Wastewater Lagoon Certification
Day 5: Review of Days 1 to 4, Practice Exam

Outline for Today

1. Review of Days 1 to 4 (half day)
   A. Day 1: Wastewater Treatment Fundamentals
   B. Day 2: Wastewater Lagoon Troubleshooting
   C. Day 3: Wastewater Collections
   D. Day 4:
2. Exam (half day)

Pre-Quiz

1. What’s an example of preliminary treatment?
2. What an example of primary treatment?
3. What’s an example of secondary treatment?
4. What’s an example of tertiary treatment?
5. What are some characteristics of wastewater?
6. What does preliminary treatment reduce?
7. What do primary clarifiers remove?
8. What does HDT stand for?
9. What are the two types of fixed film treatment processes?
10. What is chlorine contact time and why is it needed?
11. What is a sludge judge?

A. WASTEWATER TREATMENT FUNDAMENTALS

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

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Basic Wastewater Treatment Processes

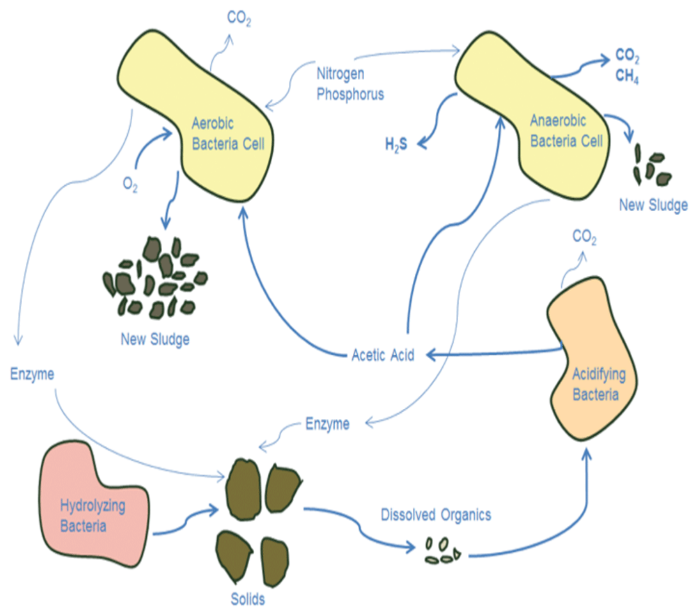
1. Physical
2. Biological
3. Chemical

Physical

- 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 9

- 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

Wastewater Characteristics

Parameter	Low Strength	Medium Strenth	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

Preliminary Treatment

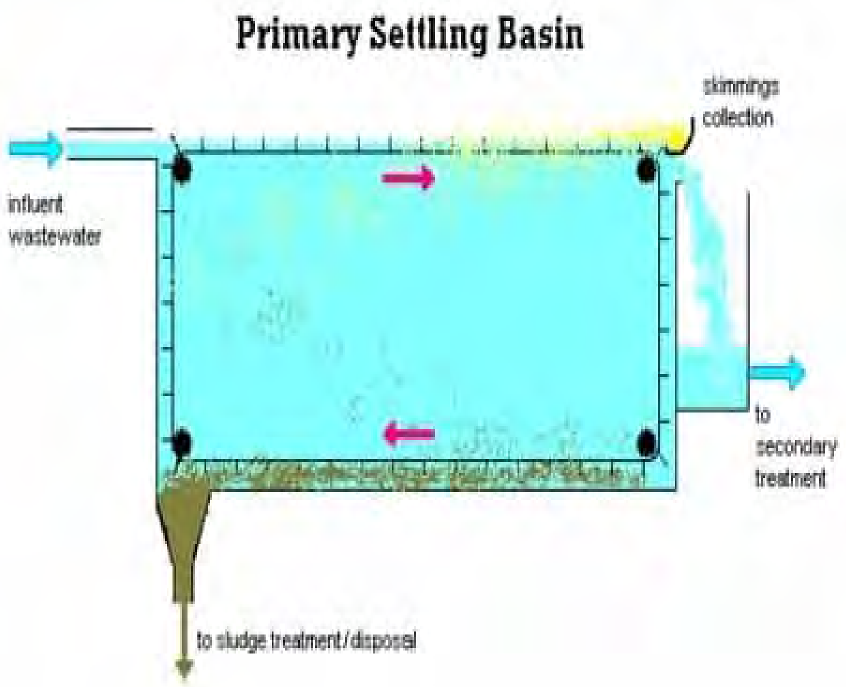
- Headworks - Remove the larger materials
  - Wood
  - Cardboard
  - Rags
  - Grit
  - FOG
  - Scum

Grit Basins

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

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

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

Rectangular Clarifiers

Design

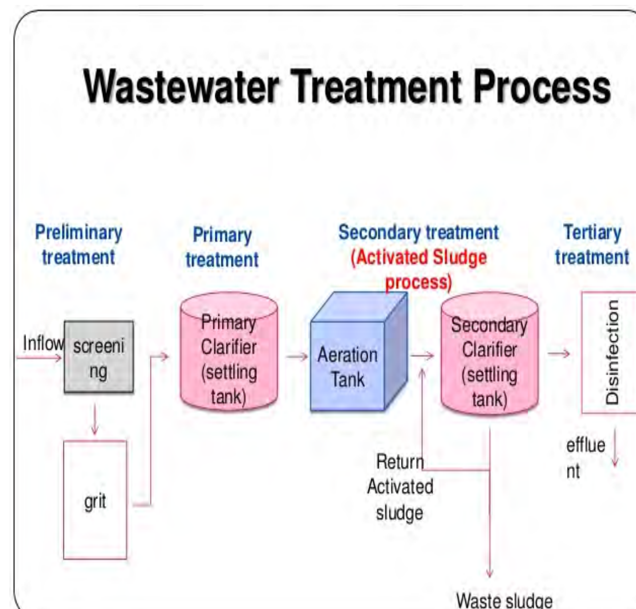
- Tank up to 300 feet in length and 80 feet in width
- Length to width > 5:1
- Depths of 10 to 12 feet, up to 16 feet
- Floor slope 1%
- Freeboard of 1.5 to 2 feet

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

Secondary Treatment 14

- 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

Acronym Quiz

What do these acronyms stand for?

1. BOD
2. COD
3. TSS
4. HDT

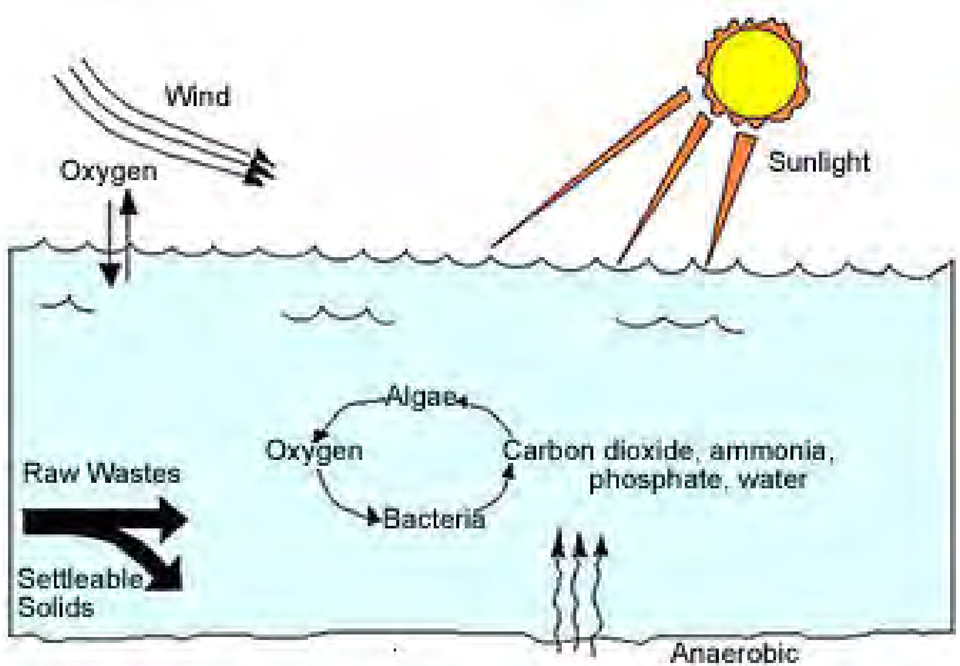
Ponds

- 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

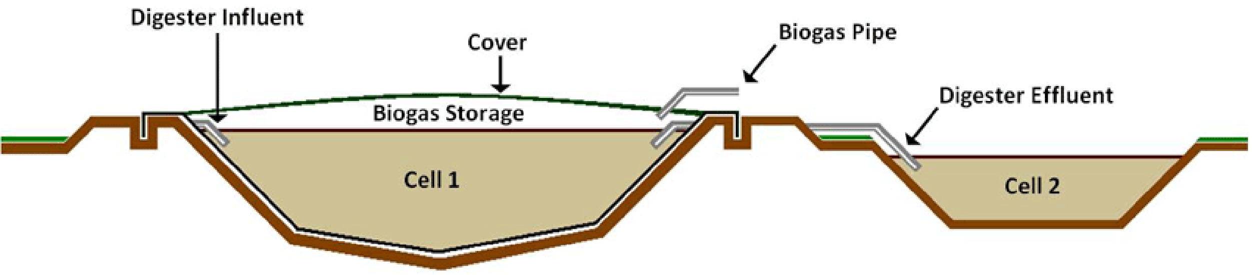


Aerobic Ponds

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

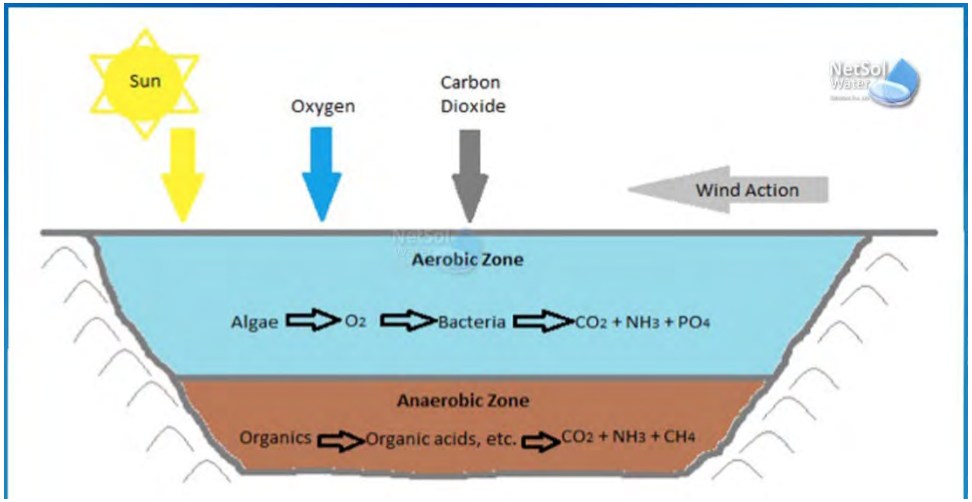
Anaerobic Ponds

- 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



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

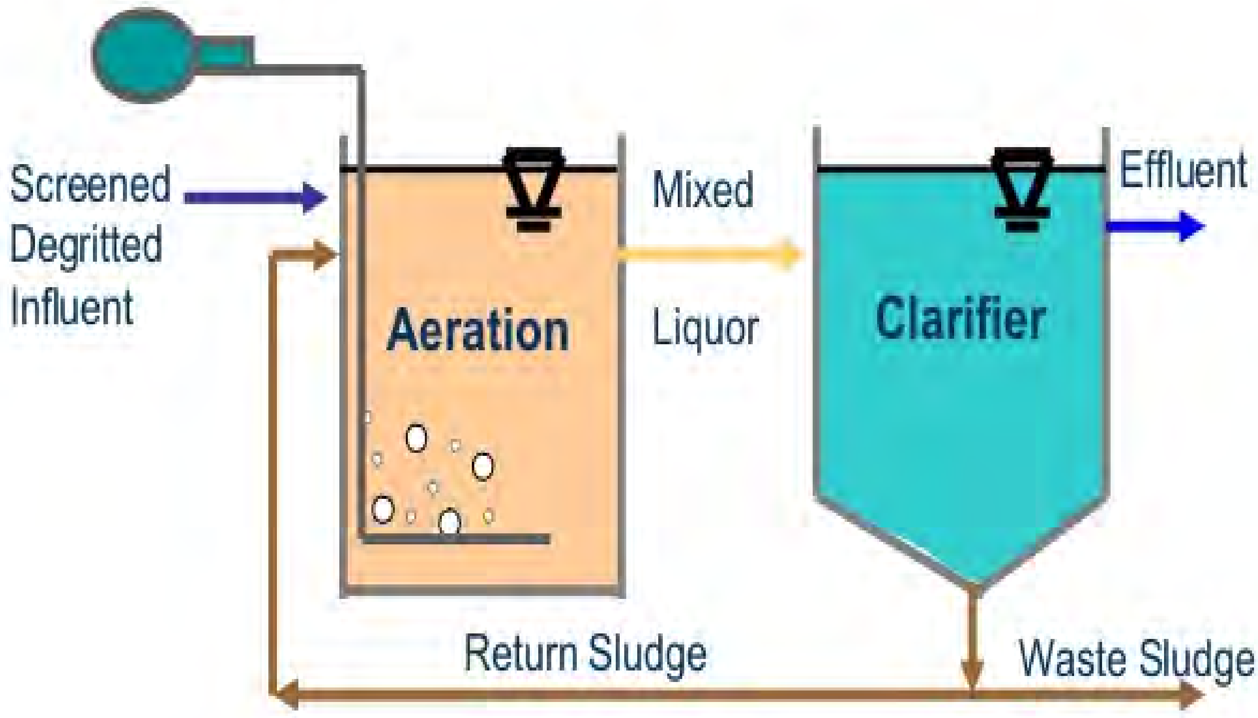
Sampling and Analysis

- 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

Fixed Film: 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

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 in to solids handling

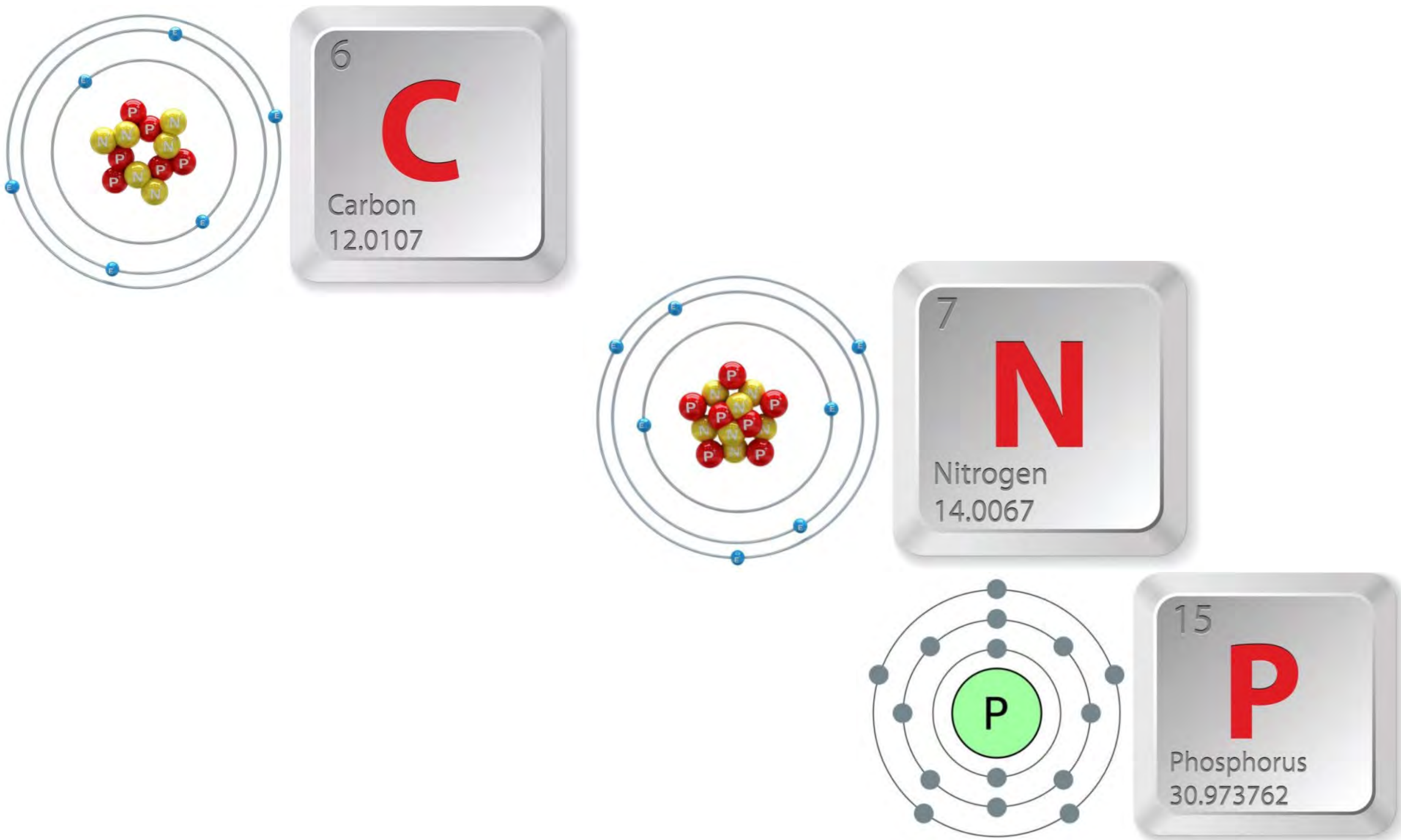
Overview

- 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

Quiz

1. What are the 2 types of fixed film treatment?
2. What are the two tanks involved in the activated sludge process?
3. What is the difference between the two?
4. Why is RAS and WAS and where are they sent after the second stage of treatment?

What are Nutrients?



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

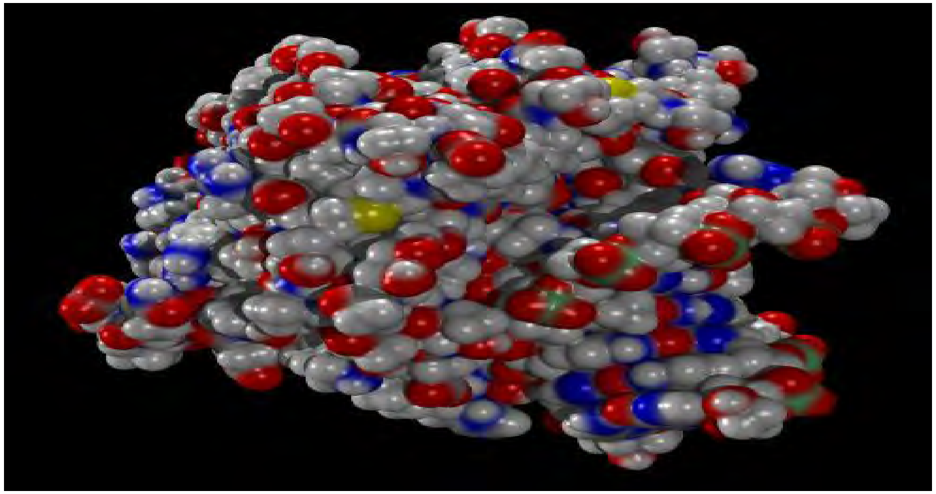
- 99% is in the form of TKN
  - 40% organic nitrogen
  - 59% ammonia/ammonium
  - This ratio is dependent on pH, temperature and detention time in the collection system
- Less than 1% nitrate and nitrite

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



Biological Nitrification

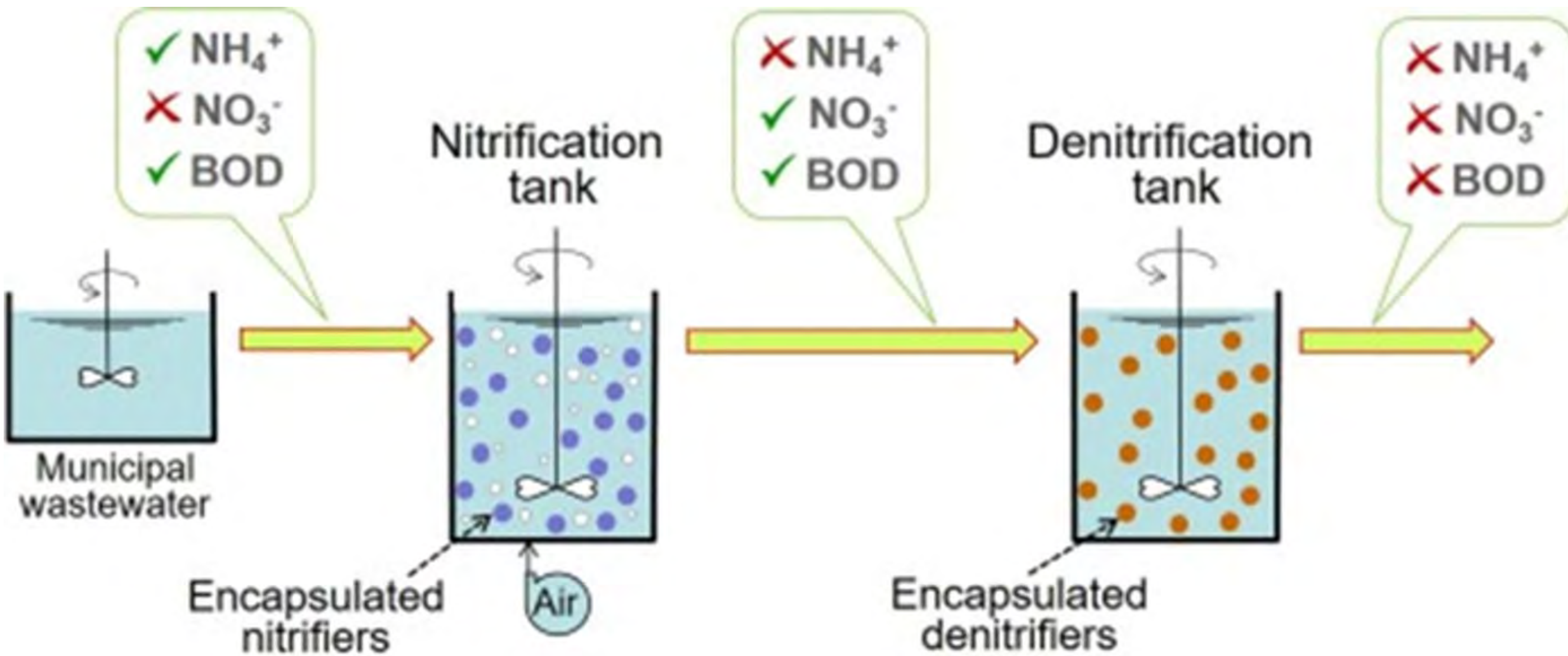
Nitrification

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

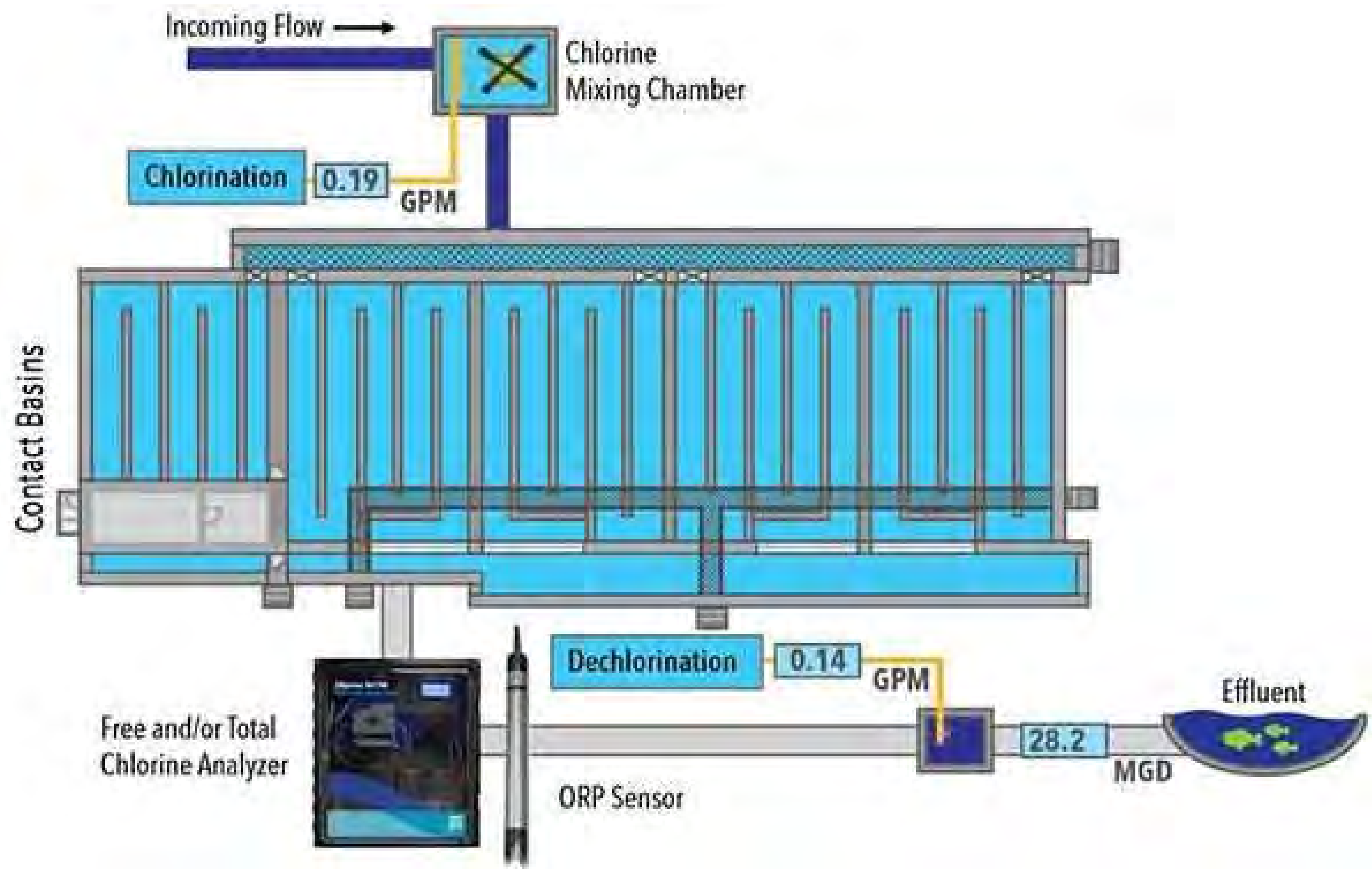
Disinfection

- 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

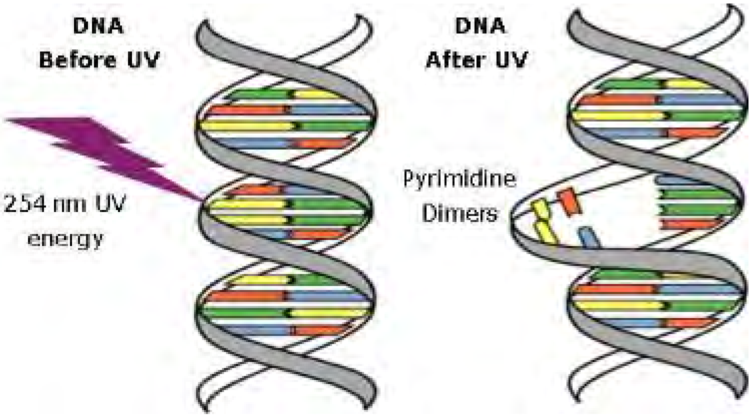
- Produces hypochlorous acid and hypochlorite ion when added to water
- Percent of each ion varies w/ pH and temp
- Dose = demand + residual
- Total residual = combined residual + free residual
- Pathogen inactivation = chlorine residual concentration and time (CT)

Chlorine Disinfection Process Variables

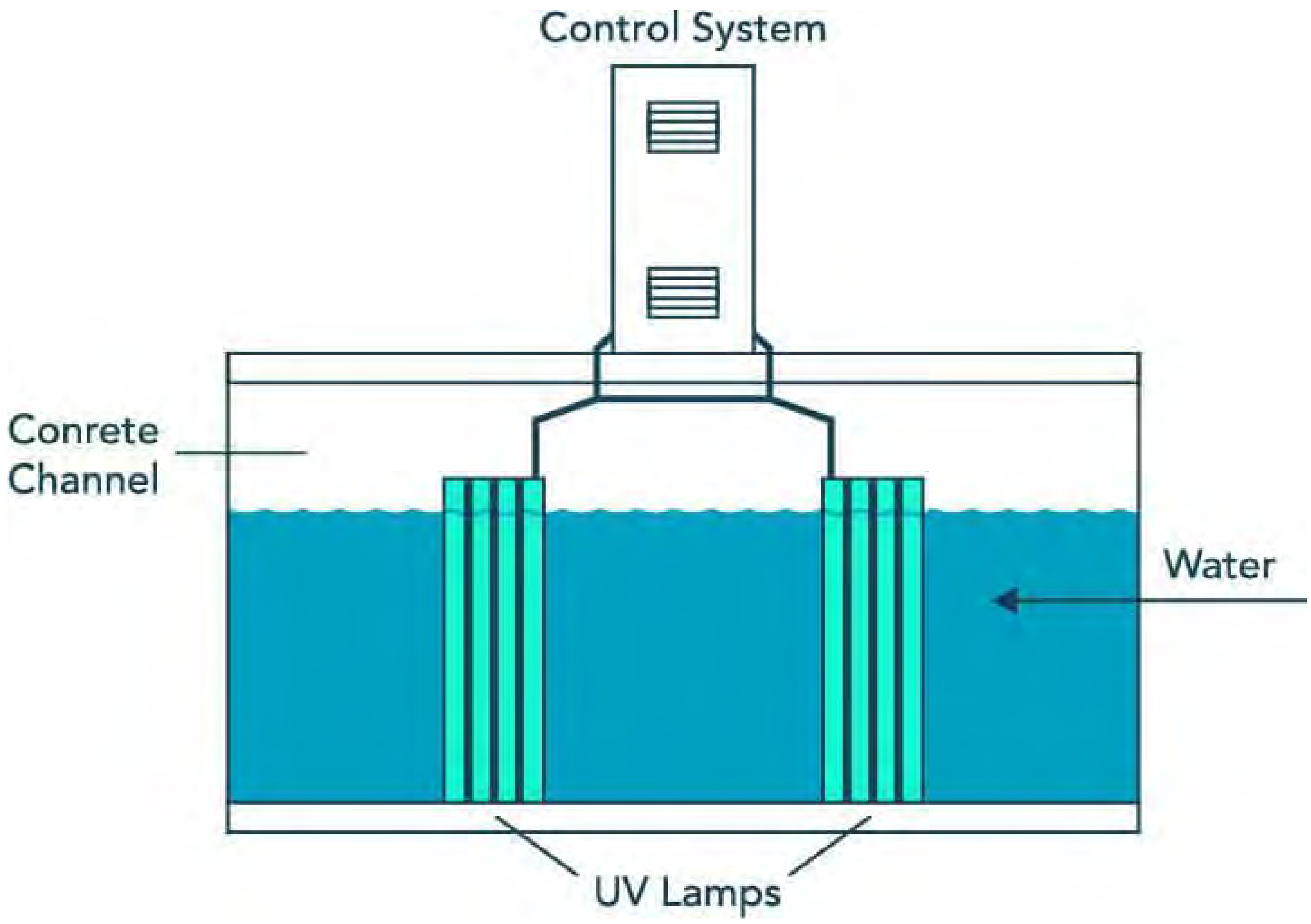
- Chlorine efficiency determined by CT and chlorine residual concentration
- Cold water harder to disinfect than warm
- High pH water is harder to disinfect than low
- Poor upstream performance increase chlorine demand
- Adjust CT to meet effluent goals

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

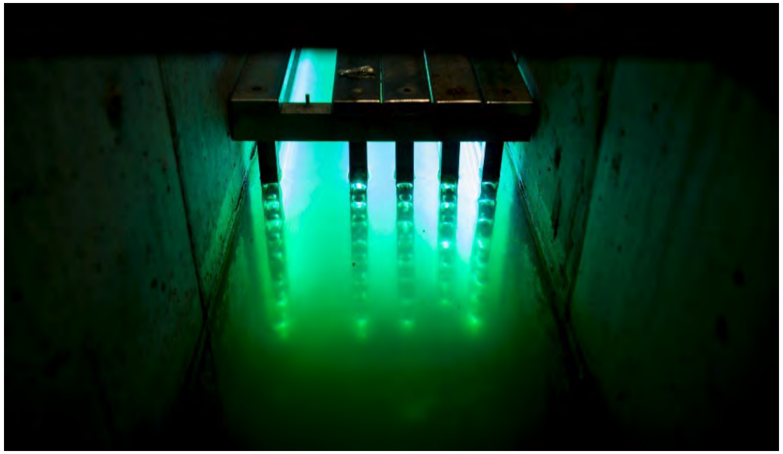


UV Disinfection

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

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




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

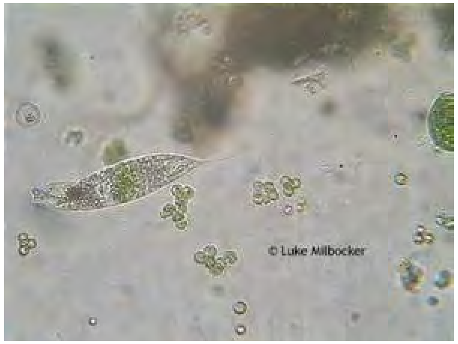
Quiz

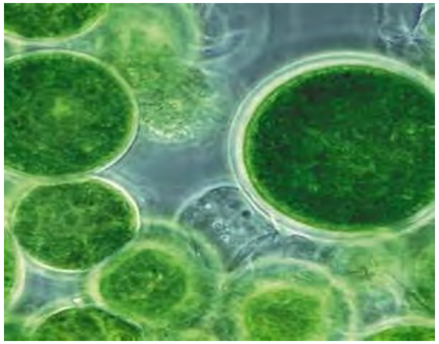
6. Draw a flow diagram of a WWTP process.

B. WASTEWATER LAGOON TROUBLESHOOTING

Wastewater Lagoon Microbiology

- Consider what we eat: Carbohydrates, fats, oils, grease, proteins, cellulose and sugars eventually enter the lagoons to be further digested by wastewater microbes
- Bacteria, algae, protozoa, nematodes, filamentous





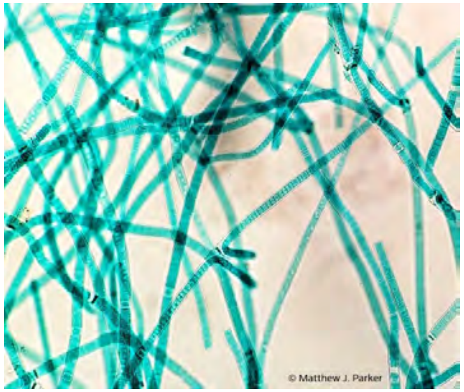
Lagoon Ecosystem

- The excretions of trillions of microbes make lagoon wastewater very complex
- Organisms in lagoons range from the tiniest virus to the more complex protozoa, rotifer, daphania, nematodes, arthropods, insects and small vertebrates



Lagoon Ecosystem

- In lagoons microbes are not uniformly distributed throughout the lagoon.
- Each species and group exits where they can find appropriate nutrition and suitable physical/chemical conditions.



Chemical Influences

- Loading
- Alkalinity
- pH
- Salinity
- Toxicity
- Composition of liners and dikes

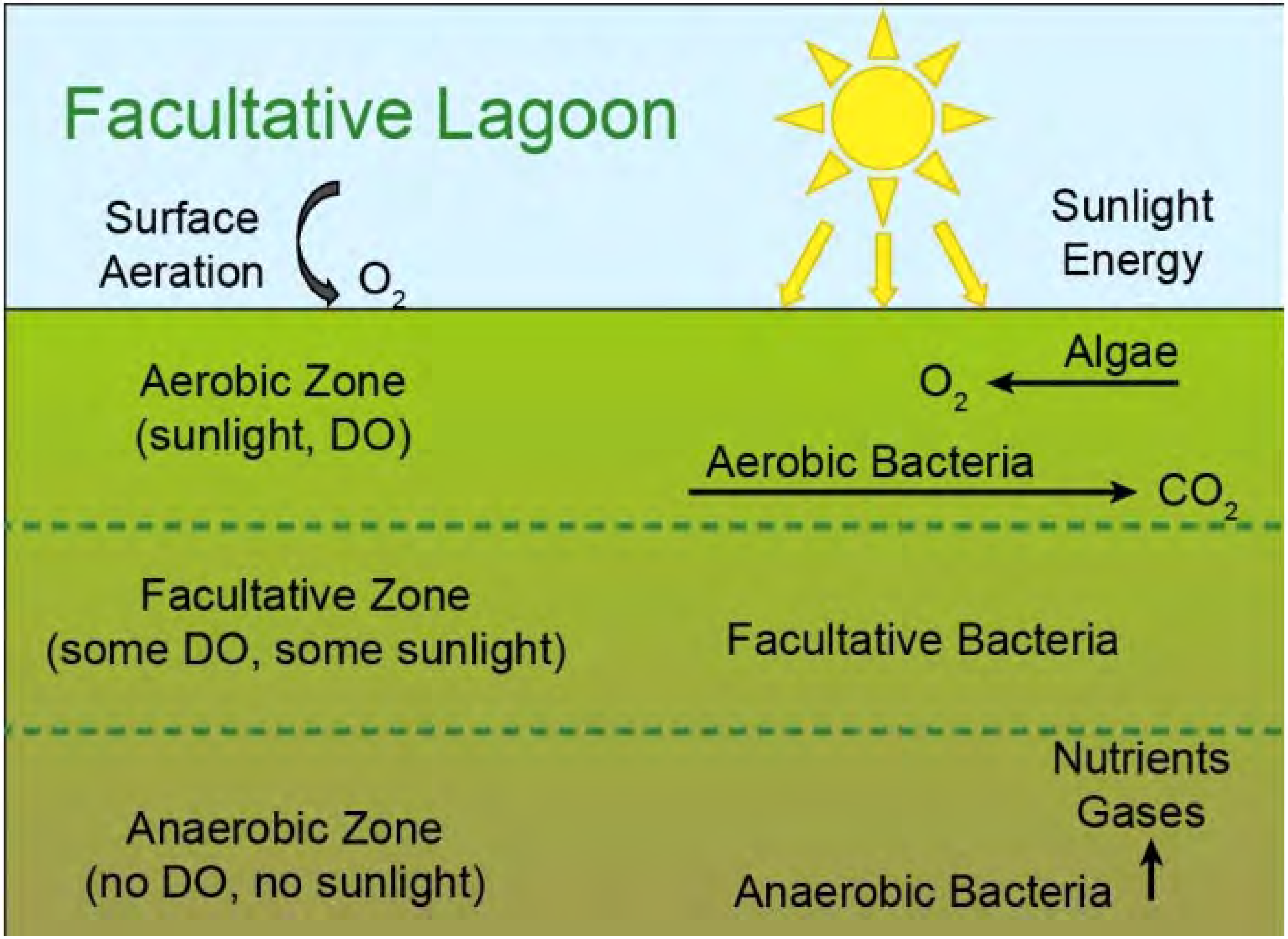
Physical Influences

- Pond configuration
- Pond hydraulics
- Retention time
- Seepage/I & I
- Pond dimensions
- Aeration/mixing

Facultative Lagoon

- Three different wastewater lagoons stacked on each other
- Aerobic: Requiring free oxygen (cells need oxygen to live)
- Anaerobic: Microorganisms break down biodegradable material in the absence of oxygen
- Facultative: Capable of existing in varying environmental conditions
- Facultative parasite can live independently of its host

Facultative Lagoon

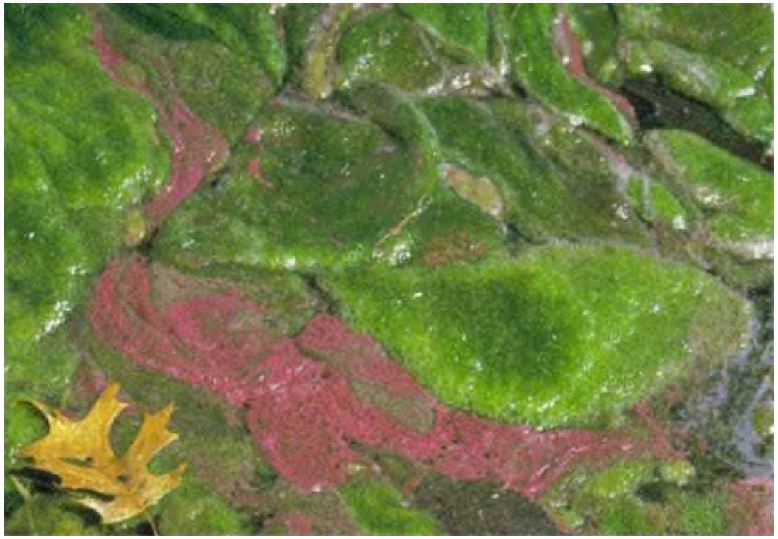


The Aerobic Zone

- Controls pathogens
- Removes BOD and CO_2
- Generates oxygen through photosynthesis
- Controls odors by sulfide oxidation
- Rids wastewater of nutrients through ammonia stripping and nitrification
- Remove metals by elevating the pH
- Re-aerate the lagoon surface

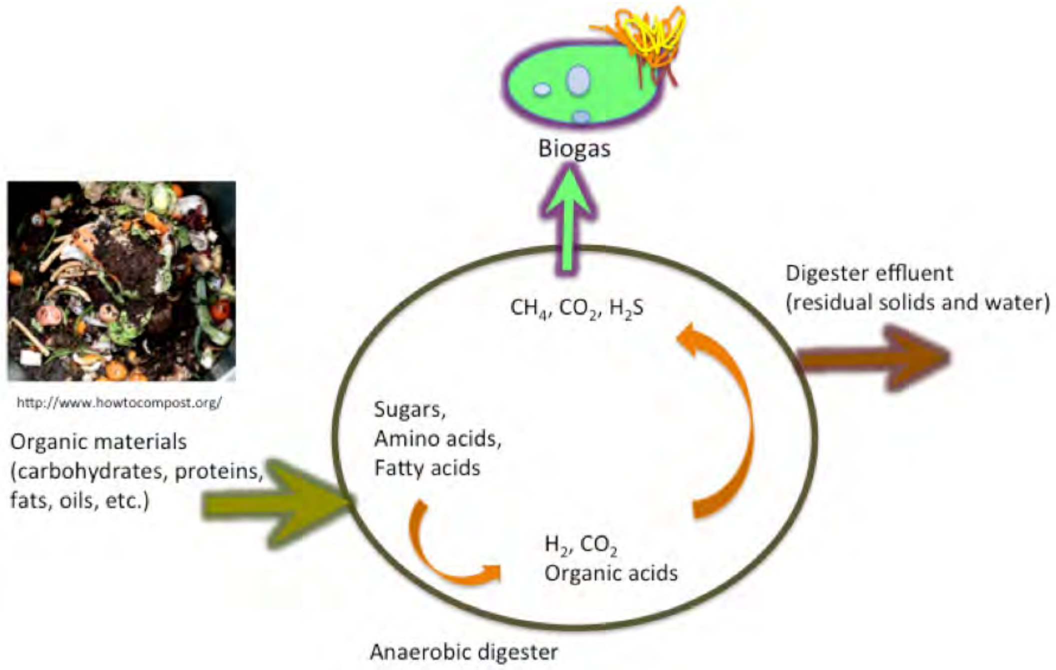
Anoxic Zone

- Low air zone just below the aerobic layer
- Favors the growth of purple sulfur bacteria, which controls the odors by consuming H_2S
- Denitrification



Anaerobic Layer

- Bottom layer
- Generates CO_2
- Retains nutrients
- Sludge digestion
- Sludge storage
- TSS control
- Nitrifiers/denitrifiers
- Removes BOD
- Recovers alkalinity



Bacteria

- Feed on other members of the food chain
- Decompose organic matter
- Assimilate nutrients
- Control disease causing organisms
- Degrade pollutants, toxins,
- Control odors
- Oxidize inorganic compounds: ammonia, H_2S, nitrate, sulfur
- Form floc particles: stabilization / settleabilty

One teaspoon contains 100,000,000s bacteria

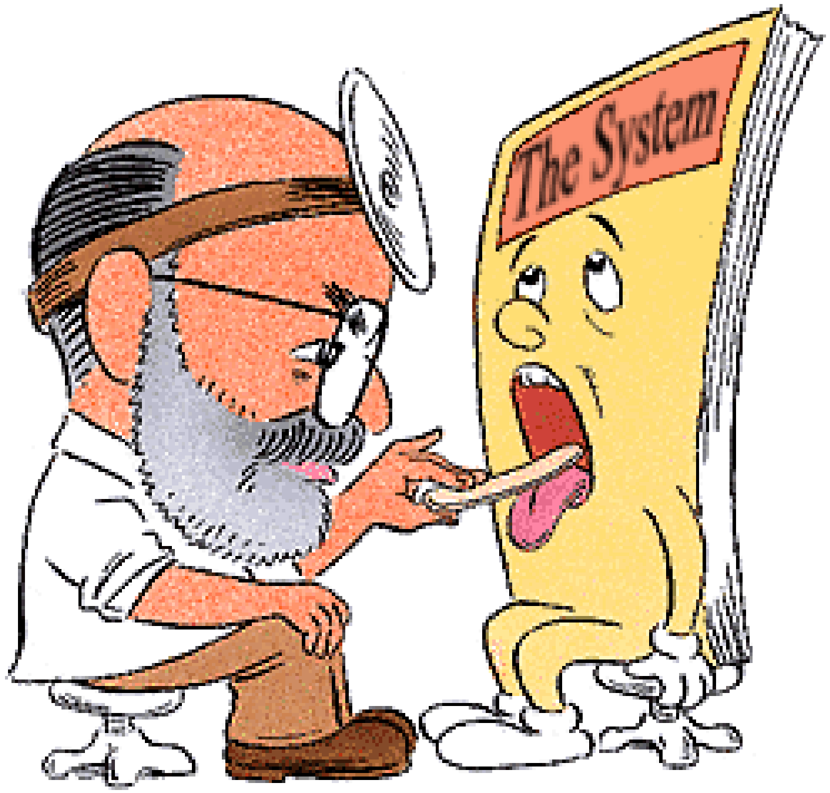
Algae

- Supply oxygen to aerobic bacteria, protozoa
- Assimilate nitrogen and phosphorous reducing N and P concentrations in receiving water
- Elevate pH
  - Kills pathogens
  - Control odors
  - Precipitate metals
  - Ammonia volatilization
- Helps control odors by generating oxygen
- Cause TSS and BOD problems – use oxygen at night
- Form mats and stink , create toxins

Protozoa

- Control pathogens
- Consume organic matter
- Assist in nutrient cycling
- Lower BOD and TSS
- Help clarify water

Diagnosing Lagoon Problems



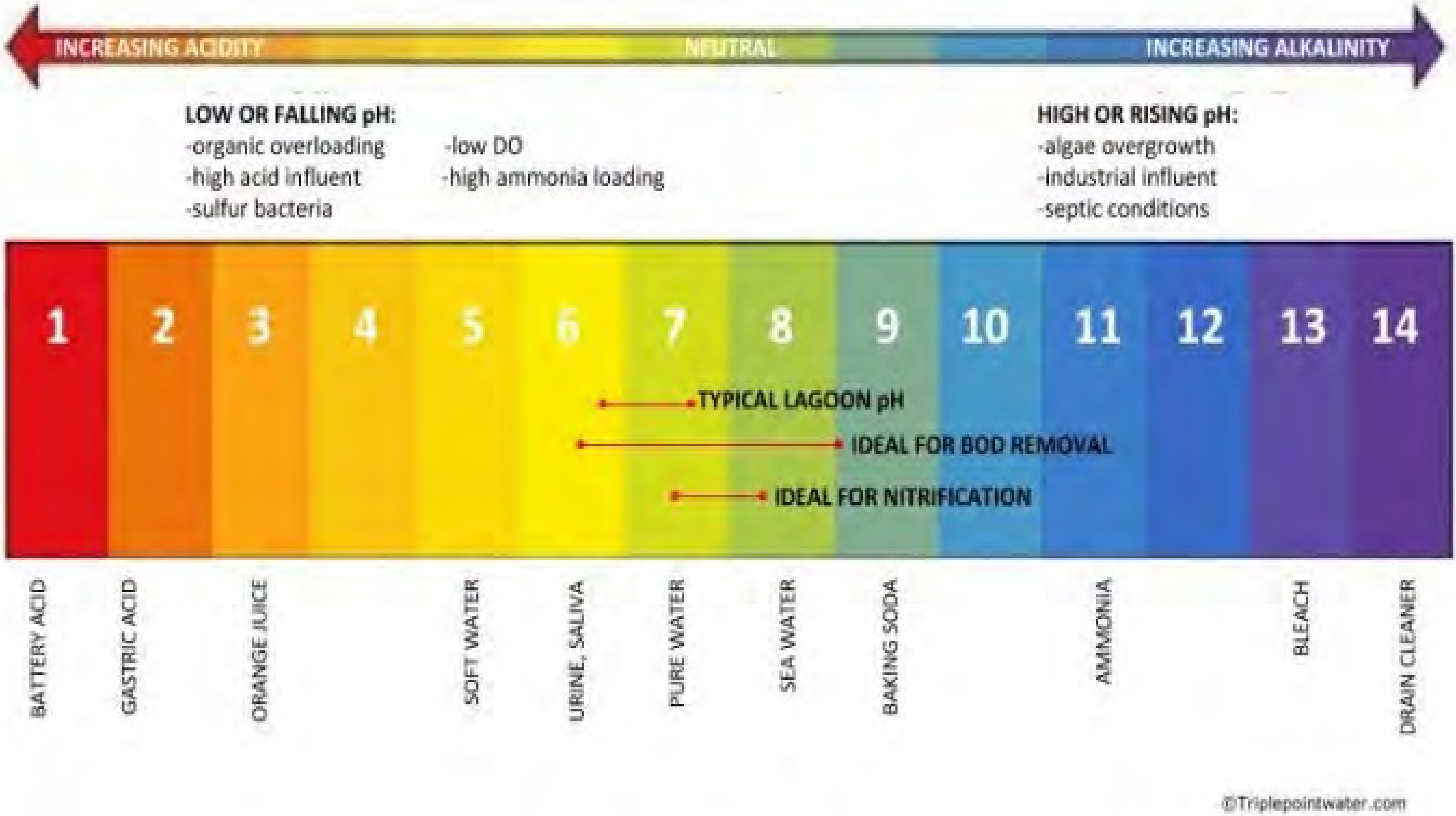
Recommended Tests

- BOD
- TSS
- pH
- Dissolved oxygen
- NH_4
- Alkalinity
- Temperature
- Chlorophyll
- Sludge depth
- Fecal coliform
- Flow
- VSS

$$\frac{\text{BOD5 (in)} - \text{BOD5 (out)}}{\text{BOD5 (in)}} \times 100$$

$$\frac{500 - 20}{500} \times 100$$

$$\frac{480}{500} = 0.96 \times 100 = 96\%$$



INCREASING ACIDITY
NEUTRAL
INCREASING ALKALINITY
LOW OR FALLING pH:
-organic overloading
-high acid influent
-sulfur bacteria
-low DO
-high ammonia loading
HIGH OR RISING pH:
-algae overgrowth
-industrial influent
-septic conditions
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TYPICAL LAGOON pH
IDEAL FOR BOD REMOVAL
IDEAL FOR NITRIFICATION
BATTERY ACID
GASTRIC ACID
ORANGE JUICE
SOFT WATER
URINE, SALIVA
PURE WATER
SEA WATER
BAKING SODA
AMMONIA
BLEACH
DRAIN CLEANER
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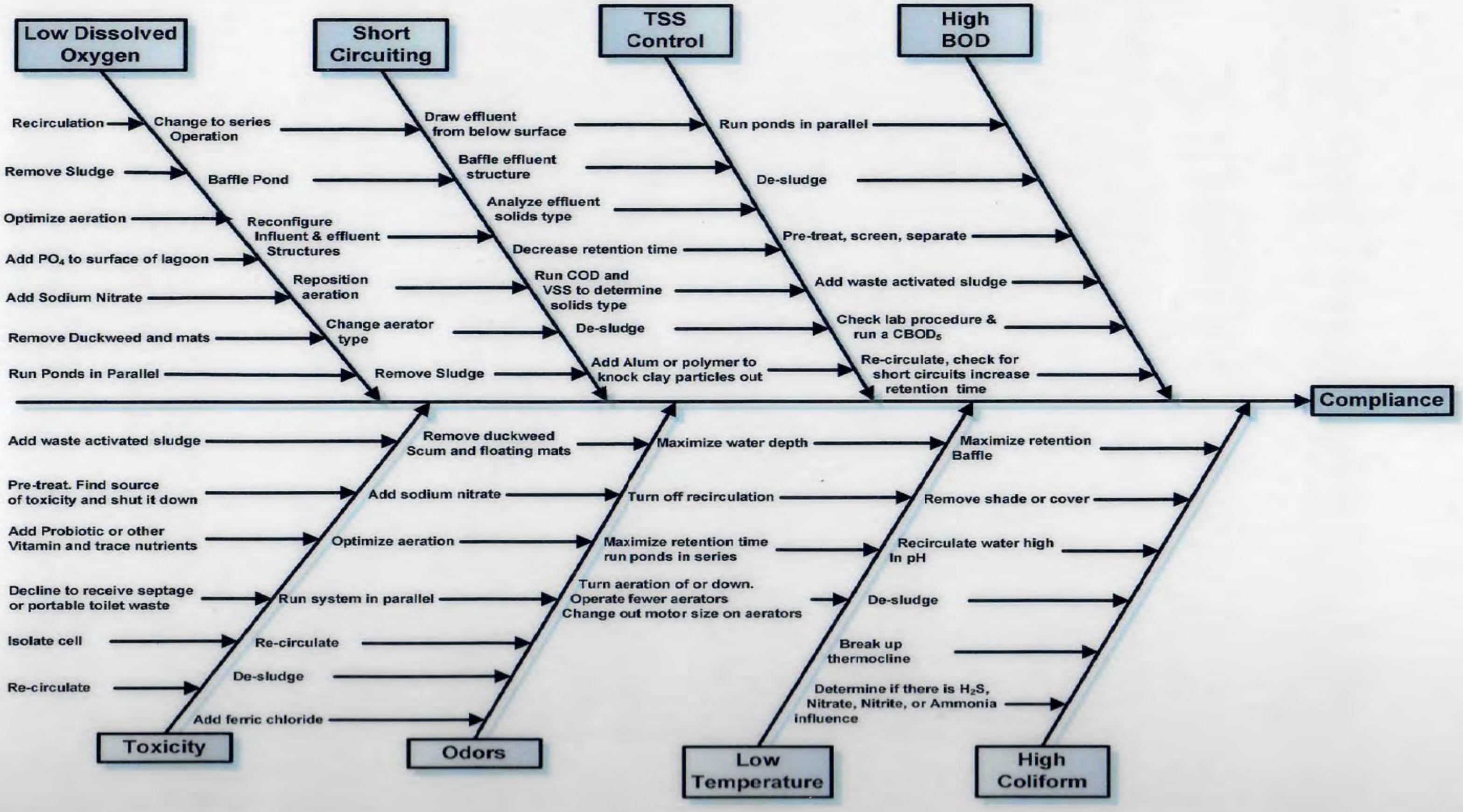
Wastewater Lagoon Troubleshooting Chart

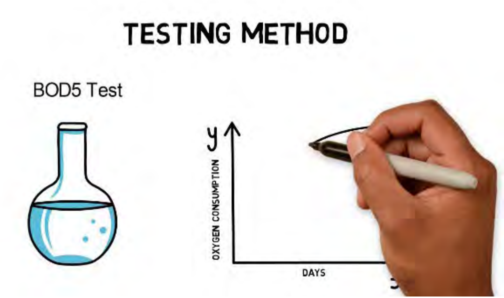


Testing to Diagnose Pond Problems

- TBOD: Total BOD test
  - Test run without adding nitrification suppressant
- CBOD: Carbonaceous BOD (w/nitrification suppressant)
  - Used to determine NBOD (nitrogenous BOD)
  - NBOD represents relative number of nitrifying bacteria present in a sample being tested for BOD

  BOD - CBOD = NBOD
- SCBOD: Soluble carbonaceous BOD
  - Used to determine if benthal feed-back is occurring
  - Used in conjunction w/ other BOD tests to determine algae's part in generating BOD

  CBOD - SCBOD = PCBOD (particulate BOD)



Testing to Diagnose Pond Problems

- TSS
  - Shows particulate matter leaving the lagoon
- pH
  - Diagnose algae problems
- DO
  - Determine aerator efficiency, organic overloading, odors, nitrification
- NH_4
  - Nitrification of ammonia places an oxygen demand on lagoons
  - 4 lb of O_2 for 1 lb of NH_4 oxidized

Testing to Diagnose Pond Problems

- Alkalinity
  - Algae consumes alkalinity and drives up pH
  - Levels above influent cause sulfide generation or denitrification
- Temperature
  - Microbial activity is temperature dependent
  - Affects chemical and biological reaction rates
  - Settleability, O_2 and CO_2 solubility
  - Operators can predict potential problems
- Chlorophyll-a
  - Measure of algae abundance
  - Determines if non-volatile solids are leaving the pond

Testing to Diagnose Pond Problems

- Sludge depth
  - Accumulated sludge creates issues including short-circuiting, benthal feedback, odors, high TSS, poor BOD removal
- Fecal coliform
  - High levels indicates lagoon overload, improper lagoon sizing, or accumulated sludge is growing pathogens
- Flow
  - Essential in calculating loading and retention time
- VSS
  - Volatile component of TSS

Using Test Results to Diagnose Lagoon Problems

- BOD removal efficiency = $\frac{BODin - BODout}{BODin} * 100$
- TSS:BOD ratio

  Ratio < 1, old sludge solubilization and release of BOD

  Ratio = 1, poor treatment or short circuiting

  Ratio = 1.5, normal treatment performance

  Ratio = 2 to 3, algae bloom or overgrowth, loss of old sludge particles
- High effluent BOD
  - Excessive algae growth, nonsettleable bacterial floc, or nitrification in the test bottles

Determining Cause of TSS and BOD Problems

TSS Solids Type	Possible Meaning
Raw Solids	Short circuiting, too few ponds on-line, high fecal numbers
Sludge Particles	Pond turnover, wind mixing, too much aeration
Dispersed Bacteria	Process upset, low DO, short circuiting
Sulfur Bacteria	Anoxic, overloaded. Rotten egg odors, red colored pond
Filamentous Bacteria	Anoxic, low DO
Bacterial Floc	Turbulent. Increase retention time
Algae	Normal
Protozoa	Normal
Copepods	Normal
Daphnia	If in abundance, watch for low DO and TSS
Higher Life Forms	Normal

Determining Cause of TSS and BOD Problems

- Effluent BOD Tests:
  1. TBOD
  2. SBOD
  3. CBOD

- Compare:

  TBOD = CBOD + NBOD

  CBOD = BOD + NBOD

  PCBOD = CBOD - SCBOD

- Meaning:

  PBOD > 70% of TBOD indicates solids loss

Diagnostic BODs

Test	Definition	Meaning
BOD_5	Standard 5-day test. BOD = CBOD + NBOD	Used to measure strength of WW. Needed to calculate NBOD.
$SBOD_5$	Sample first run through a filter. Measures readily oxidizeable portion of WW. SBOD = SCBOD + SNBOD	Step towards calculating SCBOD. unusual to see SBOD higher than 20% in effluent.
$CBOD_5$	BOD test run with nitrification suppressant added to measure effect on DO. CBOD = BOD - NBOD	Measure of lagoons ability to stabilize waste. NBOD = relative number of nitrifying bacteria.
$SCBOD_5$	BOD test after filtration and nitrification suppressant has been added to test bottle. SCBOD = CBOD - PBOD	Influence of sludge blanket in feeding BOD back to the water column. Used with CBOD to determine algae's effect on BOD test. If PBOD > 70% of BOD in effluent; solids loss problem.

Determining Cause of TSS and BOD Problems

- VSS/TSS ratio
  - % of suspended material that is organic
  - Indicates if digested pond solids are leaving with effluent
- Remaining SBOD consists of:
  - Polysaccharides
  - Proteins
  - Lipids
  - Organic acids
  - Carbohydrates
  - Vitamins
  - Fatty acids
  - Exocellular enzymes
  - Nitrogen
  - Phosphorus
  - Other readily digested organic matter

Determining Cause of TSS and BOD Problems

- Typically 80% of SBOD is removed in the first cell
- SBOD is compared with other cells to determine if accumulated sludge is releasing soluble nutrients into the water column
  - accumulated sludge is storage for microbial food and represents a possible internal load
  - return of organic matter and other nutrients from sediments of the aerobic layer

Determining Cause of TSS and BOD Problems

- Benthal feedback: Resolubilizing of ammonia, phosphorus, trace-nutrients, and other dissolved substrates
  - Causes algal blooms that result in DO crashes at night
  - Increases in ammonia indicate benthal feedback
  - Means that it’s time to remove sludge
- COD/BOD ratio: Reveals fraction of organic matter that is non-biodegradable

Sample and Test

★ Sample Points

Sample and Test

- BOD
- CBOD
- SBOD
- DO
- TSS, VSS, COD
- Temperature
- pH
- Chlorophyll-a

Sample and observe the type of solids existing the final effluent. Under the microscope, look for:

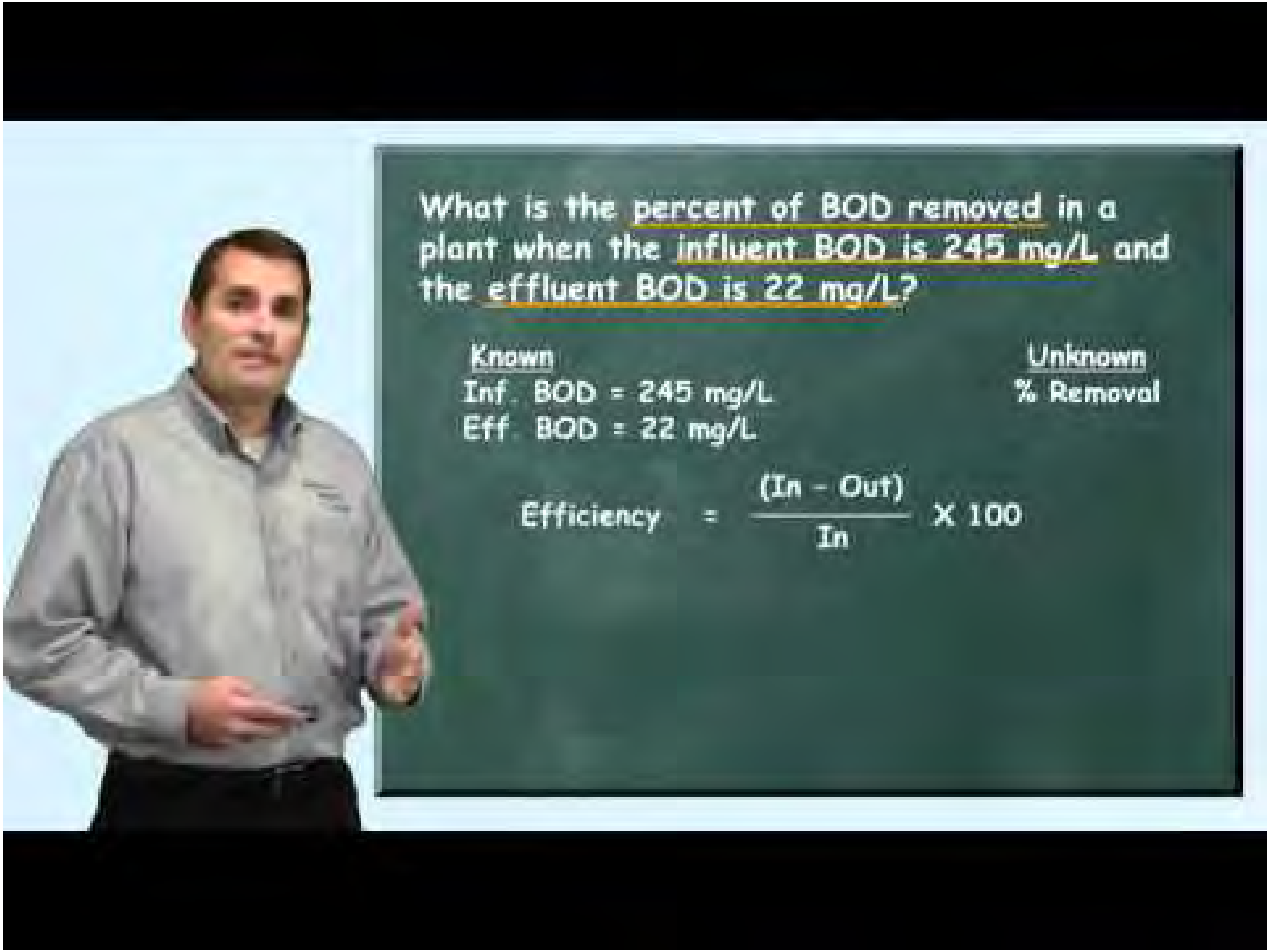
TSS Solids Type	Possible Meaning
Raw Solids	Short circuiting, too few ponds on-line, high fecal numbers
Sludge Particles	Pond turnover, wind mixing, too much aeration
Dispersed Bacteria	Process upset, low DO, short circuiting
Sulfur Bacteria	Anoxic, overloaded. Rotten egg odors, red colored pond
Filamentous Bacteria	Anoxic, low DO
Bacterial Floc	Turbulent. Increase retention time
Algae	Normal
Protozoa	Normal
Copepods	Normal
Daphnia	If in abundance, watch for low DO and TSS
Higher Life Forms	Normal

Calculate and Compare

- Determine BOD removal efficiency of each pond

$$\text{BOD removal efficiency} = \frac{BODin - BODout}{BODin} * 100$$

- Things to consider:
  - Pond may be feeding BOD back into the system
  - Operator may decide to take pond offline or temporary bypass
  - Formation of BOD can be the result of organic matter from sludge restabilizing in the water column
  - May indicate too much algae in BOD test bottle


What is the percent of BOD removed in a plant when the influent BOD is 245 mg/L and the effluent BOD is 22 mg/L?
Known
Inf. BOD = 245 mg/L
Eff. BOD = 22 mg/L
Unknown
% Removal
Efficiency = (In - Out) / In X 100

Calculate Actual Loading

$$\text{Organic Loading }\left(\frac{\frac{lb\ BOD}{acre}}{day}\right) = \frac{(BOD, \frac{mg}{L})(Flow, MGD)(8.34\frac{lb}{gal})}{Lagoon\ area\ in\ acres}$$

$$\text{Metric }\left(\frac{\text{kg}\frac{\text{BOD}}{\text{day}}}{\text{M}^3}\right)$$

- Organic loading can range between 10 to 50 lb of BOD per acre
- One acre of primary pond for every 100 to 120 design population
- Approximately 22 lb BOD/acre/day

Typical BOD Loading Rates, Facultative

Pond Type	Application Loading	Detention Times (days)	Population per acre
Cold water lagoons	Raw or municipal wastewater from primary treatment <8.5 lbs BOD/acre/day	> 200	< 200
Cold season climate, short temperature summers	Raw municipal wastewater 9 - 45 lbs BOD/acre/day	100 - 200	200 - 1,000
Temperate to semi-tropical, occasional ice cover, raw	Raw municipal wastewater 45 - 135 lbs BOD/acre/day	31 - 100	1,000 - 3,000
Tropical, uniformly warm temperatures, sunny, no cloud cover	35 - 315 lbs BOD/acre/day	17 - 33	3,000 - 7,000

Typical BOD Loading Rates

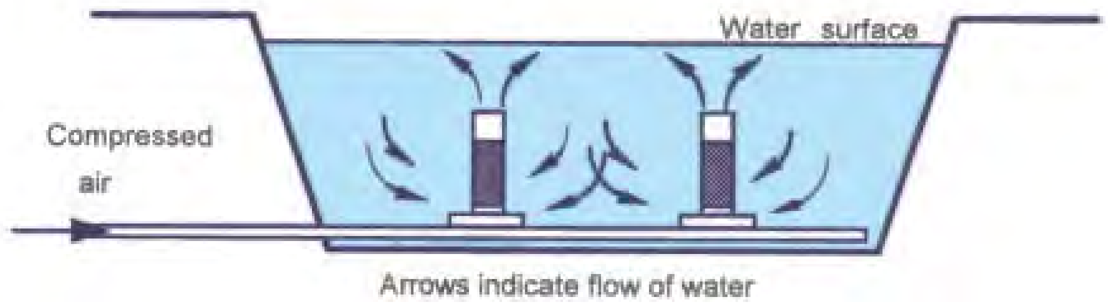
Pond Type	Application Loading	Detention Times (days)	Population per acre
Aerated	Industrial wastewaters or where small foot print is desired 7.5 - 290 lbs/BOD/acre/day	7 - 20	1,700 - 3,400
Anaerobic	Industrial wastewaters 145 - 720 lbs BOD/acre/day	20 - 50	

Recommended BOD Loading Rates

Season	Temperature	Loading Rate
Winter (average)	15^{o}C (59^{o} F)	40 to 80 lbs/acre/day
Winter (cold)	0^{o} C to 15^{o}C (32^{o} F to 59^{o} F)	20 to 40 lbs/acre/day
Winter (very cold)	< 0^{o}C (32^{o} F)	10 to 20 lbs/acre/day
Warm	> 15^{o}C (59^{o} F)	89 lbs/acre/day

Lagoon Loading

- Facultative ponds rely on algae and the sun's influence to add DO to the water column
- Aerated lagoons supply oxygen mechanically and can handle higher loading rates
  - 50 to 200 lb BOD/acre/day
  - Oxygen required is 1.75 to 2.50 lb O_2/lb BOD applied when sludge oxygen demand is included



Lagoon Loading

- Effects of spring thaw and benthal feedback on pond loading
  - Benthal release (accumulated sludge) can double or triple oxygen demand during spring
  - May require O_2 input of up to 6 lb per lb of BOD
- Effects of industrial waste, grease trap waste and septage
  - Typically composed of high strength organic materials
  - Most facultative ponds are not equipped to handle these
  - Prior to receiving, operator must know the design loading of the pond, how much septage to receive, and how many people the lagoon can support

Signs of Lagoon Overloading

- Color changes and smell
  - Red streaks and rotten egg smell indicate anaerobic conditions
  - Gray to black indicates precipitated insoluble metal sulfides and loss of aerobic quality (anaerobic conditions)
- Drop of DO concentrations
- low pH values
- Increases in BOD
- Drop in protozoa count

Troubleshooting BOD

Organic Overloading

- Increase aeration time, add air, place another lagoon on line
- Check sampling and handling techniques
- Reduce loads due to industrial wastes, grease trap wastes or septage
- Increase recirculation
- Additional mixing
- Use parallel operation, lighten load to one pond
- Add oxygen source; calcium nitrate, hydrogen peroxide
- Pull affected pond offline
- Add activated sludge from another treatment plant


Great Mixing Here
No Mixing Here
no sludge or slurry disturbance

Troubleshooting BOD

Short-Circuiting

- Improve inlet/outlet configuration / structures
- Solve infiltration and inflow problems
- Add baffles, recirculation, aeration
- Reposition aeration to mix sludge
- Remove sludge
- Break up summer time thermoclines w/ aeration/mixing

Troubleshooting BOD

Ice-Covered Lagoon

- Conserve heat by reducing aeration run time
- Don’t operation recirculation
- Operate lagoons as deep as possible
- Add air and mix when ice has thawed

Ice-Off: Thaw

- Add air and mixing
- Add 4 lb/lb BOD added

Troubleshooting BOD

Algae Bloom

- Increase mechanical mixing, add shade, floating cover, add algal predator (daphnia), add copper sulfate
- Reduce retention times to < 2.5 days
- Change lagoon configuration to multiple cells in series
- Increase lagoon operating depth
- Break up floating operating mats w/water spray, rakes, mixers, fire-hose or motorboat
- Bypass lagoon

Troubleshooting BOD

Additional troubleshooting (Page 46 - 47)

- Lab error
- Bottom solids escaping
- Bacterial floc
- Partial nitrification
- Toxic material in influent

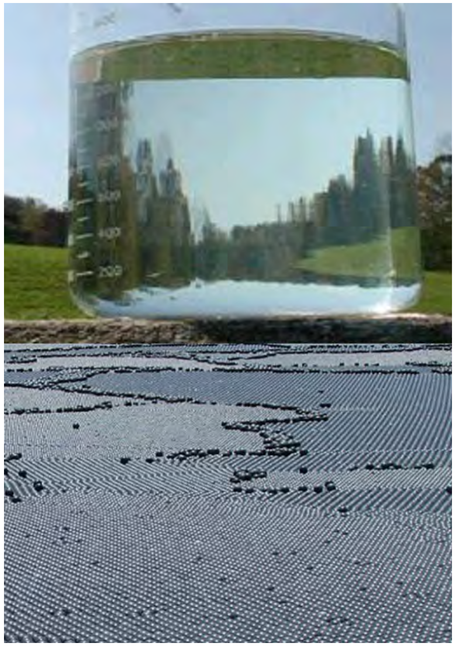
Strategies to Control Algae

Aeration

1. CO_2 is vital for algae growth, aeration mixes water to strip off CO_2
2. Creates foam that covers parts of the pond, reduces sunlight penetration, deprives algae
3. Disrupts thermal stratification, reduces retention time
4. Keeps floc and particles suspended, scatters sunlight, DO absorbs light instead of the algae

Strategies to Reduce and Control TSS

1. Controlling retention time
2. Controlled discharge
3. Confine algae in each treatment cell by varying the depth water is drawn, each transfer pipe and effluent pipe
4. Discharge from the cell w/ the best water quality
5. Chemical control
6. Shading
7. Barley straw
8. Using natural algae predators
9. Baffles
10. Dissolved air floatation
11. Other methods…



Strategies to Reduce and Control TSS

Other methods for controlling algae:

- Over land flow
- Rock filters
- Constructed wetlands
- Micro-screening
- Sand filtration
- Water hyacinth
- Centrifuges
- Alum or polymer in quiescent portion of effluent pond

TSS Control

TSS: BOD5 Ratio	Causes
<1.0	Old sludge solubilization and release of soluble BOD (benthal feedback) Nitrification in the BOD test bottle
1.0	Poor treatment or short-circuiting, with untreated wastewater mixing with the effluent
1.5	Normal for most lagoon systems
2.0–3.0	Algal overgrowth; loss of old sludge particles

Calculating Pond Retention Time

Theoretical Pond Retention Time:

$$Detention\ Time\ (days) = \frac{Pond\ Volume}{Flow\ Rate/day}$$

Short-Circuiting: How can you tell?

1. The pond is not meeting limits on BOD or fecal coliform
2. BOD and TSS values are high and TSS:BOD ratio = 1
3. If back-calculated K rates are significantly lower than design
4. Visual observation
    a. If winds push water towards effluent
    b. Accumulation of trash, grease, and algae mats piling up in one area
    c. Accumulated sludge in one area
5. Facultative pond temp, pH, and DO dramatically vary at different depths
    a. Measure every 6 inches from top to bottom

Effects of Temperature on Mixing

- Cooler fall temperatures
  - As air temp drops, surface water cools and becomes more dense displacing warmer water (densimetric mixing)
  - Microbial activity slows, BOD accumulates
- Cold winter temperatures
  - Surface freezes, DO doesn’t reaerate, denser cold water displaces warm
  - Some bacterial activity continues, CO2 trapped, raises pH
- Spring thaw
  - Density driven mixing, stored up BOD may cause overloading, aeration is typically needed
- Warm summer weather
  - Upper surface high in DO, high pH, supports algae growth
  - Deeper layer colder, supports anaerobic activity, low DO, low pH

Fixing Short-Circuiting Issues

- Check influent piping
  - Wastewater than runs through a manifold distributes more evenly
- Change type of aerators or reposition
  - Directional aspirating mixers or change existing patterns
- Redesign influent/effluent structures and transfer pipes
  - See page 81 for arrangement designs
- Baffles
  - Proven to increase retention time
  - Should be 70% of the pond width, minimum of 2 baffles used
- Remove sludge

Signs That it's Time to Remove Sludge

1. Increase in BOD
2. Increase in TSS
3. Floating, rising sludge
4. Odors
5. Color change in lagoon
6. Increase in turbidity
7. Increase in effluent ammonia and phosphorus
8. Increase in coliform and other pathogenic microbes
9. Blue and green algae bloom
10. Sludge particles leaving effluent
11. Unexplained high chlorine demand

Measuring Sludge Blanket

Sludge Judge

- Reliable and accurate
- Large diameter
- 2-inch clear plastic tube
- Measures two things:
    1. Sludge blanket mass
    2. Sludge blanket thickness

Sludge Judge

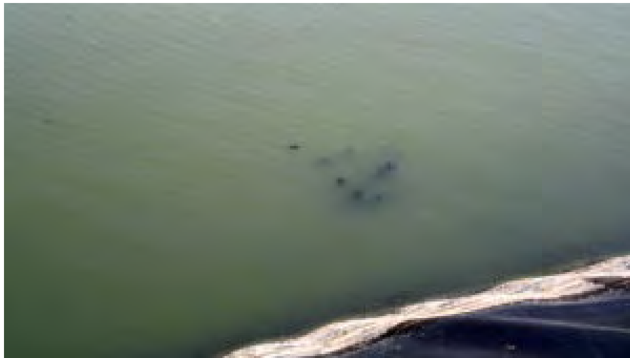
Sludge Removal

Lagoon Oxygen Testing

- Maintain DO levels of 2 mg/L
- Measure DO at different times of the day, different locations, different depths
  - Early morning, mid-day
- Example calculations p. 114-115

Signs Indicating Oxygen Stressed Conditions

1. Daphnia turn pink to red
2. Filamentous bacteria are present
3. Large concentrations of purple sulfur bacteria turn pond pink to red
4. Excess scum and floating mats of sludge
5. Color changes to grey
6. Reduced BOD removal efficiency
7. Sulfur/rotten egg odors



DO Profile Chart

- Page 118
- Useful table when performing an oxygen profile
- Set up the same as a sludge judge grid
- Record DO and temperature and different locations and depths
- Add pH, nitrogen, phosphorus, TSS, VSS, and tracer concentrations to identify short-circuiting channels

Lagoon System Mixing &Dissolved Oxygen Profile Chart

Depth	A1		A2		A3		A4		A5		B1		B2		B3		B4		B5		C1		C2		C3		C4		C5		D1		D2		D3		D4		D5	
	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH	DO	T/pH
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Oxygen Toxicity

- Anaerobic sludge digestions suffers in shallow ponds in windy areas as oxygen rich water rolls down to the anaerobic zone
  - Inhibits the digestion of sludge
- Oxygen barriers or fencing to create undisturbed anaerobic digester pits
- Figures 7.8 to 7.10, p. 119-120

Solutions to Low DO

1. Add aeration
2. Run ponds in parallel if loading is too high
3. Recirculate oxygen from downstream pond to top of primary
4. Remove duck weed, scum, floating mats of algae, sludge
5. Cut down bushes, trees, cattails, willows
6. Stop septage and grease trap waste influent to reduce loading to the pond
7. Can turn off aerator in afternoon and on at night to conserve reserve O_2
8. Pretreatment
9. Chemical solutions to low DO
    a. Sodium nitrate
    b. Peroxide
    c. Probiotics
    d. Magnesium
    e. Phosphorus, nitrogen

Possible Causes of Low DO

Physical influences

- Shading
- Wind obstructions
- Poor aerator placement
- Low retention time

Possible Causes of Low DO

Chemical

- Hydrogen sulfide
- Low alkalinity
- High ammonia levels
- pH > 8.5
- Excess manganese or magnesium
- Colors of grey, black, or red with odors
- Filamentous bacteria
- Purple sulfur bacteria

Possible Causes of Low DO

Biological

- Daphnis or rotifers
- Clear water
- Low algae populations
- Blue green algae mats

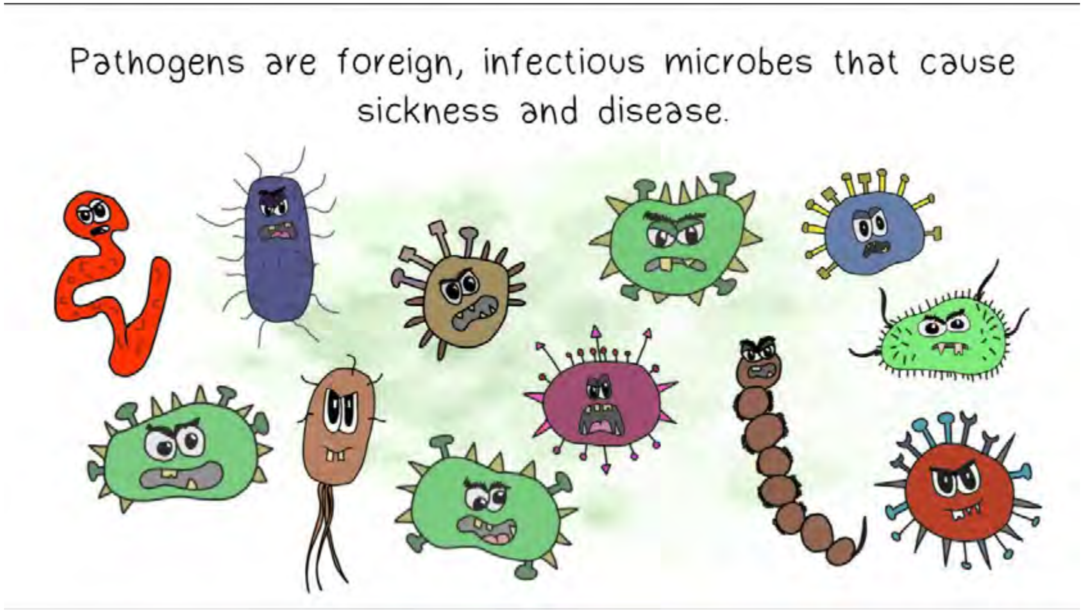
Quiz

1. If a facultative lagoon is not aerated, how is oxygen provided to the system?
2. You should maintain DO concentrations >3mg/l in lagoons. (T/F)
3. DO concentrations should be measured multiple times per day at different locations and depths. (T/F)

Pathogens

Fecal contaminated water can transmit diseases such as:

- Typhoid fever
- Dysentery
- Cholera
- Hepatitus
- Polio
- Gastroenteritic
  - Entamoeba
  - Giardia
  - Cryptosporidia
- Ascariasis and other intestinal diseases caused by parasites (e.g., tape worm, round worm, hook worm)



What EPA Inspectors Look for

1. Scheduled inspection of pond lining and levees
2. Weed control program
3. Insect control in the vicinity
4. Burrowing animal control
5. Regular site inspections of lagoons and facilities
6. Daily readings of aerator operating times
7. All non-operating equipment must be tested once a month

EPA's recommended process control checklist: p. 166

Record Keeping

1. Preventive maintenance records (for each piece of equipment)
2. Preventive maintenance schedule
3. Service report cards
4. Where parts can be purchased
5. Spare parts inventory
6. Operation and maintenance instructions
7. Specifications on equipment from suppliers
8. Equipment inventory

Pond Modifications for Cold Weather Operations

Anaerobic Ponds

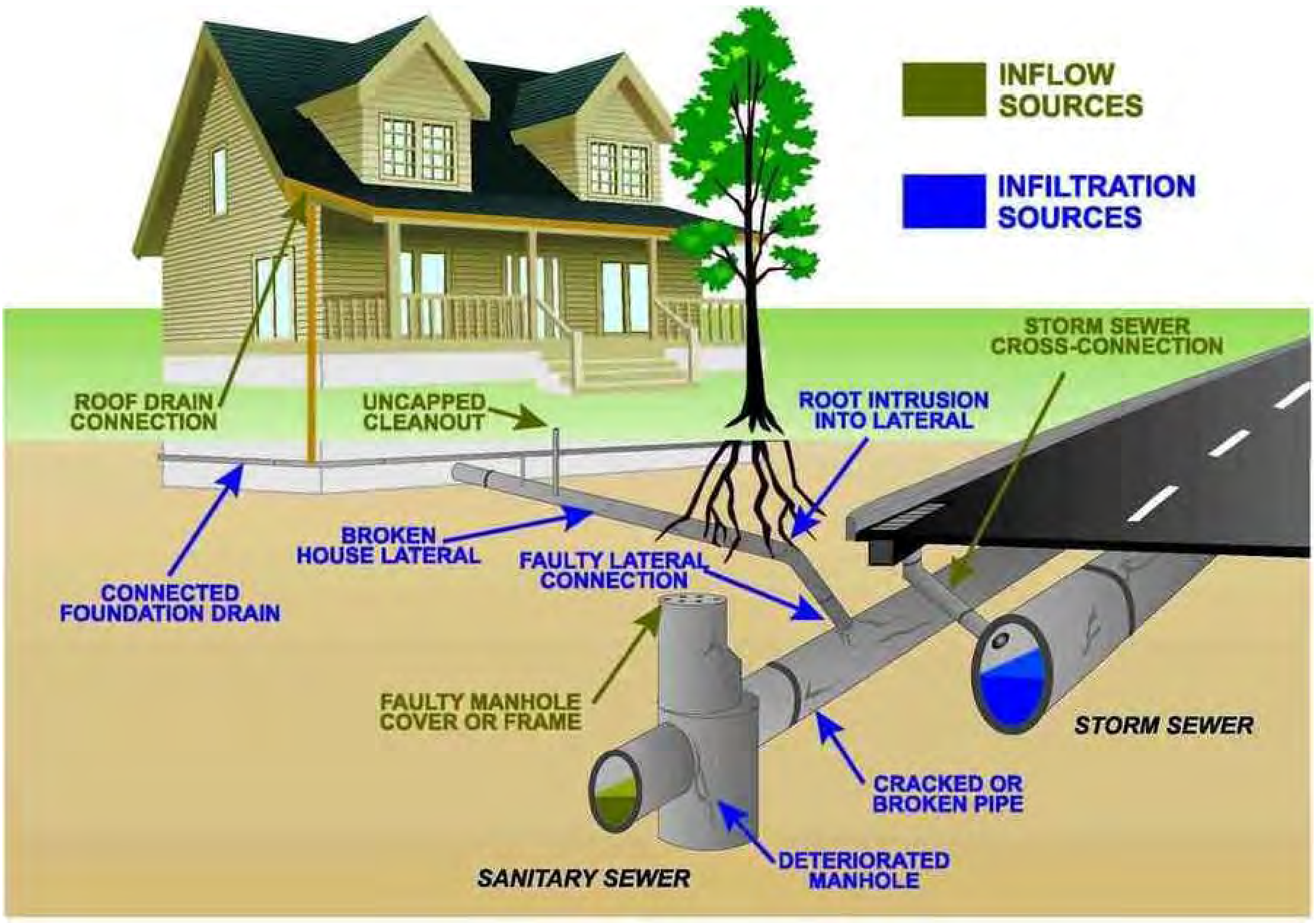
- Deep digestion pits can be dug into existing lagoons, cell depth of 12 to 16 feet
- Digestion pits are warmed from influent
- Short retention times maximize heat storage (2 to 4 days)
- p. 180

C. WASTEWATER COLLECTIONS

Collection System Components

- Laterals
- Branch sewer
- Sewer main
- Collectors or subcollectors
- Trunk lines
- Interceptors
- Wastewater treatment location
- Lift stations
- Manholes
- Vents
- Junction boxes

Infiltration and Inflow



Gravity Collection System

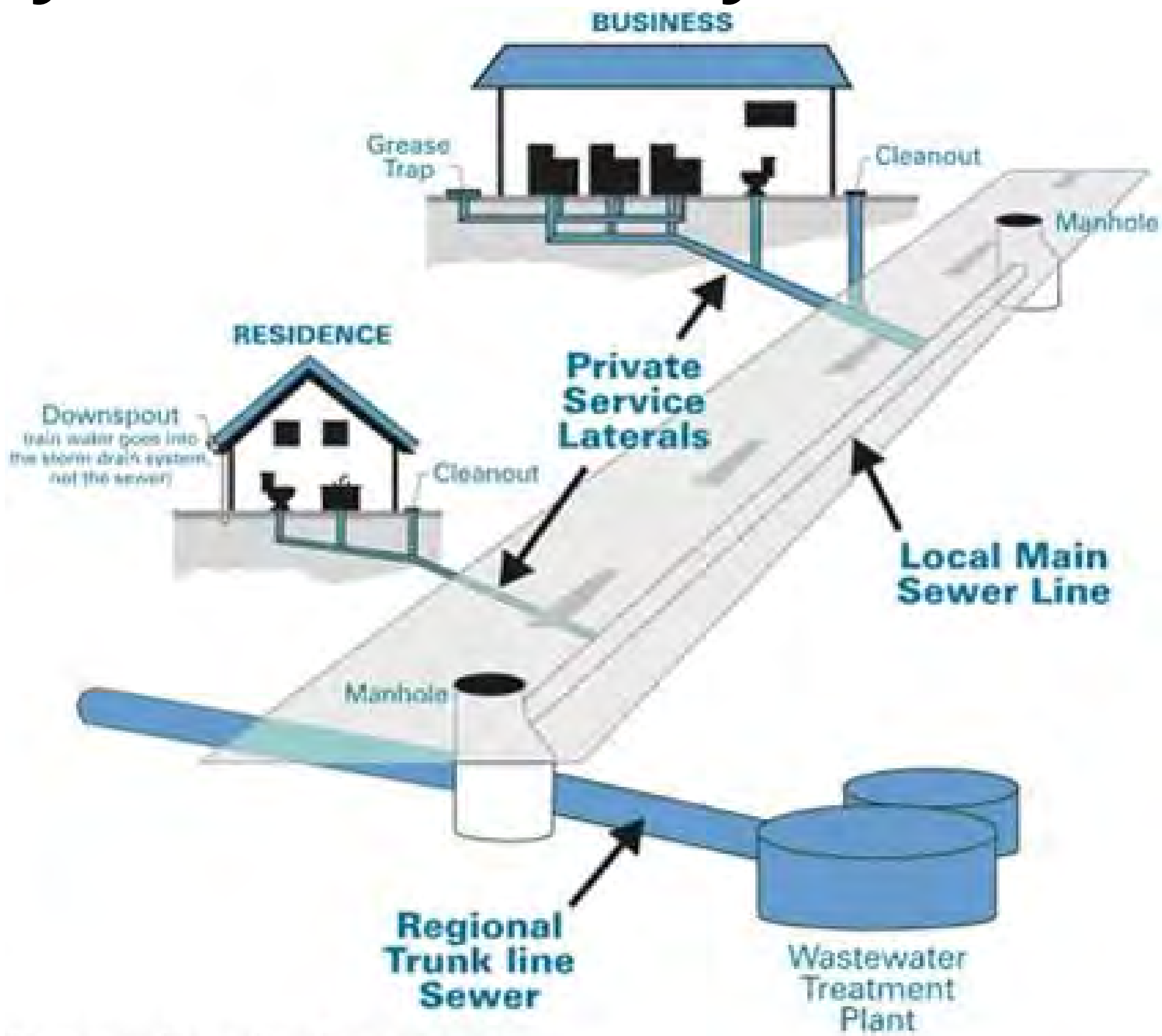
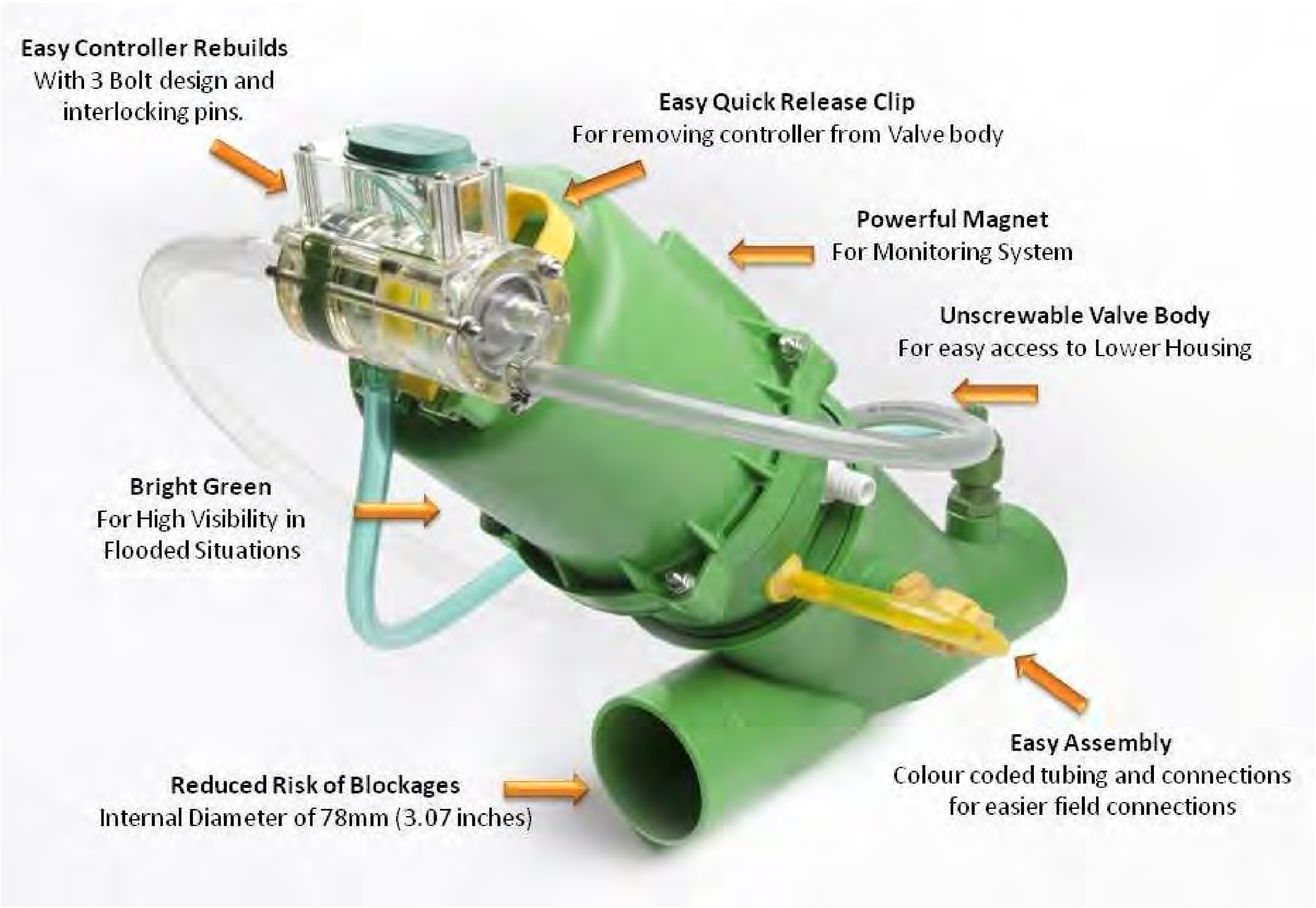


Diagram of a sanitary sewer system

Vacuum Collection System



Materials of Construction

- Plastic pipe
- Vitrified clay
- Reinforced concrete
- Ductile iron
- Cast iron
- Asbestos cement
- Joints and couplings

Collection System Piping

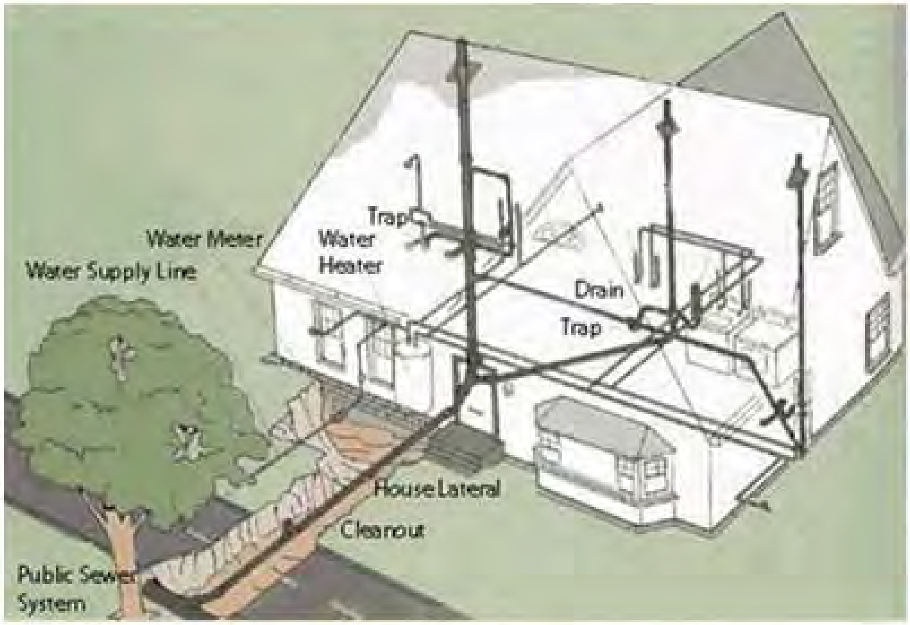
- Vitrified clay (VCP)
- Concrete (CP)
- Ductile iron (DI)
- Asbestos cement (AC)
- Polyvinyl chloride (PVC)
- High density polyethylene (HDPE)

Backflow Preventer

- Designed to only allow flow in one direction
- Prevent [illegible] omes

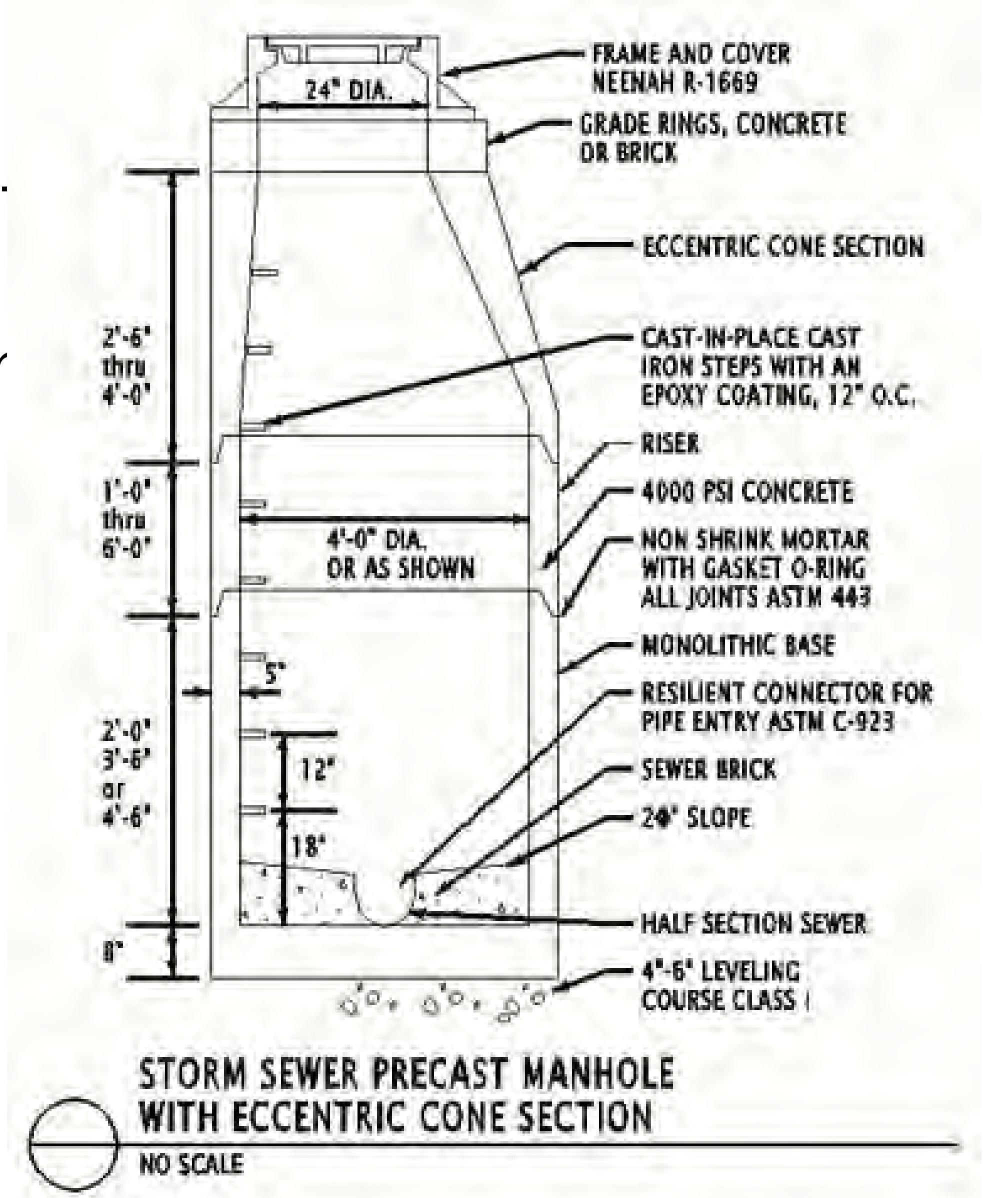
House/Building Connections

- Typically 4-inch diameter for service laterals
- Cleanouts for each connection
- Tie directly into the main



Manholes

- Manholes are placed a
  changes in direction,
  elevation, pipe sizes, ar
  junctions



Collection System Nomenclature

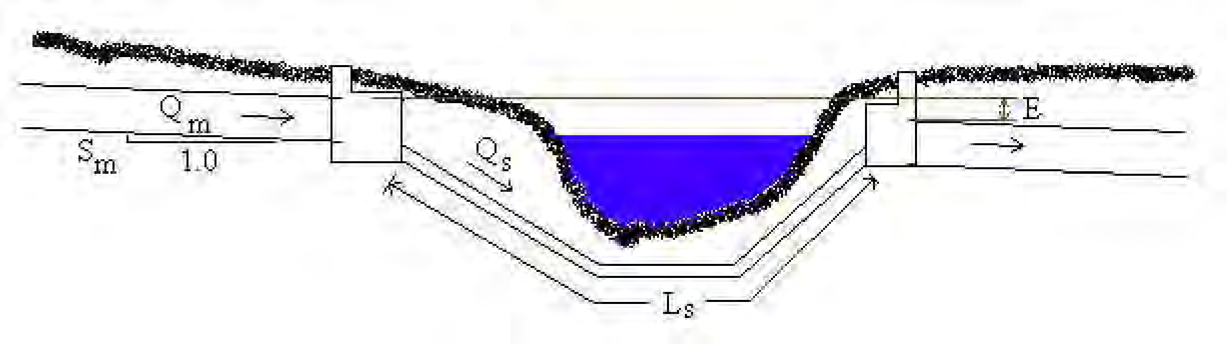
- Tap: A sewer tap is a means of connecting to an existing sewer line
- Saddle tap: A saddle is a pliable device placed over the newly cut hole in the sewer line and held in place with clamps
- Calder coupling: Flexible coupling used to connect two pipes together
- Inverted siphon: Section of sewer line used to carry wastewater under a depression
  - Stream
  - Storm sewer
  - Large water line

Appurtenances

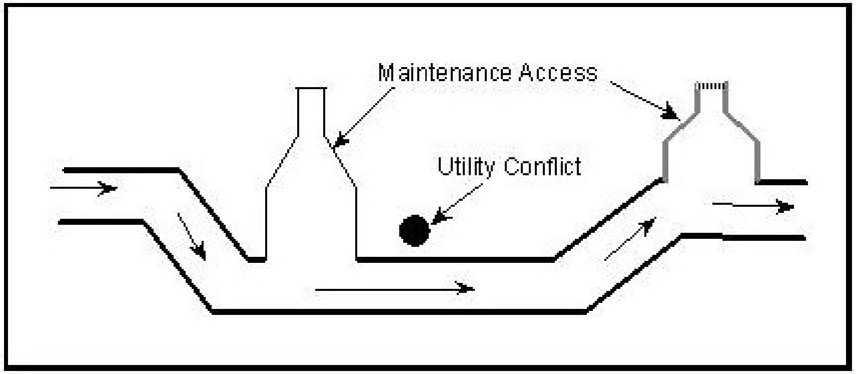
Tap and Saddle Tap

Calder Coupling

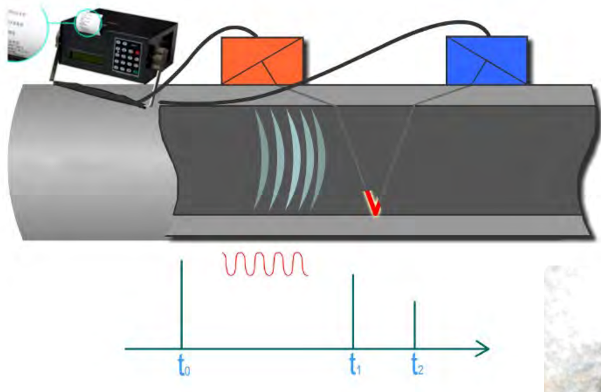
Inverted Siphon



Inverted Siphon



Flow Meters



Odor Control

Under anaerobic (septic) wastewater conditions, sulfides cannot be oxidized. Therefore, they combine with hydrogen to produce hydrogen sulfide gas, creating the "rotten egg" odor associated with septic wastewater.

Components of a Lift Station

- Wet well
- Flow distribution
- Operating levels
- Wet well access
- Wet well inlet channel
- Wet well safety
- Wet well hardware
- Wet well electrical systems
- Bar racks
- Dry wells
- Radio communication
- Backup generator
- Check valves

Wet Well/Submersible Pumps

- Wet wells are essentially holding tanks
- Wastewater flows into the wet well by gravity
- Wet well contains submersible pumps
- Level controls (floats) tell the pumps when to turn on/off
- Wastewater is pumped out of the wet well through a force main

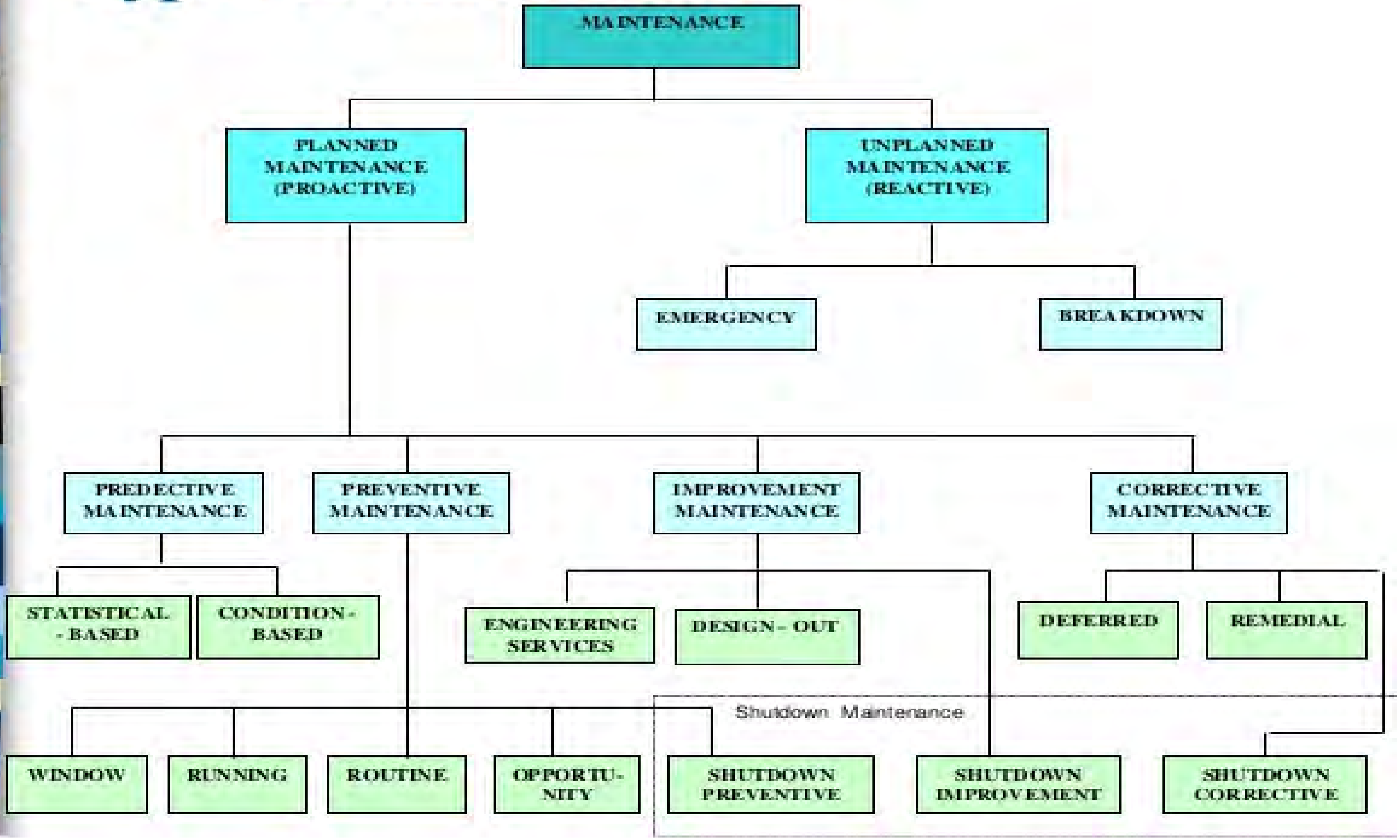
Valve Vault

Gate Valves

Plug Valves

Check Valves

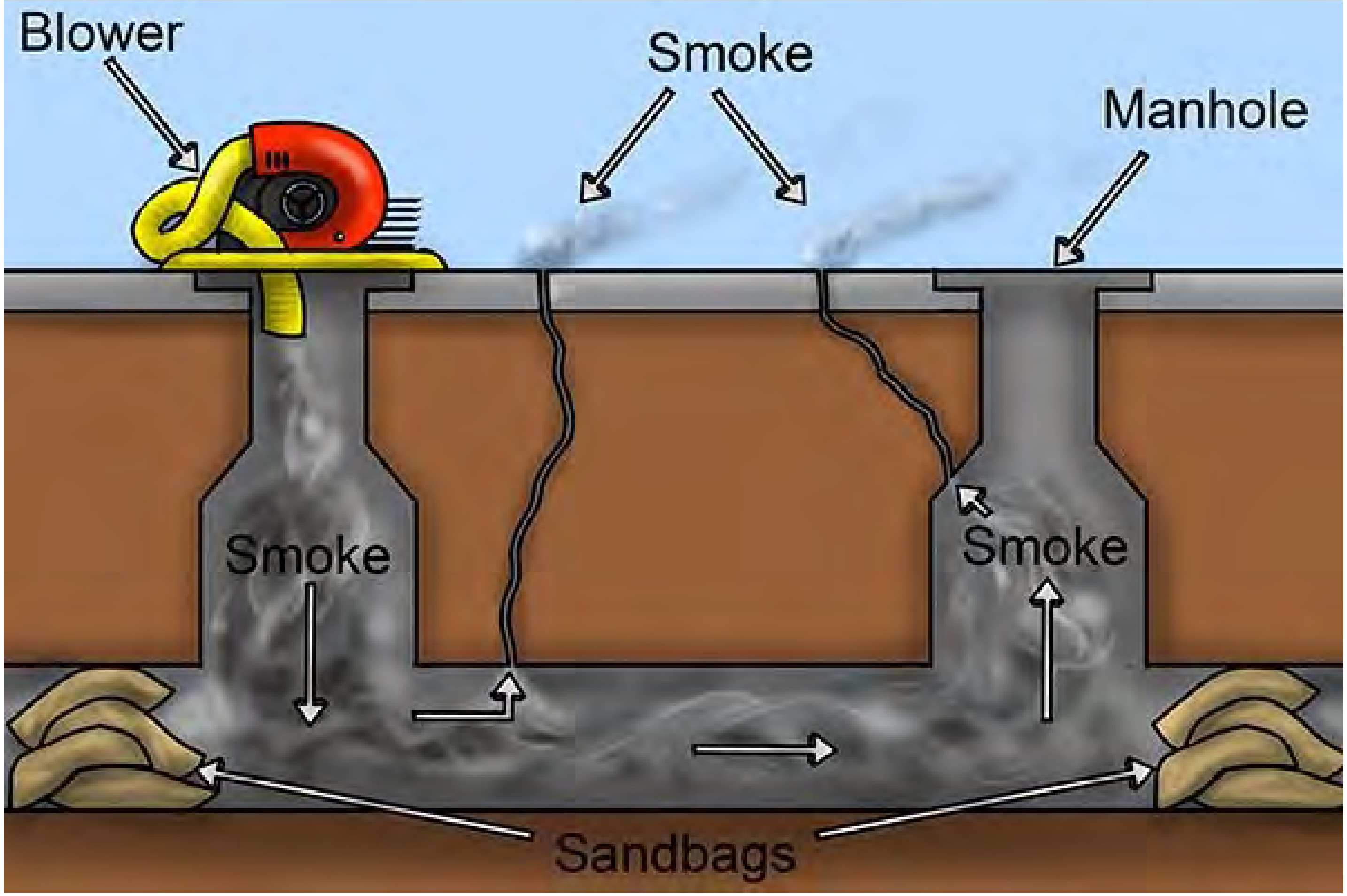
Types of Maintenance



Collection System Testing

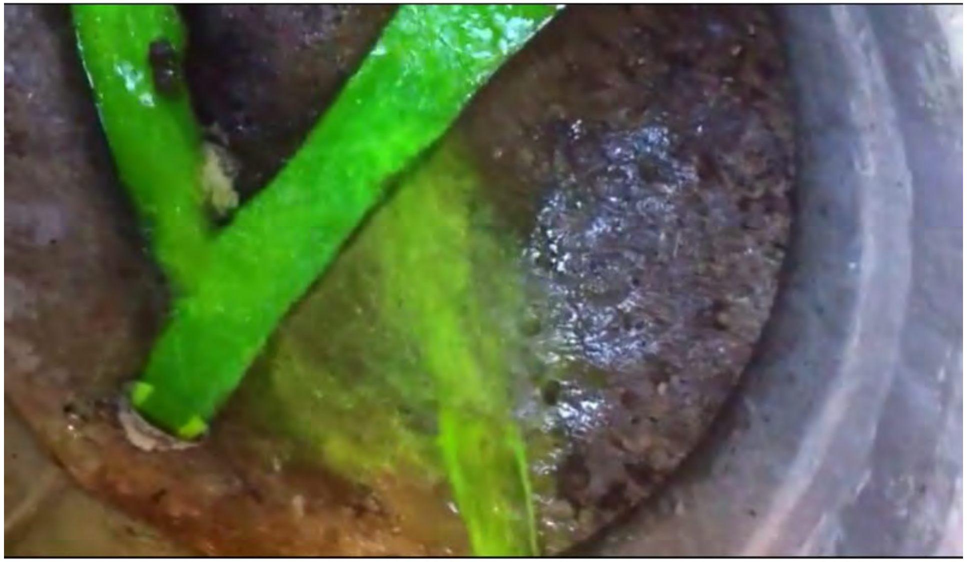
- Sewer system testing techniques are often used to identify leaks which allow unwanted infiltration into the sewer system and determine the location of illicit connections and other sources of stormwater flow.
- Two common types of testing:
  - Smoke testing
  - Dye water testing

Smoke Testing



Dye Water Testing

- Concentrated colored dye
- Establish connections
- Confirm smoke test results
- Test for structure damage
- Customer involvement
- Determine flow characteristics:
  - Velocities
  - Patterns
  - Directions



Closed Circuit TV (CCTV)

Grease Control

- Grease trap control
- Fats, oil, and grease (FOG)
- Grease traps must be maintained by businesses
- Restaurant protocol
- FOG ordinances
- Decomposing material will increase hydrogen sulfide gas
- Grease control agents:
  - Bio-acids
  - Digesters
  - Enzymes
  - Bacteria cultures
  - Catalysts
  - Caustics
  - Hydroxides
  - Neutralizers

Industrial Pretreatment

- Industrial pretreatment is when the customers treat their wastewater before discharging it to the sewer system.
- This could be chemical treatment such as pH adjustment or physical treatment such as a grease trap

Safety

- OSHA requirements: chemical hazards
- Confined space procedures
- Electrical hazards
- Lockout/tagout procedures
- Bloodborne pathogen hazards
- Personal protection equipment
- Atmospheric hazards
- Traffic control
- Excavation procedures

Federal regulations

- Clean Water Act
- National Pollutant Discharge Elimination System (NPDES) Program
- Combined Sewer Overflow Control Program
- Great Lakes, Upper Mississippi River

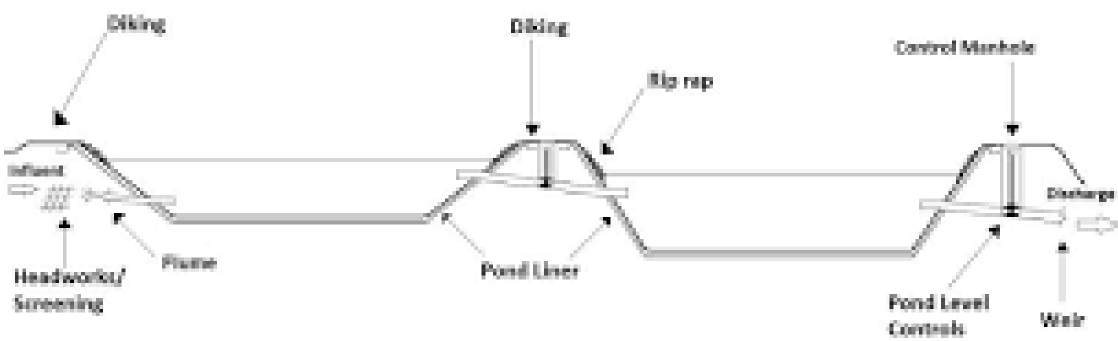
D. LAGOON DESIGN, CONSTRUCTION, AND ADVANCED TREATMENT

Design Criteria

- Loading rates
- Flow
- HRT
- Location
- Soil conditions
- Wastewater characteristics
- Pond configuration and shape
- Inlet/outlet structures
- Hydraulics
- Treated effluent disposal
- Solids disposal
- Flow measuring devices
- Inlet/outlet structures
- Note:
  - Each state has different design standards

Pond Configuration

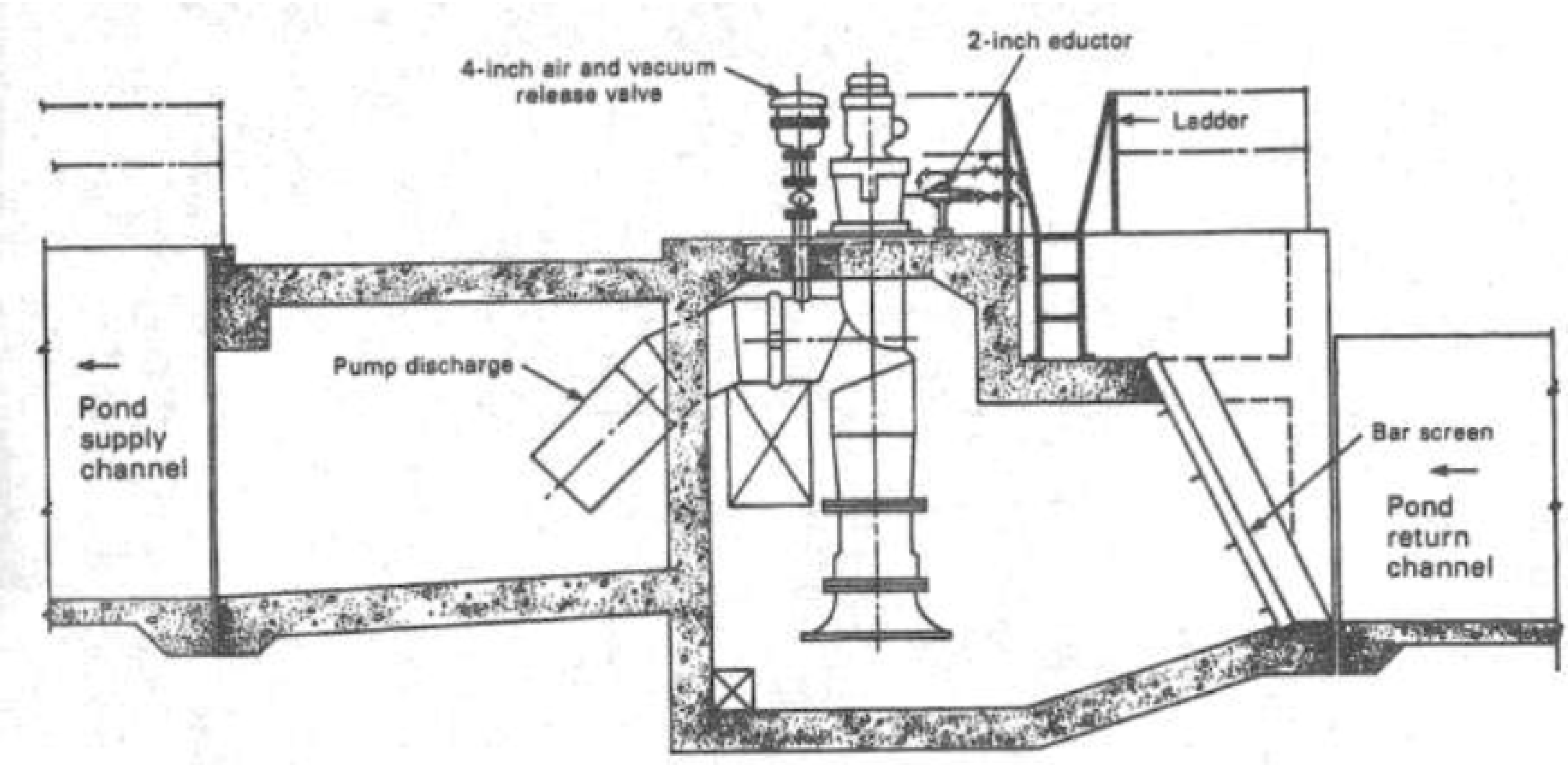
- Number of impoundments needed is decided during design
- Operated in series or parallel
  - Pipes connecting each pond
  - Valves to isolate each pond
  - Separate influent pipe to each pond



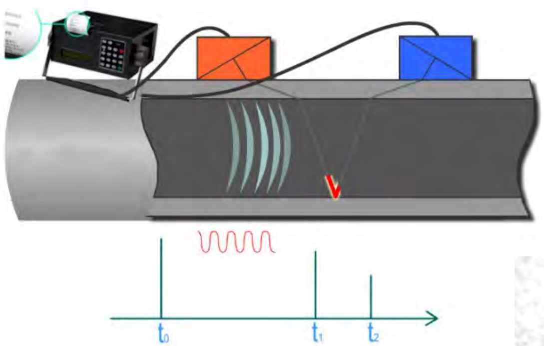
Bentonite Clay Liners

Geosynthetic Liners

Pond Recirculation



Flow Measuring Devices



Inlet/Outlet Structures

- Design and placement avoids short-circuiting
- Split influent between lagoons
- Split effluent to recirculate or discharge
- Must be sealed properly
- Aligned perpendicular to wind

Headworks/Screening

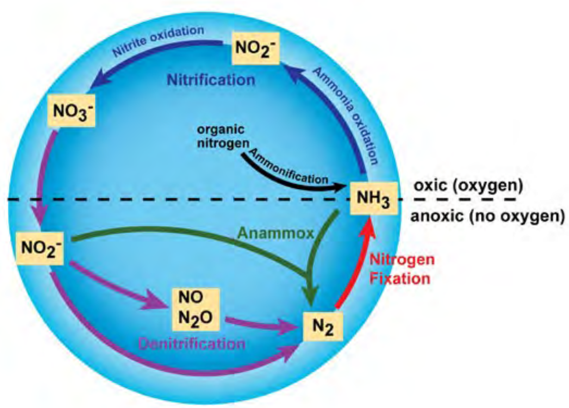
- Remove trash/solids from influent

Quiz

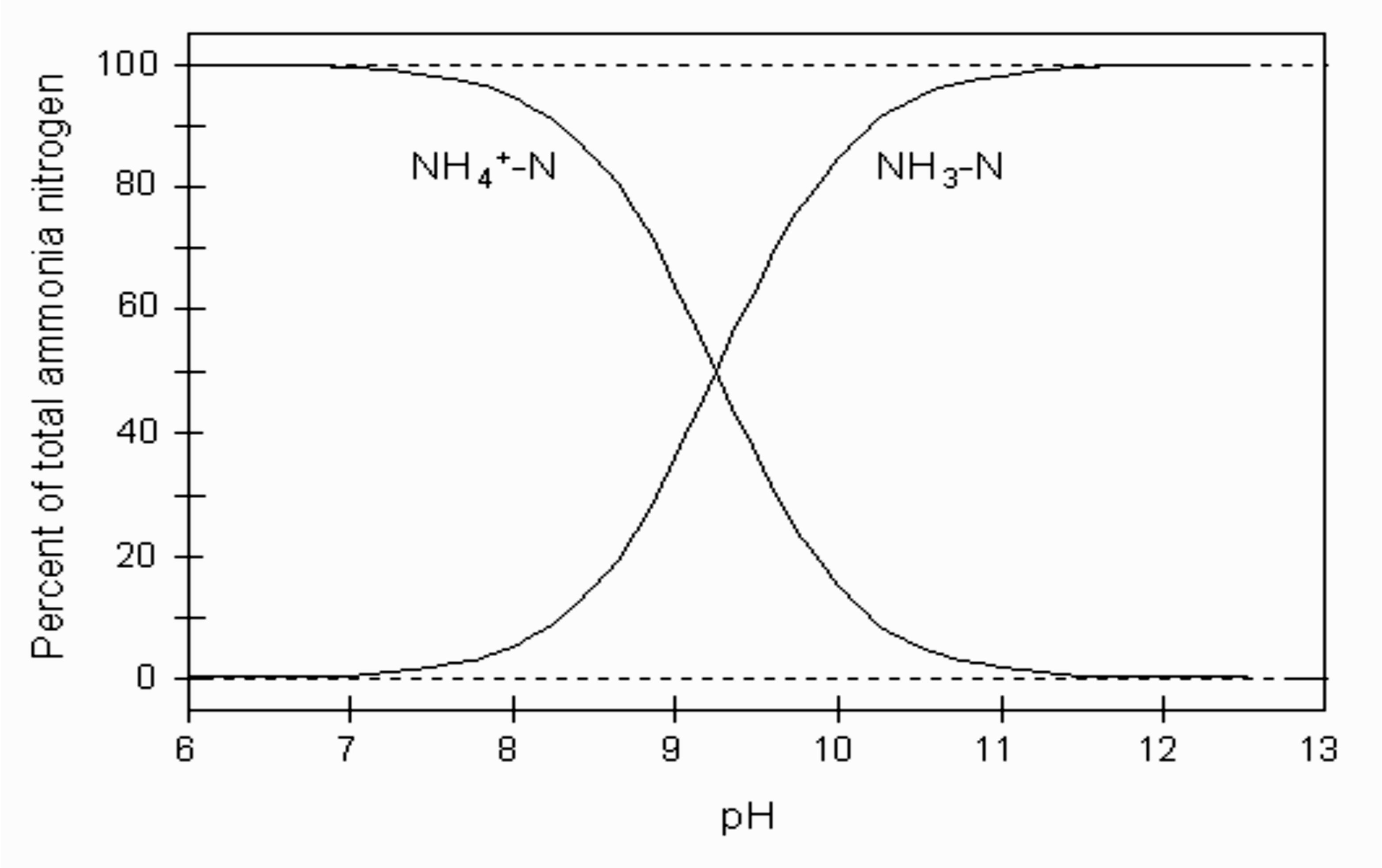
1. What are the two ways in which ponds are operated?
2. Why are liners necessary?
3. What materials are the typical liners constructed of?

Chemical Reactions of Nitrification/Denitrification

Process	Reaction
Fixation	$N_2\,(g) + 8H^+ + 8e^- \rightarrow 2NH_3\,(g) + H_2\,(g)$
Ammonification	$NH_2\text{-}CO\text{-}NH_2 + H_2O\,(l) \rightarrow 2NH_3(g) + CO_2\,(g)$
Nitrification (Two Steps)	(1) $NH_4^+ + 1.5O_2\,(g) \rightarrow NO_2^- + 2H^+ + H_2O\,(l)$ (2) $NO_2^- + 0.5O_2\,(g) \rightarrow NO_3^-$
Denitrification	$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$



Ammonium ion vs. unionized ammonia - pH and temp sensitive



Phosphorus Removal

Removal of Ortho-P may Occur Through:

1. Enhanced Biological Update
2. Chemical Precipitation

Questions?

POST-

Post-Quiz

1. What’s an example of preliminary treatment?
2. What an example of primary treatment?
3. What’s an example of secondary treatment?
4. What’s an example of tertiary treatment?
5. What are some characteristics of wastewater?
6. What does preliminary treatment reduce?
7. What do primary clarifiers remove?
8. What does HDT stand for?
9. What are the two types of fixed film treatment processes?
10. What is chlorine contact time and why is it needed?
11. What is a sludge judge?

Post-Quiz

1. What is an example of preliminary treatment?

   Screening

Post-Quiz

2. What is an example of primary treatment?

   Primary clarifier

Post-Quiz

3. What is an example of secondary treatment?

Activated sludge

Post-Quiz

4. What is an example of tertiary treatment?

   Disinfection

Post-Quiz

5. What are some characteristics of wastewater?

BOD, COD, TSS

Post-Quiz

6. What does preliminary treatment reduce?

Trash, rags, FOG

Post-Quiz

7. What do primary clarifiers remove?

    BOD, TSS

Post-Quiz

8. What does HDT stand for?

   Hydraulic Detention Time

Post-Quiz

9. What are the two types of fixed-film treatment processes?

RBCs and trickling filters

Post-Quiz

10. What is chlorine contact time, and why is it needed?

    Measurement of length of time it takes for chlorine (most commonly used water-treatment disinfectant) or other disinfectants to kill *giardia lamblia* at a given disinfectant concentration. Needed to effectively kill the pathogens.

Post-Quiz

11. What is a sludge judge?

Clear tube used to measure depth of sludge

2. EXAM