OUTLINE AND PRE-QUIZ

# Wastewater Lagoon Training

Day 1: Wastewater Treatment Fundamentals

Day 2: Wastewater Lagoon Troubleshooting

Day 3: Wastewater Collections and Mikero-organisms under the MIKEroscope

Day 4: Wastewater Lagoon Design and Construction & Advanced Treatment Topics

Day 5: Review and Exam

# Outline for Today

1. Introduction to wastewater
2. Wastewater characteristics
3. Preliminary treatment of wastewater
4. Primary treatment of wastewater
5. Fundamentals of biological treatment
6. Wastewater treatment ponds
7. Fixed film treatment
8. Activated sludge
9. Nutrient removal
10. Disinfection

# Pre-Quiz

1. What does WWTP stand for?
2. Why is it important to treat wastewater?
3. What does BOD stand for?
4. What is an example of a secondary treatment process?
5. What is the difference between and aerobic zone and an anaerobic zone?
6. What is the limit for nitrogen in WWTP effluent?
7. What permits apply to wastewater treatment facilities?
8. What are 2 types of disinfection methods?

# 1. INTRODUCTION TO WASTEWATER

# Why Treat Wastewater?

- Untreated wastewater is harmful to the environment
- Affects animals in the area
- Overwhelms the natural treatment processes
- Kills fish
- Spreads waterborne diseases
- Violates safe drinking water standards

# Components of wastewater

- Water
- Solids
- Biochemical oxygen demand (BOD)
- Nutrients
- Fats, oils, and grease
- Bacteria and pathogens

# The Clean Water Act

- Promulgated in 1972
- All dischargers must have a permit
- Sets secondary treatment standards
- Comprehensive laws regarding disposal of wastewater and sludge
- Goal is to ensure receiving water and swimmable and fishable
- Requires permits for discharging to waters of the U.S.
- Sets penalties

# Basic Wastewater Treatment Processes

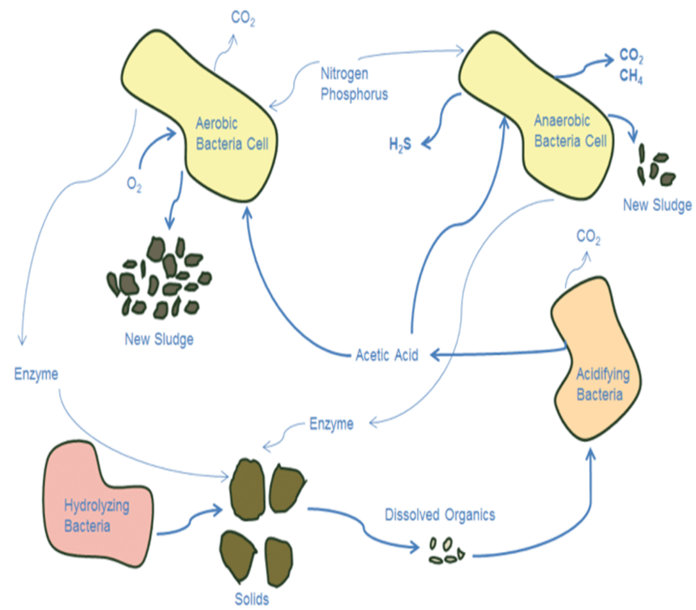
1. Physical
2. Biological
3. Chemical

# Physical 9

- Mechanically separate solids from wastewater
- Screening is first separation process
- Particles that are too small to be screened are settled out using gravity
- Bubble curtain of compressed air at the bottom of the tank
- Skimming the surface
- Filtration

# Biological 

- Organic matter and nutrients became a food source
- Bacteria and other organisms break down waste
- Raising bacteria to do the work



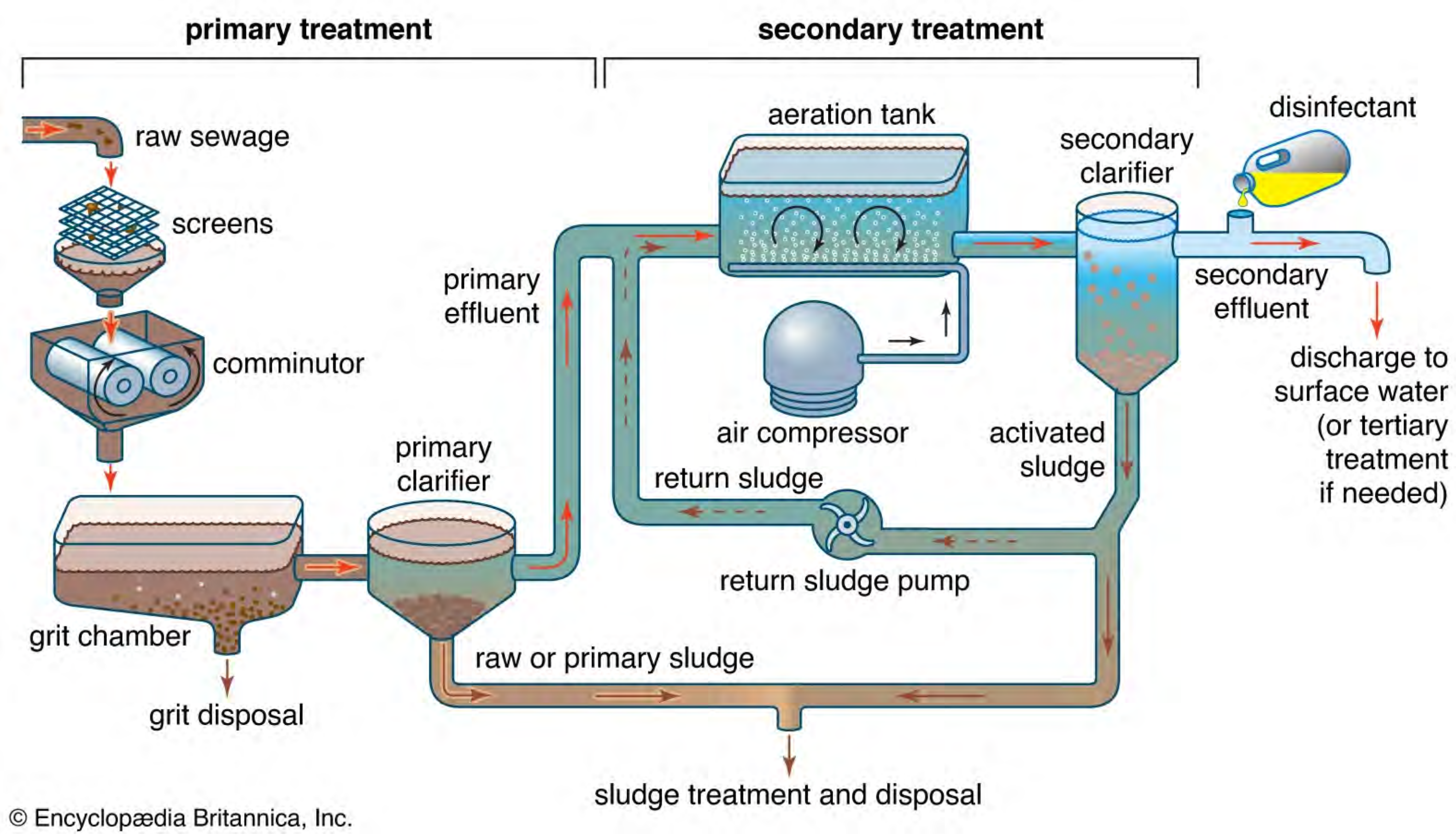
# Chemical

- Sodium hydroxide, sodium carbonate to adjust pH
- Ferric chloride for odor control
- Alum for coagulation
- Chlorine to disinfect
- Sodium bisulfate, sulfur dioxide for dechlorination
- Polymer for dewatering solids

# Liquid Treatment Processes

- Collection System
- Preliminary Treatment
- Primary Treatment
- Secondary Treatment
- Ponds
- Activated Sludge
- Trickling Filters and Rotating Biological Contactors (RBCs)
- Physical-Chemical Treatment
- Advanced Wastewater Treatment
- Disinfection
- Effluent Discharge
- Tertiary Treatment

# Liquid Treatment Processes



# Liquid Treatment Processes

*Preliminary Treatment*

- Physical treatment process
- Takes place at the WWTP headworks
- Removes large debris and solids
- Includes screening, grit removal, flow measurement, and equalization

# Liquid Treatment Processes

*Primary Treatment*

- Physical treatment process
- Decreases velocity of wastewater to remove settleable and floatable material
- May use gravity or flotation
- Reduces size and cost of secondary treatment
- Cannot remove colloidal material, soluble BOD, soluble P, or ammonia
- Removal rates depend on influent characteristics
- Paired with anaerobic digestion and other forms of sludge stabilization that don’t require oxygen

# Liquid Treatment Processes

*Secondary Treatment*

- Biological treatment process
- Microorganisms consume organic material in WW and convert into more microorganisms, carbon dioxide, and water
- Increases particle size so biological solids can be separated by gravity
- Fixed film processes (trickling filters and RBCs)
- Suspended growth processes (ponds and activated sludge)

# Liquid Treatment Processes

*Tertiary Treatment*

- Physical, biological, or chemical
- Treatment beyond the secondary treatment standards
  - Removal of ammonia, nitrate, phosphorus, metals, other constituents
- Includes technologies such as filtration and chemical precipitation

# Liquid Treatment Processes

*Disinfection*

- Reduces the numbers of bacteria and pathogens in the effluent
- Protects human health and the environment
- Common types of disinfection
  - Chlorine gas
  - Sodium hypochlorite (bleach)
  - UV light

# Solids Treatment Processes

- Solid material is removed
- Sludge stabilization (sludge – biosolids)
- Thickening
- Dewatering
- Digestion
- Chemical stabilization
- Composting
- Reduce organic material, odors, pathogens, biodegradable toxins
- Bind heavy metals to inert solids

# Solids Treatment Processes

- Screenings and Grit
  - Disposed of in landfills
- Primary Sludge
  - Consists of organic and inorganic solids
  - Separated from raw wastewater by gravity
- Secondary Sludge
  - Composed of microorganisms grown during secondary treatment
  - Goes through a thickening process before it's treated further
- Chemical Sludge
  - Generated at WWTPs that have tertiary treatment, such as phosphorus removal

# Types of Residuals

- Primary sludge: Unprocessed (raw) organic/inorganic solids

  2-6% solids
- Secondary sludge: Microorganisms

  < 1% solids
- Chemical sludge: Dependent on treatment chemicals (alum)
- Tertiary treatment: Phosphorous removal

# Solids Treatment Processes

## *Thickening*

- Physical treatment process to remove water and decrease the volume of sludge
- Thickened sludge typically between 2 and 8% total solids
- Less volume, hauling costs reduced

1. Pre-thickening – DAFTS, centrifuges, gravity belts, rotary drum
2. Post-thickening – after stabilization (digestion) before beneficial use
3. Recuperative thickening – thickening biosolids

# Solids Treatment Processes

*Stabilization - Digestion*

- Converts sludge into biosolids, reduces pathogens
- Biological or chemical treatment process
- Aerobically (presence of oxygen)
  - Primary or secondary sludge can be digested
  - Uses microbes in open or closed tanks or ponds or break down organic matter into carbon dioxide, water, and ammonia
- Anaerobically (absence of oxygen)
  - Only primary sludge can be digested
  - Uses microbes in a closed tank containing little to no oxygen

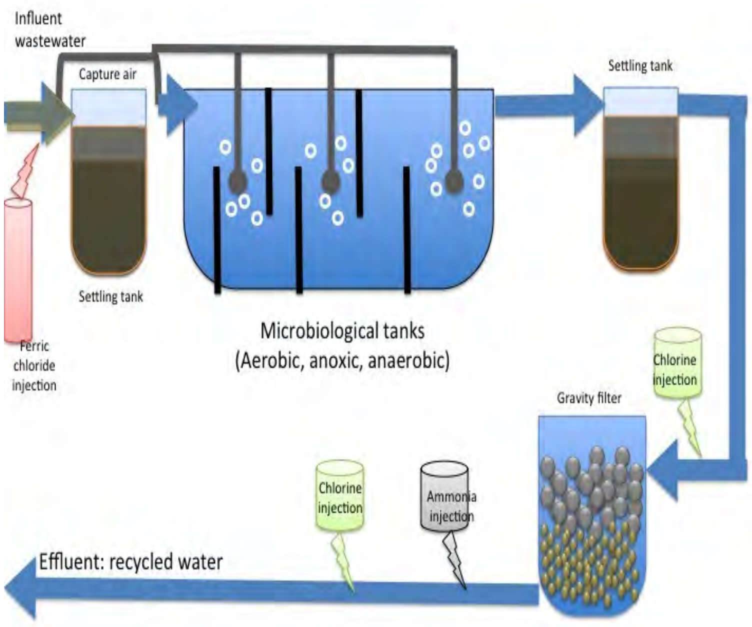
# Digestion

- Digestion may be done aerobically or anaerobically
- Primary sludge is digested anaerobically
- Digesters contain primary and secondary sludge
- Endogenous respiration: Reduce the volatile solids and pathogen content
- After digestion sludge can meet the 503 regulations
- Aerobic digestion: Microbes break down organic matter into carbon dioxide, water and ammonia
  - 40 days / 40% reduction in volatile solids

# Solids Treatment Processes

*Chemical Stabilization*

- Raising the sludge pH: 12.0 for 2 hours and maintain at 11.5 for 22 hours
- Reduces pathogens and odors
- 40 CFR 503



# Solids Treatment Processes

*Dewatering*

- Physical treatment process
- Reduces total volume for disposal
- After sludge stabilization
- Similar technology used in thickening, may use belt filter press, plate and frame press, centrifuges
- Process referred to as “cake”

# Regulatory Requirements for Biosolids

- Disposal depends on treatment
- Combustibles: Incinerated or landfill
- Grit: Landfill
- Biosolids: Land application
- CFR 503: Requirement for pathogen reduction
- Soil amendment / fertilizer
- Class A: Pathogen reduction below detectable limits
- Class B: Land applied for private land

# Regulatory Framework

- Clean Water Act (federal)
- U.S. Environmental Protection Agency
- Primacy Agency

# Regulatory Framework

- NPDES Permitting
  - Permit limits
  - Required monitoring and reporting
- State TMDL Program
- State Discharge Permits (GWQB)

# National Pollutant Discharge Elimination System Program (NPDES)

- The NPDES permit program, created in 1972 by the Clean Water Act (CWA), helps address water pollution by regulating point sources that discharge pollutants to waters of the United States.
- If you discharge from a point source into the waters of the United States, you need an NPDES permit.

# NPDES Permit Limits for WWTPs

Loading (lbs/day) = pollutant concentration (mg/l) * 8.345 lbs/gal * design flow (MGD)

30-day average $BOD_5$/TSS loading = 30 mg/l * 8.345 lbs/gal * 0.02 MGD = 5.0 lbs/day
07-day average $BOD_5$/TSS loading = 45 mg/l * 8.345 lbs/gal * 0.02 MGD = 7.5 lbs/day

A summary of the technology-based limits based on 0.02 MGD Design Flow

| EFFLUENT CHARACTERISTICS | DISCHARGE LIMITATIONS | | | |
|---|---|---|---|---|
| Parameter | 30-Day Avg. | 7-Day Avg. | 30-Day Avg. | 7-Day Avg. |
| Flow | N/A | N/A | Measure MGD | Measure MGD |
| $BOD_5$ | 5.0 lbs/Day | 7.5 lbs/Day | 30 mg/L | 45 mg/L |
| $BOD_5$, % removal, minimum | $\geq$ 85% | --- | --- | --- |
| TSS | 5.0 lbs/Day | 7.5 lbs/Day | 30 mg/L | 45 mg/L |
| TSS, % removal, minimum | $\geq$ 85% | --- | --- | --- |
| pH | NA | NA | 6.0 - 9.0 s.u. | |


QUIZ

# Quiz

1. All direct dischargers are required to have a discharge permit. (T/F)

True

# Quiz

2. Where are screenings and grit typically sent?

   Landfill

# Quiz

3. What does primary sludge consist of?

Organic and inorganic solids separated from wastewater

# Quiz

4. What does secondary sludge consist of?

Microorganisms grown during secondary treatment

# Quiz

5. Aerobic digestion does not contain oxygen. (T/F)

   False

# Quiz

6. Secondary treatment uses chemicals and bacteria to increase particle size. (T/F)

   True

# 2. WASTEWATER CHARACTERISTICS

# Wastewater Sources

1. Domestic
2. Commercial
3. Industrial

Wastewater is conveyed through isolated piping networks or collection systems.

# Typical Concentrations in WW

| Parameter | Low Strength | Medium Strength | High Strength |
|---|---|---|---|
| Total Solids, mg/L | 437 | 806 | 1612 |
| Total dissolved solids, mg/L | 374 | 560 | 1121 |
| Total suspended solids, mg/L | 130 | 195 | 389 |
| BOD5 | 133 | 200 | 700 |
| COD | 339 | 508 | 1016 |
| Total nitrogen, mg/L as N | 23 | 35 | 69 |
| Oil and grease, mg/L | 51 | 76 | 153 |
| Total phosphorus, mg/L | 3.7 | 5.6 | 11.0 |

# Influent Flow Variations

- Average wastewater flows range from 54 to 120 gallons per capita per day (gpcd).
- Smaller service areas experience greater variation in flows.
- Domestic flows experience a diurnal flow pattern with two peaks throughout the day.

# Biochemical Oxygen Demand

- The more organic material the wastewater contains, the more oxygen the bacteria will consume and stabilize it.
- 1 lb of BOD will consume 1 lb oxygen.
- BOD can be solid organic material: food, trash.
- BOD can be dissolved organic material: Proteins, fats, oil grease.

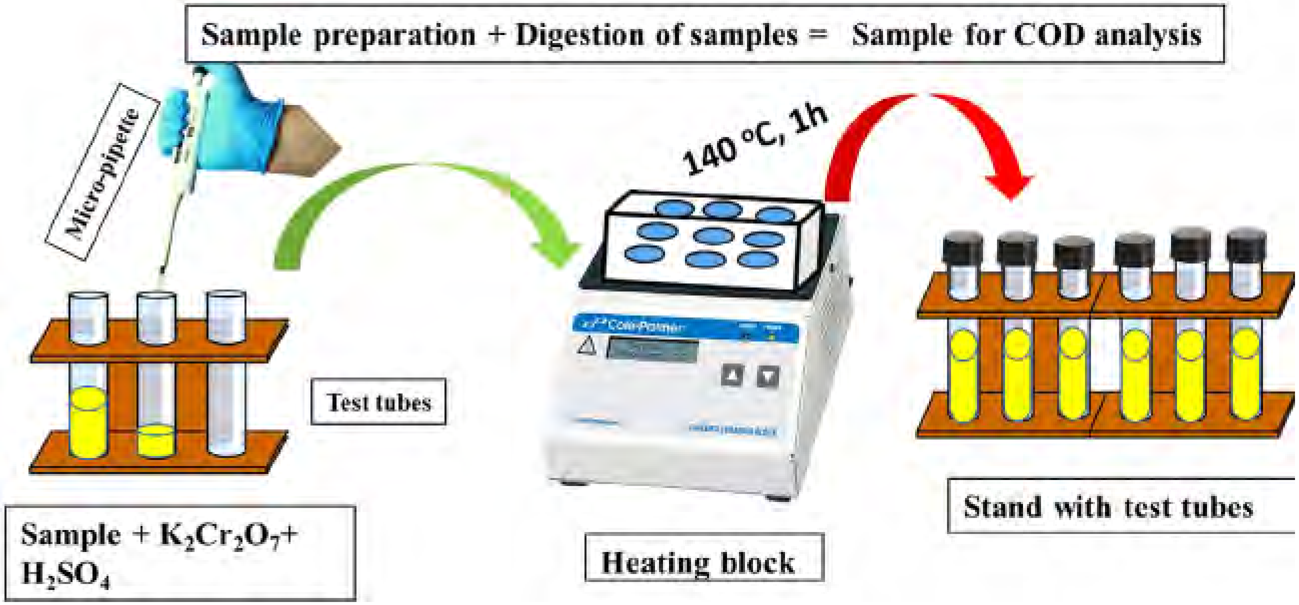
# $BOD_5$ Test

- A sample of wastewater at a measurable range
- Measure the starting dissolved oxygen (DO)
- Incubate the sample @ 20ºC (68ºF) for fixed period (5 days) in the dark
- Measure the ending DO
- BOD concentration in mg/L is calculated from the amount of oxygen consumed
- 5 days originated from England's Thames River: Water flow from river to ocean and the river temperature (18.6-20º C)

# Chemical Oxygen Demand (COD)

- Wastewater contains additional organic compounds that cannot be consumed within the 5-day BOD test.
- These organic compounds are non-biodegradable, but can be broken down chemically.
- COD is composed of these organic compounds that are consumed chemically.

# COD Testing – 2 hours




QUIZ

# Quiz

1. What are the 3 types of wastewater sources?

   ✓ Domestic
   ✓ Commercial
   ✓ Industrial

# Quiz

2. How much BOD does it take to dissolve 1 lb. of oxygen?

   1 lb.

# Quiz

3. What is COD composed of?

   Nonbiodegradable organic compounds that are consumed chemically

# 3. PRELIMINARY TREATMENT

# Preliminary Treatment

- Headworks - Remove the larger materials
  - Wood
  - Cardboard
  - Rags
  - Grit
  - FOG
  - Scum

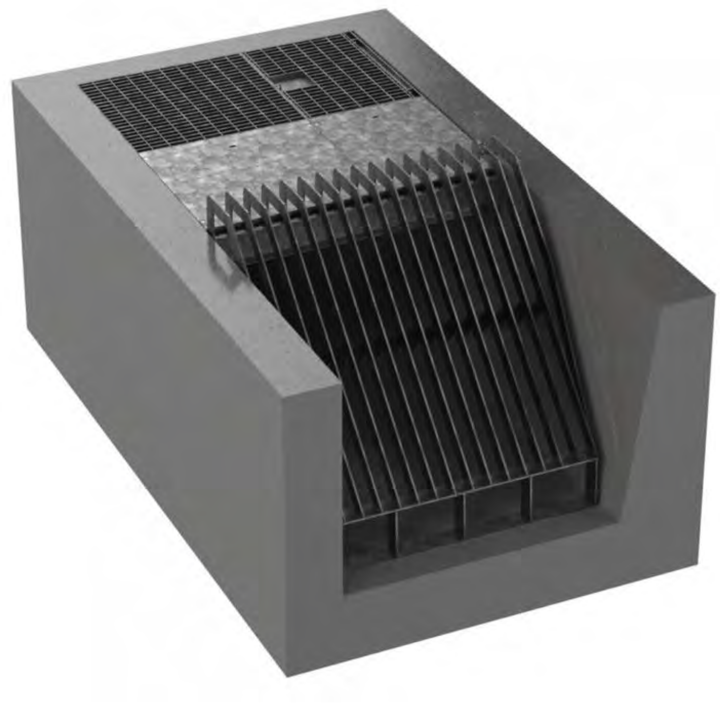
# Screening

Types:

1. Trash Screens
2. Coarse Screens
3. Fine Screens

# Trash Screens

- Sloped at an angle of 30 to 45 degrees
- Placed in a channel
- Cleaned (raked) manually or automatically several times per day
  - Manual cleaning, increased O&M
- Openings between 1.5 and 6 inches



# Bar Screens

- Resemble trash screens but have smaller spacing
- Manual or automatic cleaning
- Openings between 0.25 and 2 inches

# Fine Screens

- Remove smaller material than coarse screens
- Openings between 0.12 to 0.24 inches
- Made of wedge wire, perforated plate, or mesh
- Downstream of coarse screens

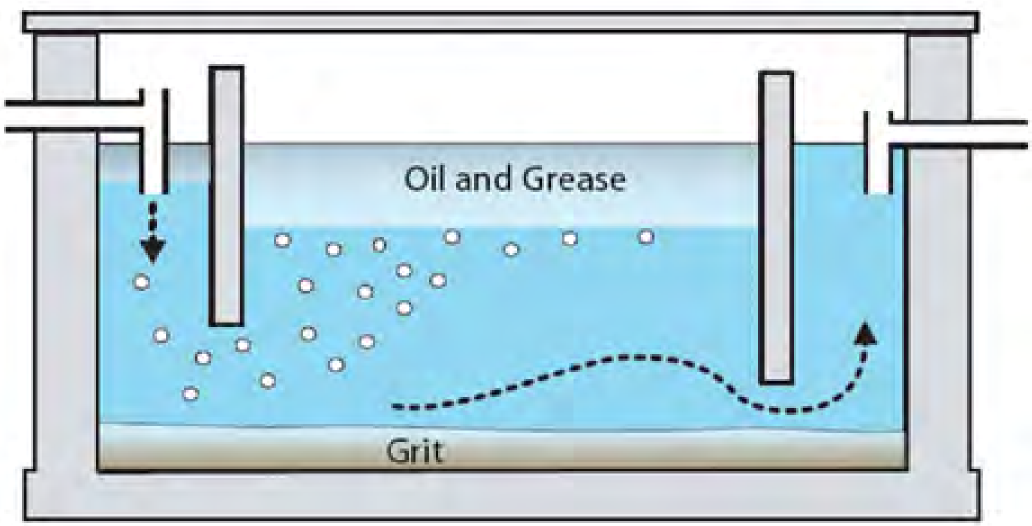
# Screen Process Control

*Cleaning Cycles*

- Timed
- Triggered by difference in water level from one side of the screen to the other
- Combination of both
- Minimum cleaning frequency is when head loss reached 3 inches

# Grit Basins

- Removes heavier particles that settle faster than organic material
- Reduces velocity
  - 0.3 m/s (1.0 ft/s)
- Protects downstream equipment

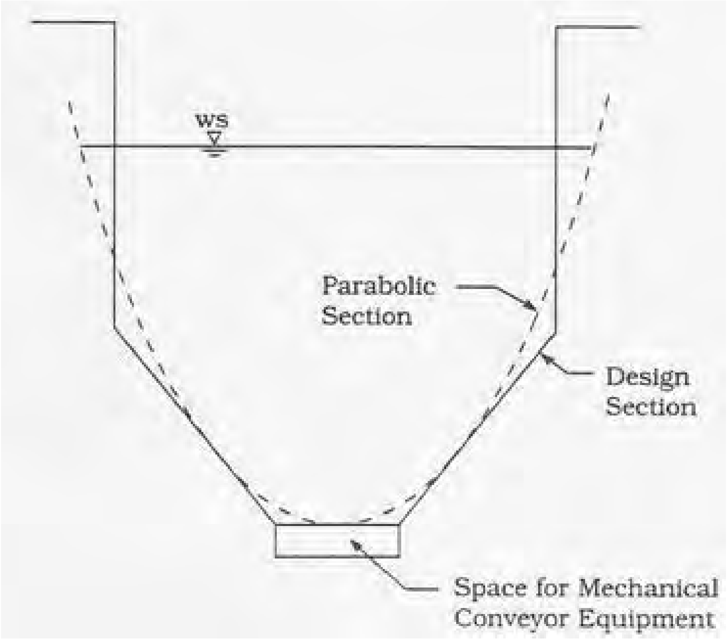


# Grit Basins

1. Velocity controlled grit systems
2. Aerated grit systems
3. Vortex grit systems

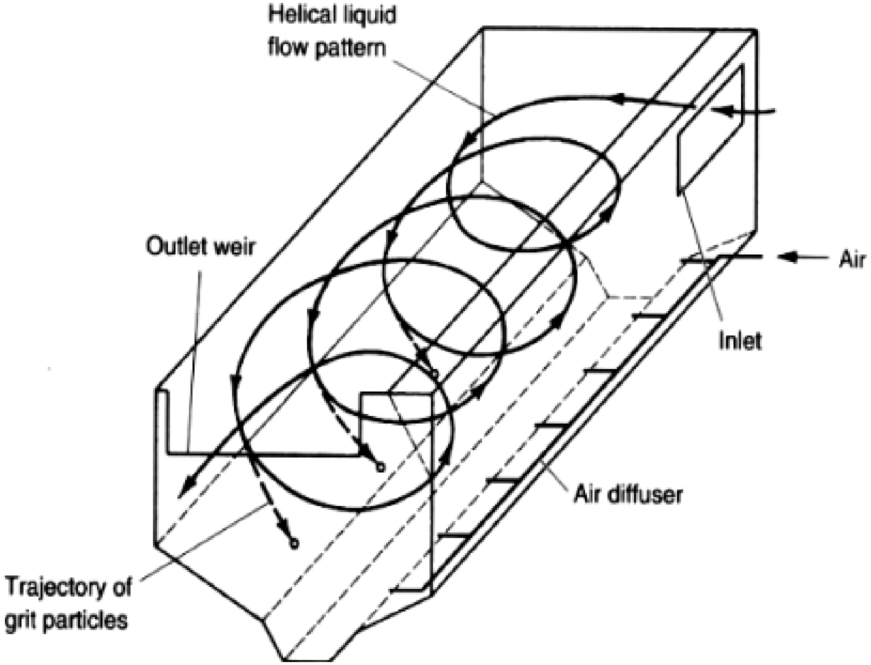
# Velocity Controlled Grit Systems

- $Velocity = \frac{Flow}{Area}$
- When the flow increases, the area must also change to maintain constant velocity
- Weirs and parabolic channels are commonly used to manage velocity
- Hydraulic retention time (HRT) is approximately between 45 and 90 seconds for horizontal flow grit chambers



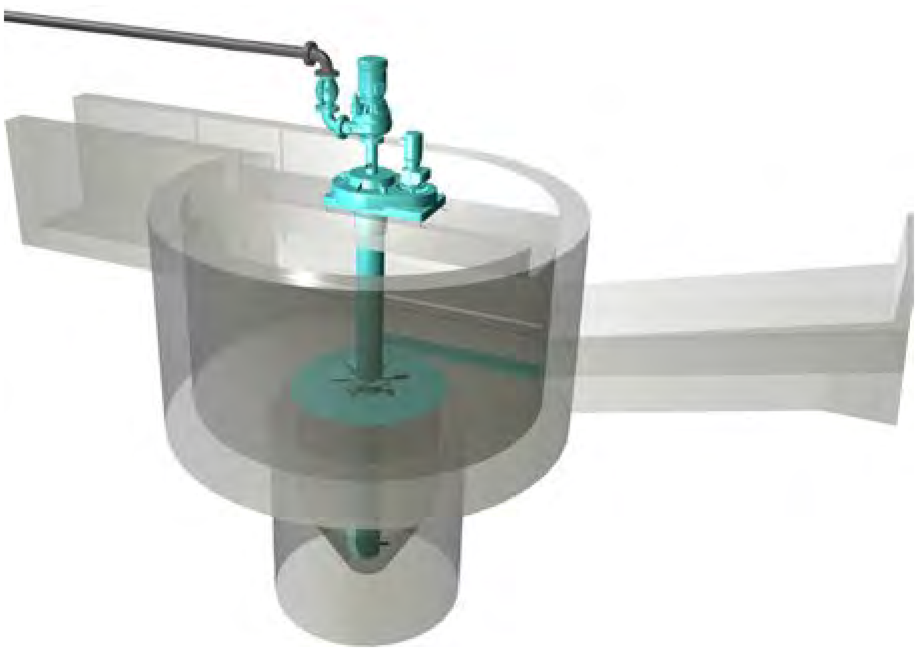
# Aerated Grit Systems

- Diffused air is introduced near the bottom of the basin (70% of the total depth)
- Creates a roll pattern and pushes grit into a hopper
- HRT is approximately 2 to 5 minutes



# Vortex Grit Systems

- Circular basins that create a whirlpool effect and settles particles to the bottom
- Target water velocity is 1.5 to 3.5 ft/s
- Grit pumps pull grit from the bottom hopper



# Grit Process Control

Adjust process to maintain target velocity:

- Velocity-controlled: adjust cross sectional area
- Aerated: adjust airflow
- Vortex: adjust paddle speed
- All: limit number of units in active service

# Grit Process Control

Inspect grit:

- Presence of organic material indicate velocity is too low
- Buildup of grit downstream indicates velocity is too high


QUIZ

# Quiz

1. Where does preliminary treatment take place?

   Headworks

# Quiz

2. Why is screening necessary?

   It protects equipment downstream.

# Quiz

3. What are the disadvantages of manual screens?

High O&M costs

# Quiz

## 4. What is grit?

Smaller particles that pass through the screens but large enough to settle faster that other organic material (sand).

# Quiz

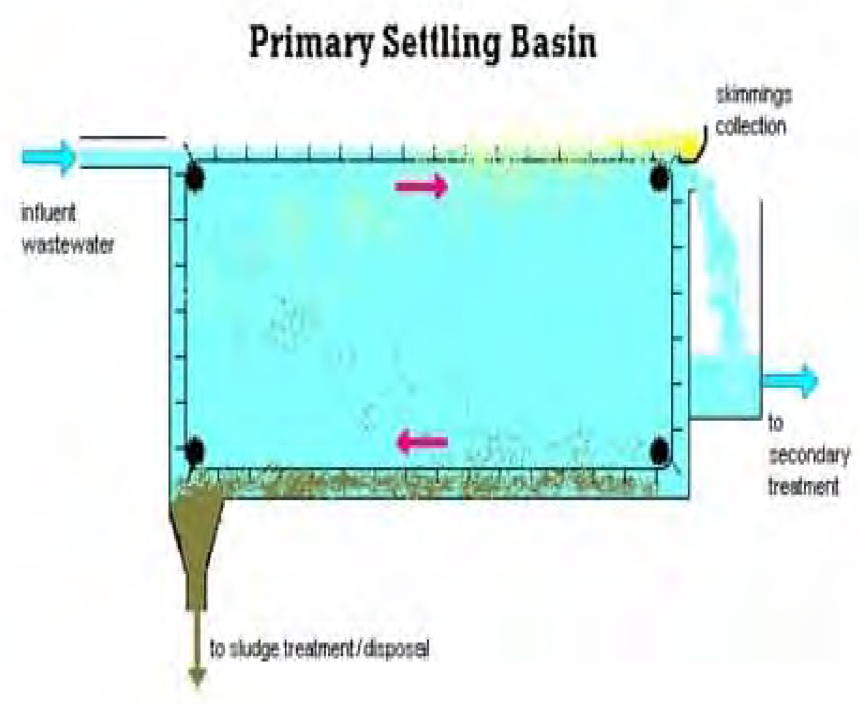
5. What is the purpose of a grit basin?

   Removes smaller solids that pass through screening to protect downstream equipment

# 4. PRIMARY TREATMENT

# Primary Treatment

- Primary clarifiers
- Slow down the water and remove heavier organic material (sludge) and lighter floatable material (scum)
- Reduces total suspended solids (TSS), BOD, and COD
- Reduces size and operating cost of secondary treatment



# Primary Clarifiers

- Hydraulic detention time (HDT)
  - Amount of time water remains in the clarifier
  - Typically 1.5 to 2.5 hours
- Removes 50 to 70% TSS
- Removes 25 to 40% BOD
- Removes 5 to 10% phosphorus

# Primary Clarifiers

- Surface Overflow Rate (SOR)
- $\text{SOR} = \frac{Flow\ (gpd)}{Surface\ area\ (sqft)}$
- Average SOR 600 to 1200 gpd/sq ft
- Peak SOR 2,500 to 3,000 gpd/sq ft
- Sludge blanket depth of 2 to 3 feet
- Sludge concentration of 3 to 6% total solids

# Circular Clarifiers

*Design*

- Circular tank up to 300 feet in diameter
- Depths of 10 to 12 feet
- Freeboard of 1.5 to 2 feet
- Floor slope 1:12
- Rotating scrapers

# Circular Clarifiers

*Three Flow Patterns*

1. Center feed, peripheral take-off
2. Peripheral feed, center take-off
3. Peripheral feed, peripheral take-off

Feed-well dissipates influent flow and directs downward to prevent short-circuiting

# Circular Clarifiers

<u>Sludge removal</u>

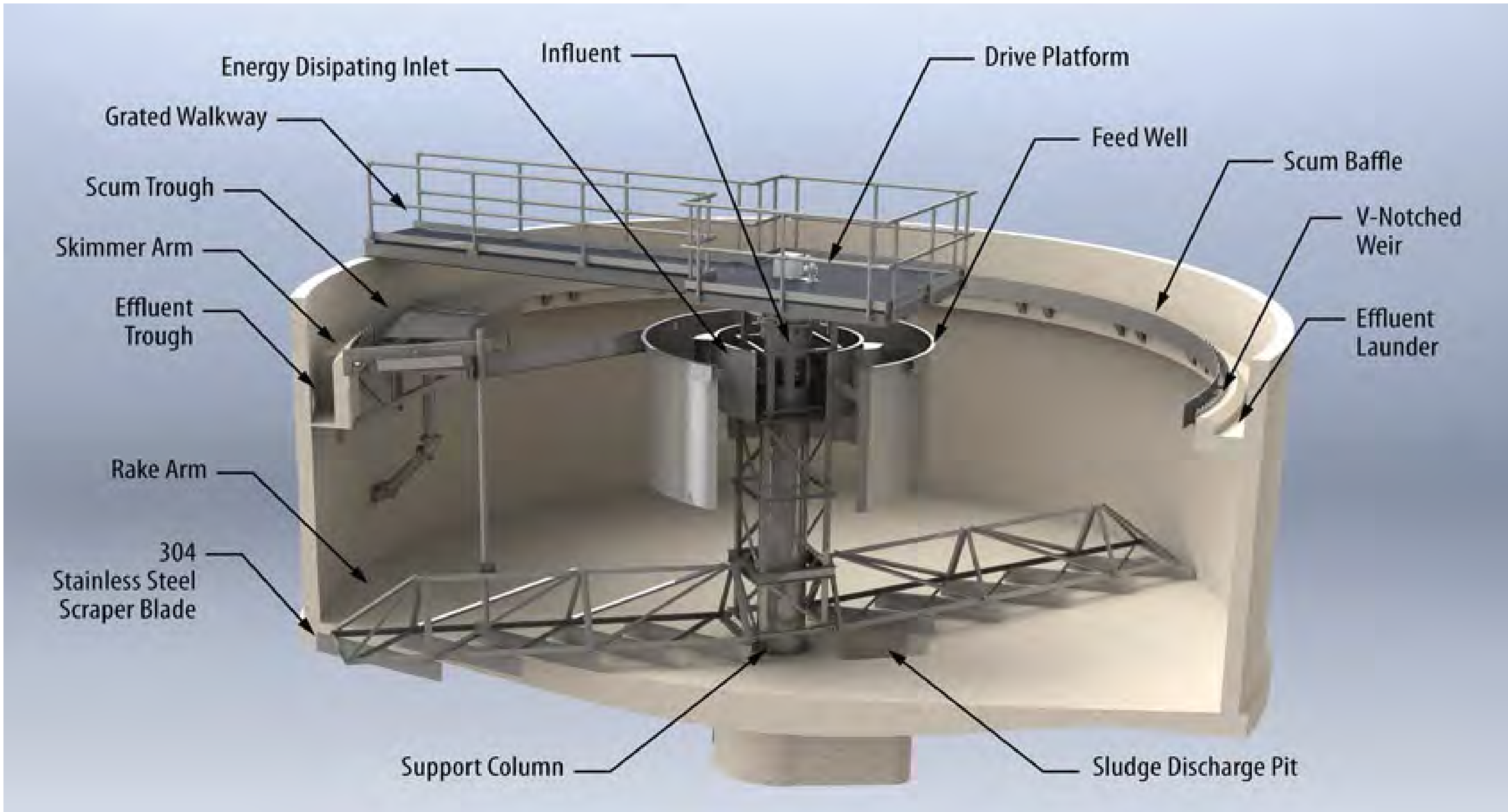
- Rotating sludge scraper with 4 blade arrangements
- Straight multiblade window shade plow (most common)
- Sludge hopper typically near center of tank
- Pumped out of hopper

# Circular Clarifiers

*Clarifier Drive*

- Typically located at center, occasionally outer wall
- Motor coupled to the clarifier mechanism through reducers
  - Worm gears
  - Increase torque and decrease speed
- Torque monitoring to prevent equipment damage
  - May sound an alarm to shut down drive if stuck

# Circular Clarifiers



# Circular Clarifiers

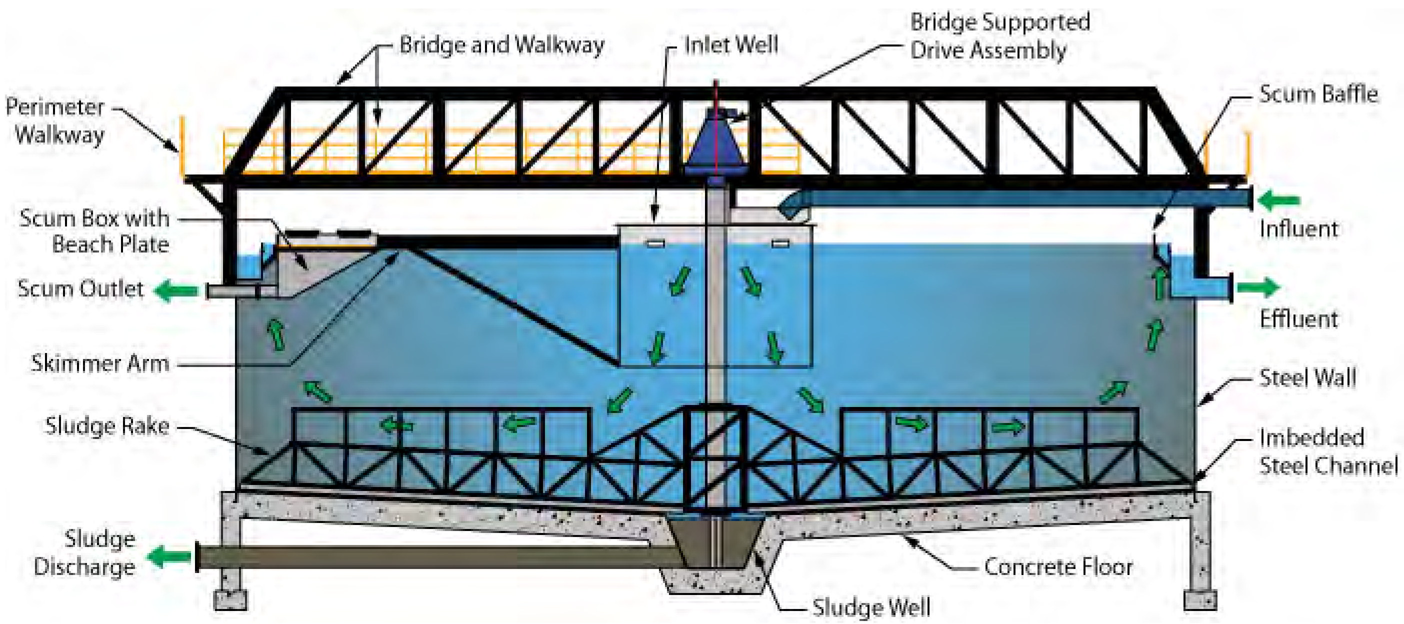
*Weirs*

- Weir plate typically 90-deg v-notch, spaced 6 to 12 inches
- Inboard launder projects into the clarifier from the outer wall
- Inset launder located several feet within clarifier tank
- Scum baffle set inside the weir prevents floatable material from passing into the final effluent

# Circular Clarifiers

*Skimming system*

- Revolving skimmer with scum beach and drop to scum box
- Revolving skimmer is typically joined to the rotating sludge scraper



# Rectangular Clarifiers

*Design*

- Tank up to 300 feet in length and 80 feet in width
- Length to width > 5:1
- Depths of 10 to 12 feet, up to 16 feet
- Floor slope 1%
- Freeboard of 1.5 to 2 feet

# Rectangular Clarifiers

*Flow Pattern*

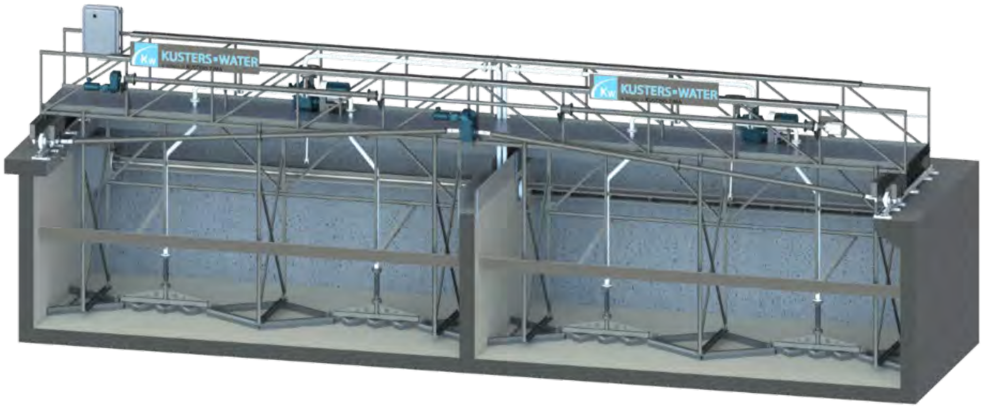
- Flow enters at one end, travels lengthwise to effluent launder
- Influent channel or manifold can distribute flow across width
- Inlet baffles dissipate influent flow and direct flow downward to prevent short-circuiting

# Rectangular Clarifiers

*Sludge Removal*

- Chain-and-flight or traveling bridge
- Chain-and-flight consists of a series of boards (flights) pulled across the floor
  - Flights may also be used for scum skimming
  - 3, 4, or 5 sprocket versions
  - Multiple chain-and-flight systems in single tank possible
- Traveling bridge has scraper mechanism that the height can be adjusted
- Pumps sludge to solids handling

# Rectangular Clarifiers



# Rectangular Clarifiers

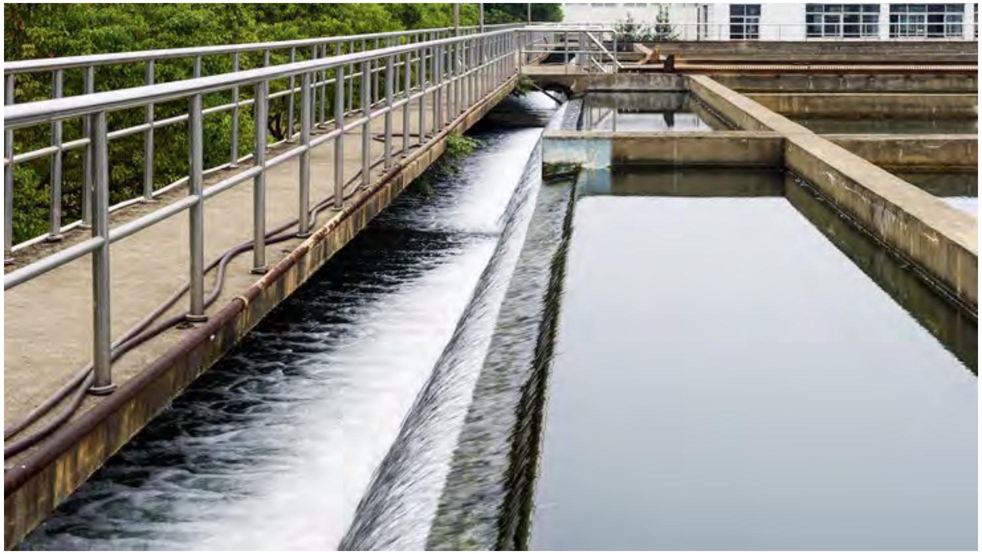
*Clarifier Drive*

- Located on outer wall
- Similar to drives in circular tanks
- Shear pin and limit switches to prevent equipment damage

# Rectangular Clarifiers

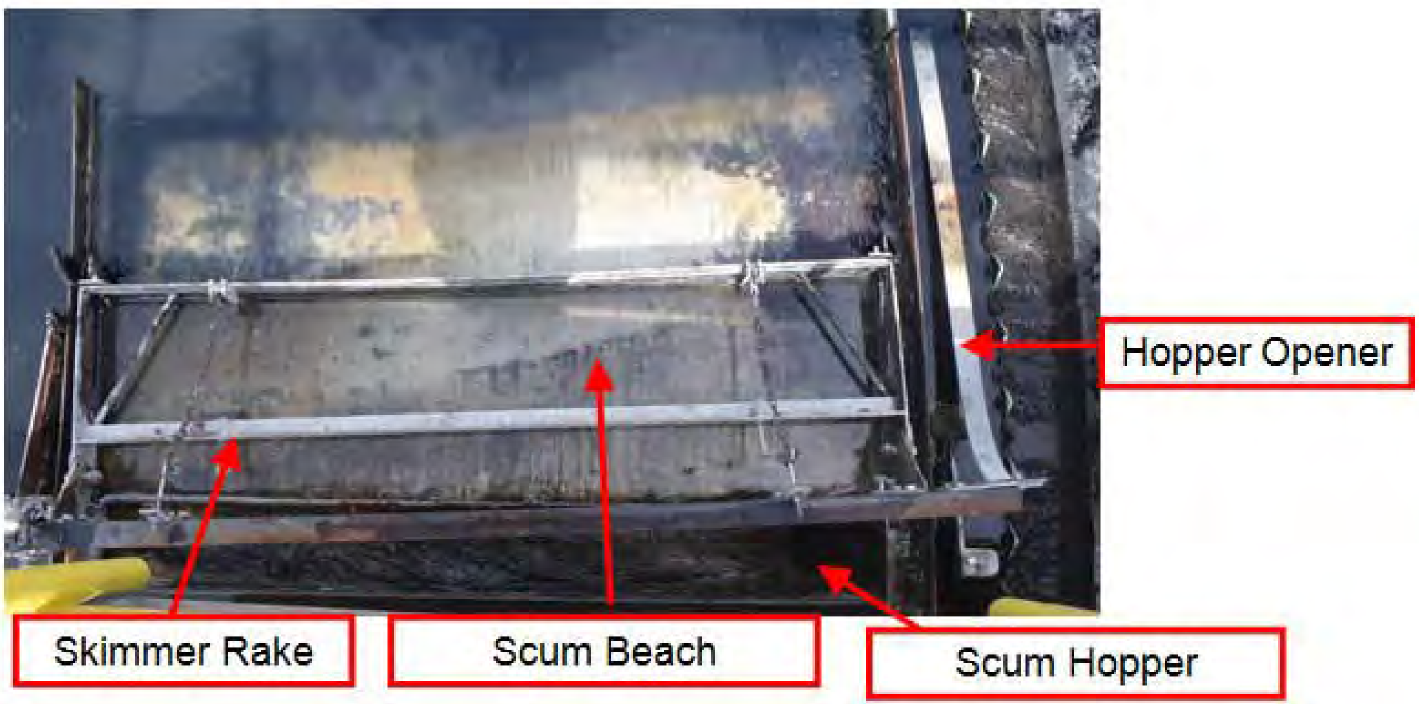
*Weirs*

- Surface overflow weirs similar to circular tanks
- Longitudinal, transverse, or grid
- Submerged launders have larger openings at regularly spaced intervals



# Rectangular Clarifiers

- Ducking skimmers, rotating skimmers
- Flights push floatable material to ducking skimmer



# Clarifiers Process Variables

- Gravity pulls particles down while SOR pushes them up and out
- HDT aids in particle retention
- Settling velocity determined by particle size, shape, density
- Flocculation can increase particle size, help remove colloidal material (chemicals can be added)
- Particles settle faster in warmer, less dense water


QUIZ

# Quiz

1. What does primary treatment reduce?

   Heavy organics and scum (floatable)

# Quiz

2. What do primary clarifiers remove?

   TSS, COD, and BOD

# Quiz

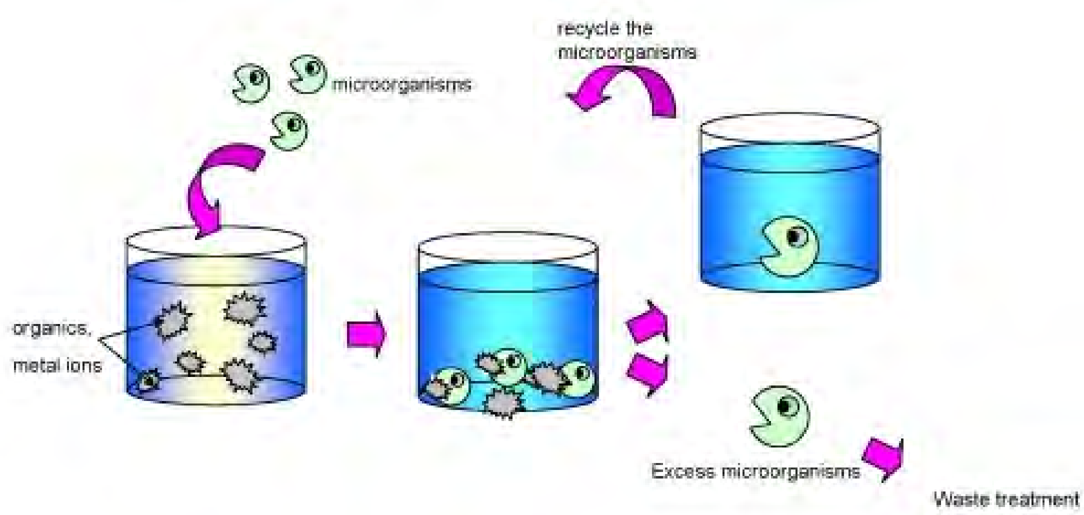
3. What is the typical HDT for a clarifier?

   1.5 to 2 hours

# 5. FUNDAMENTALS OF BIOLOGICAL TREATMENT

# Introduction

- Biological treatment depends on a healthy community of bacteria
- Very little biological oxygen demand (BOD) and total suspended solids  (TSS)
- Removal of nitrogen and phosphorus



# Biological Treatment 

- Biological treatment was developed in the early part on the 20$^{\text{th}}$ century – early 1900's
- Biological treatment depends on naturally occurring microorganisms to break down organic matter into simple substances such as carbon dioxide and water.
- Microorganisms use organic material in the wastewater as food to grow and reproduce
- The higher the concentrations the faster the biological process
- Once treatment is complete, biomass is separated, treated wastewater can be discharged safely to a receiving water.

# Physical and Chemical Requirements

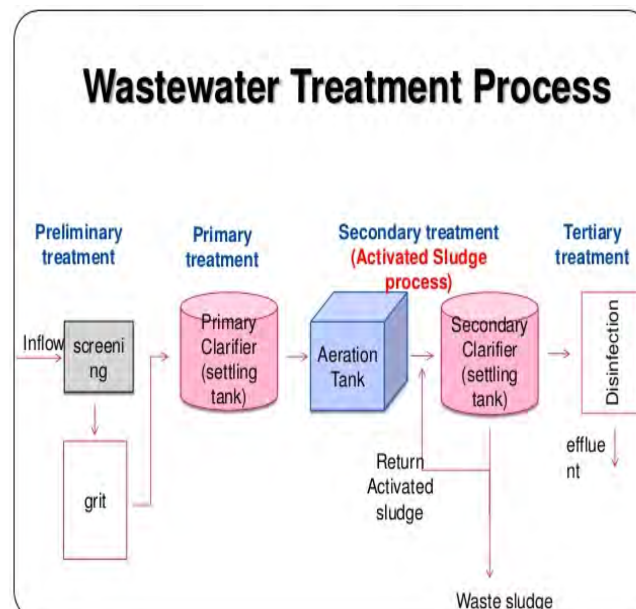
- Specialized bacteria convert ammonia to nitrite and nitrate or uptake phosphorus
- Microorganisms form biofilms or flocs, bug communities
- Biofilms form on surface particles
- Flocs grow suspended in the wastewater
- Microorganisms incorporate biodegradable matter and convert it to biomass
- Exopolymer: Sticky substance that helps bacteria stick together
- Biofilms and floc are denser than water; gravity will separate them

# Microbiology

- Biomass may contain up to 300 different types of microorganisms
- Categorized in 4 groups
  - Bacteria
  - Protozoans
  - metazoans
  - viruses

# Secondary Treatment

- Most large particles are removed
- Colloidal particles remain; they can take 2 years to settle!
- Secondary treatment can efficiently (chemically and biologically) remove 85% of TSS and BOD
- Effluent concentrations of 10-30 mg/L

# Secondary Treatment Standards

Table 1.2

| Violation Type | Description | Max $/day | Imprisonment (yrs) |
|---|---|---|---|
| Negligent | Not intentional | $25,000 | 1 |
| Knowing | The operator knew a permit violation would result from their action | $50,000 | 3 |
| Knowing Endangerment | The operator took an action 1) knowing that it was a permit violation, and 2) knowing it would result in harm to the environment | $250,000 | 15 |

# Quiz

1. Once treatment is complete and biomass is separated, treated wastewater can be safely discharged. (T/F)
2. What percent of TSS and BOD can be removed by secondary treatment?
3. What is organic matter broken down in to?


QUIZ

# Quiz

1. Once treatment is complete and biomass is separated, treated wastewater can be safely discharged. (T/F)

True

# Quiz

2. What percent of TSS and BOD can be removed by secondary treatment?

   85%

# Quiz

3. What is organic matter broken down into?

$CO_2$, $H_2O$

# 7. FIXED FILM TREATMENT

# Purpose and Function

1. Trickling filters
2. Rotating biological contactors (RBCs)

- Remove dissolved organics and fine organic solids
- Convert soluble and colloidal material into a biological film
- May remove ammonia, nitrite, and nitrate
- Low energy, low O&M

# Trickling Filters and RBCs

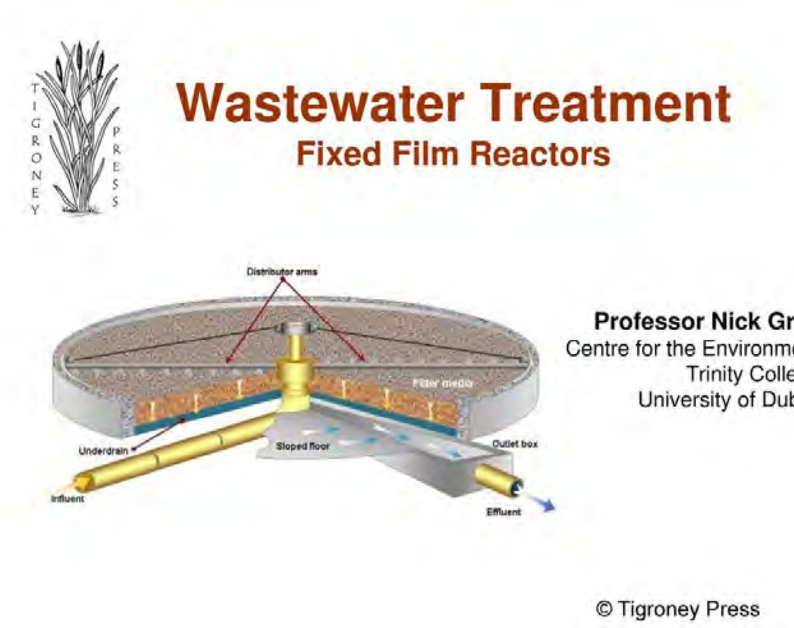
- Same microorganisms as activated sludge
- Wastewater is sprayed on the bacteria attached to media
- Media is supported by an underdrain
- Rotating batch reactors (RBC) popular in the 1970s
- Stacked plates or wheels submerged 30-70% in wastewater
- Rotate with microorganisms forming a biofilm

Trickling Filter

RBC

# Trickling Filter

- Media
  - Rock, redwood slats, or plastic
  - Loose pieces randomly stacked together
  - Voids allow WW and air to move pass through
  - High surface area for biofilm growth per volume of media
  - Media not submerged, supported by underdrain

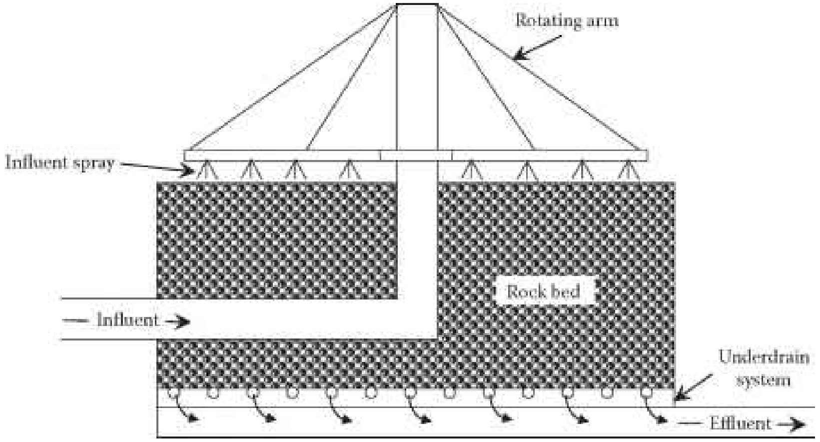


# Trickling Filter

- Square or rectangular tanks
- Concrete of steel
- May or may not be water tight
- May have ventilation ports along bottom perimeter for natural ventilation

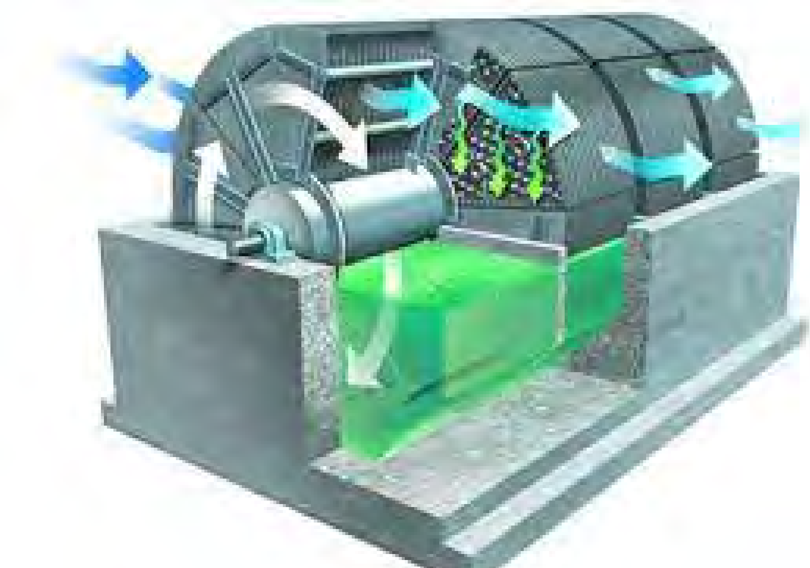
# Trickling Filter

- Wastewater pumped to the top of media
- Rotary or fixed nozzle
- Biofilm thickness influenced by distributor speed
  - Faster = thicker biofilm
- Organic loading rate
  - Mass BOD per volume of media; influences biofilm thickness



# RBCs

- Plastic media wheels may be up to 12ft diameter
- Media rotated through WW with mechanical drive or air driven
- Air driven units: air bubbles rise from the bottom of the tank to push on side of the media wheel



# RBCs

- HRT varies between 45 minutes and 4 hours depending on treatment objectives
  - More time is needed to remove ammonia
- Biofilm exposed to air
- Effluent flows out over end of the tank

# RBCs

- Organic loading rate
  - Mass of BOD per sq ft of media surface area
- Hydraulic loading rate
  - Volume of wastewater treated per sq ft of media surface area
- Hydraulic detention time
  - Time WW spends in the RBC tank
- Rotational speed
  - Faster speed = thicker film

# Process Control for Fixed-Film

- Measure total and soluble BOD
- Measure settled or soluble BOD in effluent
- Record effluent DO concentrations
  - Trickling filters: daily
  - RBCs: each stage of treatment
- When removing ammonia:
  - Monitor pH, alkalinity, ammonia, nitrate, and nitrate in influent and effluent

# Maintenance for Fixed-Film

- Daily observation for malfunctions
- Make sure rotation is smooth and spay nozzles aren't clogged
- NEVER stop a rotating RBC by hand
- Check for water in drive oil
- Regular maintenance in accordance with manufacture O&M


QUIZ

# Quiz

1. What are the two methods of fixed-film treatment?

   Trickling filters, RBCs

# Quiz

2. What is the purpose of fixed-film treatment?

- ✓ Remove DO and fine organic solids
- ✓ Remove ammonia, nitrate, nitrate

# Quiz

3. What is the organic loading rate?

   Mass BOD per volume or area of media

# Quiz

4. Biofilm thickness is influenced by distributor speed. (T/F)

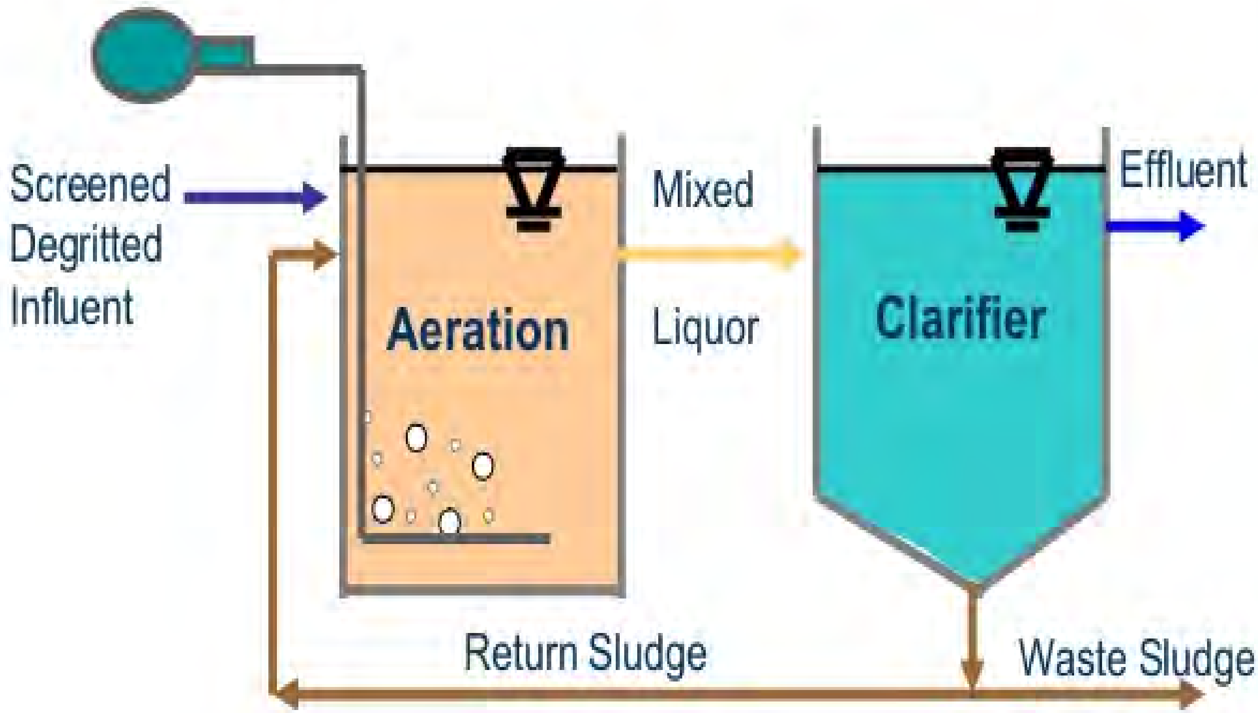
True

# 8. ACTIVATED SLUDGE

# Theory of Operation

- Microorganisms convert organic solids into new microorganisms and waster products
- Process may remove BOD, $NH_3$-N, $NO_3$-N, and $PO_4$-P
- Microorganisms grow in colonies called floc.
- Floc is more dense than water and settles in the secondary clarifier
- Flocculated mass is mixed liquor suspended solids (MLSS) or mixed liquor volatile suspended solids (MLVSS)
- MLSS settles as a mass and particles fall at the same speed

# TYPICAL ACTIVATED SLUDGE PROCESS



# Overview

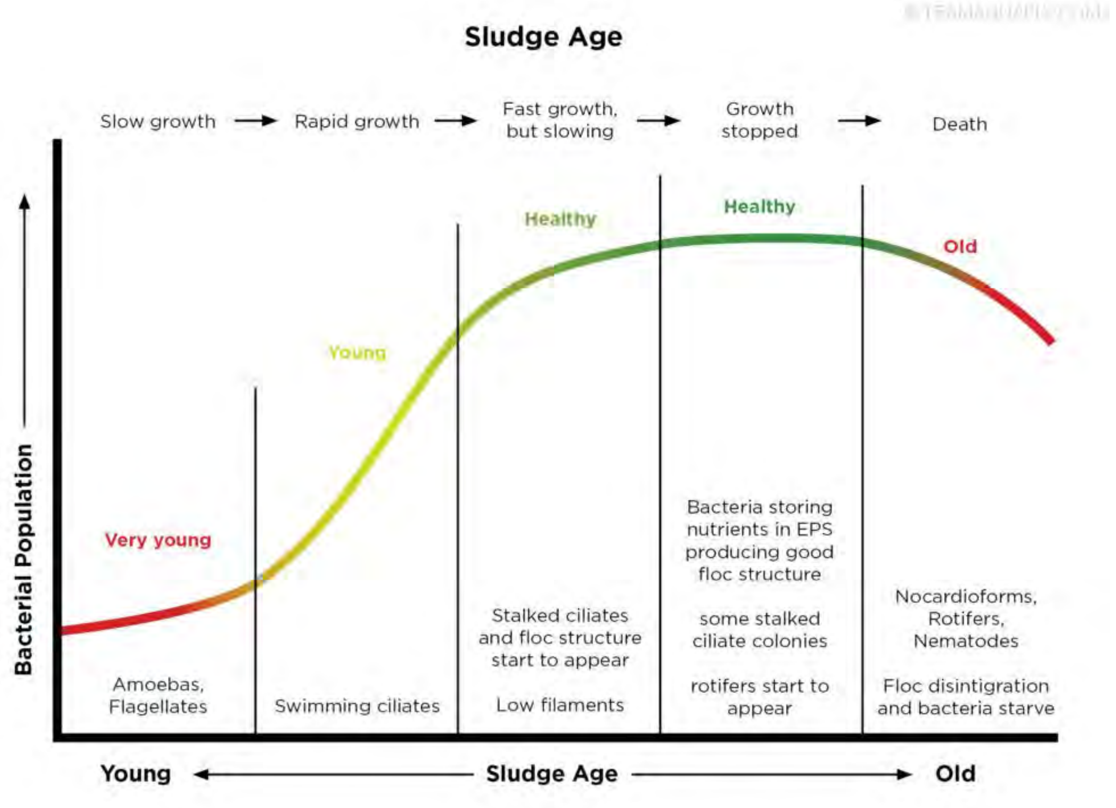
- Consists of AS basin where floc is exposed to influent or primary effluent and air
  - Followed by settling in secondary clarifier
- Return activated sludge (RAS) pipe returns settled sludge to the front of the process
- Waste activated sludge (WAS) pipe removes excess sludge and returns into solids handling

# Overview

- Accelerates natural treatment process
  - Builds up large population of microorganisms
- Sludge age = amount of time solids spend in the system
- Sequencing batch reactor (SBR) combines treatment and clarification in the same basin
- Floc contains many different organisms that can flourish or die depending on environmental conditions
  - Protozoa and metazoan are indicators of environmental conditions

# Overview

- Goal is to balance floc formers and filament formers so particles will flocculate, settle, and compact



# Design Parameters

- AS basin design based on sludge age
- Volumetric loading rate (VLR) = mass BOD per volume of basin
- High-rate, conventional, and low-rate designs
  - Conventional and low-rate meet secondary treatment standards for BOD and TSS
- Clarifiers have hydraulic and solids handling capacity
  - Hydraulic capacity = surface overflow rate (SOR)
- Solids loading rate (SLR) = mass of MLSS clarifier surface area
- Clarifier design based on SLR and SOR

# Equipment

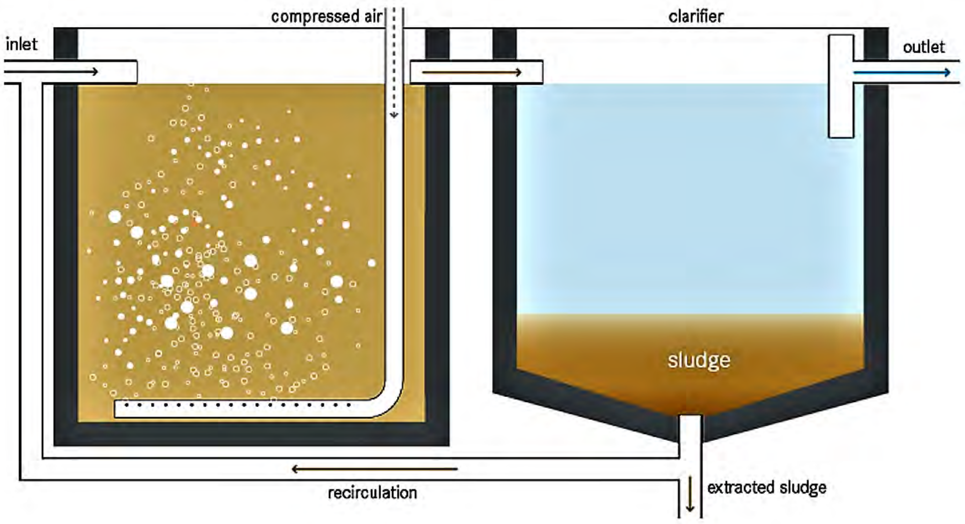
- AS basins may be concrete or steel
  - Minimum of 2 basins
- Food to microorganism ratio (F/M) increased for filament growth
- Small basin receives all RAS and influent
  - Anaerobic, anoxic, or aerated
- Secondary clarifiers are similar to primary clarifiers

# Aeration

- Aeration systems provide air and mixing:
  - Diffused air functions similarly to an aquarium air stone
  - Jet aeration combines aeration and pumping
  - Surface splash mechanical aerators agitate MLSS and create turbulence for oxygen transfer
  - Submerged mixers keep MLSS in suspension in anoxic and anaerobic zones

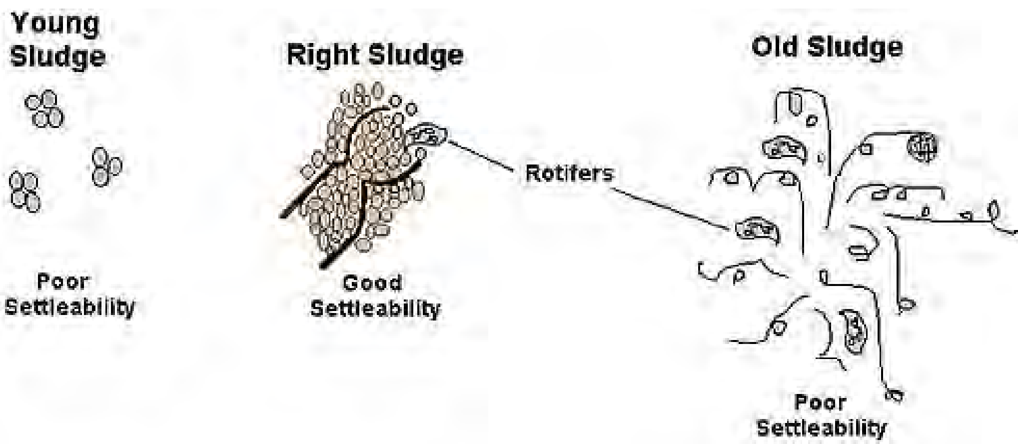
# Process Variable - AS Basin

- Process variables: HDT, VLR, WAS
- WAS
  - Determines sludge age
  - Controls mass of the total solids
  - Indirectly controls growth rate of microorganisms
- WAS influences process biology, sludge settleability, and level of treatment achieved



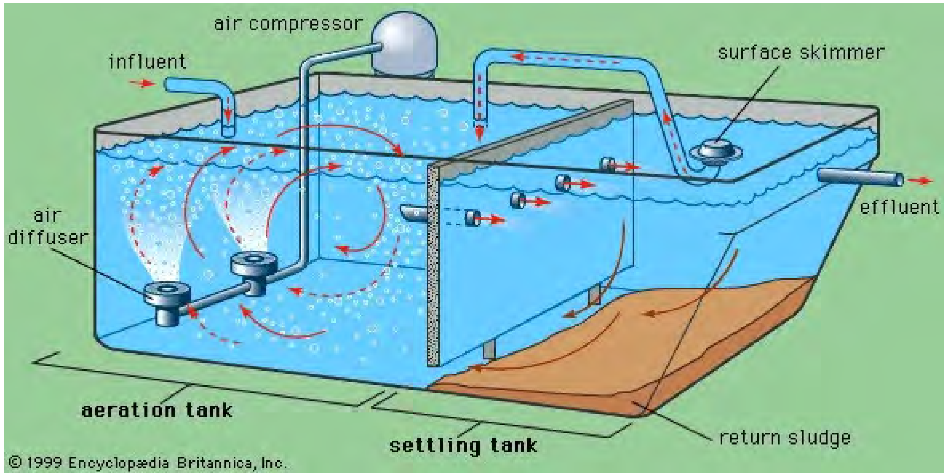
# Process Variable - AS Basin

- Amount of WAS removed determined by selecting target sludge age and calculating mass of MLSS to remove
- Sludge age is the primary control variable for activated sludge
- Sludge age determines will determine sludge wasting rate, MLSS concentration, F/M microbiology, and sludge settleability



# Process Variable, AS Basin

- When sludge age increases, MLSS increases
  - MLVSS, F/M, and wasting rate decrease
- Microorganism growth rates affected by availability of BOD, DO, and $NH_3$-N, and water temp
- F/M = BOD available per equal amount of MLVSS
- F/M directly related to the growth rate of microorganisms



# Process Variable, Secondary Clarifier

- RAS returns settled solids to the activated sludge basin
- RAS and WAS together control HDT and solids detention time in the activates sludge process
- RAS controls the clarifier solids detention time
- RAS concentration can be calculated if the MLSS concentration, influent flow, and RAS are known
- Decreasing RAS flowrate increases RAS concentration until maximum compaction has been made
- RAS, influent flow, MLSS concentration, and clarifier surface area determine SLR

# Process Variable, Secondary Clarifier

- Determines if a clarifier is overloaded (SLR too high) or underloaded.

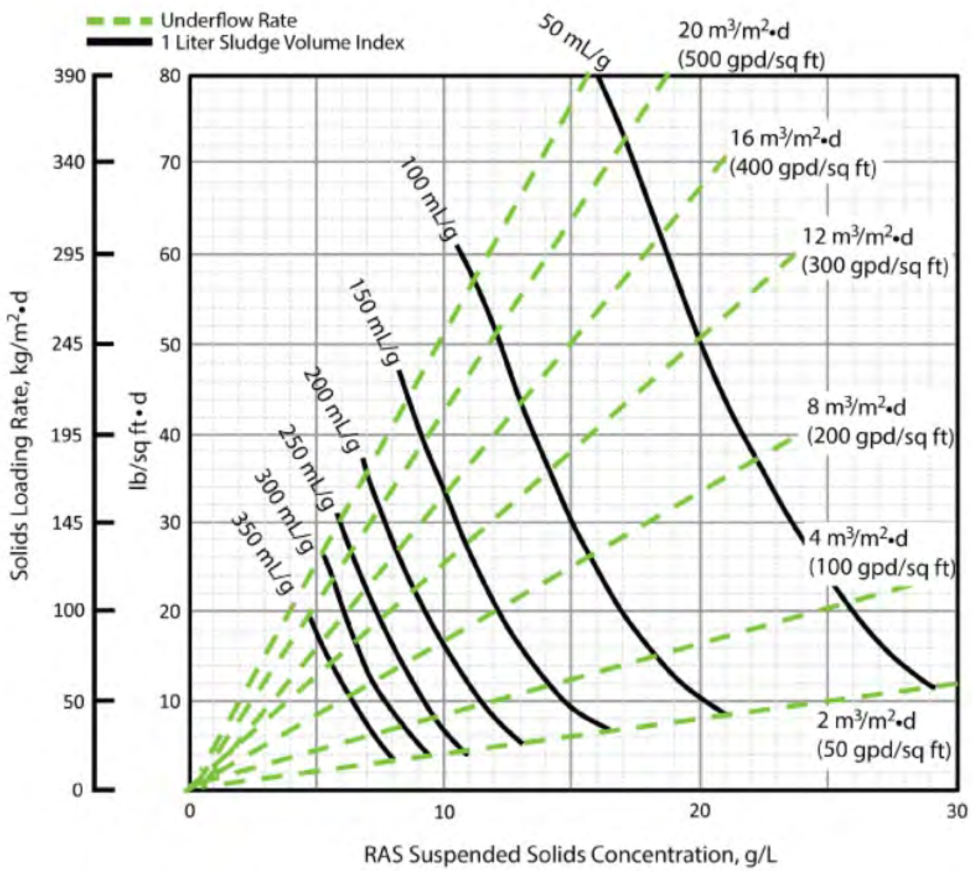



**Figure 3 Daigger Clarifier Operating Chart (Modified from Daigger, 1995)**

# Process Control, AS Basin

- Different operating modes combined ranges of SRT, F/M, loading rate, and HDT
- Correct SRT setting will produce MLSS that will flocculate, settle, compact, and meet treatment goals
- Select an SRT based on:
  - Water temperature
  - Treatment goals
  - Washing out undesirable microorganisms
- DO concentrations should match F/M to prevent growth of low DO filaments

# Process Control, Secondary Clarifier

- Maintain blankets below 2 feet
- Blanket depth increases when clarifier is overloaded
  - SLR too high
- Variables that may be adjusted to influence clarifier SLR:
  - RAS flowrate
  - MLSS concentration
  - Clarifier surface area
  - SVI (add chemicals)

# Process Control, Secondary Clarifier

- Pacing RAS flow to the influent flow results in a nearly constant RAS concentration and maintains blanket depth
- Minimize RAS flow rates to save money while meeting other process goals

# Daily Operation

- Walkthroughs, equipment inspections
- Monitor water temperature and DO concentrations
- Monitor alkalinity and pH (nitrification)
- Settleometer tests
  - Record SSV5, SSV30
  - Calculate SSC30 and SVI

# Daily Operation

- Sludge judge to monitor clarifier blanket depths
- Adjust RAS flowrates as needed
- Collect and analyze samples to calculate sludge age
  - Compare sludge age to target
  - Adjust waste rate accordingly

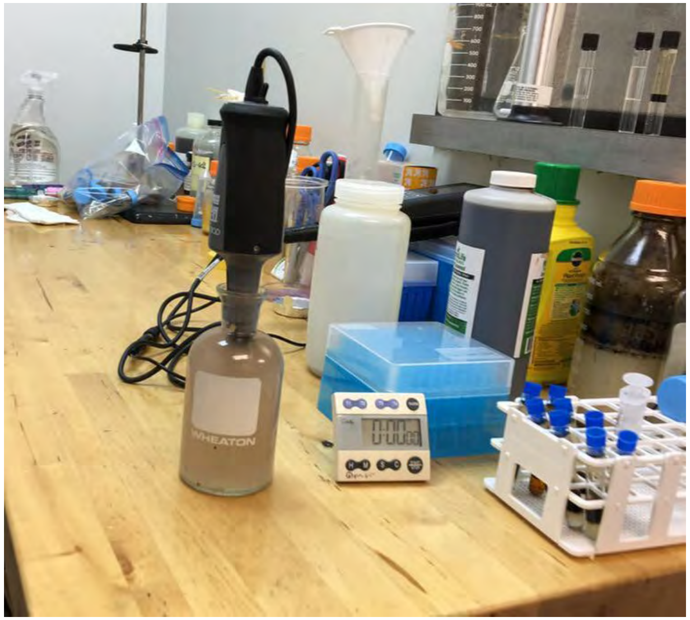
# Data Collection, Sampling, Analysis

- Visual inspections of basin and clarifier surfaces
- Sludge judge
  - Sample 2/3 in from edge if bottom slopes towards hopper
- Settleometer test with 2L Mallory
- Microscopic examination every 2 weeks
  - Measure sludge settleability
- OUR and SOUR tests
  - Measure the toxicity of the environment

# Testing

1. OUR - Oxygen Uptake Rate
   – How much oxygen a sample of AS consumes

2. SOUR - Specific Oxygen Uptake Rate
   – Divides OUR test by the concentration of MLVSS in the AS process




QUIZ

# Quiz

1. What are the two tanks involved in the activated sludge process?

✓ Activated sludge basin

✓ Secondary clarifier

# Quiz

2. What is the difference between the two?

   *Activated sludge basin*: where treatment takes place. Aerated or mechanically mixed to suspend particles. Induced microorganisms.

   *Secondary clarifier*: slow flowrate. Larger particles settle, creating sludge blanket. NOT aerated or mixed. Sends RAS back to sludge basin, WAS is removed, and effluent is treated.

# Quiz

3. What is RAS and WAS, and where are they sent after the second stage of treatment?

   “Return activated sludge” and “waste activated sludge.” RAS is recycled to a sludge basin, and WAS is disposed of.

# Quiz

4. What are OUR and SOUR tests, and why do we need them?

   Oxygen Uptake Rate and Specific Oxygen Uptake Rate

   They measure the toxicity of the activated sludge process environment.

# 6. WASTEWATER TREATMENT PONDS

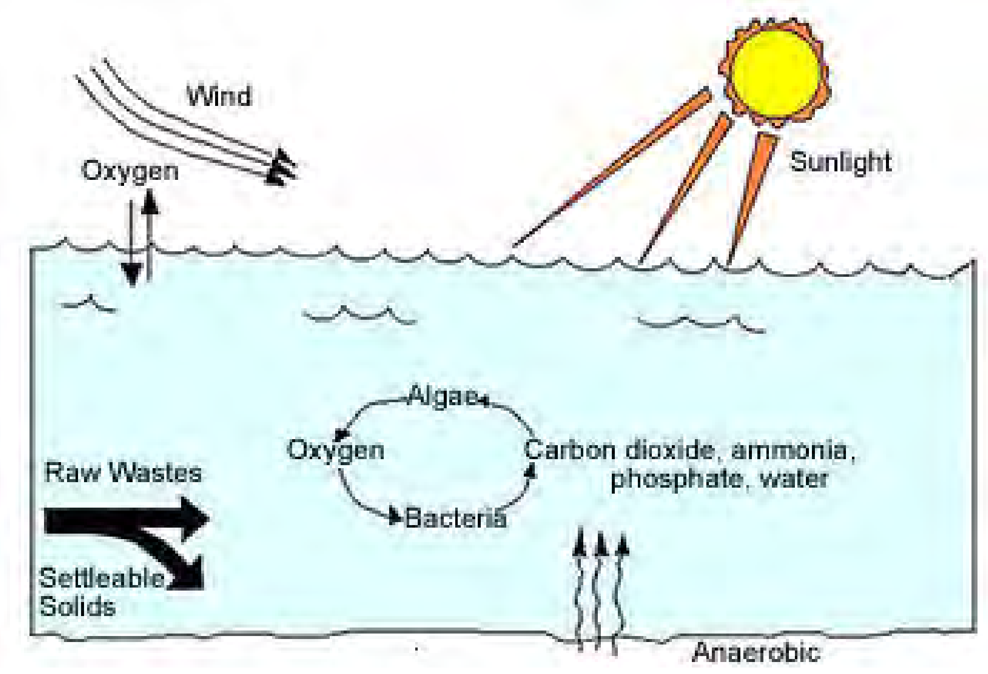
# Ponds

- Lagoons
- Biological secondary treatment process
- Simplest form of wastewater treatment
- Ponds make up 50% of all WWTPs in the U.S.
- Large footprint
- Common in rural areas
- Multi-celled

# Ponds

Three types of ponds

1. Aerobic ponds
2. Anaerobic ponds
3. Facultative ponds

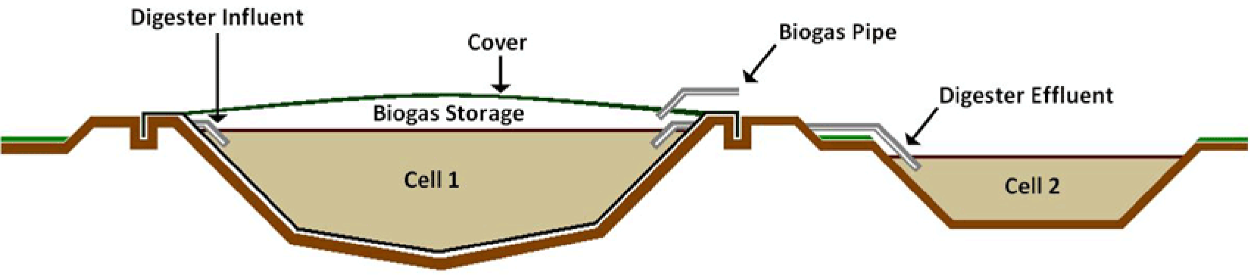


# Aerobic Ponds

- Oxidation ponds and contain DO
- 1 to 3 feet deep to allow sunlight to penetrate
- Prevents solids from settling
- Algae produces DO by photosynthesis

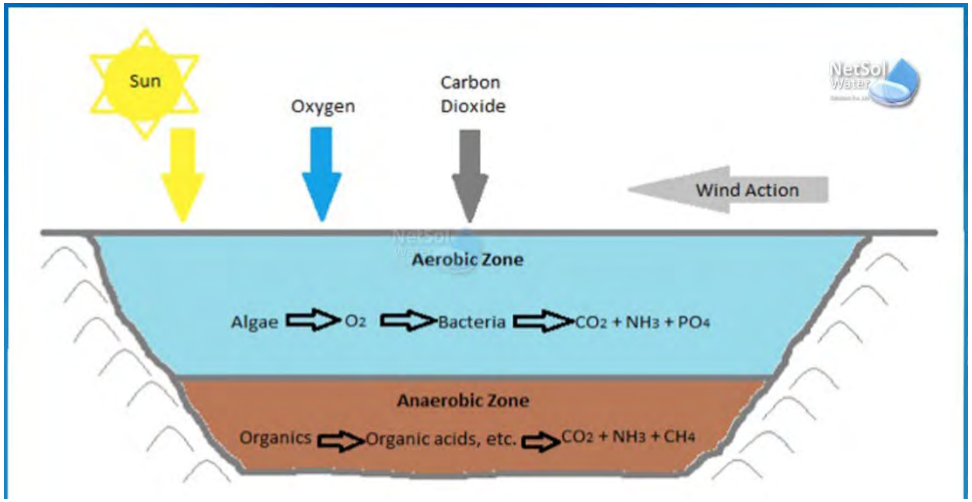
# Anaerobic Ponds

- DO, nitrite, and nitrate are unavailable
- Create byproducts, including organic acids, methane gas, and carbon dioxide
- Typically 8 to 16 feet deep
- Breakdown of BOD is a slow process
- Used for treating strong industrial and agriculture waste




# Facultative Ponds

- Most common
- Upper aerobic layer, deeper anaerobic layer
- Anaerobic layer contains settled sludge
- 3.5 to 7 feet deep
- HDTs of 25 to 180 days



# Facultative Ponds

- Typically consist of three connected ponds
- Primary ponds receive raw influent
- Settling ponds act as clarifiers
- Algae produces oxygen during the day and used by bacteria to consume BOD
- Algae consumes oxygen to produce $CO_2$ at night

# Facultative Ponds

- Pond size is determined by water temperature, BOD load, and available oxygen
- Colder water requires larger ponds
- Parallel ponds are used in winter and when DO cannot be contained in primary ponds
- Facultative ponds meet secondary treatment standards

# Equipment and Maintenance

- Constructed from earth and sloped for stability
- Grass, riprap, and gravel used to prevent erosion
- Liners prevent groundwater contamination
- Maintain areas around the pond to keep stability
- Use pipes, canals, and gate valves to isolate ponds for cleaning

# Process Variables

- $Organic\ Loading\ Rate = \frac{Mass\ of\ BOD\ applied}{Surface\ area\ of\ pond(s)}$
- Oxygen must be matched to the organic load or the pond becomes anaerobic
- Oxygen increases during the day and decreases at night
- HDT depends on water temp and oxygen availability
  - Naturally aerated ponds may require 180 days or longer
- Sludge accumulates in the bottom of all ponds
  - Eventually, 60% of the organic matter will be converted into $CO_2$ and methane

# Process Control

- Daily observation of pond appearance
- Ponds color indicates condition of pond
  - Dark sparkling green: good, high pH and DO
  - Dull green to yellow: pH & DO are decreasing
  - Gray to black: anaerobic conditions
  - Tan to brown: more brown algae than green algae
  - Red or pink: purple sulfur bacteria (anaerobic) or red algae
  - Milky: septic, typically overloaded

# Process Control

- Balance the influent organic load with the amount of available oxygen
  - Switch between parallel and series
  - Recirculate oxygenated water between ponds
  - Increase surface aerator run speed or time
- Monitor influent and effluent
- Monitor sludge buildup
- Control algae growth

# Sampling and Analysis

- DO and water temp in each pond should be measured daily
- Sampling frequencies for BOD, TSS, and fecal coliform are set in the discharge permit
- Sludge blanket depth should be measured at least annually


QUIZ

# Quiz

1. What are the three types of ponds?

   - ✓ Aerobic
   - ✓ Anaerobic
   - ✓ Facultative

# Quiz

2. Which is the most common?

   Facultative

# Quiz

3. Oxygen content is higher at night than during the day. (T/F)

False

# Quiz

4. How often should DO and water temperature be measured?

   Daily

# Quiz

5. Why does oxygen need to be matched to the organic load?

So the pond doesn’t become anaerobic

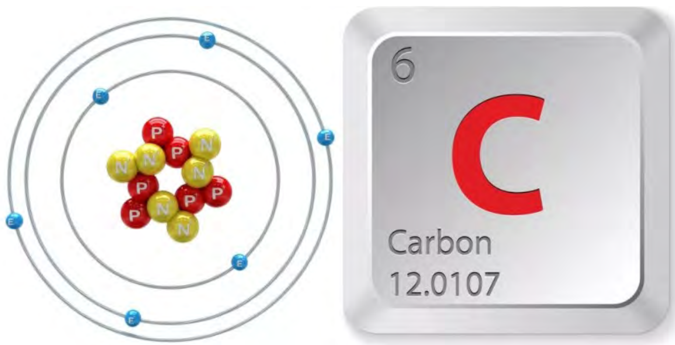
# Quiz

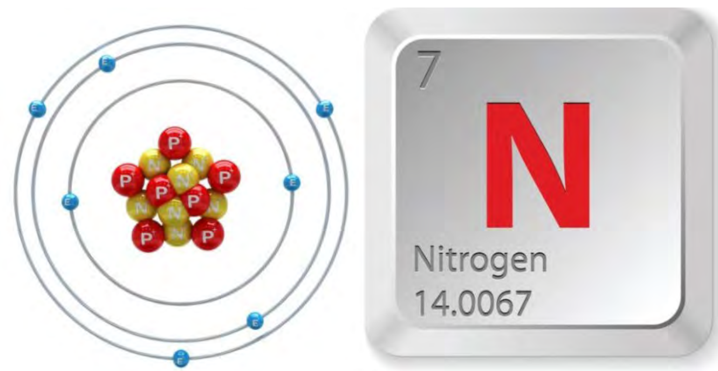
6. What condition does a sparkling green pond represent?

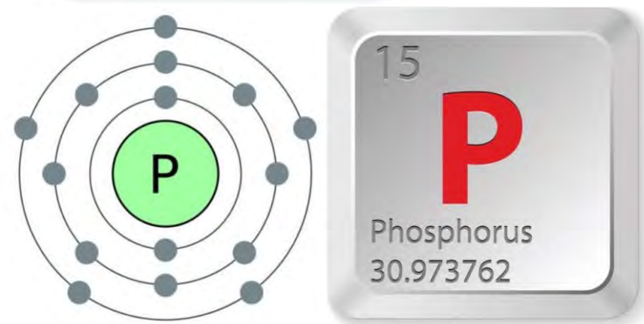
   Good, high pH and DO

# 9. NUTRIENT REMOVAL

# What are Nutrients?

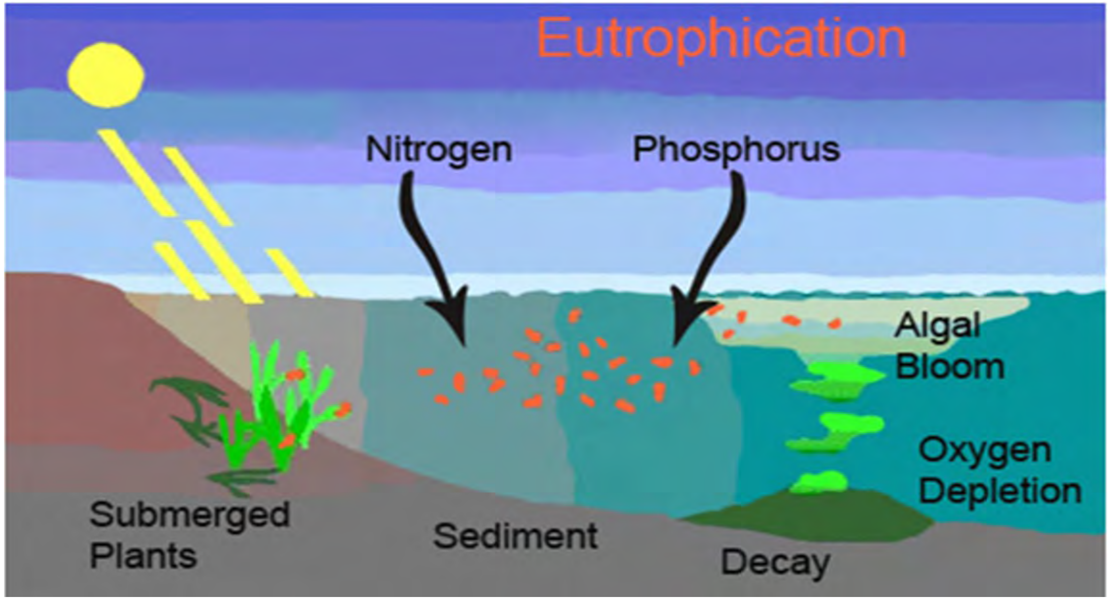


# Why Remove Nutrients?

The nutrients in wastewater contribute to eutrophication: "excessive richness of nutrients in a lake or other body of water, frequently due to runoff from the land, which causes a dense growth of plant life and death of animal life from lack of oxygen."



# “Typical” Wastewater

- Influent nitrogen: 23 to 69 mg/L total N, 60 to 70% of which is ammonia-nitrogen; remaining 30 to 40% is organic
- Ammonium typical 5 mg/L, no $NO_3^-$ or $NO_2^-$
- Influent phosphorus: 6 to 8 mg/L as P for domestic WW
- Sources are human waste, food and certain soaps and detergents.

| Parameter | Units | Sewage in North America[a] | | |
|---|---|---|---|---|
| | | Weak | Medium | Strong |
| Total suspended solids (TSS) | mg/l | 100 | 220 | 350 |
| Ammonium ($NH_4^+$) | mg/l | 12 | 25 | 50 |
| Nitrate ($NO_3^-$) | mg/l | 0 | 0 | 0 |
| Nitrite ($NO_2^-$) | mg/l | 0 | 0 | 0 |
| Chemical oxygen demand (COD) | mg/l | 250 | 500 | 1000 |
| Dissolved oxygen (DO) | mg/l | – | – | – |
| Hydrogen potential (pH) | pH units | – | – | – |
| Redox potential (Eh) | mV | – | – | – |
| Orto phosphate ($PO_4^{3-}$) | mg/l | – | – | – |
| Sulfate ($SO_4^{2-}$) | mg/l | 20 | 30 | 50 |
| Chloride ($Cl^-$) | mg/l | 30 | 50 | 100 |

[a] Metcalf and Eddy (1991)

# Forms of Nitrogen in Wastewater

1. Ammonia ($NH_3$-N)
2. Nitrite ($NO_2$-N)
3. Nitrate ($NO_3$-N)
4. Nitrogen Gas ($N_2$)

# Forms of Nitrogen

Total Kjeldahl nitrogen (TKN) =

Organic N + $NH_3$-N

Total inorganic nitrogen (TIN) =

$NH_3$-N+ $NO_2$-N+ $NO_3$-N

# Influent Nitrogen

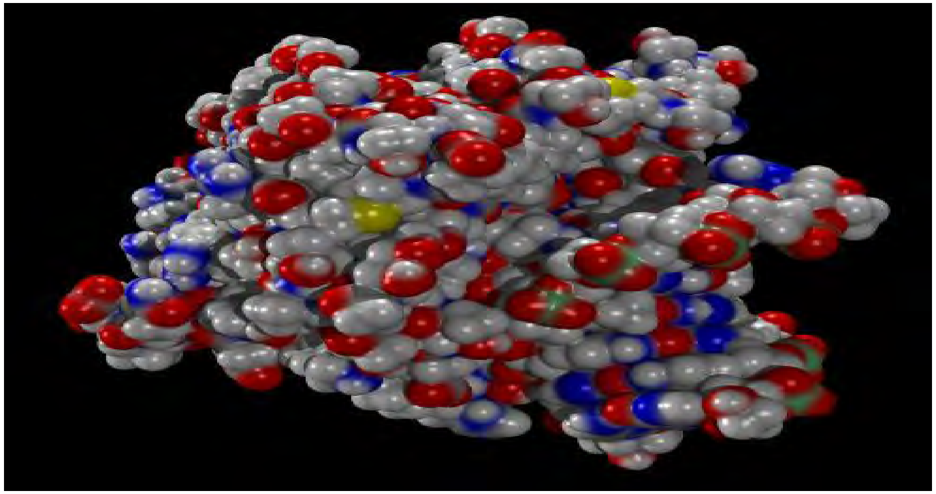
- 99% is in the form of TKN
  - 40% organic nitrogen
  - 59% ammonia/ammonium
  - This ratio is dependent on pH, temperature and detention time in the collection system
- Less than 1% nitrate and nitrite

# Forms of Influent Phosphorus

- Phosphate (aka orthophosphate) $H_2PO_4^-$ or $HPO_4^{2-}$
- Polyphosphate
- Organic phosphorus

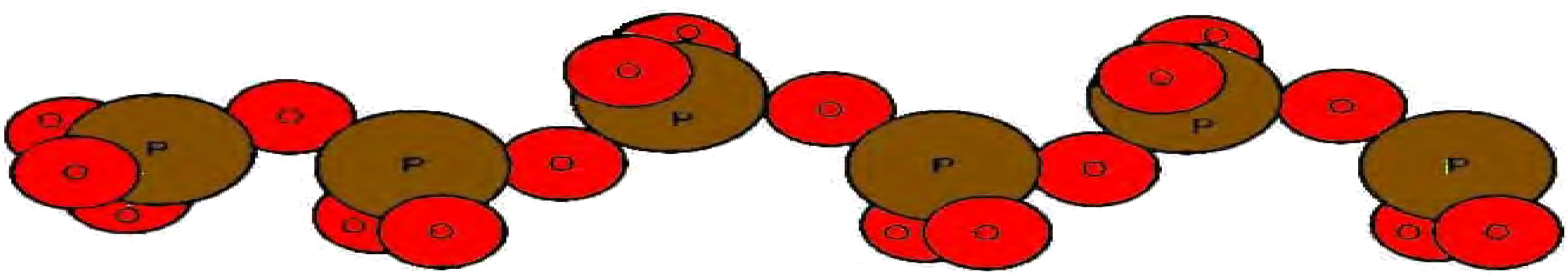
# Forms and Source of P

- Organic Phosphorus
  - Complex organic compounds
  - Soluble or particulate
  - Decomposes to Ortho-P

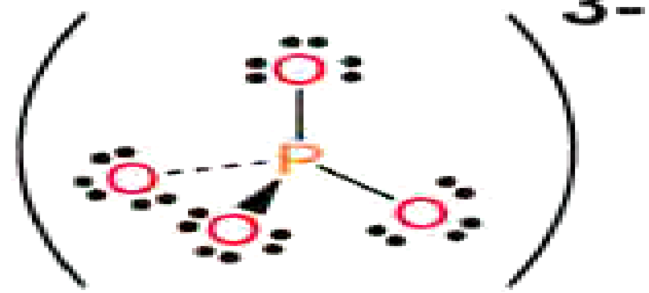


# Forms and Sources of P

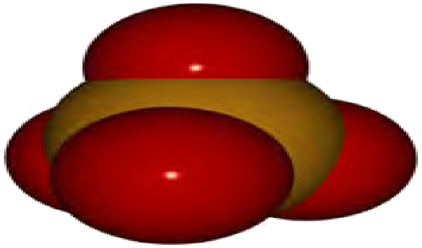
- Polyphosphate (condensed phosphate)
  - Chained molecules
  - Soluble
  - Home, industrial detergents
  - Potable water treatment
  - Decomposes to Ortho-P



# Forms and Sources of P

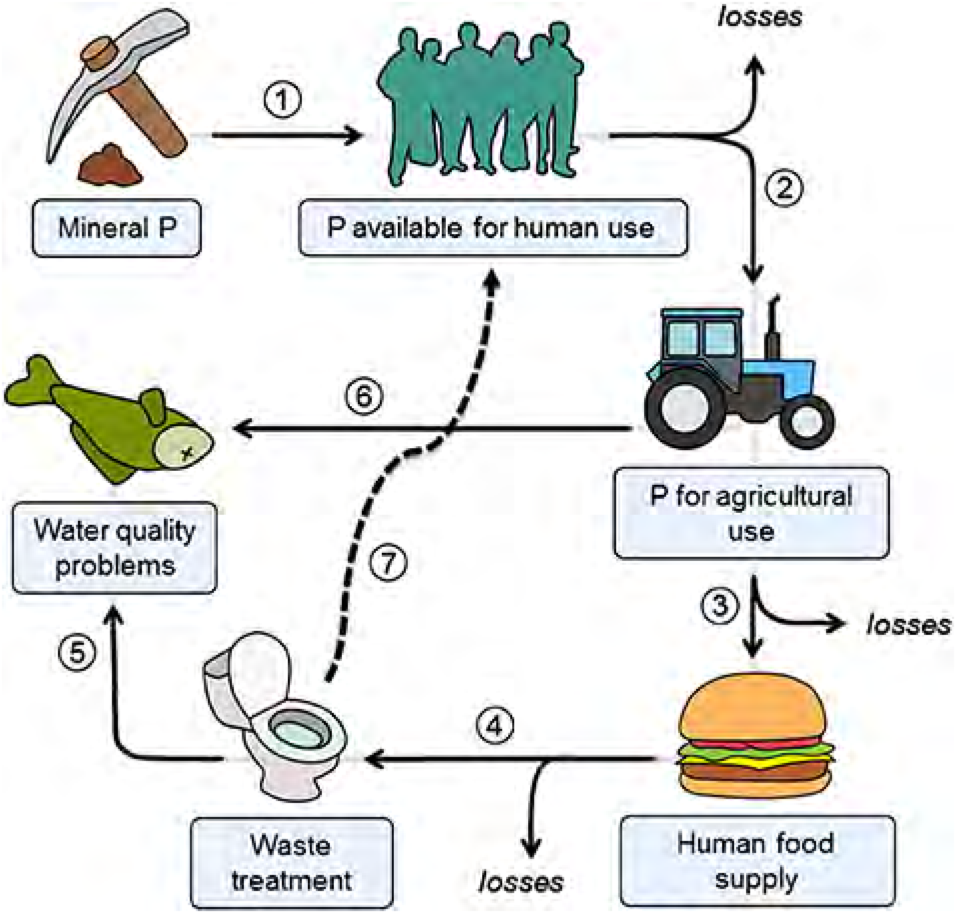



- Orthophosphate
  - Simple phosphate, $PO_4$
  - Soluble
  - Household cleaning agents
  - Industrial cleaners
  - Phosphoric acid
  - Conversion of organic and poly phosphate



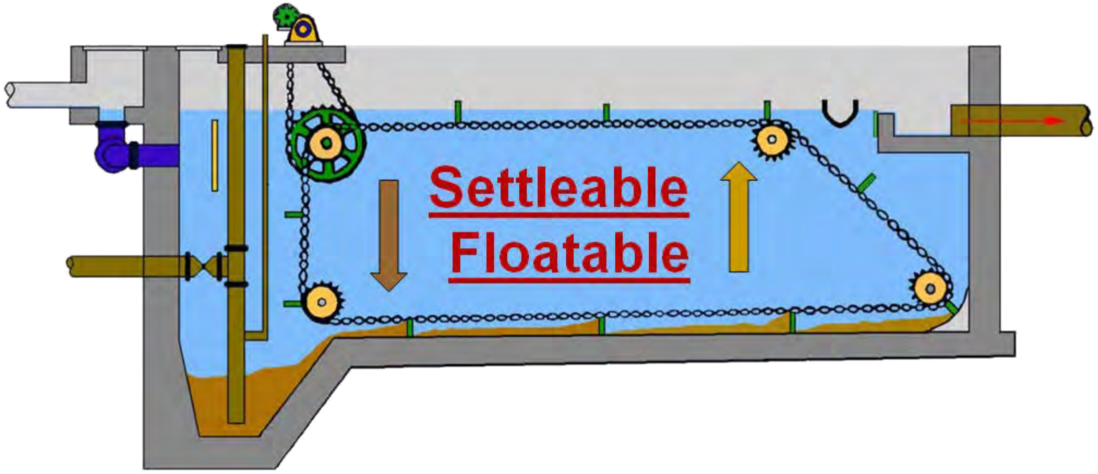
# Influent Total Phosphorus

- 6 to 8 mg/L as P for domestic waste
- Could be higher from industrial sources



# Mechanisms for N and P Removal

- Bacteria cells contain N and P, which are incorporated to the biomass that is removed either through settling (ponds), sloughing (fixed film) or wasting (activated sludge).



# Quiz

1. Why do N and P need to be removed from wastewater?
2. What is a typical concentration of P in influent wastewater?
3. What is a typical concentration of nitrate in influent wastewater?

# Biological Nitrification

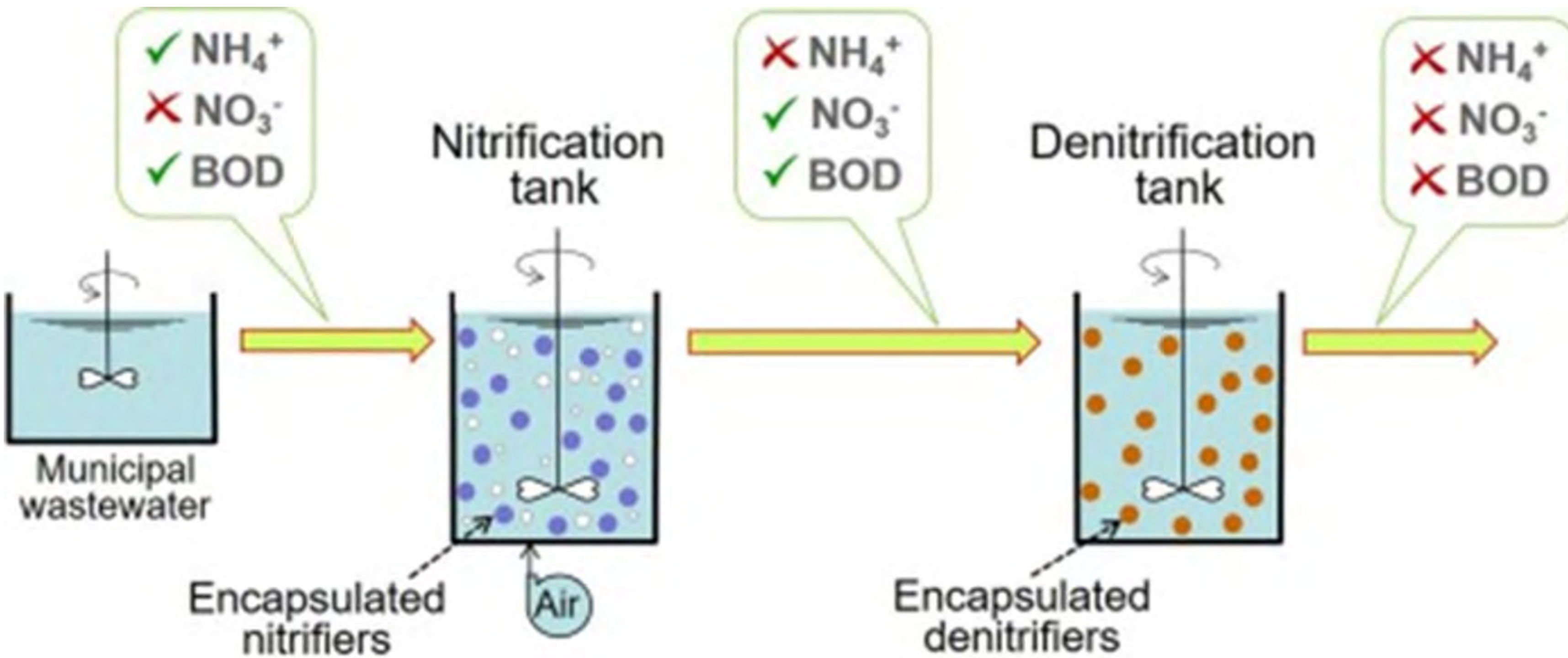
# Nitrification

*Two-Step Process*

1. Ammonia oxidizing bacteria (AOB): Convert ammonia ($NH_3$-N) to nitrite ($NO_2$-N)
2. Nitrite oxidizing bacteria (NOB): Convert nitrite ($NO_2$-N) to nitrate ($NO_3$)j

The NOB grow faster than the AOB when the water temperature is below 25°C (77°F)

# Nitrification

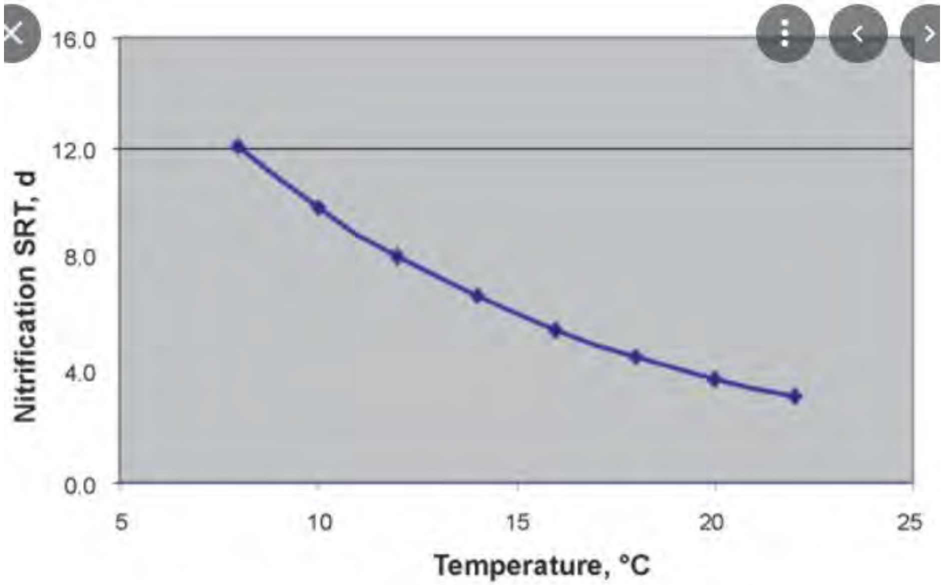


# Process Variables for Nitrification

- Temperature
- Aerobic solids retention time (SRT)
- Organic loading rate (OLR)
- Dissolved oxygen (DO)
- pH
- Alkalinity
- Nitrogen loading patterns
- Presence of inhibitory compounds

# Process Variables for Nitrification

- Temperature: typical between 39°F and 113°F; optimum is about 86°F
- Aerobic SRT: most important variable for removing ammonia in activated sludge processes



# Process Variables for Nitrification

- Organic Loading Rate (OLR): High OLRs favor growth of heterotrophic bacteria over nitrifying bacteria. NOB won't become a significant portion of the biofilm until soluble BOD5 is <20 mg/L or the 5 day CBOD is less than 20 mg/L
- For biofilm process, removal and nitrification are generally sequential, so this will be more of a factor.

# Process Variables for Nitrification

- Dissolved oxygen (DO) concentration: Nitrification not limited if DO>2.0 mg/L

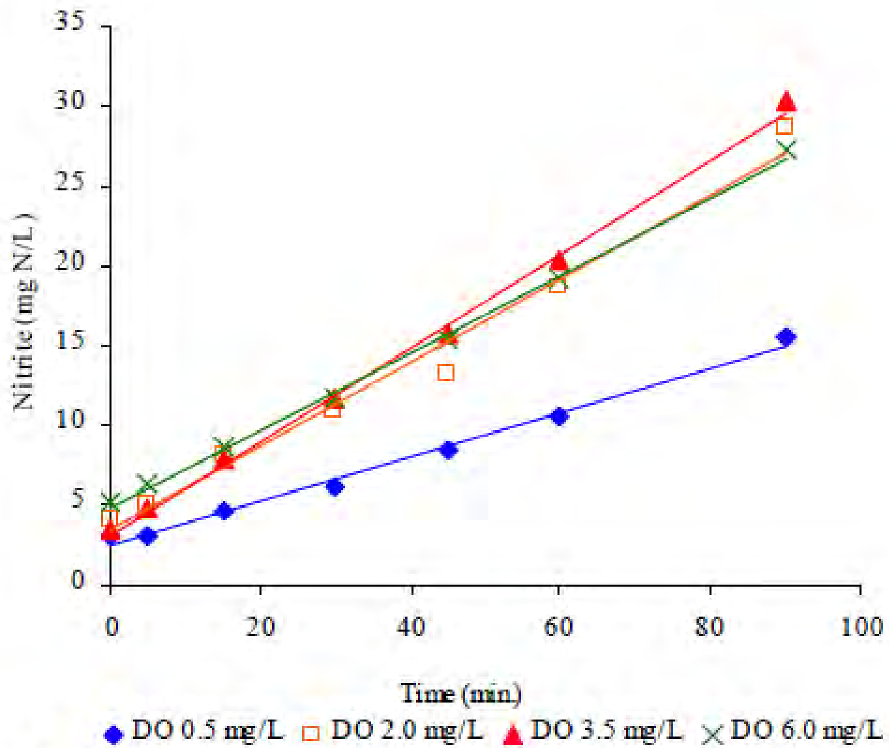


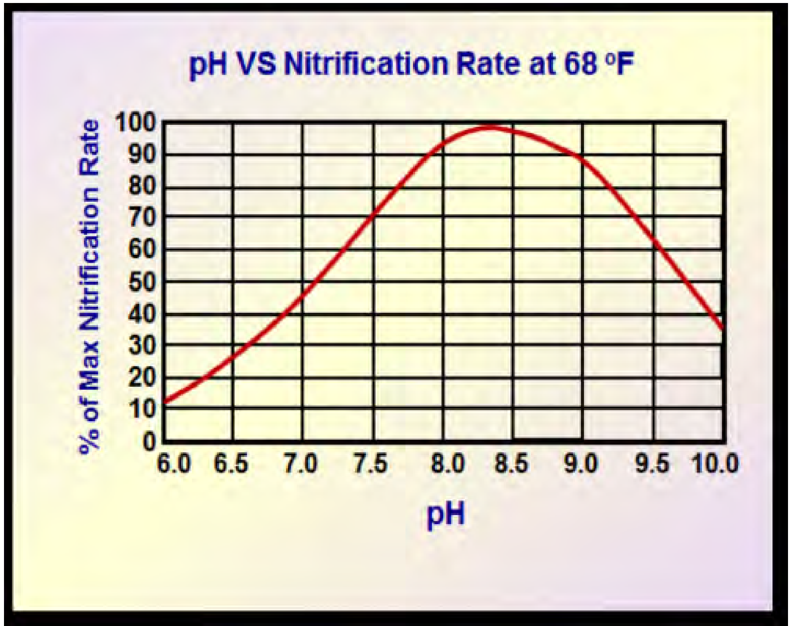

Fig. 3: Nitrite accumulation at different DO concentrations

# Solids Retention Time

- SRT = Mass of MLSS in the aeration tank (lb) divided by the mass of solids wasted each day (lb/d)
- Must be long enough for nitrifying bacteria to reproduce
- Nitrification "all or nothing" = either they have enough time to reproduce and build up a stable population or NOT
- Theoretical minimum is 2 days at 20°C (68°F) and about 5 days at 10°C (55°F)
- Safety factors between 2 and 3.5 are usually used

# Process Variables for Nitrification

- pH and alkalinity: Nitrification rates decrease rapidly if pH<6.8
- However, nitrification produces acid, which consumes alkalinity.
- If enough alkalinity is consumed, the pH will decrease.
- A minimum effluent alkalinity of 50 mg/L and preferably 100 mg/L as $CaCO_3$ should be maintained



# Nitrogen Loading Pattern

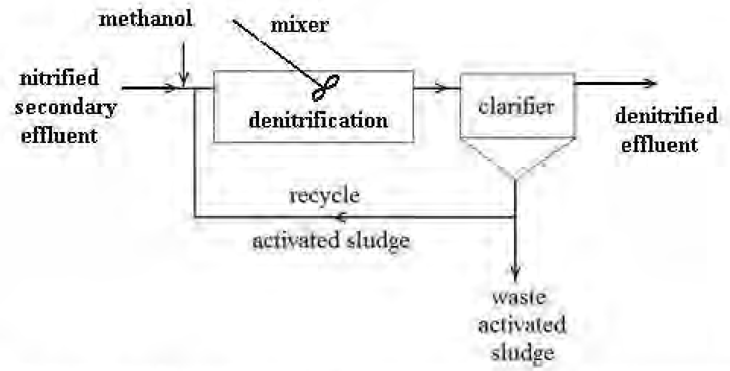
- If environmental factors are not limiting, the quantity or mass of AOB and NOB will be a function of the ammonia loading
- Nitrifiers can't react quickly to peak loading…number reflect average loading

# Quiz

1. Nitrification is a three-step process involving two groups of bacteria. (T/F)
2. The NOB obtain their energy from nitrite and their carbon from alkalinity. (T/F)
3. The AOB grow faster than the NOB when the water temperature is below 25°C (77°F). (T/F)

# Denitrification

The conversion of nitrate to nitrogen gas




Denitrification Process Flow Diagram

# Conditions for Denitrification

1. Carbon source (measured as $BOD_5$ or COD)
2. Low DO
3. Sufficient HDT

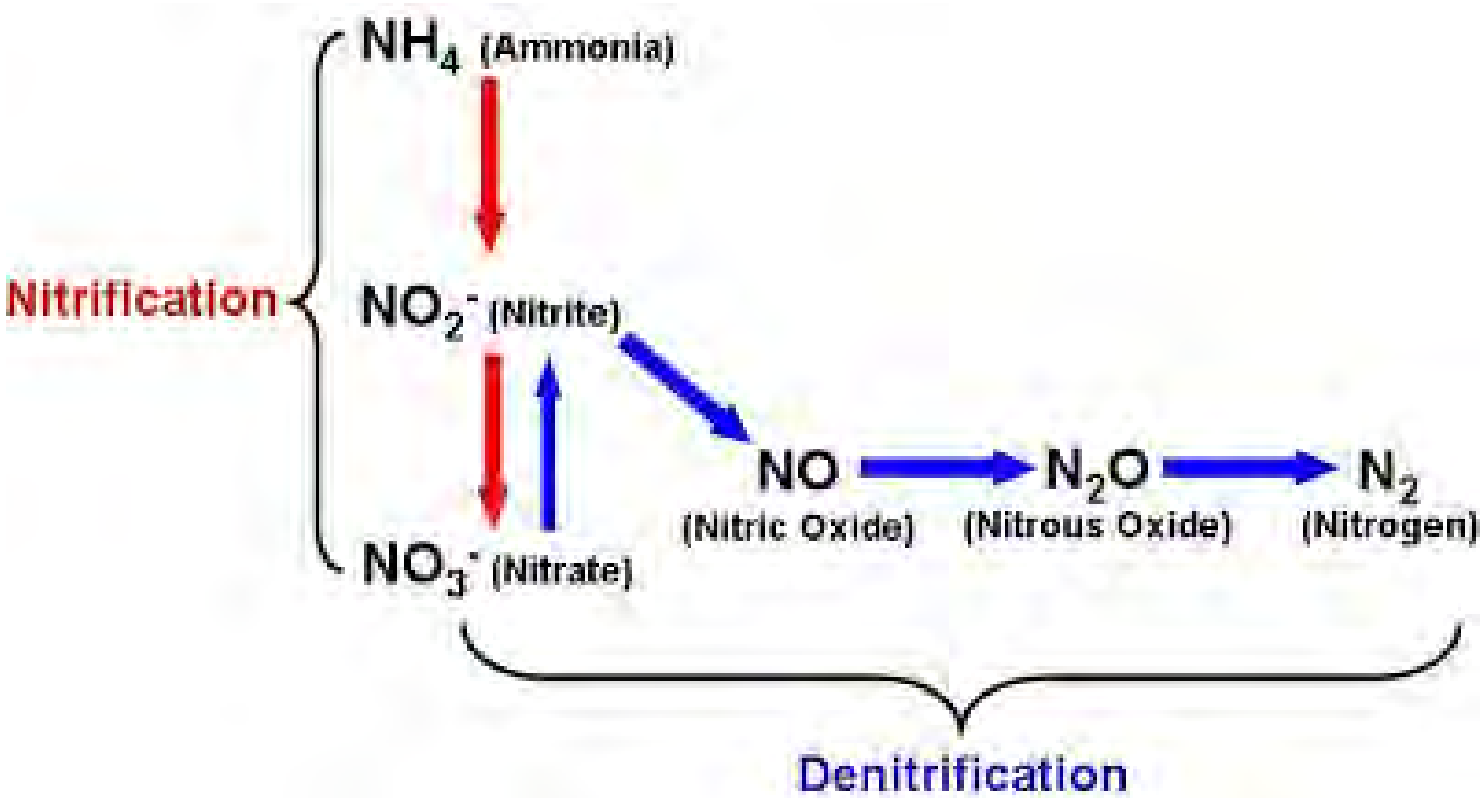
# Process Variables for Denitrification

- BOD or COD Demand: 4 mg/L of influent or primary effluent $BOD_5$ (~8 mg/L COD) is needed for every 1 mg/L of nitrate-nitrogen (4:1)
- Facilities with primary clarifier may not have enough BOD to achieve low effluent nitrate values
- Supplemental carbon sources: Methanol, molasses, food wastes

# Process Variables for Denitrification

- Availability of organic carbon
- Scarcity of DO
- Process configuration
- Higher F/M = faster denitrification

# Nitrification/Denitrification




QUIZ

# Quiz

1. What is *denitrification*?

    It is the process of removal of nitrogen from wastewater.

# Quiz

2. What is the ratio of BOD to $NO_3$-N needed?

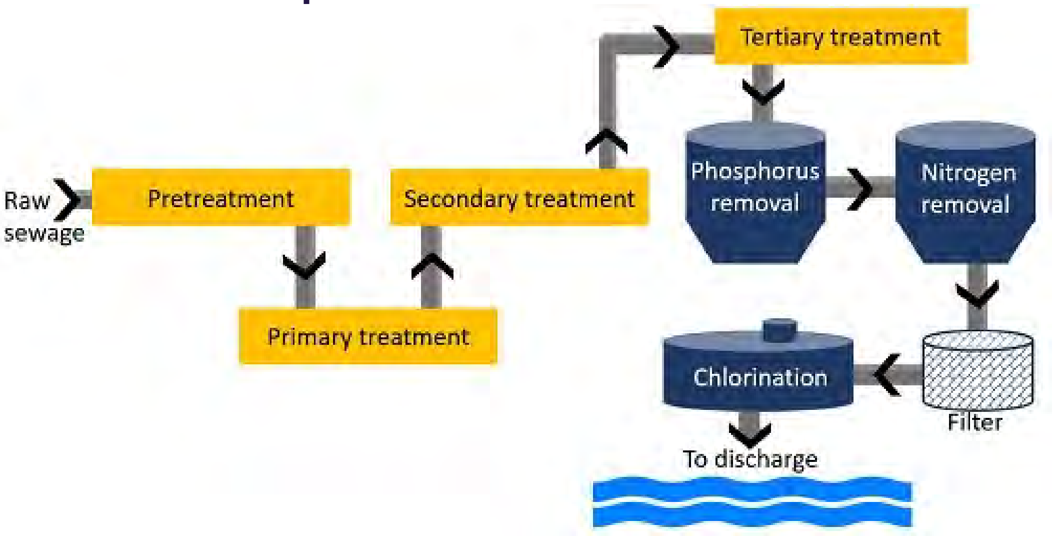
   4:1

# 10. DISINFECTION

# Disinfection

Why is disinfection needed?

- Protect public health and the environment
- Inactivate pathogens
  - Pathogens cause disease and illness
- Damaged pathogens can't reproduce



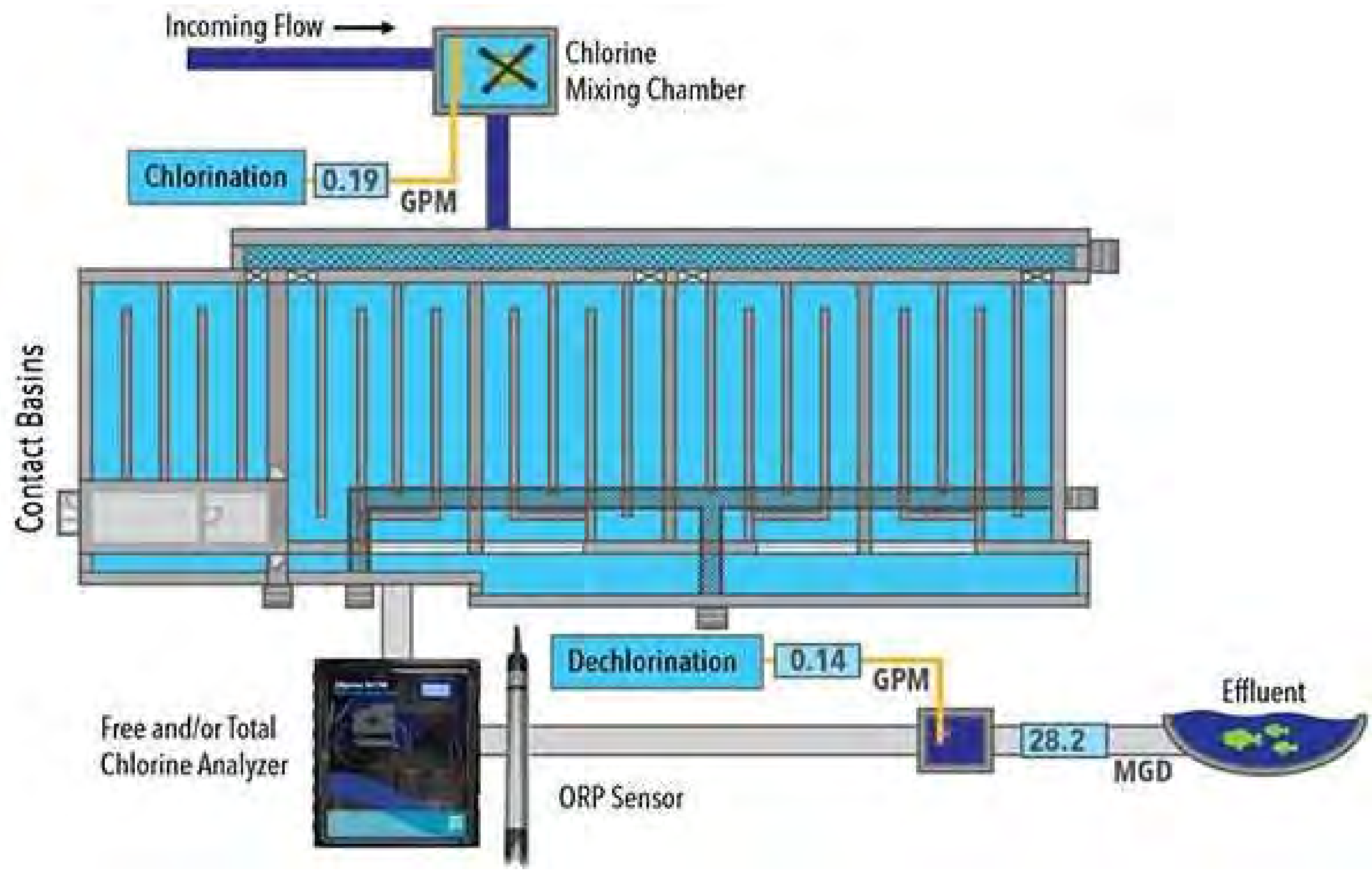
# Disinfection

- Last step in the treatment process
  1. Chlorine Disinfection
  2. UV Disinfection

# Chlorine Disinfection

- Destroys proteins and enzymes required for pathogens to function
- Dechlorination neutralizes chlorine, protects environment
  - sulfur dioxide or sulfite salts
- Chlorine available in 3 forms:
  1. Gas
  2. Liquid sodium hypochlorite
  3. Sodium calcium hypochlorite (HTH)

# Chlorine Disinfection



# Chlorine Disinfection

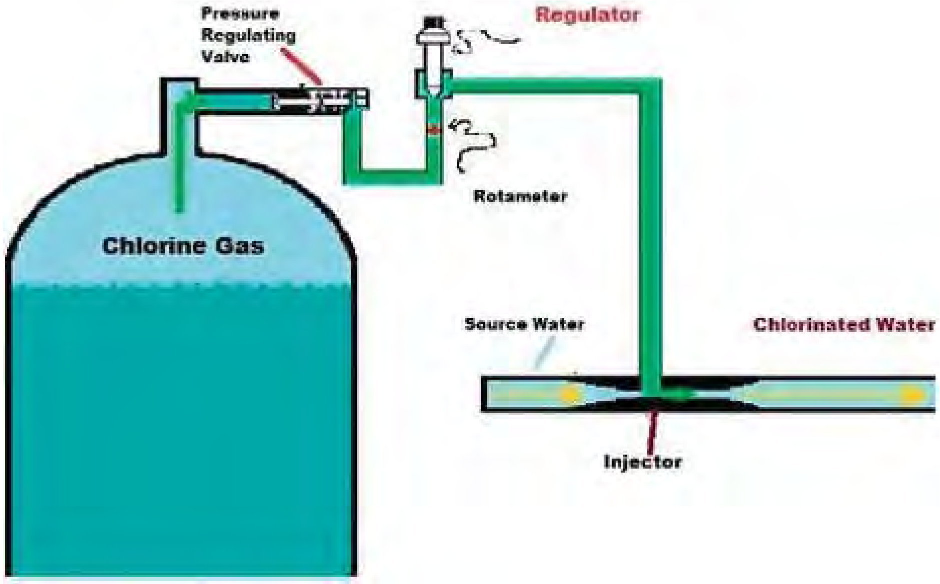
- Produces hypochlorous acid and hypochlorite ion when added to water
- Percent of each ion varies w/ pH and temp
- Dose = demand + residual
- Total residual = combined residual + free residual
- Pathogen inactivation = chlorine residual concentration and time (CT)

# Chlorine Disinfection

- Dose depends on water quality
- Required CT varies
- Generally, 15 minutes of CT at peak hour design flow or 30 minutes of CT at average flow

# Chlorine Disinfection

- Chlorine containers filled to 80% capacity for expansion
- Equipped with fusible plugs to relief pressure
- Chemical metering pump for chlorine concentration



# Chlorine Disinfection

1. Vaporizers (liquid to gas)
2. Hypochlorinators (liquid)
3. Tablet feeders (solid)

# Chlorine Disinfection Process Variables

- Chlorine efficiency determined by CT and chlorine residual concentration
- Cold water harder to disinfect than warm
- High pH water is harder to disinfect than low
- Poor upstream performance increase chlorine demand
- Adjust CT to meet effluent goals

# Chlorine Disinfection Process Control

- Chlorine feed rate
  - Manual
  - Flow pacing (match flowrate)
  - Residual control
  - Compound loop control uses flow and chlorine residual to adjust dose

# Chlorine Disinfection O&M

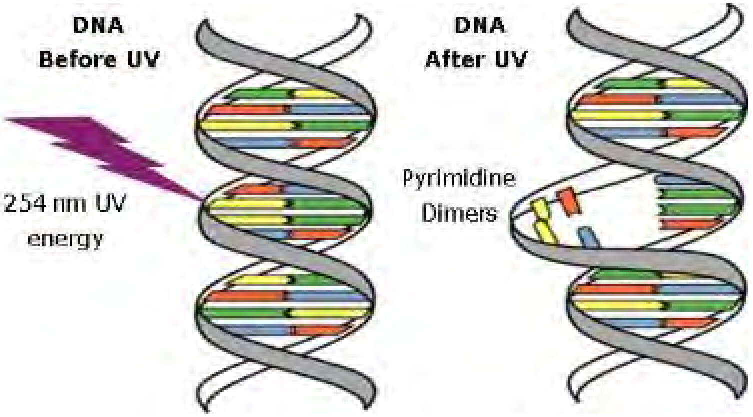
- Monitor residual concentration
- Adjust chlorine dose to meet effluent goals
- Monitor cylinder and container weights
- Look for condensation or icing
- Test safety equipment and leak monitoring equipment
- Remove hypochlorite deposits with dilute hydrochloric acid
- Keep debris and settled solids from accumulating in the contact chamber

# Quiz

1. Why is disinfection needed?
2. What are the three types of chlorine disinfection?
3. What is CT and what are the general time requirements for peak and average flow?
4. Cold water is harder to disinfect than warm. (T/F)

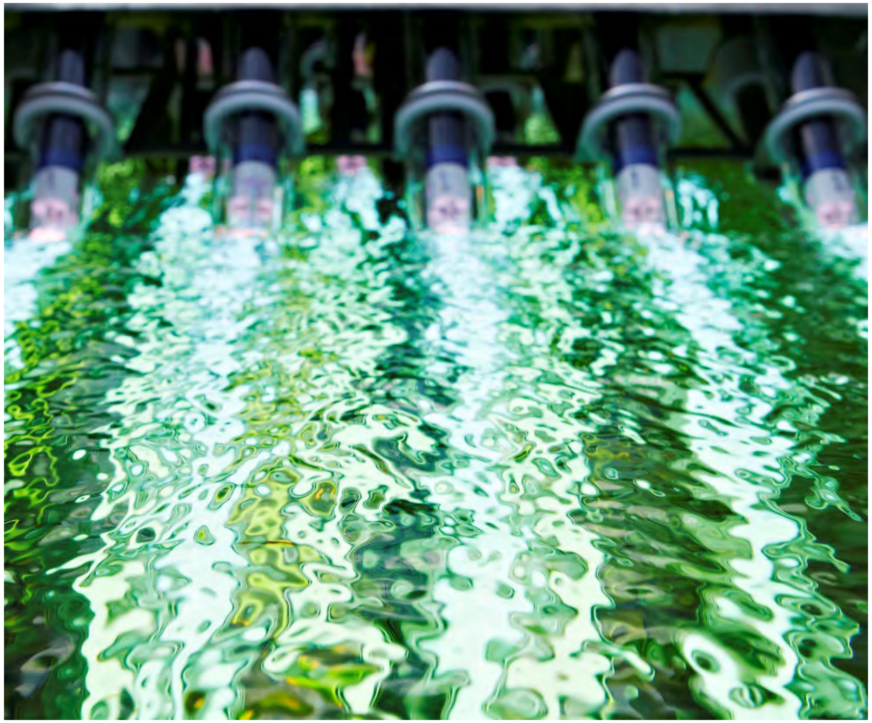
# UV Disinfection

- UV light damages DNA
- Thymine damages form
- Teeth in the DNA ‘zipper’ are stuck together so DNA can’t be replicated
- UV radiation is generated by passing energy through mercury vapor
- Low-pressure and amalgam lamps produce light at 254 nm
- Medium pressure lamps produce light at multiple wavelengths



# UV Disinfection

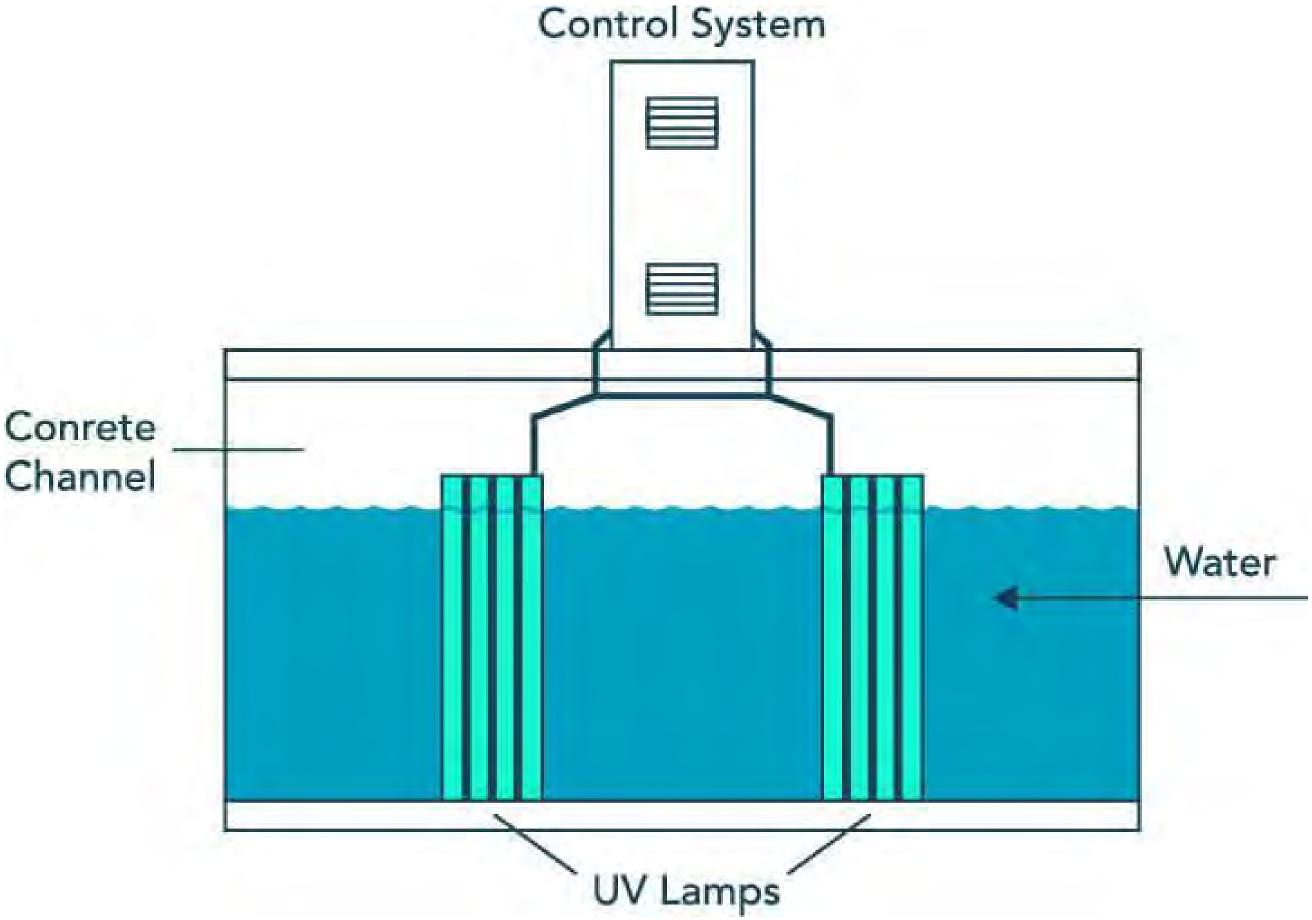
- Fluence = UV light intensity
- Fluence rate = UV light per unit of time ($mJ/cm^2$ or $mW*Sec/cm^2$)
- Fluence rate = UV dose
- Fluence rate depends on water quality



# UV Disinfection

- Mercury vapor lamps grouped into modules
- 1 module = 1 or more lamps and ballast for power
- Modules grouped into banks
- Typically 2 or more banks in a series
- Lamps oriented vertically, horizontally, or angle
- Lamps placed parallel or perpendicular to flow path

# UV Disinfection



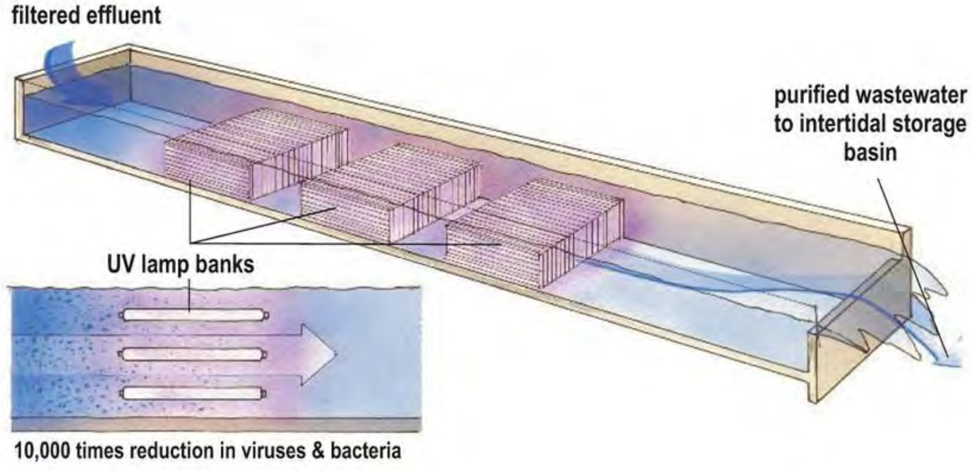
# UV Disinfection

- Sensors that monitor and control UV light output
  - UV intensity sensors
  - UV transmittance meters
  - Level and flow monitoring
  - Temperature monitoring

# UV Disinfection

Three types of UV lamps

1. Low-pressure
2. Amalgam
3. Medium-pressure

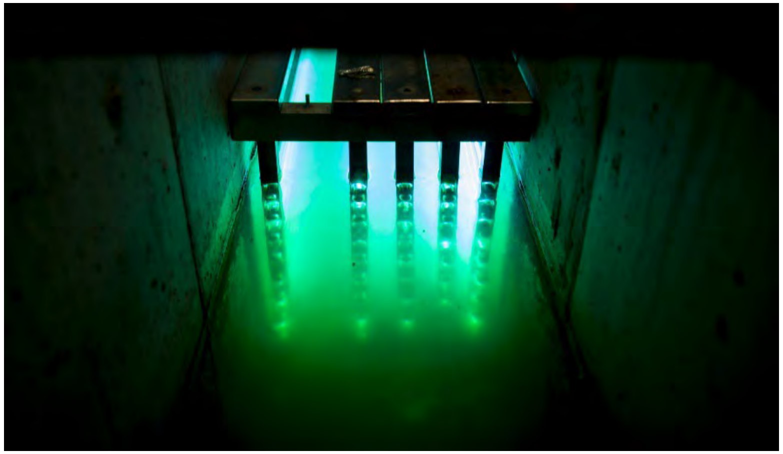


# UV Disinfection

- Low pressure and amalgam lamps generate UV light at 254 nm
- Medium pressure lamps generate UV light at multiple wavelengths
- Lamps are encased in quarts sleeves
- Lamps must be completely submerged when operating

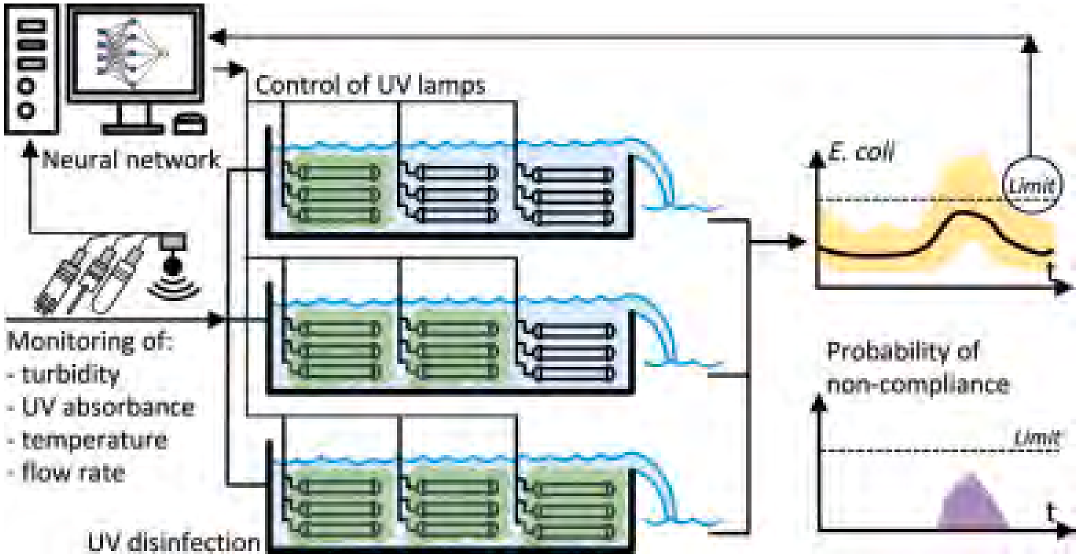
# UV Disinfection, Process Variables

- Contact time only a few seconds
- Turbulent flow ensures all water is exposed
- UV efficacy determined by UV light transmittance and CT
- Poor performance of upstream processes reduces transmittance
- Adjust UV fluence to meet effluent goals



# UV Disinfection, Process Control

- Flow and dose pacing used by most UV systems
- Increase/decrease power to increase/decrease UV light production
- Transmittance and intensity measurements may be used to adjust dose



# UV Disinfection, O&M

- Operate per manufacturer
- Monitor lamp life and replace as needed
- Check and calibrate sensors daily
- Clean quartz sleeves as needed
- Replace ballasts when they fail
- Clean UV channel regularly


QUIZ

# Quiz

1. How does UV light disinfect?

It damages DNA and eliminates reproduction.

# Quiz

2. What are the 3 types of UV lamps?

- ✓ Low pressure
- ✓ Amalgam
- ✓ Medium pressure

# Quiz

3. What is fluence and fluence rate?

Fluence = UV light intensity

Fluence rate = UV light per time

# Quiz

4. Contact time for UV systems may only be a few seconds. (T/F)

True

# Quiz

5. Lamps don’t need to be completely submerged to work. (T/F)

False

# Quiz

6. Draw a flow diagram of a WWTP process.

# POST-

# Post-Quiz

1. What does WWTP stand for?
2. Why is it important to treat wastewater?
3. What does BOD stand for?
4. What is an example of a secondary treatment process?
5. What is the difference between aerobic zone and an anaerobic zone?
6. What is the limit for nitrogen in WWTP effluent?
7. What permits apply to wastewater treatment facilities?
8. What are two types of disinfection methods?

# Post-Quiz

1. What does WWTP stand for?

   Wastewater Treatment Plant

# Post-Quiz

2. Why is it important to treat wastewater?

- ✓ Protect public health and the environment from pathogens found in wastewater
- ✓ Meet regulatory requirements

# Post-Quiz

3. What does BOD stand for?

   Biochemical oxygen demand

# Post-Quiz

4. What is an example of a secondary treatment process?

   Activated sludge; trickling filter

# Post-Quiz

5. What is the difference between aerobic zone and an anaerobic zone?

   The presence or absence of oxygen (*aerobic* = with oxygen; *anaerobic* = without oxygen)

# Post-Quiz

6. What is the limit for nitrogen in WWTP effluent?

It depends on your permit. Typically, the limit is 10 mg/L.

# Post-Quiz

7. What permits apply to wastewater treatment facilities?

   - ✓ National Pollutant Discharge Elimination System (NPDES) if discharging to a water body of the U.S.
   - ✓ Discharge permits issued by States

# Post-Quiz

8. What are two types of disinfection methods?

- ✓ Chlorine disinfection
- ✓ Ultraviolet radiation

# Questions?