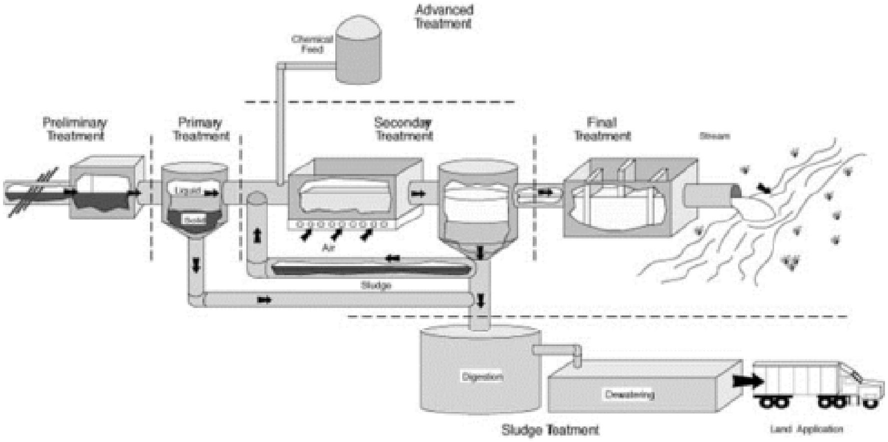
# Introduction to Wastewater Week 2




Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

# Introduction to Wastewater Treatment

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# Activated Sludge Part II

## Recap from Part I

- ***Activated Sludge***: is a biological treatment process utilizing mixing and aeration to form flocs in the suspended column.
- This fundamental process is the heart of activated sludge treatment
- Organics + $O_2$ + nutrients + inert matter → $CO_2$ + $H_20$ + new microorganisms + additional inert matter

# Recap from Part I

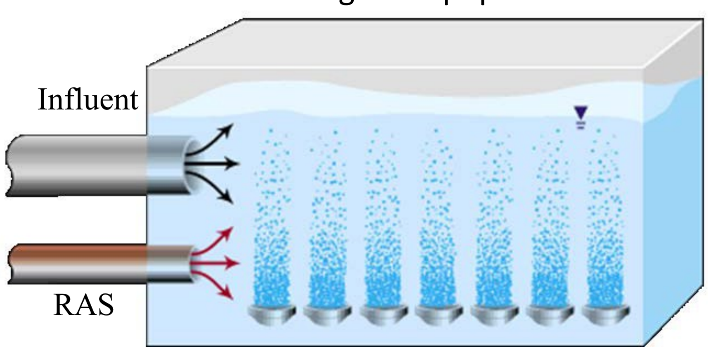

# Activated Sludge Process Design

- Plug-flow (conventional)
- Step Feed
- Contact Stabilization
- Bardenpho
- Kraus
- Pure Oxygen
- Complete mix
- Extended aeration
- Oxidation ditches
- High-rate aeration


**BUBBLES**

## Biological Reactors

- Biological reactors provide oxygen and mixing that promote contact with waste
- RAS maintains the microorganism population



## Biological Reactors

- In biological reactors, adequate DO must be maintained.

The typical concentration range for most reactors is:

“1.0 to 4.0 mg/L, with 2.0 being optimum”

- You need 2.0 DO for Ammonia removal, 1.0 DO for BOD removal (SAC)

## Note

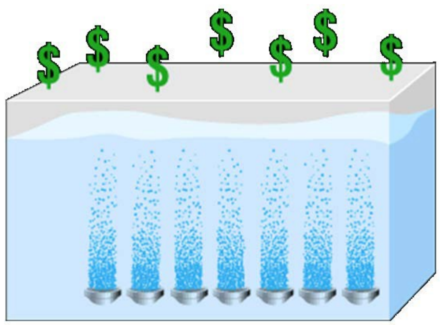
***Off/on aeration*** is simply turning aerators/blowers/mixers/ on and off periodically

This allows for lower costs and has been found to ***optimize*** plant performance

Discussed more later

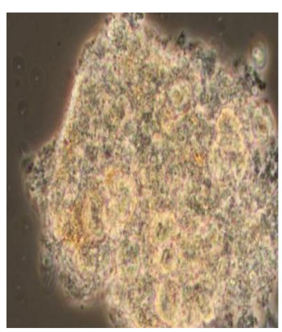
## Over Aeration

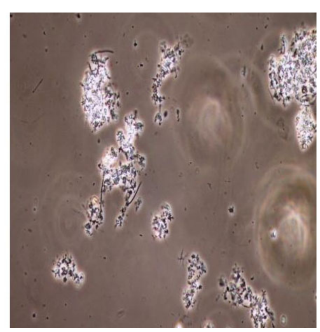
- Adding dissolved oxygen to the mixed liquor creates the highest single electrical demand at most activated sludge facilities
  - Can account for 40-70% of the total power demand at a typical plant
- Over aerated basins at DO levels of 6 mg/L or more can ***shear the floc*** and waste energy.



## Note

- ***Shear floc*** is the phenomenon when you over aerate MLSS causing the floc particles to be torn apart.





- Results in poor settleability.
  - Causes *pin floc*

# Pure Oxygen System

- Chattanooga, TN

- Pure oxygen systems use mechanical mixers similar to a complete mix plant but in a covered tank
- This process has the smallest biological reactor (Dr. Moore)

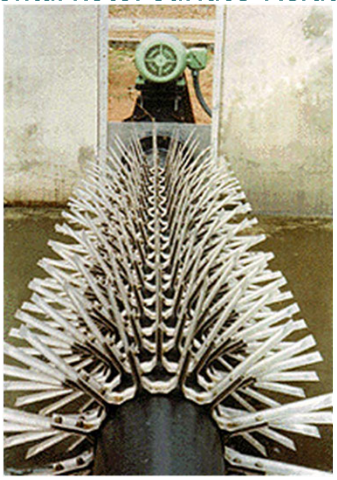
# Aeration Systems

- Surface aerators
- Diffused aeration systems
- Hybrid devices

Old style

## Surface Aerators

**Horizontal Rotor Surface Aerator**



**Surface Aerator**

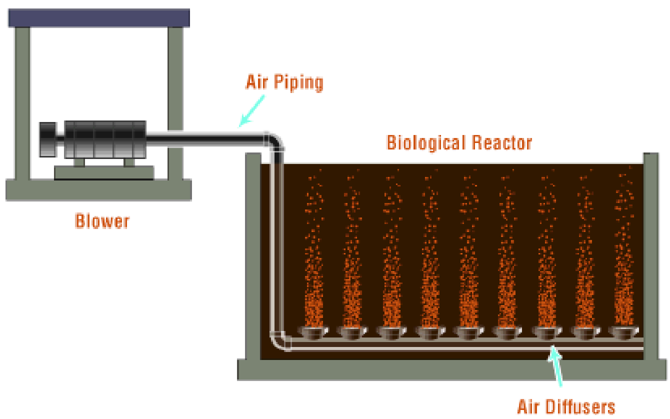
(Also subsurface mixers)

## Surface Aerators

- For surface aerators, the most common way to control the DO and mixing is through the use of variable-speed motors
- Typically, a two-speed motor is used
- Often generates splashing and mist
- ***Aspirators***

***Aspirator***-a pontoon device that draws air into the vent and expels it through a nozzle in the mixed liquor

## Diffused Aeration System




## Diffused Aeration Systems

- Air System
  - Filters
  - Valves & Controls
  - Blower & Motor
  - Piping
- Diffusers
  - Coarse Bubble: Non-Porous
  - Fine Bubble: Porous
    - Ceramic (old)
    - Rubber (new)
    - Domes/Disks
    - Plates
    - Tubes

## Note

**It is critical to keep air filters clean**

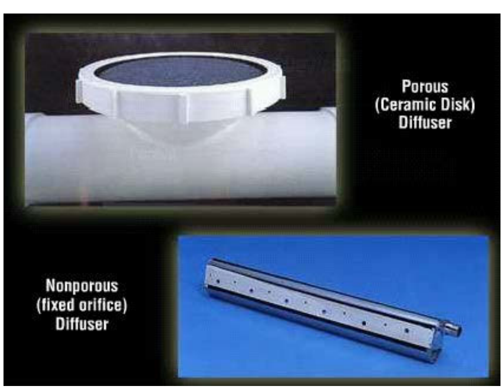
Obstruction in the flow of oxygen leads to less efficient and effective aeration.

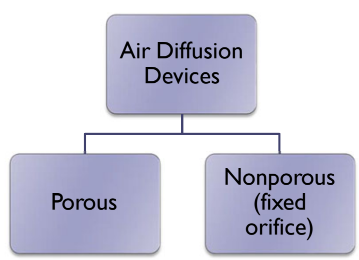
When sludge starts to clog the diffusers and impede the flow of oxygen, it causes backpressure that puts pressure on the blower and aeration tank. It can make the blowers have to work harder and increase the power consumption of the plant.

Increased backpressure, which causes excessive wear and tear on the blowers, also decreases blower lifespan.

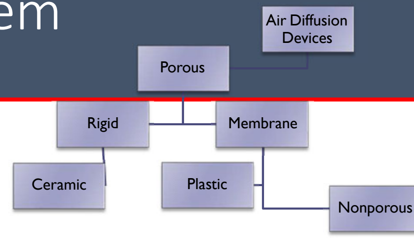
## Diffused Aeration System

- Because the terms "fine bubble diffuser" and "coarse bubble" diffuser are often not clearly defined, the use of these designations can be very confusing

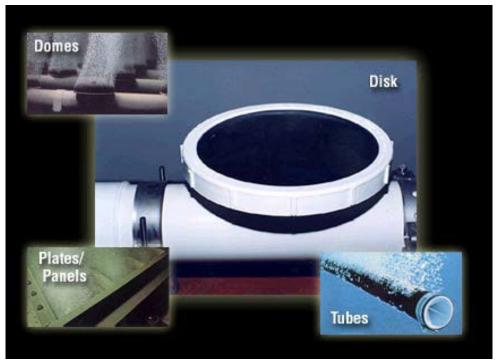


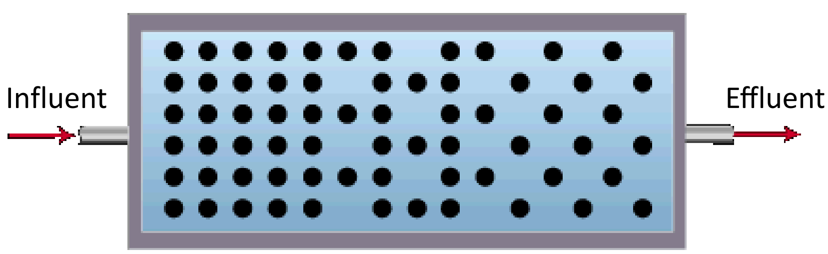
## Diffused Aeration System



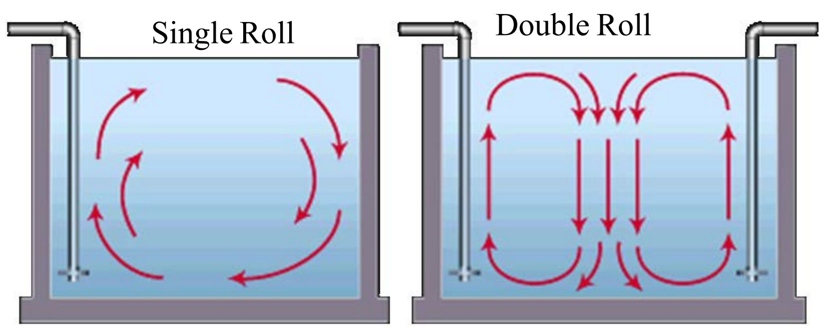

- Membrane Diffuser




## Biological Reactor



# Mixing with Aeration,Conventional




# Aeration

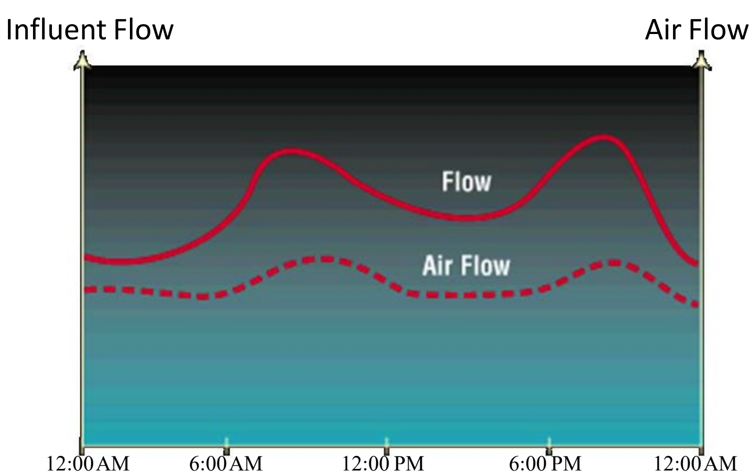
- Maintenance is required on aeration systems air filters
  - A dirty air filter will be the most probable cause for a drop in blower output
  - This can be determined by reading the differential pressure between the intake and the discharge of the filter or using a manometer
    - When using a manometer (mercury filled), if the reading increases more than two or more inches from the initial reading,the air filter should be cleaned
    - Shut off the blower and tag and lock out for safety

## Note

Manometer = measures pressure.

You could gauge your maintenance needs off of this.

## Influent Flow vs. Air Flow



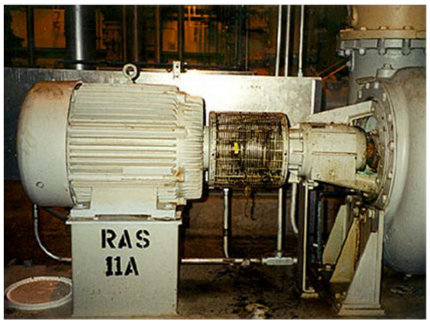

You can have DO meters in the basin that control the amount of diffusion, or you could use DO meter to dictate aeration.

## Off/On Aeration (Pulsed, Cyclic, Phased)

- Increasingly used for nutrient removal
- Aeration equipment is cycled "ON" and then "OFF" to select for different types of bacterial metabolism
- Aerobic- Oxic- free oxygen is present, used for CBOD removal and a must for ammonia & phosphorus removal
- Anoxic- no free oxygen, but there is the bound oxygen nitrate & nitrite ($NO_3$ & $NO_2$) for CBOD removal and Total Nitrogen removal
- Anaerobic- fermentation is beginning, no free oxygen, no $NO_3$ & $NO_2$, but there are other forms of combined oxygen like $SO_4$, $CO_2$-$HCO_3$-$CO_3$, needed for phosphorus removal

**Return Activated Sludge Systems**

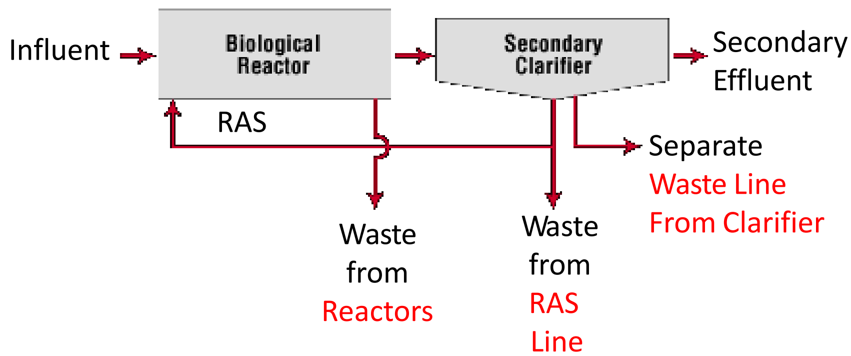
## Centrifugal RAS Pump




- Return sludge results high MLSS and fast treatment
- It is very important to have the RAS enter the biological reactors at a point where thorough mixing occurs
- There are 2 methods of RAS rates:
  - Constant return rates
  - Rate based on % of influent flow
    - 25-40%

## Waste Activated Sludge Systems

# Waste Sludge Options




- WAS from RAS line is usually most common. In this case, the RAS concentration would be the same as the WAS concentration.

# Waste Sludge Options

- The amount of sludge wasted from the process affects all the following:
  - Growth rate of microorganisms
  - Oxygen consumption
  - Mixed liquor settleability
  - Nutrient quantities needed
  - Occurrence of foaming/frothing
  - Possibility of nitrification
  - Effluent quality

## Waste Sludge Options

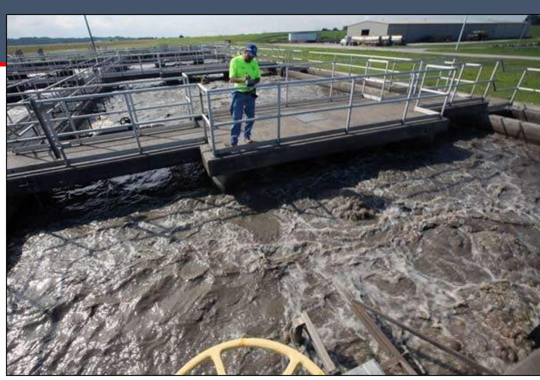
- Increasing the wasting rate will:
  - Decrease the MLSS concentration
  - Decrease the MCRT
  - Increase the F:M ratio
  - ~Increase the SVI

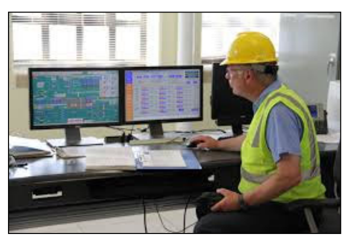
## Wasting Rates

- MLVSS that need to be wasted accumulate primarily from new cell production by the microorganisms.
- If you fail to waste the correct amount, you will unintentionally waste solids by losing suspended solids in the effluent.
  - A gradual increase in the amount of solids over the weirs of the secondary clarifier is usually an indication that the WAS is too low.

## Wasting Rates

- If the WAS is not adequate, the microorganisms maystarve, the F:M will decrease, sludge blanket and MLSS will increase and the effluent may deteriorate after a period of time.
- The most important feature of a WAS pumping system is its flexibility to allow different wasting rates.
  - Develop a wasting strategy that works best for your facility.
    - Wasting could be once a day for bigger plants, or once/twice a week for smaller plants.





**Process Control**

We know a lot, but poor performance does occur.

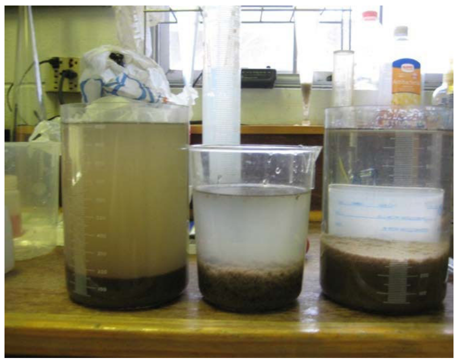
## How do you control your activated sludge process?

- How do you get the results you want?
- What results do you want?

## Process Control

- If the process is right the results will be right
- Operators use the tools provided to adjust the Activated Sludge process,
  - i.e. the environment that the bugs live in, so the bugs make good effluent

# Process Control



- Process Control Goal:
  - Stable Process that meets regulatory requirements
  - Know the plant and process
  - Monitor the process
  - Adjust the process

Note supernatant clarity

# Process Variables: Influent

- Influent
  - Flow:
    - Normal
    - Low~weekend
    - High~rainwater flooding
  - Type of Pollutant:
    Organic- CBOD, FOG, Chlororganic compounds, hydrocarbons.
    Organic nitrogen or ammonia
  - Concentration of the pollutants
  - pH
  - Temperature

# Process Variables: Facilities

- Facility Design
  - Flow Pattern and Sewage Feed Point
  - Type of treatment units:
    - primary clarifier, aeration basins, secondary clarifers, selectors, filters, recycle, RAS, WAS, manual or automatic control and adjustment
  - Number of treatment units

Note the 2 basins attached at front end (bottom left side of picture): these are anaerobic selectors. That flows into 4 anoxic selectors. The oxidation ditches are aerobic. This system was designed for biological removal of phosphorus, Nitrogen, and BOD.

# Process Control Tools

- Adjust
  - Air: flow(cfm),Dissolved Oxygen(DO), concentration (mg/L)
  - Return rate: percent of influent flow, gallons, lbs
  - Waste rate: gallons, lbs

  - Mode of operation: most powerful operator tool but most plants are not designed for this change
  - Number of units used: clarifiers, aeration tanks, blowers
  - Rate and location of sewage feed: mode of operation

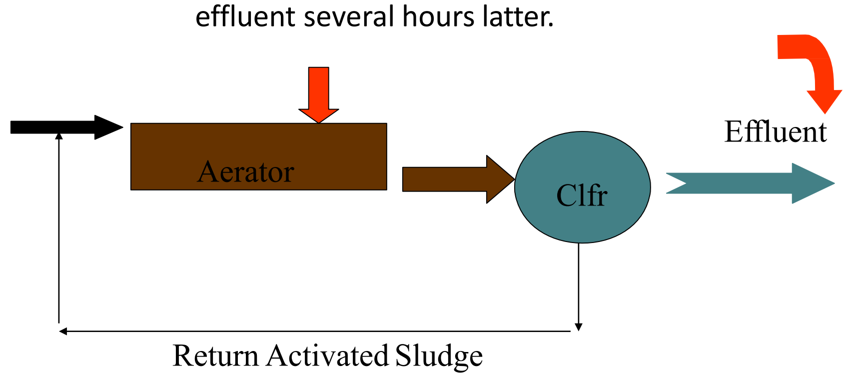
  - Influent control: industrial pretreatment, I/I control, these two often take time

## Process Monitoring Methods

- Human senses
  - Visual appearance, odors, noise, mixing
- Process tests
  - Flow, D.O., pH, temp., alkalinity, ORP, turbidity
  - Settlometer, Sludge judge
  - MLSS, MLVSS
  - Centrifuge spins,TSS meter
  - Microscopic evaluation
  - Oxygen Uptake Rate, Specific Oxygen Uptake Rate

## Process Control

What aerator test "now" will assure you of good effluent? When that water reaches the effluent several hours latter.




*How do we correct what is in the aeration basin so that the effluent will be good?*

## Process Control

- You choose the method that assures you that effluent will meet permit.
- NPDES permit
  - Part II.A.4 Proper Operations and Maintenance
    - "...adequate process controls..."
    - Though almost hidden, this is a Permit requirement
- Find a method that works for you and use it!

- Trouble Shooting
  - Every plant experiences trouble from time to time. Having a Process Control Baseline is important in these events.

## Observations, Aeration Basin

- Odors
  - Fresh plowed field
  - Hog pen
- Turbulence
  - Boiling, dead spots
- Foam and Scum
  - Fresh, crisp, light-colored foam
  - Billowing white foam
  - Thick, scummy, dark foam
- Balanced Flow to All Units

## Sensory Process Control

- Clarifier Issues
  - Bulking, sludge quality
  - Billowing, hydraulic overload
  - Clumping, denitrification
  - Ashing/Pin Floc, old sludge
  - Straggler Floc, young sludge

## Observations- Influent/Effluent Odors, color, solids

foam in effluent (at cascading outfall) due to coagulant/polymer (added for PO4 removal)

## Foam

**Start-up, Recovery, Billowing White Foam**

**Old Sludge,Thick, Scummy, Dark Tan**

## Foam

**Prehistoric Sludge, Black, Thick, Stable**

**Light Crisp Unstable Foam**

# Foam

**Nocardia**

**Industrial Surfactant Foam**

# "Normal" Foam

"Fresh, crisp, light-colored foam"

## Observations, Clarifier

**Rising clumps – Denitrification**

Clumps the size of your fist, look like cow patties floating to the surface. This is generally associated with denitrifying in the sludge blanket.

**Solids Wash Out- High Flow**

Blanket is coming up and over the weir = Bulking blanket and subsequent wash out

## Observations, Clarifier

**Bulking- Filaments**

**Filamentous Scum, M. Parvicella**

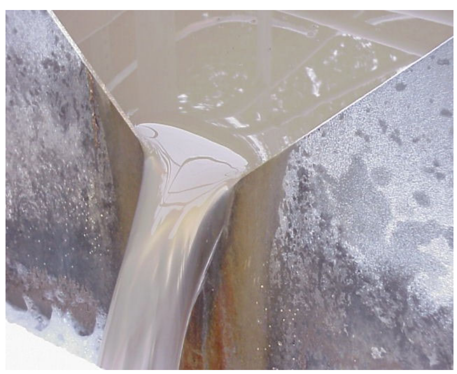
## Observations, Clarifier

**Ashing- Old Sludge Age/Denitrification**

**Pristine Effluent**

## Observations, Effluent

**Clear Mountain Stream vs. Ooops, not a good day**



## Let's Review

| WAS Change | SRT | F:M | MLSS | MLVSS |
|---|---|---|---|---|
| | | | | |
| | | | | |

## Let's Review

RAS Sludge Blanket

RAS Sludge Blanket

Scenario:

**Sludge Bulking??**

## Process Control Testing
## Good Data = Good Decisions

- Sampling Factors:
  - Timely
  - Representative
  - Testing Factors:
    - Timely
    - Unbiased
    - Accurate

- Types:
  - D.O., pH, temp, alkalinity, ORP, turbidity, conductivity
  - Settlometer, Sludge judge
  - MLSS, MLVSS
  - Centrifuge spins,TSS meter
  - Oxygen Uptake Rate, Specific Oxygen Uptake Rate
  - Microscopic evaluation

## Process Control Tests

- Flow Rates, accurate flow measurements of premier importance.
- Locations
  - Influent Q
  - RAS,WAS, other
- Dissolved oxygen
  - Aeration tank effluent
  - Profiles - longitudinal, vertical
  - RAS may be helpful if clarifiers are clumping
  - ***OUR/SOUR***

## Note

***SOUR/OUR = Specific Oxygen Uptake Rate or Oxygen Uptake Rate***

- Shows the rate at which oxygen is used by the bacteria
- Indicates if BOD is being metabolized at a normal rate
- SOUR test removes the variation in uptake rate due to different amounts of MLSS and differing levels of volatile material.
- Reflects changes in BOD and not differing MLSS

40 CFR 503 meet SOUR: less than 1.5 mg/O2/g total solids/h
"proper digestion"

## Process Control, continued

- pH
  - Indicator of toxicity
  - Related to Alkalinity
  - Indicator of nitrification problems

## Process Control, continued

- Temperature
  - Use D.O. meter
  - Affects speed of bacterial metabolism, or perhaps no metabolism!
  - Most common impact is slowing of nitrification, so we allow MLSS to be higher in the winter.
    - when temp drops to 10 degrees C in winter it can cut the biological activity by half.
    - It also affects Denitrification rates, but to a much lower degree.

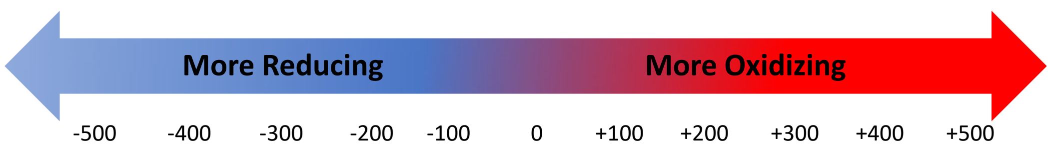
## Process Control, continued

- Alkalinity
  - Necessary for complete nitrification
- ORP-Oxidation Reduction Potential,Redox
  - pH meter with ORP probe
  - Indicated the oxidative state of the solution
  - Most useful where treatment processes continue and DO is 0.0mg/L
- Turbidity
  - Indicator of completeness of flocculation

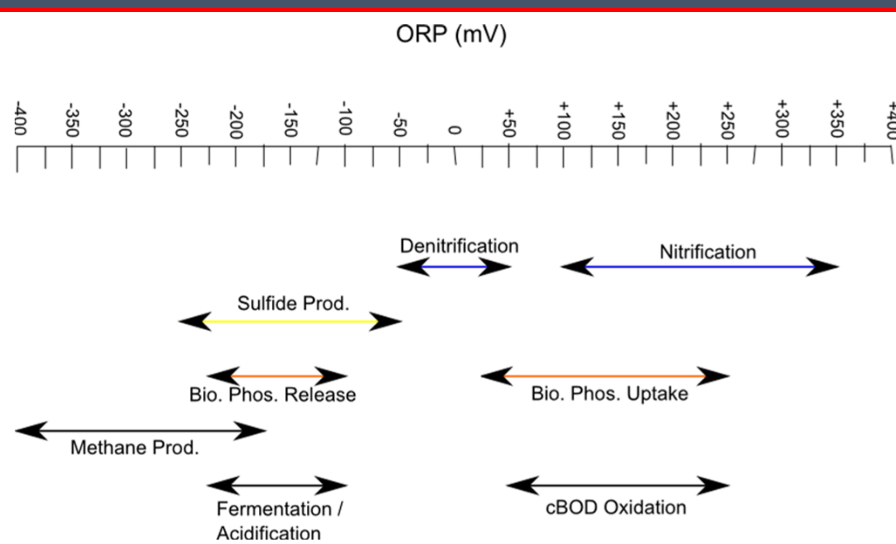
# Note

***ORP- Oxygen Reduction Potential***

- The electrical potential required to transfer electrons from one element to the other
- This is used as a qualitative measure of the state of oxidation in the wastewater
- Measured in millivolts (mV)




# Note



## Process Control, continued

- Settlometer
  - Use settlometer <u>not graduated cylinder</u>
  - Indicator of clarifier performance
  - How well the biomass- settles, compacts, and clears
  - May give mixed signals
- Sludge Judge- Profile of the clarifier
- MLSS, MLVSS, Centrifuge spins, TSS meter
  - Indicators of biomass inventory
  - Most commonly used in TN
- Microbiological Exam

## Sludge Judge, Core Taker

CCSS = Clarifier Core Suspended Solids

- Sludge Judge
  - Depth of blanket- from bottom of clarifier to the top of the sludge layer
  - Depth to blanket - from the top water level down to the top of the sludge blanket
  - Core Sample – the entire contents of the sampler into a bucket
    - Multiple Clarifiers?
      - Combine core samples in one bucket

## Settlometer- benchtop clarifier

- Key Readings
  - 5 min.- indicates how well the sludge settles
  - 30 min.- indicates how well the sludge compacts
  - Clarity of the supernatant- indicates how well the sludge flocculates and clears
  - Blanket quality- flocculation and settling impacts
  - Rise time- indicates how long it may take for the clarifier to clump
- Other Indications
  - Record each 5 min. reading for 30 min.,then each 10 min. reading for the next 30 min.
  - Graph the data, calculate Settled Sludge Concentration.
  - Set RAS rate.

## Settlometer –Use a wide mouth container

Photo from: giaphapmoitruong.net

- Identical MLSS
- Three short settlometers had $SSV_{30}$ = 400
- The graduated cylinders had $SSV_{30}$ = 600
- Takeaway: Narrow cylinders hinder settling

# 5 min. Normal, Dispersed

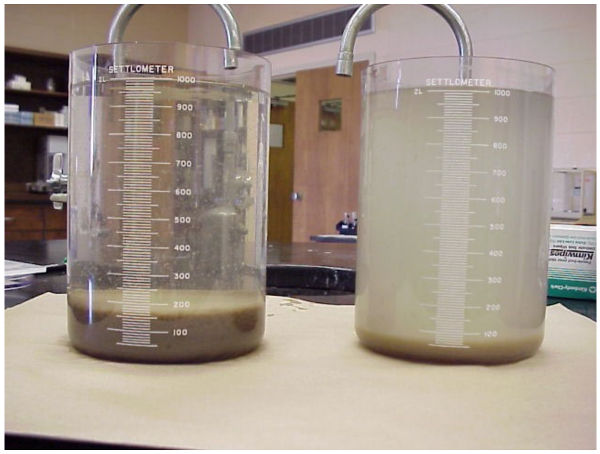
Normal Young

# 10 min.

## 15 min.

## 30 min.

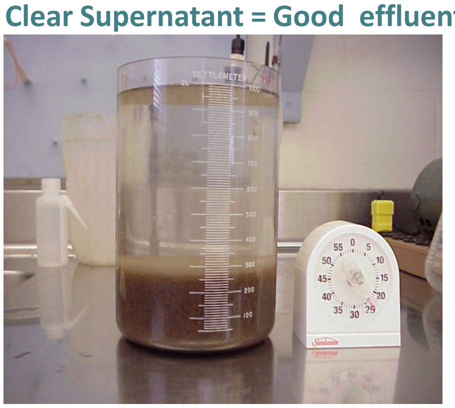
## 30 min. – Right side has dispersed growth, settles poorly



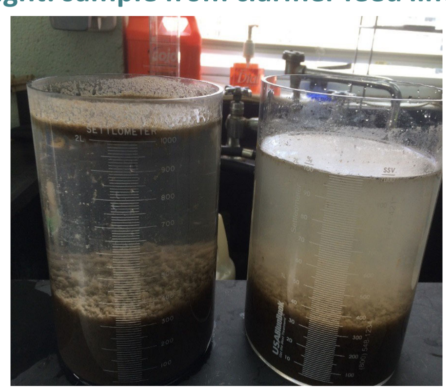

Again, Young Sludge:
- Individual bacteria are growing so fast that they haven't flocked yet
- Sticky coating has not formed/matured yet in young sludge

## Clarity of Supernatant

**Clear Supernatant = Good effluent**

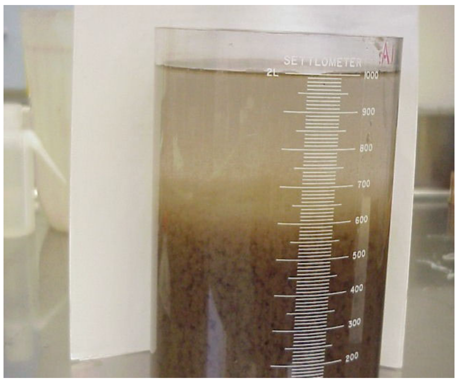


**Left: sample from aerator**
**Right: sample from clarifier feed line**



Floc Shear

## Settlometer, Blanket Observation



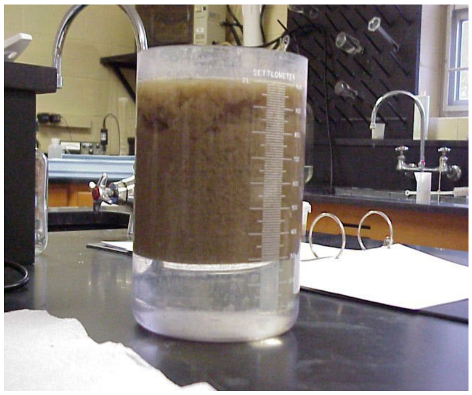
- Blanket Observation
  - Granular, Compact, Fluffy, Feathery
  - Large, Small
  - Blanket, Individual Particles
  - Clear or Cloudy
  - Edge
    - Crisp, spongey, feather-edged, homogeneous

## Settlometer, Blanket Observation

Ohio Environmental Protection Agency

- Filamentous Bacteria
  - Blanket Coning associated with filaments
  - Also very clear supernatant
  - Check Sludge Volume Index (SVI)
    - Calculation that indicates the tendency of aerated solids to thicken or become concentrated during sedimentation/thickening process
    - Greater than 150 may be filaments
    - Greater than 200 probably is filaments

## Settlometer- Rise Time



- RiseTime
  - Allow the Settlometer to sit until the settled blanket floats
  - Short time to rise (<60 min)= high potential for clarifier clumping
  - Long time to rise (>120 min) = far less potential for lumping
  - Look closely to see nitrogen gas bubbles

## Settleometer

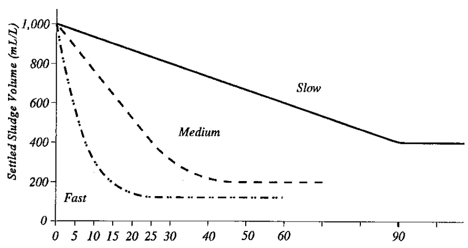
- Reasons for NO Settling:
  - Dispersed Growth
  - Biomass Dead
- Reasons for Slow Settling:
  - Young Biomass
  - Too much Biomass
  - Filaments

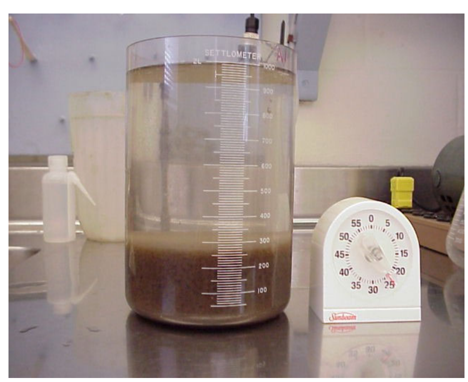
# Settleometer


- Reasons for fast Settling
  - Old over oxidized sludge, with turbid supernatant
  - But wasting is not always the correct reaction, check color, history & SOUR

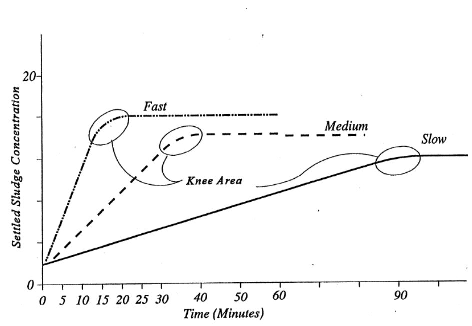
# Settlometer, Graphs

Graph the actual settled volumes, then construct the Settled Sludge Concentration.



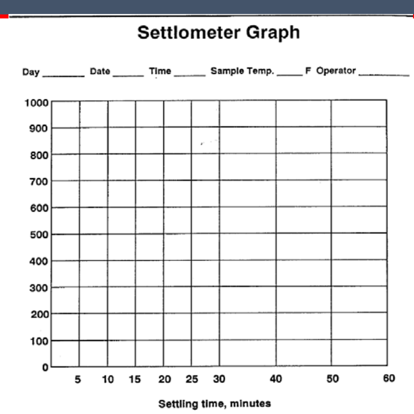



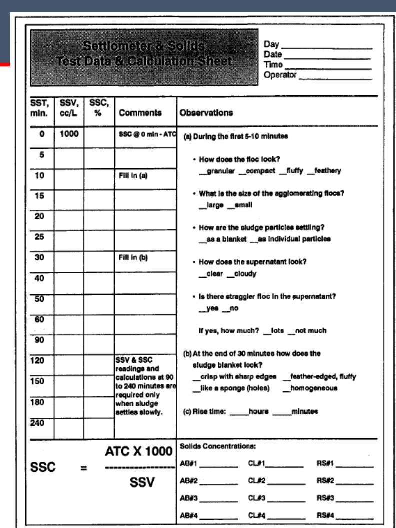
## Settled Sludge Concentration




- Calculated from SSV (Settled Sludge Volume)
- Time zero + MLSS mg/L
- Use 5-10 minute readings
- SSC = $\frac{\text{MLSS} * 1000}{\text{SSV}}$
- Knee area represents the "maximum" thickness that is reasonably possible for the RAS

## Settlometer, Worksheets



**Settlometer & Solids Test Data & Calculation Sheet**

Day ____________
Date ____________
Time ____________
Operator ____________

| SST, min. | SSV, cc/L | SSC, % | Comments |
|---|---|---|---|
| 0 | 1000 | | SSC @ 0 min - ATC |
| 5 | | | |
| 10 | | | Fill in (a) |
| 15 | | | |
| 20 | | | |
| 25 | | | |
| 30 | | | Fill in (b) |
| 40 | | | |
| 50 | | | |
| 60 | | | |
| 90 | | | |
| 120 | | | SSV & SSC readings and calculations at 90 to 240 minutes are required only when sludge settles slowly. |
| 150 | | | |
| 180 | | | |
| 240 | | | |

Observations

(a) During the first 5-10 minutes

- How does the floc look?
  __granular __compact __fluffy __feathery
- What is the size of the agglomerating flocs?
  __large __small
- How are the sludge particles settling?
  __as a blanket __as individual particles
- How does the supernatant look?
  __clear __cloudy
- Is there straggler floc in the supernatant?
  __yes __no

  If yes, how much? __lots __not much

(b) At the end of 30 minutes how does the sludge blanket look?
__crisp with sharp edges __feather-edged, fluffy
__like a sponge (holes) __homogeneous

(c) Rise time: _____hours _____minutes

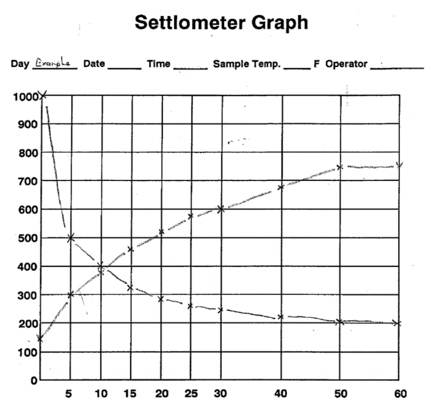
$$SSC = \frac{ATC \times 1000}{SSV}$$

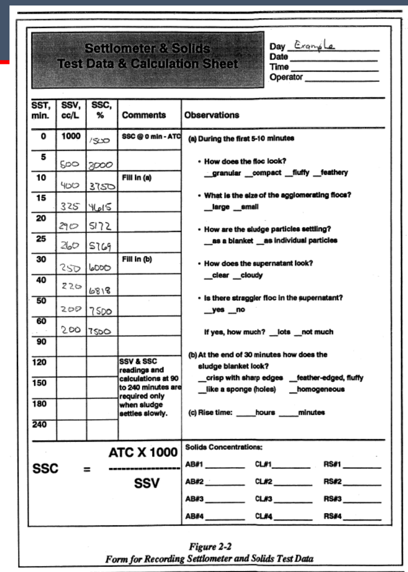
Solids Concentrations:

AB#1 ________ CL#1 ________ RS#1 ________
AB#2 ________ CL#2 ________ RS#2 ________
AB#3 ________ CL#3 ________ RS#3 ________
AB#4 ________ CL#4 ________ RS#4 ________

*Figure 2-2*
*Form for Recording Settlometer and Solids Test Data*

# Example Settleometer Test



**Settlometer & Solids Test Data & Calculation Sheet**

Day Example
Date
Time
Operator

| SST, min. | SSV, cc/L | SSC, % | Comments |
|---|---|---|---|
| 0 | 1000 | 1500 | SSC @ 0 min - ATC |
| 5 | 500 | 3000 | |
| 10 | 400 | 3750 | Fill in (a) |
| 15 | 325 | 4615 | |
| 20 | 290 | 5172 | |
| 25 | 260 | 5769 | |
| 30 | 250 | 6000 | Fill in (b) |
| 40 | 220 | 6818 | |
| 50 | 200 | 7500 | |
| 60 | 200 | 7500 | |
| 90 | | | |
| 120 | | | SSV & SSC readings and calculations at 90 to 240 minutes are required only when sludge settles slowly. |
| 150 | | | |
| 180 | | | |
| 240 | | | |

Observations

(a) During the first 5-10 minutes

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If yes, how much? __lots __not much

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AB#3 ____ CL#3 ____ RS#3 ____
AB#4 ____ CL#4 ____ RS#4 ____

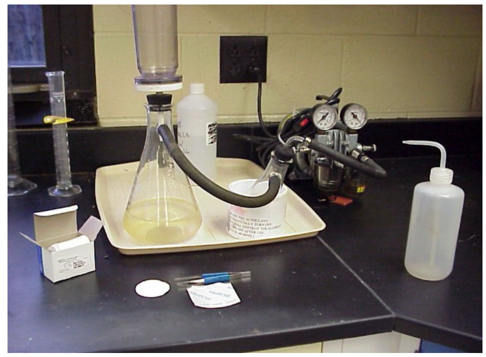
*Figure 2-2*
*Form for Recording Settlometer and Solids Test Data*

# More Process Control Tests – Biomass Solids

- MLSS, MLVSS - Mixed Liquor Suspended Solids and Mixed Liquor Volatile Suspended Solids - needed for Solids Inventory, Mean Cell Residence Time, and Food to Microorganism calculations.
- Quicker Tests to do MCRTcalculations.
  - Centrifuge- Al West
  - TSS Meter, even faster
- Microscopic Exam- useful to check floc quality, filamentous bacterial presence and type (Phase Contrast) and a secondary indicator of sludge age

## Biomass Solids

- Biomass (MLSS) Inventory Tests
  - MLSS- gravimetric
  - Centrifuge- quicker, Sludge Units
  - TSS meter- even quicker
    - Test three locations, sometime four
  - Aeration basin
  - RAS
  - Clarifier Core
  - Sometimes Effluent TSS is used



## Mixed Liquor Suspended Solids

- Most Common Advanced Lab test for Process Control
- Process Control goal is to maintain a constant MLSS based on historic performance
- Looks at only Aerator

# Biomass Inventory/MCRT

- Inventory of Biomass should answer three questions:
  1. How much sludge is in the system?
  2. Where is it located?
  3. How long has it been there?
  - Experience has shown us certain mean cell residence times will give us certain effluent qualities.
- With these answers, process control is easy

# MCRT

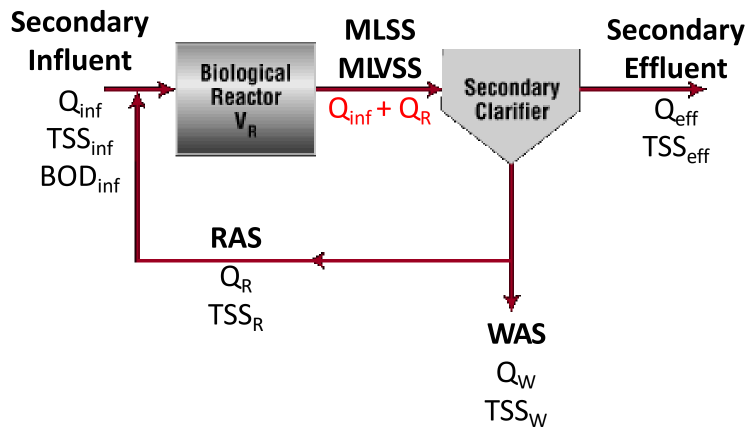
$$MCRT\ (days) = \frac{Suspended\ Solids\ \mathbf{in}\ the\ System}{Suspended\ Solids\ \mathbf{leaving}\ the\ System}$$

## Solids Inventory and Control

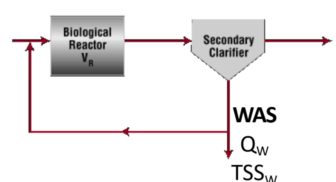
## Solids

- As BOD is reduced, additional microorganisms are produced. The microorganisms grow and reproduce as they remove food/pollutants from the water.
- To keep a balanced system, what grew today must be removed.
- Measuring flow and solids concentration allows calculation of mass balances.

# Solids Inventory

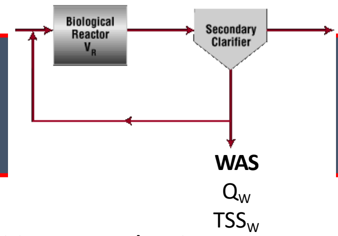



# Solids Wasted




- WAS, lbs/day = ($TSS_W$, mg/L)($Q_W$, MGD)(8.34 lbs/gal)
- Example: WAS flow of 200 gpm with a WAS TSS of 8050 mg/L
- How many pounds of WAS are wasted perday?

# Solids Wasted



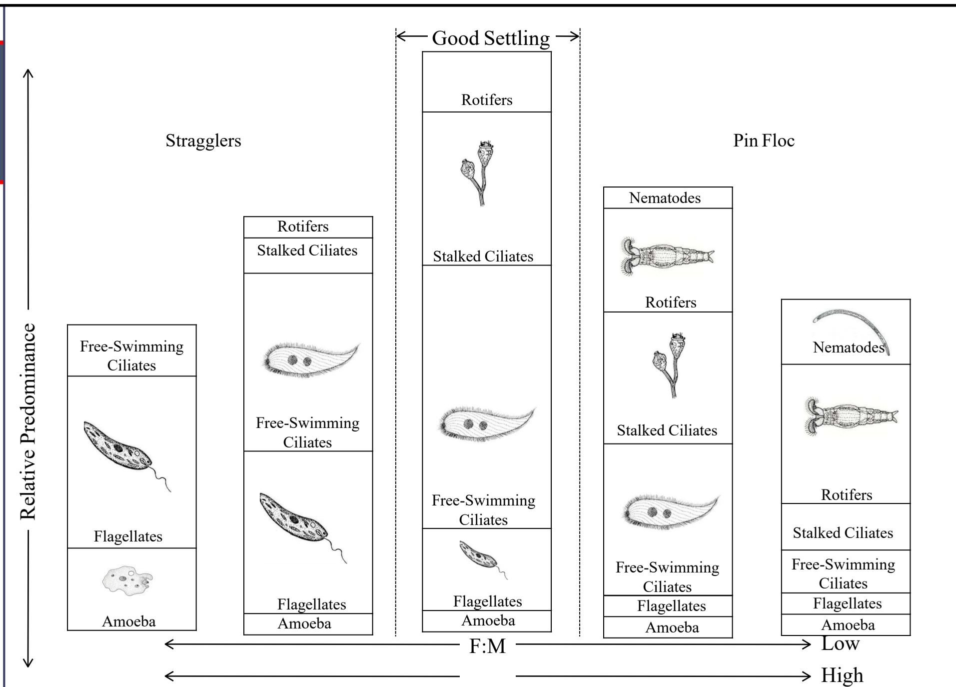

- WAS, lbs/day = ($TSS_W$, mg/L)($Q_W$, MGD)(8.34 lbs/gal)
- Example: WAS flow of 200 gpm with a WAS TSS of 8050 mg/L

(200 gpm)(1440 min/day) /1,000,000 = 0.288 MGD

- WAS, lbs/day = (8050 mg/L)(0.288 MGD)(8.34 lbs/gal)
- = 19,335 lbs/day WAS

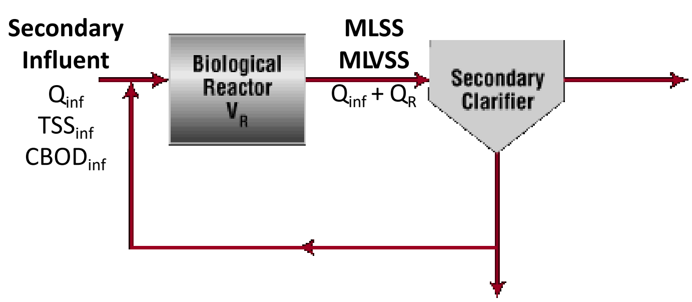
# F:M Ratio

- One of the most important process control parameters is maintaining the optimum amount of solids to remove BOD from influent wastewater.
- BOD = "food"
- Activated sludge solids = "microorganisms"
- **F:M Ratio**
- Food (BOD, lbs/day) divided by Microorganisms (MLVSS, lbs)




## F:M Ratio

- $$\text{F:M} = \frac{(\text{CBOD}_{inf}, \text{mg/L})(Q_{inf}, \text{MGD})(8.34\ \text{lbs/gal})}{(\text{MLVSS, mg/L})(\text{Aerator Vol, MG})(8.34\ \text{lbs/gal})}$$



## F:M Ratio

- Target F:M values
  - Conventional = 0.2 – 0.5
  - Nitrifying less than or equal to 0.10
  - Extended Aeraton = 0.05-0.15
- F:M based on BOD measurements does not give immediate process control feedback, 5 days late at best!
- Running averages of F:M provide useful monitoring input
- F:M can be based on COD measurements when immediate process feedback is required
  - $\text{Target F:M}_{COD} = \frac{\text{Target F:M}_{BOD}}{\text{BOD:COD}}$

## F:M Example

| | |
|---|---|
| $BOD_{inf}$ | 145 mg/L |
| $Q_{inf}$ | 15 MGD |
| MLVSS | 2500 mg/L |
| Aerator Volume | 2 MG |

➢ $\text{F:M} = \frac{(BOD_{inf},\ mg/L)(Q_{inf},\ MGD)(8.34\ lbs/gal)}{(MLVSS,\ mg/L)(Aerator\ Vol,\ MG)(8.34\ lbs/gal)}$

➢ $\text{F:M} = \frac{(145\ mg/L)(15\ MGD)(8.34\ lbs/gal)}{(2500\ mg/L)(2\ MG)(8.34\ lbs/gal)} = 0.44$

## F:M Ratio

BOD/MLSS Changes?

| Calculated F:M | Result | Action |
|---|---|---|
| Less than target F:M | Too many microorganisms in process | Increase wasting rate |
| Greater than target F:M | Not enough microorganisms in process | Reduce wasting rate |

- Excess sludge to waste:
  - Excess M to waste (Microorganisms) = Current M – $\frac{\text{F(Food)}}{\text{F:M Target}}$

## F:M Ratio

- Excess sludge to waste:
  - Excess M to waste (Microorganisms) = Current M – $\frac{\text{F(Food)}}{\text{F:M Target}}$
- Formulas:
  - Desired MLVSS, lbs = $\frac{\text{BOD or COD, lbs}}{\text{Desired F:M ratio}}$
  - Desired MLSS, lbs = $\frac{\text{Desired MLVSS, lbs}}{\text{\% Vol. Solids, as decimal}}$
  - SS, lbs to waste = Actual MLSS, lbs – Desired MLSS, lbs

## Excess Sludge to Waste Example

- Given the following data, use the desired F:M ratio to determine the lbs SS to be wasted:

Aeration Vol = 1,300,000gal
$Q_{inf}$ = 3,190,000 gpd
BOD = 115 mg/L

MLSS = 2980 mg/L
%VS = 70%

- Desired F:M = 0.15 lbs BOD/day/lb MLVSS
- Desired MLVSS, lbs = $\frac{\text{BOD, lbs}}{\text{Desired F:M ratio}}$

$$= \frac{(115\text{ mg/L})(3.19\text{ MGD})(8.34)}{0.15}$$

= 20,396.86 lbs desired MLVSS

## Excess Sludge to Waste Example

- Given the following data, use the desired F:M ratio to determine the lbs SS to be wasted:

Aeration Vol = 1,300,000gal
$Q_{inf}$ = 3,190,000 gpd
BOD = 115 mg/L
Desired F:M = 0.15

MLSS = 2980 mg/L
%VS = 70%
Desired MLVSS = 20,396.86 lbs

- Desired MLSS, lbs = $\frac{\text{Desired MLVSS, lbs}}{\text{\% Vol. Solids, as decimal}}$

$$= \frac{20{,}396.86\text{ lbs}}{0.70}$$

= 29,138.37 lbs desired MLSS

## Excess Sludge to Waste Example

- Given the following data, use the desired F:M ratio to determine the lbs SS to be wasted:

| | |
|---|---|
| Aeration Vol = 1,300,000 gal | MLSS = 2980 mg/L |
| Qinf = 3,190,000 gpd | %VS = 70% |
| BOD = 115 mg/L | Desired MLVSS = 20,396.86 lbs |
| Desired F:M = 0.15 | Desired MLSS = 29,138.37 lbs |

- SS, lbs to waste = Actual MLSS, lbs – Desired MLSS, lbs
  = (2980 mg/L)(1.3 MG)(8.34) – 29,138.37 lbs
  = 32,309.16 lbs – 29,138.37 lbs
  = 3170.79 lbs to waste

## Pounds Formula !!!!

- Real life and guaranteed test Question.
- How many pound of MLSS are in the aeration basin?
- Size MG * MLSS mg/L * 8.34 (lbs/gal) = pounds(lbs)
- 10 MG * 2500 mg/L * 8.34 = 208,500 lbs

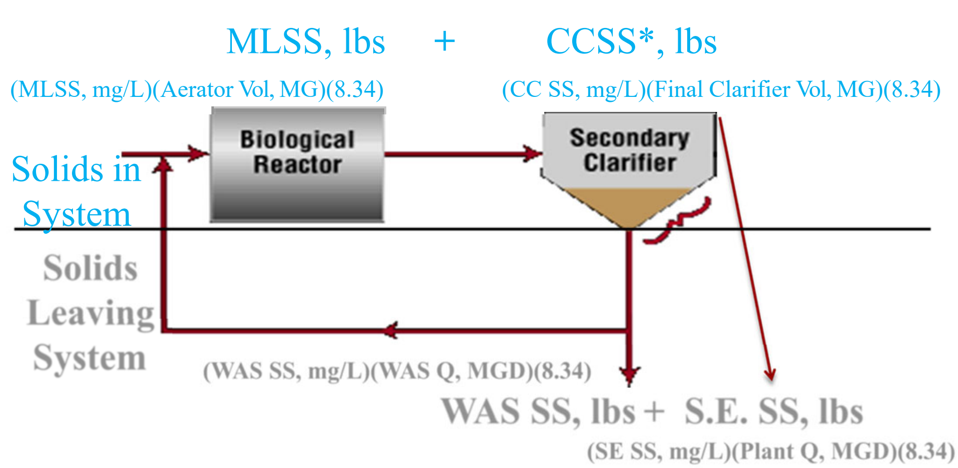
# MCRT

- Mean Cell ResidenceTime
  - The average time a given unit of cell mass stays in the biological reactor.
  - Higher MCRTs create higher MLSS concentrations
  - Lower MCRTs create lower MLSS concentrations

- $$\text{MCRT, days} = \frac{\text{Suspended Solids in System, lbs}}{\text{SS Leaving System, lbs/day}}$$

# MCRT

* CCSS is the average clarifier core SS concentration of the entire water column sampled by a core sampler.



# MCRT

- Given the following data, use the information below to determine the MCRT, days:

| | |
|---|---|
| Aeration Vol = 1.5 MG | MLSS = 2460 mg/L |
| Final Clar.Vol = 0.11 MG | WAS SS = 8040 mg/L |
| PE Flow = 3.4 MGD | SE SS = 18 mg/L |
| WAS Pump Rate = 60,000 gpd | CC SS = 1850 mg/L |

- $\text{MCRT} = \dfrac{(2460\text{ mg/L})(1.5\text{ MG})(8.34) + (1850\text{ mg/L})(0.11\text{ MG})(8.34)}{(8040\text{ mg/L})(0.06\text{ MGD})(8.34) + (18\text{ mg/L})(3.4\text{ MGD})(8.34)}$

$$= \frac{30774.6\text{ lbs MLSS} + 1697.19\text{ lbs CCSS}}{4023.216\text{ lbs/d WAS} + 510.408\text{ lbs/d SE SS}} = \frac{32471.79\text{ lbs}}{4533.624\text{ lbs/d}}$$

= 7.2 days

# MCRT

- Note that when using this equation, the highly variable solids concentration throughout the clarifier sludge blanket can make this calculation difficult
- If Clarifier Core Suspended Solids (CCSS) sample is not taken, but you are given the clarifier volume, add that to your aerator volume before figuring your MLSS lbs.
- Target MCRT:
  - High Rate = 5 – 10 days
  - Conventional = 5 – 15 days
  - Nitrifying = 8 – 20 days
  - Extended Aeration = 20+

# MCRT

- Given the following data, use the information below to determine the MCRT, days(same as previous, just missing the CCSSsample:

  Aeration Vol = 1.5 MG MLSS = 2460 mg/L
  Final Clar.Vol = 0.11 MG WAS SS = 8040 mg/L
  PE Flow = 3.4 MGD SE SS = 18 mg/L
  WAS Pump Rate = 60,000 gpd

- MCRT = $\frac{(2460\ mg/L)(1.5\ MG + 0.11\ MG)(8.34)}{(8040\ mg/L)(0.06\ MGD)(8.34) + (18\ mg/L)(3.4\ MGD)(8.34)}$

  $= \frac{(2460\ mg/L)(1.61\ MG)(8.34)}{4023.216\ lbs/d\ WAS + 510.408\ lbs/d\ SE\ SS} = \frac{33031.404\ lbs}{4533.624\ lbs/d}$

  = 7.3 days

# MCRT

- MCRT/solids inventory must be adjusted as temperatures change.
- Temperature changes affect
  - Metabolic rates of microorganisms
  - Oxygen transfer rates
  - Solids settling rates

| MCRT | RAS Rate |
|---|---|
| Low | 30 – 40% of influent |
| High | Up to 150% of influent |

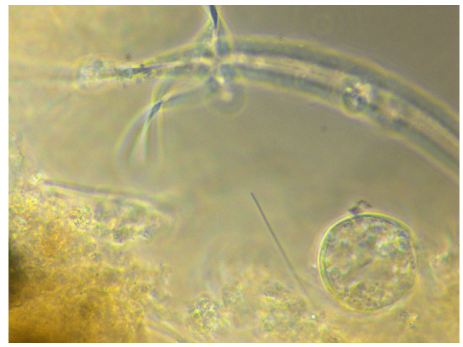

**Dissolved Oxygen Control**

## DO Requirements

- For low-BOD wastewater, the minimum airflow rate is often based on mixing rather than DO requirements.
- Typically, oxygen requirements are met when the DO in the mixed liquor is at 1.5 mg/L, but many plants do more.
- Reference manuals will often recommend ranges of 1- 3mg/L or 1- 4mg/L, and state 1.0 mg/L is needed for BOD removal and 2.0mg/L is needed for Ammonia removal,but in real life plants will operate at lower levels
  - And for nutrient removal air is often cycled off allowing DO to drop to 0.0 mg/L for short periods of time

# Low DO

- Signs that low-DO conditions may be present:
  - Odors
  - Dominance of “low-DO” filamentous bacteria
  - Turbid effluent
  - Gray or black mixed liquor
  - *H. Hydrosis*- Low DO filaments thrive at DO levels in the range of 0.3-0.7mg/L day in and day out. It is the continuous low that is the problem



# Uniform Mixing

- Reactors should be monitored to ensure mixing is uniform

## Septic Sludge

- Location: almost any basin
- Reason: too long without air, improper mixing, often a design issue
- Symptoms: Odors,clumping, poor treatment
- Solutions: pinpoint the reason and correct it.
  - Increase oxygen, mixing, wasting, clean pipelines, pumps, valves
  - Correct flow: RAS, WAS, other

## Toxic Discharge

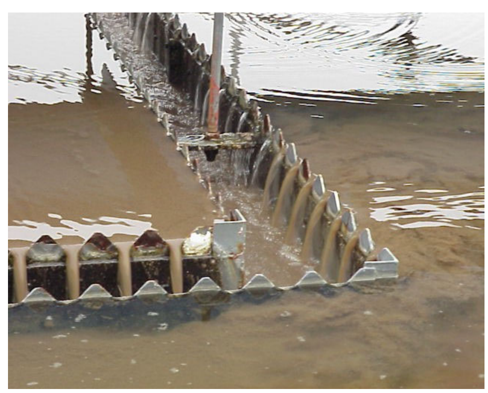
- Aerator DO suddenly way UP!
- SOUR- Specific Oxygen Uptake Rate, way down or
  - 0.0 mg/hr/g MLVSS
- Some causes: high/low pH, toxic chemicals, metals, pesticides, oils
- Actions: hold and treat off line, maintain air, reduce/stop wasting, up MLSS,

## Trouble Shooting

- Trouble shooting observations and data
  - Influent, In the Plant, Effluent
- Trouble shooting steps:
  - Check operational data and logs ~ three weeks of data
  - Talk to other operators and on other shifts
  - Review recent adjustments and tests
  - Check for variation in:
    - Influent
    - Plant equipment
    - Activated Sludge Biology
- Act according to the majority of signals
- Allow 2-3 MCRT's for protozoa predominance to stabilize

## Elevated Effluent TSS – The most common violation

- Bulking Sludge- the sludge blanket settles poorly and/or it rises and overflows the effluent weir fowling the effluent.
  - Hydraulic Overload- I/I, "Billowing Sludge"
  - Glutted System-waste
  - Biomass quality
    - Slime Bulking- India ink test,
      - ~nutrient deficiency
    - Cation Ratio - Ca, Mg, Na, K
    - Filaments - ID and fix

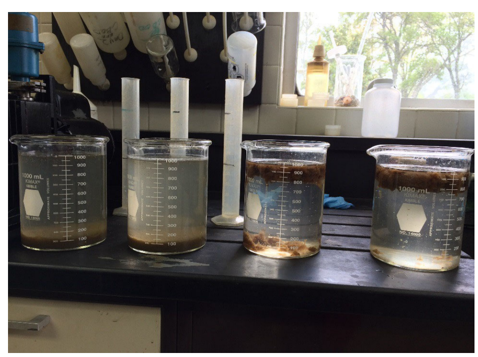


# Elevated Effluent TSS – The most common violation

- Clarifier Clumping - the settled blanket denitrifies and nitrogen gas rises floating part or all of the settled blanket.
- Increase RAS
- Increase WAS
- Increase Aerator DO
- Denitrify somewhere else
  - ~ in the aerator

# Clarifier Denitrification

- Clarifier "Clumping"
- Generally from Denitrification, could be septic
- Skimmers often remove the clumps, but may not
- Books reccomend:
  - $SSV_{60}$ blanket stays down
  - $SSV_{120}$ blanket may begin to rise
  - If it floats at 60, waste or increase RAS



## Clarifier Covered in "Ash", Pin Floc

- Pin Floc may occur when:
  - Denitrification is beginning to occur in the clarifier
  - F:M is extremely low and beyond normal extended aeration old over-oxidized mixed liquor
  - Mixed liquor contains excessive levels of grease
  - Floc Shear

## Clarifier Effluent - Straggler Floc

- Straggler Floc
- Generally light colored, large, fluffy particles
- Could be caused by filaments, check with microscope
- Generally high F:M or short MCRT

## Elevated Effluent *SBOD*, TSS - Turbidity

- Possible Causes
  - Shock Load: high flow, industrial discharge, collection system cleaning, internal load ~ solids processing,
- Check: baseline and current Process Control Data
- Evaluate and Act
  - Adjust DO if low, verify viable biomass (MLVSS), change mode of operation, start or stop parallel basins, change discharges from slug to 24/7

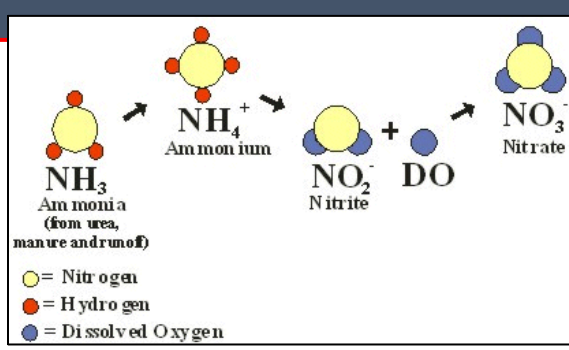
***Soluble BOD*** = measures the BOD in the soluble portion of the sample. Some industrial waste can be very high in sBOD

## Temperature Impacts

- "Grade 4" Package Plant
  - Above ground steel construction results in more dramatic temperature impacts.
- Summer, Generally:
  - Need higher DO and lower MLSS
- Winter, Generally:
  - Need lower DO and higher MLSS

# Low effluent pH

- Is influent pH low also?
  - Correct with chemicals
    - Check effluent alkalinity
  - Alkalinity low-
    - Supplement with chemicals
    - Begin denitrification within the plant

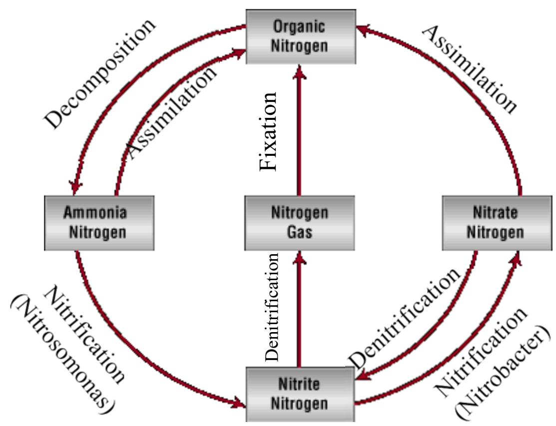



**Nitrification**

Biological conversion of ammonia to nitrate

# Nitrogen Cycle

- The activated sludge process can also be operated to remove nitrogen and/or phosphorus.




# Nutrients

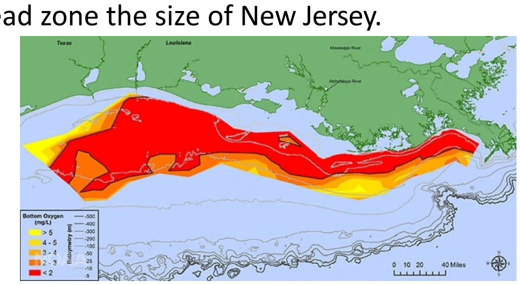
- Algal blooms can be caused by excess nutrient levels
- Aquatic and marine dead zones can be caused by an increase in chemical nutrients in the water, known as eutrophication.
- Chemical fertilizer is considered the prime cause of dead zones around the world

# Eutrophication

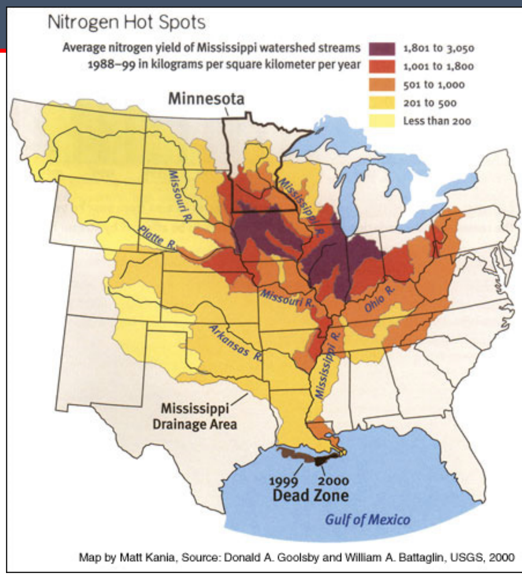
- ***Eutrophication*** is an increase in chemical nutrients (compounds containing nitrogen or phosphorus) in an ecosystem, and may occur on land or in water.
- However, the term is often used to mean the resultant increase in the ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.
- Once algae blooms, it will die off and as the algae decay bacteria will consume it and use up all the oxygen.

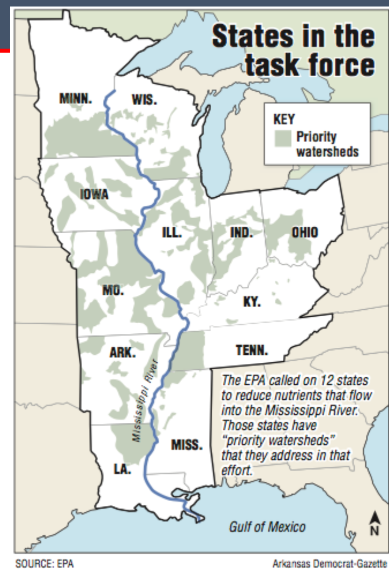
# Eutrophication

- Gulf of Mexico
  - Currently the most notorious dead zone is a 8,543 mi² region in the Gulf of Mexico, where the Mississippi River dumps high- nutrient runoff from its vast drainage basin, which includes the heart of U.S. agribusiness, the Midwest.
  - The drainage of these nutrients are affecting important shrimp fishing grounds.
  - This is equivalent to a dead zone the size of New Jersey.



## Eutrophication




## Reversal of Dead Zones

- Dead zones are reversible.
- The Black Sea dead zone, previously the largest dead zone in the world, largely disappeared between 1991 and 2001 after fertilizers became too costly to use following the collapse of the Soviet Union and the demise of centrally planned economies in Eastern and Central Europe.
- Fishing has again become a major economic activity in the region

## Nitrification

- A bacterial process that converts ammonia nitrogen to nitrate and consumes alkalinity.

- $\underset{\text{Ammonia}}{NH_4} + \underset{\text{Oxygen}}{1.5\ O_2} \xrightarrow{\text{Nitrosomonas}} \underset{\text{Nitrite}}{NO_2^-} + \underset{\text{Acid}}{2\ H^+} + \underset{\text{Water}}{H_2O} + \text{Energy}$

- $\underset{\text{Nitrite}}{NO_2^-} + \underset{\text{Oxygen}}{0.5\ O_2} \xrightarrow{\text{Nitrobacter}} \underset{\text{Nitrate}}{NO_3^-} + \text{Energy}$

## Note

***Nitrosomas = AOB***

***Nitrobacter = NOB***

- ***AOB = Ammonia Oxidizing Bacteria***
- ***NOB = Nitrite Oxidizing Bacteria***

*Species of autotrophic bacteria*

- $\underset{\text{Ammonia}}{NH_4} + \underset{\text{Oxygen}}{1.5\ O_2} \xrightarrow{\text{Nitrosomonas}} \underset{\text{Nitrite}}{NO_2^-} + \underset{\text{Acid}}{2\ H^+} + \underset{\text{Water}}{H_2O} + \text{Energy}$

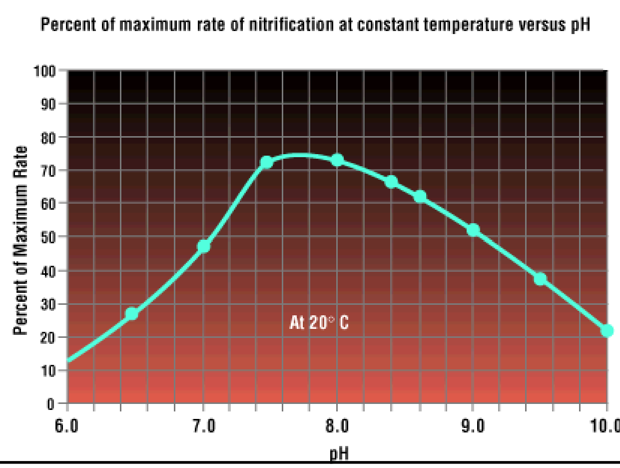
The Acid in the equation is what uses up the 7.1 mg/L alkalinity per mg/L ammonia oxidized.

# Process Modes for Nitrification

- Activated sludge process
- Trickling filter
- Rotating biological contactor (RBC)
- Oxidation pond
- Land treatment (overland flow)
- Wetland treatment (Hyacinth cultures)

# Nitrification vs. pH

- A pH between 7.5 and 8.5 is considered optimal.

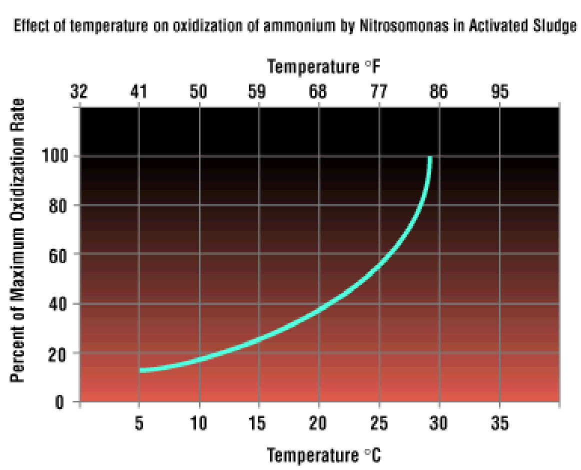


## Alkalinity and pH

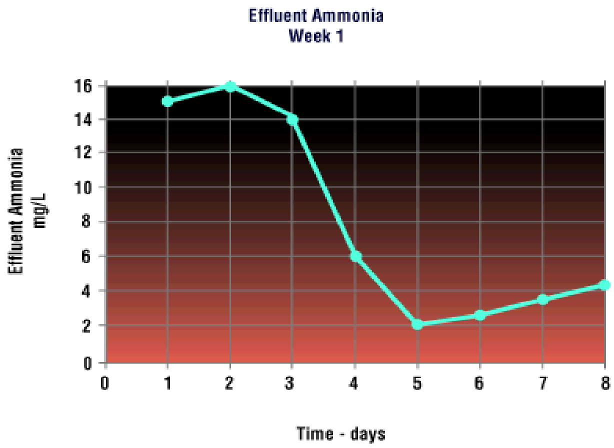
- Alkalinity is a key parameter in nitrifying systems.
- To adequately control pH
  - Calculate the total amount of alkalinity required
  - Calculate the additional alkalinity that must be added

## Nitrification vs. Temperature

- The optimum wastewater temperature range is 60-95ºF (15-35ºC) for good nitrification.



## Nitrification



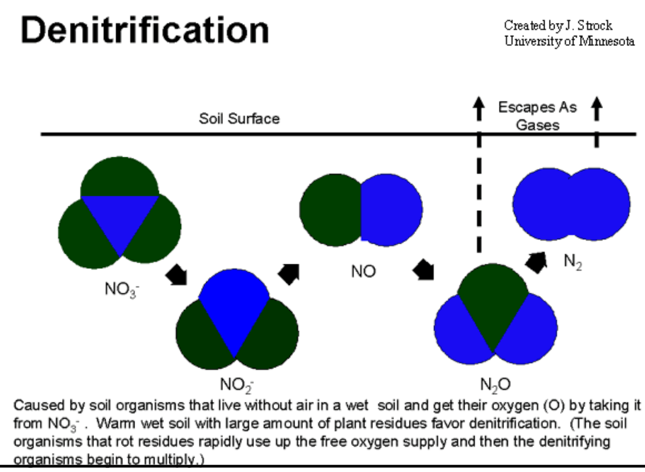

- Most processes will require an MCRT of 4 days or more to nitrify.
- If a plant has to recover from a toxic shock load, killing the nitrifying bacteria, allow several weeks for a full recovery

## Nitrification

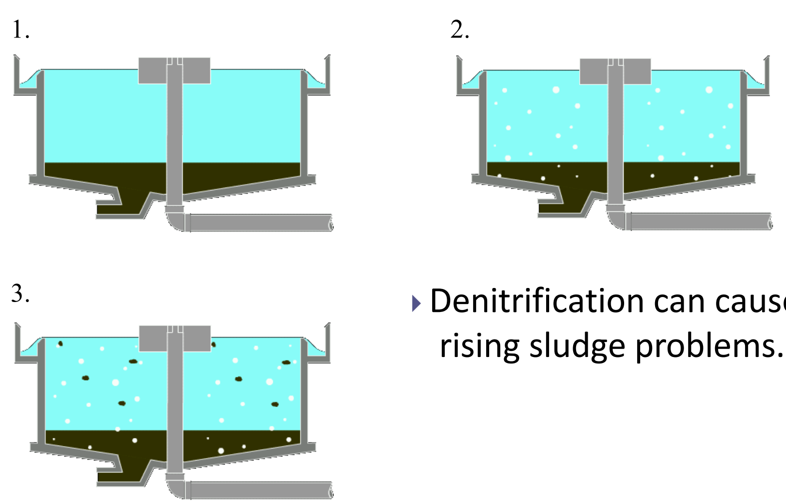
- Nitrification typically requires 25% more oxygen than conventional processes.
- Factors influencing nitrification:
  - DO
  - Alkalinity/pH
  - MCRT
  - Temperature

## Denitrification

- Denitrification can occur unintentionally causing operational difficulties.




## Denitrification




- Denitrification can cause rising sludge problems.

## Denitrification

- Advantages of denitrification:
  - Use of nitrate returns some of the extra oxygen needed, recycle oxygen
  - A portion of the alkalinity removed by nitrification is returned, recycle alkalinity
  - Use less electricity
  - Use less chemicals
  - Slightly less biomass produced
  - Generally better effluent

## Partial Nitrification, elevated nitrite

- A bacterial process that converts ammonia nitrogen to nitrate and consumes alkalinity.
- $\underbrace{NH_4}_{\text{Ammonia}} + \underbrace{1.5\ O_2}_{\text{Oxygen}} \xrightarrow[\text{Nitrosomonas}]{\text{AOB's}} \underbrace{NO_2^-}_{\text{Nitrite}} + \underbrace{2\ H^+}_{\text{Acid}} + \underbrace{H_2O}_{\text{Water}} + \text{Energy}$
- $\underbrace{NO_2^-}_{\text{Nitrite}} + 0.5\ \underbrace{\cancel{O_2}}_{\text{Oxygen}} \xrightarrow[\text{Nitrobacter}]{\text{NOB's}} \underbrace{\cancel{NO_3^-}}_{\text{Nitrate}} + \text{Energy}$
- Nitrite, 5:1 chlorine demand! Loss of disinfection so elevated e-coli.
- 5parts chlorine: one part Nitrite

## Note

- Conversion of Nitrite to Nitrate may not occur due to low DO, low SRT, presence of inhibitory substances, etc., which will lead to a build up of Nitrite.
  - This is called "***Nitrite Lock***"
- Nitrite has a huge chlorine demand – for every pound of NO2-N going into the Chlorine contact chamber, it will consume 5 pounds Chlorine.
- If your E.coli counts are all of a sudden going through the roof, check for excessive Nitrites.
- You can use quick Nitrite strips (like pool kit test strips) to troubleshoot, they will tell you if Nitrite is present and if so, you can run a more reliable test for good data.



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Activated Sludge Part II Vocabulary

**Word Bank:**

| | |
|---|---|
| Nitrification | Coagulation |
| Sludge age | Denitrification |
| Mean Cell Residence Time (MCRT) | F:M ratio (or F/M ratio) |
| Diffuser | Supernatant |
| Biochemical Oxygen Demand (BOD) | Mixed Liquor Suspended Solids (MLSS) |
| Mixed Liquor Volatile Suspended Solids (MLVSS) | Bulking |
| Sludge Volume Index (SVI) | Rising Sludge |

1. _________________________________ refers to the clouds of billowing sludge that occur throughout secondary clarifiers and sludge thickeners when the sludge does not settle properly. In the activated sludge process, this is usually caused by filamentous bacteria or bound water.
2. The anoxic biological reduction of nitrate nitrogen to nitrogen gas is called_____________________. It is an anoxic process that occurs when nitrite or nitrate ions are reduced to nitrogen gas and nitrogen bubbles are formed as a result. The bubbles attach to the biological floc in the activated sludge process and float the floc to the surface on the secondary clarifiers. This condition is often the cause of rising sludge observed in the secondary clarifiers or gravity thickeners.
3. The abbreviation for Food to Microorganism ratio, _______________ is a measure of food provided to bacteria in an aeration tank.
4. The rate at which organisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions is known as ____________________________________. It is also referred to as the organic strength of the wastes in the water.
5. The suspended solids in the mixed liquor of an aeration tank are called ______________________________________.
6. A ______________ is a device used to break the air stream from the blower system into fine bubbles in an aeration tank.
7. The measure of time a particle of suspended solids has been retained in the activated sludge process is known as _______________________________.

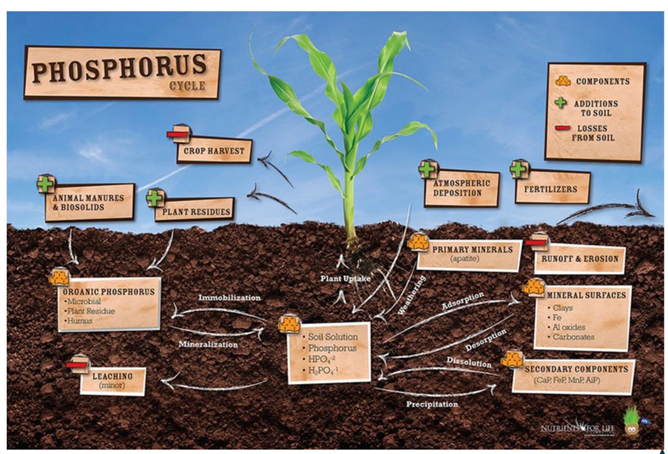
8. The process of ___________________________ describes the clumping together of very fine particles into larger particles (floc) caused by chemicals called coagulants.
9. The organic or volatile suspended solids in the mixed liquor of an aeration tank are called _____________________________________. This volatile portion is used as a measure or indication of the microorganisms present.
10. The expression of the average time that a microorganism will spend in the activated sludge process is _______________________________________.
11. Liquid removed from settled sludge is called ____________________________________. This liquid is usually returned to the influent wet well or to the primary clarifier.
12. The aerobic process of _________________________ occurs when bacteria change the ammonia and organic nitrogen in wastewater into oxidized nitrogen (usually nitrate).
13. ____________________________ occurs in secondary clarifiers of activated sludge plants when the sludge settles to the bottom of the clarifier, is compacted, and then starts to rise to the surface, usually as a result of denitrification.
14. The ____________ is a calculation that indicates the tendency of activated sludge solids (aerated solids) to thicken or to become concentrated during the sedimentation/thickening process.

# Section 2
# Phosphorous Removal

# Section 2
# Phosphorus Removal

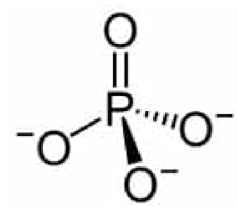
## Where does phosphorus come from?

- Fertilizers
- Manure
- Organic wastes in sewage and industrial effluent
- Soil erosion from banks is a major contributor of phosphorus in streams
  - Attaches to soil particles
- Essential element for plant life
  - Usually the limiting nutrient



## Types of Phosphorus in Wastewater

- ***Orthophosphate***
  - Simplest form of phosphate
  - Readily available to organisms
  - soluble but can be adsorbed to particles



- In Wastewater
  - This makes up 50% of total influent P

## Types of Phosphorus in Wastewater

- ***Polyphosphates*** (condensed phosphates)
  - Converted to orthophosphates via hydrolysis reactions (slow)

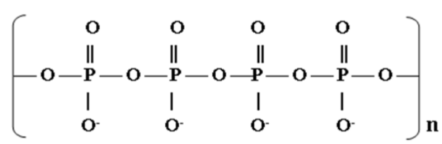
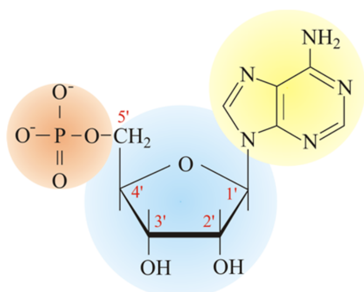


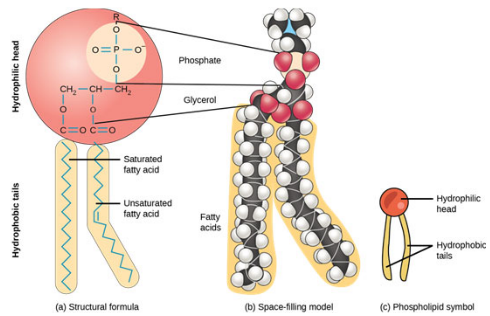
Figure. 1.1: Linear structure of polyphosphate

- In Wastewater
  - Make up 33% of total influent P
  - soluble but can be adsorbed to particles
  - are converted to orthophosphate during biological treatment

## Types of Phosphorus in Wastewater

- ***Organic phosphates*** (phospholipids and nucleotides)
  - Maybe soluble, colloidal, or particulate
  - In WW: 15% of total influent P
  - are converted to orthophosphate during biological treatment






## Types of Phosphorus in Wastewater

- Phosphate species and their abundance - function of pH
- In conventional WW treatment:
  - Total Phosphorous (TP) in raw wastewater typically 4 – 8 mg/L
  - ~5 – 10% P removed during primary setting/secondary clarification
  - ~20 – 25% P taken up in AS process during bacterial growth

## Why must phosphorus be removed?

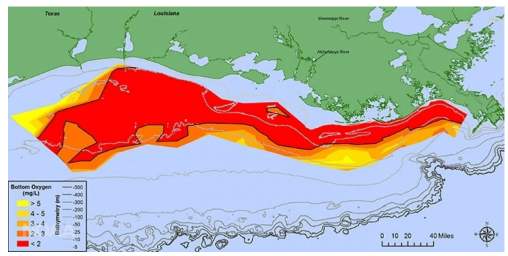
- Nutrient and food source for algae
- When combined with inorganic Nitrogen = ***Eutrophication***
- By removing phosphorus, the receiving stream will have one less nutrient that is essential for algae growth
  - **Reduction in essential nutrient = reduction in algae**

## Note

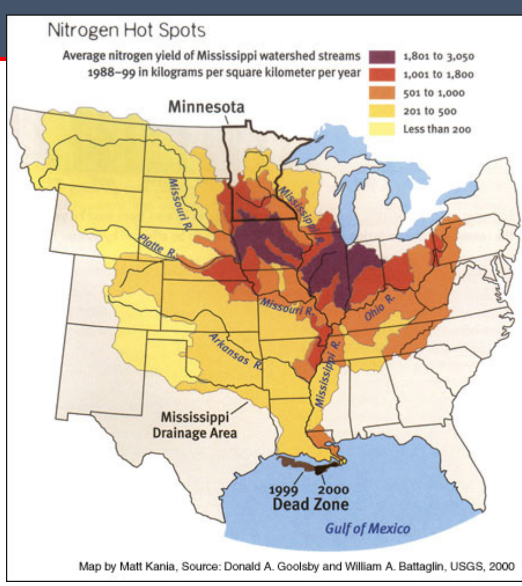
- ***Eutrophication*** is an increase in chemical nutrients (compounds containing nitrogen or phosphorus) in an ecosystem, and may occur on land or in water.
- However, the term is often used to mean the resultant increase in the ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.
- Once algae blooms, it will die off and as the algae decay bacteria will consume it and use up all the oxygen.

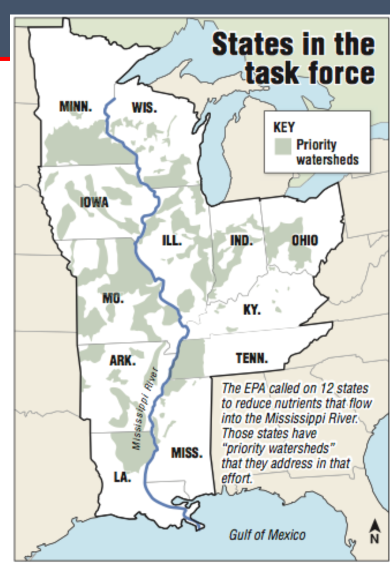
# Eutrophication

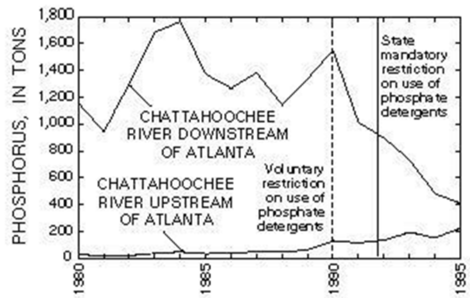
- Gulf of Mexico
  - Currently the most notorious dead zone is a 8,543 mi² region in the Gulf of Mexico, where the Mississippi River dumps high- nutrient runoff from its vast drainage basin, which includes the heart of U.S. agribusiness, the Midwest.
  - The drainage of these nutrients are affecting important shrimp fishing grounds.
  - This is equivalent to a dead zone the size of New Jersey.

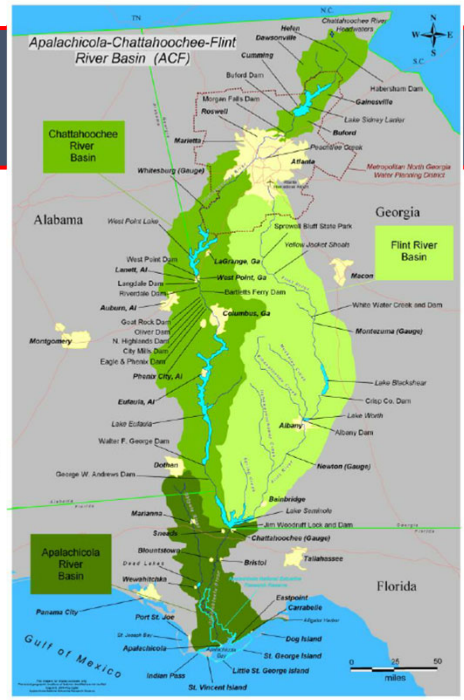



# Eutrophication

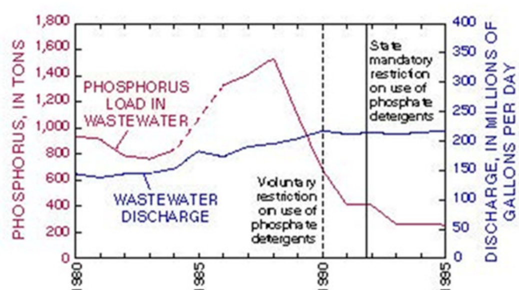





Source: www.water.usgs.gov/edu/phoshorus.html



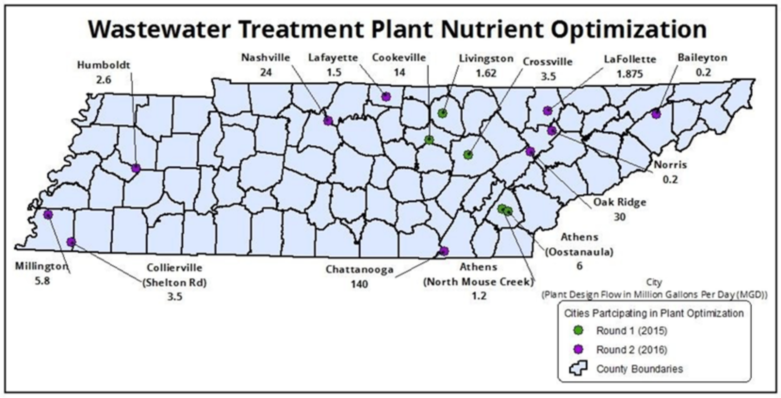

## NPDES Permit Limits

- Plants that discharge into smaller receiving streams already have NPDES permit limits
- Reported as P
- Plants may be required to report, but no limits (yet)
- Some plants monitoring, but no limits (yet)

## Tennessee Nutrient Reduction Framework

- Prioritize watersheds
  - Set watershed nutrient reduction goals
- Ensure effective point source permits
- Devise effective agricultural BMPs
- Encourage reduction from non MS4s
- Watershed monitoring
- Document and report activities

## Tennessee Nutrient Reduction Framework




## Types of phosphorus removal systems

Most common:

1. Biological Phosphorus Removal
   - Phosphorus contained within cells of microorganisms
   - “Luxury uptake”
2. Lime Precipitation
   - Addition of lime
   - Flocculation and precipiation
3. Filtration following Aluminum Sulfate Flocculation
   - Addition of aluminum sulfate
   - Similar to lime precipitation, with addition of a filter after the clarifier

Other types:

- Bardenpho process
  - Removes both Nitrogen and Phosphorus
  - Modification of the activated sludge process

## Biological Phosphorus Removal

- 2 Elements of all biological treatment systems:

1. Biomass
   - Suspended Growth - Contained in a reactor/basin
   - Fixed Growth – attached to inert media
2. Liquid-Solids Separation

- Oxygen level is key
  - Aerobic –
  - Anoxic –
  - Anaerobic –

## Biological Phosphorus Removal

- ***Selector***
  - A reactor or basin that contains compartments
    - Baffles or other devices
  - The environment can be controlled to "select" for microbial populations
    - Environmental conditions (ex: food, lack of dissolved oxygen) are intended to favor the growth of certain organisms over others

- ***Mean Cell Residence Time (MCRT)***
  - The average time a microorganism will spend in the activated sludge process or specific process phase

## Biological Phosphorus Removal

- Types of Microorganisms:

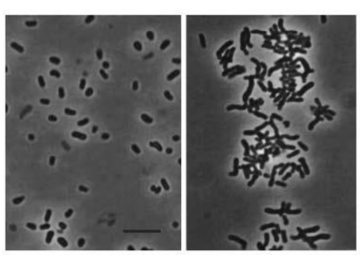
1. Autotrophs

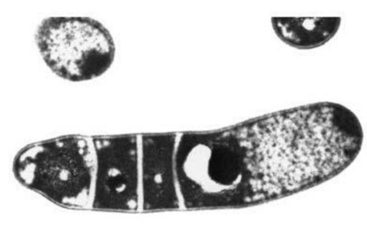
2. Heterotrophs

- Both types of organisms can be:
  - **Obligate aerobes –**
  - **Obligate anaerobes –**
  - **Facultative organisms** –

## Biological Phosphorus Removal

- ***Phosphate-Accumulating Organisms (PAOs)***
  - *Heterotrophic* and *Facultative*
  - Through design and operational conditions, they are given selective advantage to grow and function
  - *Accumulibacter*
  - *Tetrasphaera*





## Biological Phosphorus Removal – Luxury Uptake

- ***Luxury uptake*** = the process in which microorganisms take excess P into their bodies
- Microbes routinely remove some P
  - Required for survival
  - They can be forced to remove/uptake more than they actually need
  - Aerobic, then anaerobic environment

## Biological Phosphorus Removal – Luxury Uptake

1. In aerobic conditions, the microbes will take up and store P in their cells
   - Stored as Polyphosphate
2. Once they have stored maximum amount of P in their cells, they are transferred to anaerobic environment
3. Microbes chemically convert some of the carbon materials in their cells to get the oxygen they need for metabolism
   - The energy used in this chemical reaction comes from the polyphosphate stored in it's cells
   - As a result, phosphorus is released from the cells

# Biological Phosphorus Removal – Luxury Uptake

4. After releasing the P, they are returned to the aeration tank
   - Lots of food, oxygen, P
5. Since they just used up all the P in their cells, they will take up and store large quanities of P
   - "luxury uptake"
6. Remain in aerobic phase until they are completely revived
7. Sequence is repeated

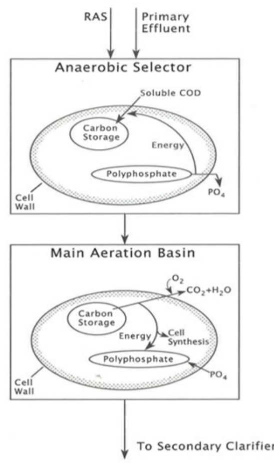
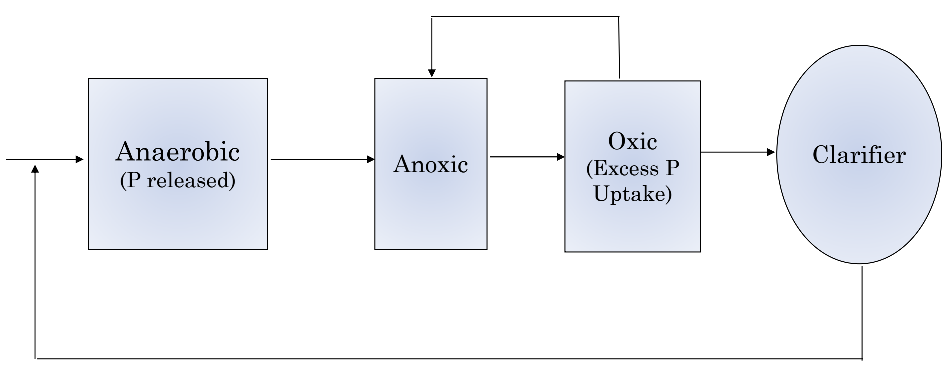



Fig. 5.2 Microorganism cell reactions during phosphorus release and luxury uptake processes

# Biological Phosphorus Removal



## Biological Phosphorus Removal

- Phosphate Accumulating Organism (PAO)
- ***Volatile Fatty Acids*** (VFA) - produced during digestion/fermentation
  - The preferred food for the PAO
  - PAO's expend energy to transform VFA's into a chemical form for storage
  - That energy comes from breaking P bonds, results in P release

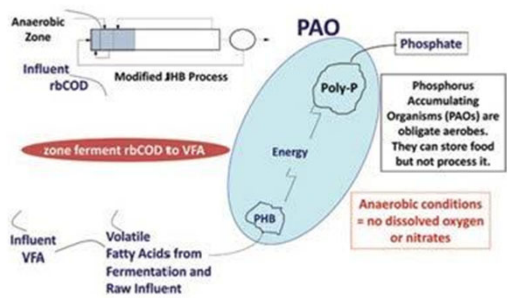
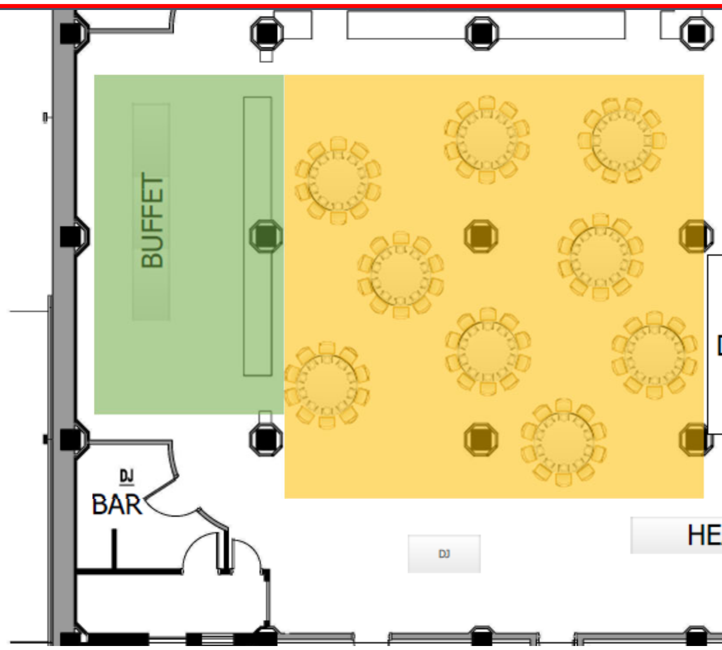


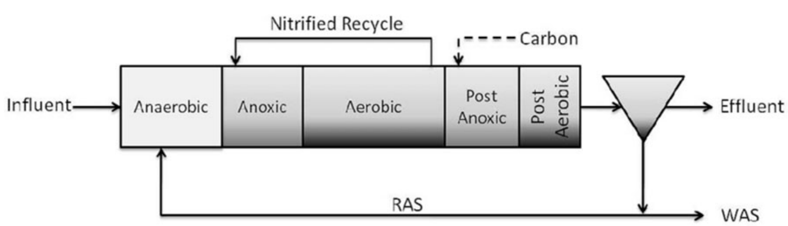
Figure 1. PAO Phosphorus Release in Anaerobic Zone

## Note

***Volatile fatty acids (VFAs)*** are produced by fermentation of CBOD under anaerobic conditions. VFAs are chemical compounds that contain five carbons or less, such as acetic acid (2 carbons), propionic acid (3 carbons), and butyric acid (4 carbons). Acetic acid is more commonly known as vinegar.




# Biological Phosphorus Removal




Five-stage Bardenpho process

## Biological Phosphorus Removal – Luxury Uptake

- Key Principles:
  - Will only occur in very controlled environment
  - Strict anaerobic conditions must be maintained in stripping tank at all times!
  - Operators must carefully regulate detention time so it is long enough to remove as much P as possible, but not so long that the microbes will die of starvation
  - Sludge recycle time is very important

## Quiz

1. What is luxury uptake of phosphorus?
2. What is happening during the aerobic phase?
3. What is happening during the anaerobic phase?
4. What is a PAO?



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# Section 3
# Intro to Lab and Sampling

# Section 3 Introduction to Lab and Sampling

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## Tools for Success

- 40 CFR 136:
  - Table IA - List of Approved Biological Methods
  - Table IB – List of Approved Inorganic Test Procedures
  - Table II – Required Containers, Preservation Techniques, and Holding Times

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

| Parameter number/name | Container[1] | Preservation[2,3] | Maximum holding time[4] |
|---|---|---|---|
| **Table IA—Bacterial Tests** | | | |
| 1–5. Coliform, total, fecal, and *E. coli*. | PA, G | Cool, <10 °C, 0.008% $Na_2S_2O_3$[5] | 8 hours.[22,23] |
| 6. Fecal streptococci | PA, G | Cool, <10 °C, 0.008% $Na_2S_2O_3$[5] | 8 hours.[22] |
| 7. Enterococci | PA, G | Cool, <10 °C, 0.008% $Na_2S_2O_3$[5] | 8 hours.[22] |
| 8. *Salmonella* | PA, G | Cool, <10 °C, 0.008% $Na_2S_2O_3$[5] | 8 hours.[22] |
| **Table IA—Aquatic Toxicity Tests** | | | |
| 9–12. Toxicity, acute and chronic | P, FP, G | Cool, ≤6 °C[16] | 36 hours. |
| **Table IB—Inorganic Tests** | | | |
| 1. Acidity | P, FP, G | Cool, ≤6 °C[18] | 14 days. |
| 2. Alkalinity | P, FP, G | Cool, ≤6 °C[18] | 14 days. |
| 4. Ammonia | P, FP, G | Cool, ≤6 °C,[18] $H_2SO_4$ to pH <2 | 28 days. |
| 9. Biochemical oxygen demand | P, FP, G | Cool, ≤6 °C[18] | 48 hours. |
| 15. Chemical oxygen demand | P, FP, G | Cool, ≤6 °C,[18] $H_2SO_4$ to pH <2 | 28 days. |
| 16. Chloride | P, FP, G | None required | 28 days. |
| 17. Chlorine, total residual | P, G | None required | Analyze within 15 minutes. |

[1] "P" is for polyethylene; "FP" is fluoropolymer (polytetrafluoroethylene (PTFE); Teflon®), or other fluoropolymer, unless stated otherwise in this Table II; "G" is glass; "PA" is any plastic that is made of a sterilizable material (polypropylene or other autoclavable plastic); "LDPE" is low density polyethylene.

# Tools for Success

- 40 CFR 136.7 Quality Assurance and Quality Control (MUR - method update rule)

**§ 136.7 Quality assurance and quality control.**

The permittee/laboratory shall use suitable QA/QC procedures when conducting compliance analyses with any Part 136 chemical method or an alternative method specified by the permitting authority. These QA/QC procedures are generally included in the analytical method or may be part of the methods compendium for approved Part 136 methods from a consensus organization. For example, Standard Methods contains QA/QC procedures in the Part 1000 section of the Standard Methods Compendium. The permittee/laboratory shall follow these QA/QC procedures, as described in the method or methods compendium. If the method lacks QA/QC procedures, the permittee/laboratory has the following options to comply with the QA/QC requirements:

(a) Refer to and follow the QA/QC published in the "equivalent" EPA method for that parameter that has such QA/QC procedures;

(b) Refer to the appropriate QA/QC section(s) of an approved Part 136 method from a consensus organization compendium;

(c)(1) Incorporate the following twelve quality control elements, where applicable, into the laboratory's documented standard operating procedure (SOP) for performing compliance analyses when using an approved Part 136 method when the method lacks such QA/QC procedures. One or more of the twelve QC elements may not apply to a given method and may be omitted if a written rationale is provided indicating why the element(s) is/are inappropriate for a specific method.

(i) Demonstration of Capability (DOC);

(ii) Method Detection Limit (MDL);

(iii) Laboratory reagent blank (LRB), also referred to as method blank (MB);

(iv) Laboratory fortified blank (LFB), also referred to as a spiked blank, or laboratory control sample (LCS);

(v) Matrix spike (MS) and matrix spike duplicate (MSD), or laboratory fortified matrix (LFM) and LFM duplicate, may be used for suspected matrix interference problems to assess precision;

(vi) Internal standards (for GC/MS analyses), surrogate standards (for organic analysis) or tracers (for radiochemistry);

(vii) Calibration (initial and continuing), also referred to as initial calibration verification (ICV) and continuing calibration verification (CCV);

(viii) Control charts (or other trend analyses of quality control results);

(ix) Corrective action (root cause analysis);

(x) QC acceptance criteria;

(xi) Definitions of preparation and analytical batches that may drive QC frequencies; and

(xii) Minimum frequency for conducting all QC elements.

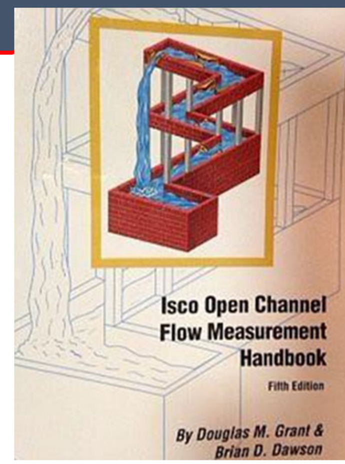
(2) These twelve quality control elements must be clearly documented in the written standard operating procedure for each analytical method not containing QA/QC procedures, where applicable.

# Tools for Success

- 40CFR136.6 (Flexibility to Modify Methods)
- Hach ® EPA compliant methods (http://www.hach.com/epa)
  - Confirm method of analysis (WW or DW)
  - equivalent, acceptable or approved (EPA compliant)
- Fleming Training Center website
- Standard Methods for Water and Wastewater Analyses (consensus body approved methods)
- State of TN, Design Criteria for Sewage Works (Technical/Engineering Documents)

## Tools for Success

- Standard Operating Procedures
  - Yearly review/signature
  - Update
  - Training
- Review of log books
  - Instrument calibration (daily)
  - Temperature
  - Maintenance
  - Sampler
  - Standard preparation
  - Calibration
- Lab instruments - yearly maintenance check (or more frequently)
  - including thermometers and weights
- Flow measurement devices – yearly maintenance check




## Reliable sampling data are obtained by collecting samples:

- At the right location
- In the correct manner
- At the right time


Operator with Improvised Sampling Device


Automated Samplers

Operator with Improvised Sampling Device

Automated Samplers

- Samples can be taken with automated equipment or improvised devices.
- Automatic samplers are typically used for influent, primary effluent and final effluent samples.
- They do not work well with mixed liquor or sludge because solids tend to clog the tubing.

## Sample Types

- The two types of samples typically taken for an activated sludge process are:

Grab

Composite

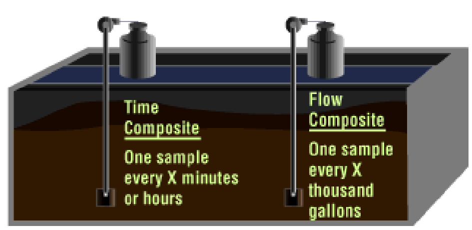
## Grab Samples

- Single volume of water
- Representative of water quality at exact time and place of sampling
- Grab samples are used to test for unstable parameters that could change if the sample were allowed to stand for any length of time
  - DO
  - pH
  - Chlorine residual
  - Temperature
  - *E. coli* and/or fecal coliform


## Composite Sample

- Representative of average water quality of location over a period of time
- Series of grab samples mixed together
- Determines average concentration
- Not suitable for all tests
- Types of composite samples:

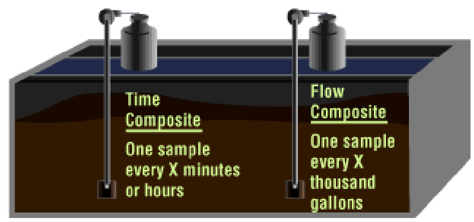
1. Fixed volume or time composite
2. Flow proportioned



## Composite Sample

2 Types of Composite Samples

- Fixed Volume/ Time Composite
- Flow Proportioned




## Composite Sample

- Composite sampling is used when:
  - This is required by the permit
  - Plant removal efficiencies are calculated
  - Average data are needed to make process adjustments

## Preventative Sampler Maintenance

- Pump tubing replacement
- Suction line replacement
- Container replacement
- Diagnostic routines
- Volume calibration
- Desiccant replacement


## Example of Flow-Proportioned Sample Collection

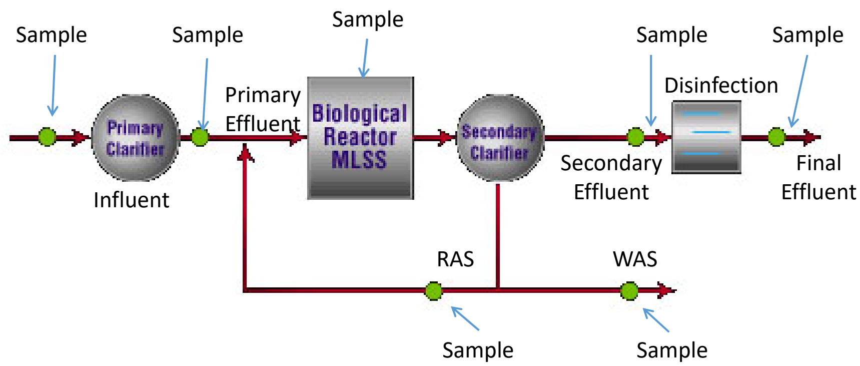
| Time | Flow | Sample Volume |
|---|---|---|
| 10:00 am | 18 MGD | 180 mL |
| 10:00 pm | 12 MGD | 120 mL |

# Sample Volume and Storage

- Volume depends on test requirements
- Use proper sampling container
- Follow recommended holding times and preservation methods
  - If bottle already has preservative or dechlorinator in it, don't over fill or rinse out

✓If you have questions regarding volume, container or holding times, check *40 CFR 136 Table II* or contact the lab if you have an outside lab do your analysis

# Sample Points



## Process Control

- Tests frequently performed by operators to quickly obtain the results and make any necessary process adjustments
- Required by NPDES permit
- Not reported
  - Keep records

## Process Monitoring and Control Tests

- $cBOD_5$
- MLSS
- MLVSS
- Centrifuge (spin) Test
- Microscopic Examination
- SOUR
- Temp
- Depth of Blanket
- Thirty-minute settleometer
- SVI
- pH
- DO
- Nitrogen
  - Ammonia
  - Nitrate
  - Nitrite
  - Total Kjeldahl (TKN)

# Biochemical Oxygen Demand (BOD)

- The BOD test is used to measure the sample's organic strength.
- Measures the amount of oxygen required by a sample during the five days of incubation


Incubated at 20 ± 1º C for 5 days ± 6 hours in the dark

# History of BOD

- Thames River - London, England
  - Five days was chosen because this was supposedly the longest time that river water in the Thames River took to travel from source to ocean in UK

## History of BOD

- This 5-day BOD test result may be described as the amount of oxygen required for aquatic microorganisms to stabilize decomposable organic matter under aerobic conditions.
- A 5-day duration for BOD determination has no theoretical grounding but is based on historical convention.
    - "In a report prepared by the Royal Commission on Sewage Disposal in the United Kingdom at the beginning of the century, it was recommended that a 5-day, 18.3°C, BOD value be used as a reference in Great Britain.
    - These values were selected because British rivers do not have a flow time to the open sea greater than 5 days and average long-term summer temperatures do not exceed 18.3°C."

-Tchobanoglous and Schroeder (1985)

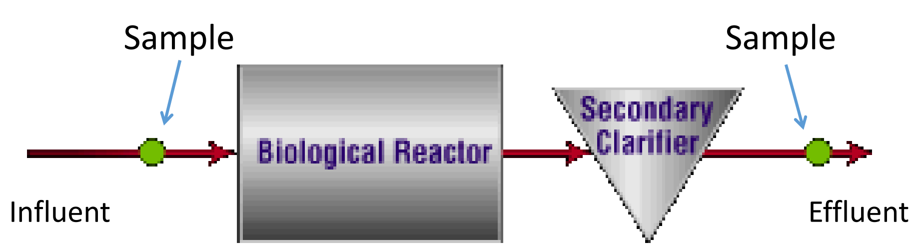
## Biochemical Oxygen Demand (BOD)

- The total BOD includes both carbonaceous BOD and nitrogenous components.
- If your permit requires CBOD only, you must add nitrification inhibitor
    - This prevents the oxidation of nitrogen compounds
- In the US and Canada, the BOD of domestic wastewater typically ranges from 100 to 250 mg/L.
- Industrial wastewater can have much higher levels of BOD.

## Biochemical Oxygen Demand (BOD)

- Typically a composite sample
- Not useful for process control
- Need minimum of 3 dilutions and run a duplicate every 20th sample (or fewer)
  - Influent and effluent are considered separate samples, so if you run BOD 5 days/week, that would be considered 20 samples within that week.

## BOD Sampling Locations




Samples should be collected before chlorine. If chlorine is present, dechlorination chemicals must be added prior to testing

## $BOD_5$ Procedure

1. Measure initial D.O.
   - DO measured by Winkler method (titration) or using a meter and electrode.
2. Incubate sample for 5 days
3. Measure final D.O.
4. The $BOD_5$ is the amount of D.O. used up over the 5-day period.


## $BOD_5$

- $BOD_5$ analysis must be done under these conditions:
  - Must be in the dark at 20ºC ± 1ºC
  - **Initial D.O.<9.0 mg/L (blanks and samples)**
  - pH range of 6.5-7.5
  - Must have an existing microbiological population. If not, sample must be "seeded"
  - **Min. sample depletion 2 mg/L and final D.O. of 1 mg/L**
  - **Max depletion of blanks is 0.2 mg/L**

## Biochemical Oxygen Demand (BOD)

**REQUIREMENTS**
**FOR**
**VALID $BOD_5$ RESULTS**

**<u>Blank depletion</u>** must be **≤ 0.2 mg/L** DO

**<u>Initial DO</u>** must be **≤ 9.0 mg/L**

Samples **<u>must deplete</u>** at least **2.0 mg/L** DO

Samples must have at least 1.0 mg/L DO **<u>remaining</u>**
at the end of the incubation period

## BOD Equations

- See Formula Book

<u>Unseeded</u>

$$BOD = \frac{[(Initial\ DO, mg/L) - (Final\ DO, mg/L)][300\ mL]}{mL\ of\ Sample}$$

<u>Seeded</u>

$$BOD = \frac{[(Initial\ DO, mg/L) - (Final\ DO, mg/L) - Seed\ Correction\ Factor, mg/L][300 mL]}{mL\ of\ Sample}$$

## BOD Calculation

- Initial DO = 8.2 mg/L
- Final DO = 4.5 mg/L
- Sample Volume = 6 mL

$$BOD = \frac{[(Initial\ DO, mg/L) - (Final\ DO, mg/L)][300\ mL]}{mL\ of\ Sample}$$

$$\text{BOD} = \frac{[(8.2\ mg/L) - (4.5\ mg/L)][300\ mL]}{6\ mL}$$

$$\text{BOD} = \frac{1110}{6}$$

$$\text{BOD} = 185\ mg/L$$

## BOD Calculation

- Use the following data to determine the BOD for this sample:
  - Initial DO = 8.1 mg/L
  - Final DO = 4.0 mg/L
  - Sample Volume = 12 mL

$$\text{BOD} = \frac{[(8.1\ mg/L) - (4.0\ mg/L)][300\ mL]}{12\ mL}$$

$$\text{BOD} = 102.5\ mg/L$$

## Ultimate BOD (aka Total BOD or Extended BOD)

- The ultimate BOD is the total amount of dissolved oxygen it would take to completely break down all the organic material in a sample over an infinite amount of time.
  - Normally never run for plant control.
- BOD consumed + BOD remaining = Ultimate BOD

## Chemical Oxygen Demand

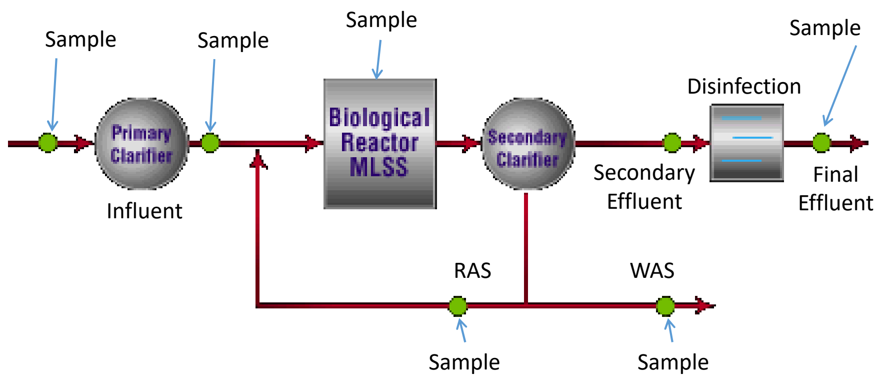
- The COD test is used for more rapid assessment of organic strength.
- The COD test measures oxidizable organic matter.
- Can be useful for process control:
  - Test yields data in 2 to 4 hours
  - BOD typically lower than COD (typical ratio is 0.5 to 1 for raw wastewater)
  - Ratio must be established for a specific plant.

## Suspended Solids

## Suspended Solids

- Amount of material suspended in sample
  - Suspended solids are a combination of settleable solids and those that will remain in suspension
- To control activated sludge processes and account for solids inventories, we need to know the suspended solids at various stages through the process
- The SS test measures the amount of solids in suspension that can be removed by filtration
  - The sample is filtered through a pre-weighed filter paper and dried in an oven at 103-105ºC

## Suspended Solids Sample Points




## Mixed Liquor Suspended Solids (MLSS) Calculation

- Use the following data to determine the MLSS for this sample.
  - Weight of filter and dry solids = 0.5955 g
  - Weight of filter = 0.4021 g
  - Sample volume = 50 mL

- SS, mg/L = $\frac{(A-B)(1{,}000{,}000)}{Sample\ Volume, mL}$
- Where
  - A = final weight of pan, filter and residue, in grams
  - B = weight of prepared filter and pan, in grams

## MLSS Calculation

- Weight of filter and dry solids = 0.5955 g
- Weight of filter = 0.4021 g
- Sample volume = 50 mL

$$\text{MLSS, mg/L} = \frac{(A-B)(1{,}000{,}000)}{Sample\ Volume, mL}$$

$$\text{MLSS} = \frac{(0.5955 - 0.4021)(1{,}000{,}000)}{50 \text{ mL}}$$

$$\text{MLSS} = \frac{(0.1934)(1{,}000{,}000)}{50 \text{ mL}}$$

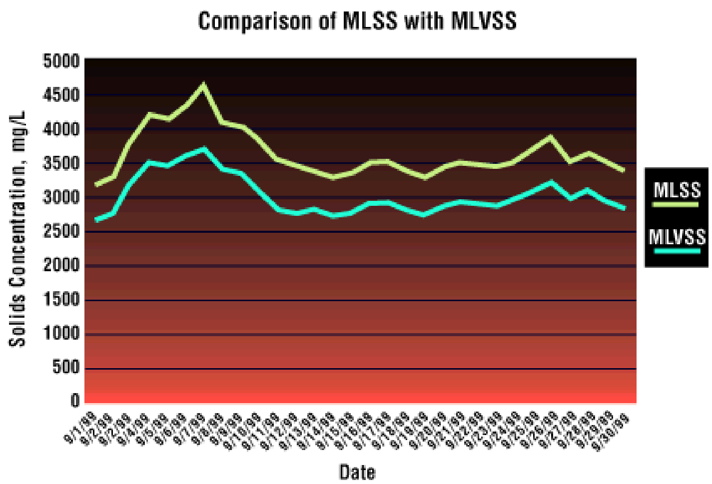
$$\text{MLSS} = 3868 \text{ mg/L}$$

## Suspended Solids

- Results of SS tests are used to determine secondary process removal efficiencies, SRT, F:M, and solids loading.

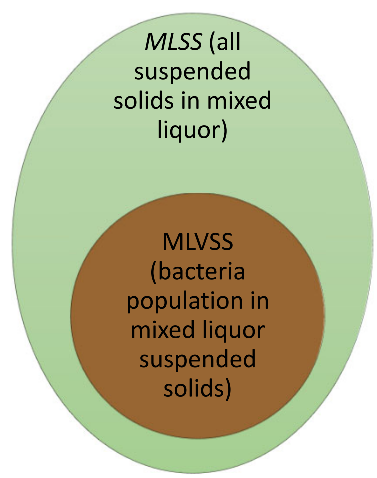
# MLSS vs. MLVSS

(Mixed Liquor Suspended Solids vs. Mixed Liquor Volatile Suspended Solids)




# MLVSS

- MLVSS is typically performed immediately following the SS test
- The filter paper and solids from the SS test are burned at 550ºC in a muffle furnace
- Indicates the portion of microorganisms in biomass
  - Usually 80-85% of MLSS



## Food to Microorganism Ratio

- F:M = $\frac{BOD\ mg/L}{MLVSS,lb}$

- See formula book or refer back to previous slides for BOD and MLVSS calculations

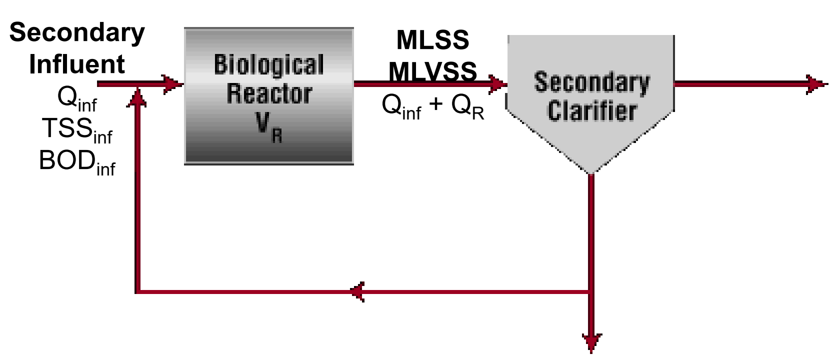
- Loading Rate, lb/day

= *(Flow, MGD)(Concentration, mg/L)(8.34 lb/gal)*

- Note: The following slides will be combining equations

## F:M Ratio (Food to Microorganism Ratio)

- F:M = $\frac{(BOD_{inf},\ mg/L)(Q_{inf},\ MGD)(8.34\ lbs/gal)}{(MLVSS,\ mg/L)(Aerator\ Vol,\ MG)(8.34\ lbs/gal)}$



## F:M Ratio

- Target F:M values
  - Conventional = 0.2 – 0.5
  - Nitrifying less than or equal to 0.10
- F:M based on BOD measurements does not give immediate process control feedback
- Running averages of F:M provide useful monitoring input
- F:M can be based on COD measurements when immediate process feedback is required
  - $\text{Target F:M COD} = \dfrac{\text{Target F:M}_{BOD}}{\text{BOD:COD}}$

## F:M Example

| | |
|---|---|
| $BOD_{inf}$ | 145 mg/L |
| $Q_{inf}$ | 15 MGD |
| MLVSS | 2500 mg/L |
| Aerator Volume | 2 MG |

- $\text{F:M} = \dfrac{(BOD_{inf}\text{, mg/L})(Q_{inf}\text{, MGD})(8.34\text{ lbs/gal})}{(\text{MLVSS, mg/L})(\text{Aerator Vol, MG})(8.34\text{ lbs/gal})}$
- $\text{F:M} = \dfrac{(145\text{ mg/L})(15\text{ MGD})(8.34\text{ lbs/gal})}{(2500\text{ mg/L})(2\text{ MG})(8.34\text{ lbs/gal})} = 0.44$

# F:M Ratio

| Calculated F:M | Result | Action |
|---|---|---|
| Less than target F:M | Too many microorganisms in process | Increase wasting rate |
| Greater than target F:M | Not enough microorganisms in process | Reduce wasting rate |

- Excess sludge to waste:
  - Excess M to waste (Microorganisms) = $\frac{\text{Current M} - \text{F (Food)}}{\text{F:M Target}}$

# F:M Ratio

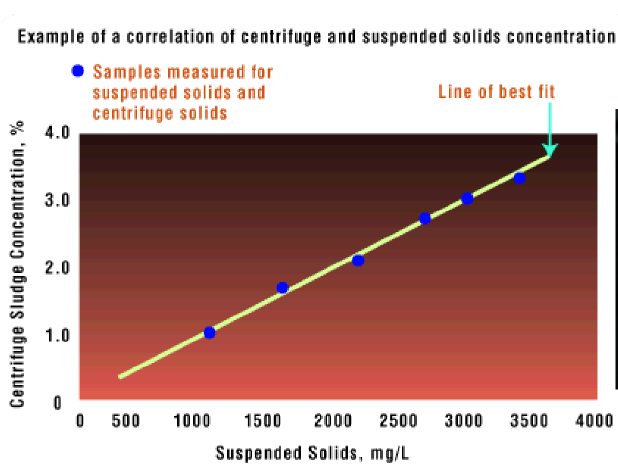
- Excess sludge to waste:
  - Excess M to waste (Microorganisms) = $\frac{\text{Current M} - \text{F (Food)}}{\text{F:M Target}}$
- Three different formulas:
  - Desired MLVSS, lbs = $\frac{\text{BOD or COD, lbs}}{\text{Desired F:M ratio}}$
  - Desired MLSS, lbs = $\frac{\text{Desired MLVSS, lbs}}{\text{\% Vol. Solids, as decimal}}$
  - SS, lbs to waste = Actual MLSS, lbs – Desired MLSS, lbs

## Centrifuge Spin Test

- The centrifuge or spin test is a way of quickly estimating the SS concentration in the mixed liquor or RAS
- You perform the test by placing a well-mixed sample in a centrifuge tube and spinning the sample at high speed for 15 minutes
- The impacted solids are expressed as percent
- Use the same sample for SS test and graph results together with different MLSS values

## Centrifuge Spin Test

- The spin test can be used to get a quick estimate of SS concentrations.

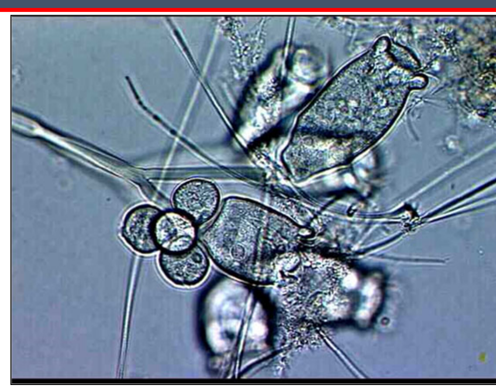


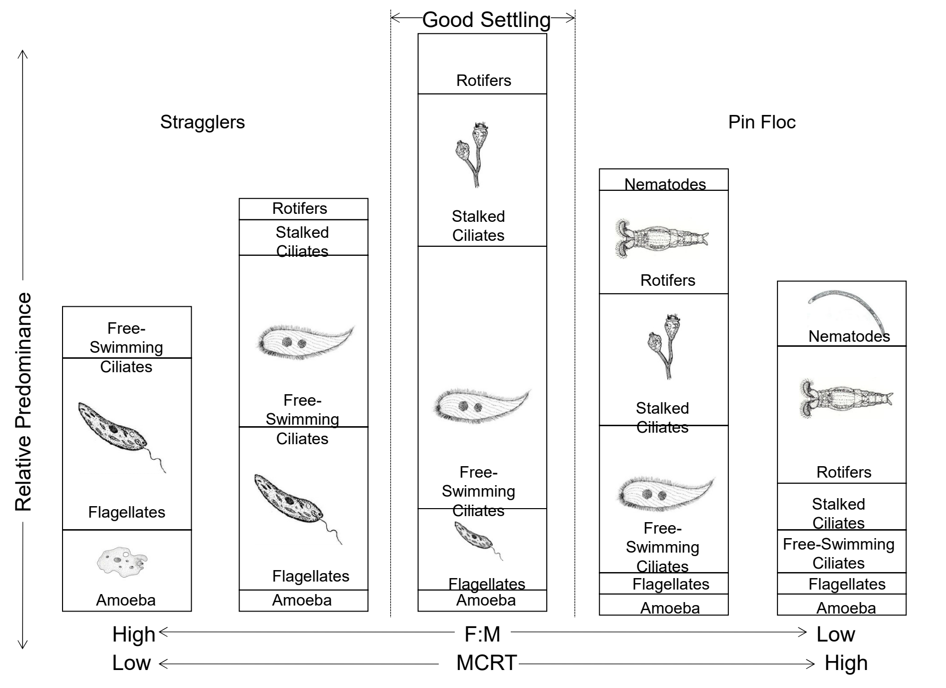

# Microscopic Examination

- Microscopic examinations should be performed immediately after sample collection
- Provides valuable information on the biological characteristics and health of the activated sludge process
- Gives warning of process problems, such as poor settling or the presence of a toxic or inhibitory material

# Microscopic Examination

1. Place a drop of mixed liquor on a slide
2. Place a cover slide on top
   - A healthy activated sludge will have a tight floc structure and many organisms present






## Sludge Age Indicator

- Amoebas indicate young sludge
- They usually predominate at plant start ups
- Environmental conditions:
  - Lots of food (BOD)
  - Insufficient biomass

## Sludge Age Indicator

- Predominance of ciliates and rotifers indicates the process is operating well

- Predominance of rotifers and worms indicates that sludge is old.

Stalked Ciliate

Ciliate

Rotifers

Nematode

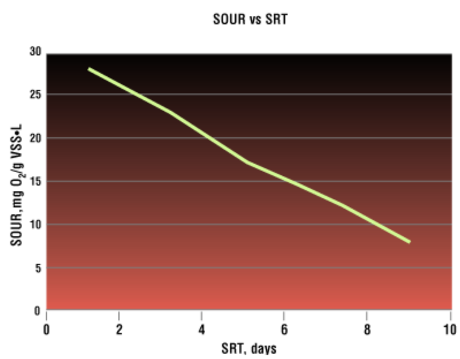
## Oxygen Uptake Rate (OUR)

- Quickly indicates biological activity
- The microorganisms are consistently using DO to oxidize organic matter for new cell growth and energy
- Rate of oxygen used varies considerably with:
  1. Age of the solids
  2. Incoming organic load

- Excess food = reproduce quickly
  - Use up oxygen at a high rate, this results in a high OUR
- As the food supply is used up or the microorganisms are affected by a toxic condition, the growth rate decreases, therefore the OUR would be low

## Oxygen Uptake Rate (OUR)

- Testing for OUR:
  - Collect grab sample
  - Measure DO at regular intervals




## OUR

- Example:
  - Initial DO = 6.1 mg/L
  - Final DO = 1.4 mg/L
    Time = 4.5 min

- OUR, $mg/L/min$ = $\dfrac{Oxygen\ Usage, mg/L}{Time, min}$

$$\text{OUR, } mg/L/hour = \frac{6.1 - 1.4}{4.5}$$
$$= 1.04$$
$$= 1.04\ (60 min/hour)$$
$$= 62.7\ mg/L/hour$$

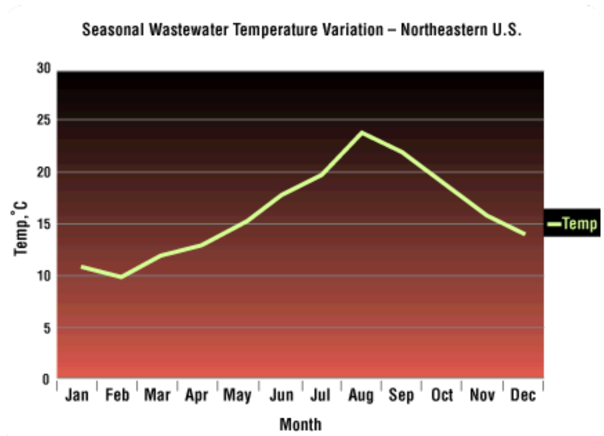
Must multiply by 60 because it's asking for HOURS, not minutes

## SOUR

- Specific Oxygen Uptake Rate
- $\text{SOUR, (mg/g)/hr} = \dfrac{SOUR, mg/L/\ min\ \ (60\ min)}{MLVSS,\ g/L\ (1\ hr)}$

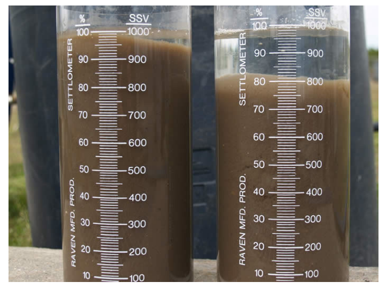
## Temperature

- Microorganisms will respond to temperature changes



## Thirty-Minute Settleometer

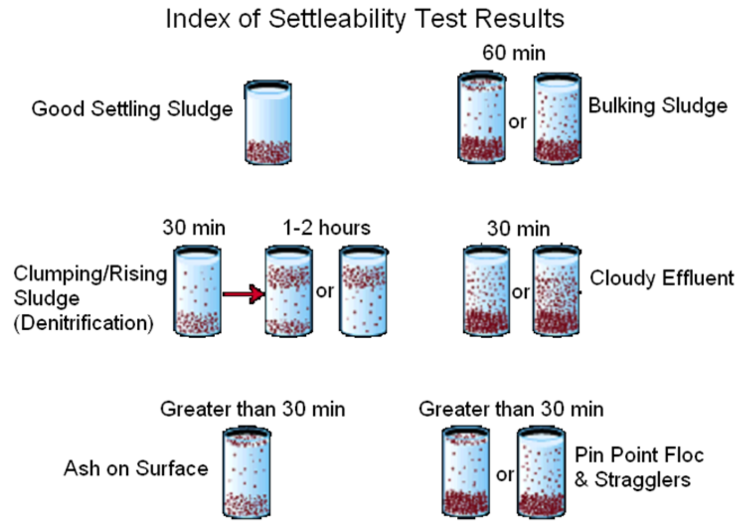
- To produce a good quality effluent, the activated sludge must settle well in the final clarifiers.
- The thirty-minute settleometer test indicates how well the mixed liquor will settle in the clarifiers.



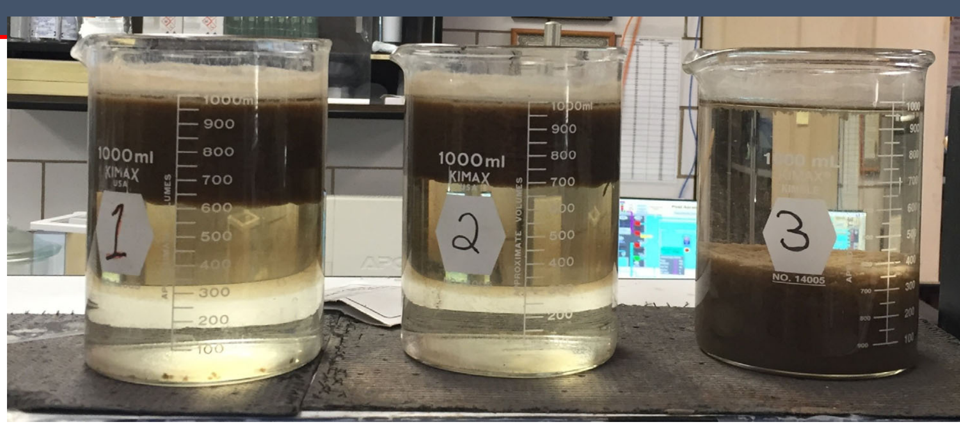
## Thirty Minute Settleometer

- The purpose of the 30-min test is to indicate the solids – liquid separation capability of the sludge that is going to the secondary clarifiers
  1. Take a 2-L sample of well-mixed mixed liquor and pour it into the settleometer as soon as possible after taking sample
  2. Allow it to settle for 30 minutes and record the level of the sludge blanket
- Note the color and clarity of the liquid and if there are any gas bubbles
- SVI can be determined with this number along with your MLSS, mg/L

# Thirty-Minute Settleometer




# "Popped" Settleometer

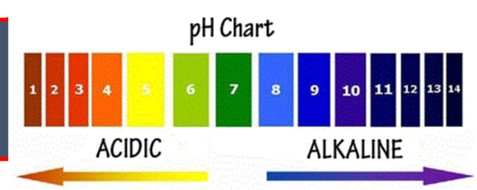



<2-2.5 hours = denitrification in secondary clarifier

# Sludge Volume Index (SVI)

- ***Sludge Volume Index (SVI)* -** The ratio of the volume (in milliliters) of sludge settled from a 1000-mL sample in 30 minutes to the concentration of mixed liquor (in milligrams per liter [mg/L]) multiplied by 1000.
- $$\text{SVI, mL/g} = \frac{(\text{Settled Sludge Vol, mL/L})(1{,}000)}{\text{MLSS, mg/L}}$$
- The proper SVI range for your plant is determined at the time your final effluent is in the best condition regarding solids and BOD removals and clarity.
  - Preferable range is 50-150 mL/gram

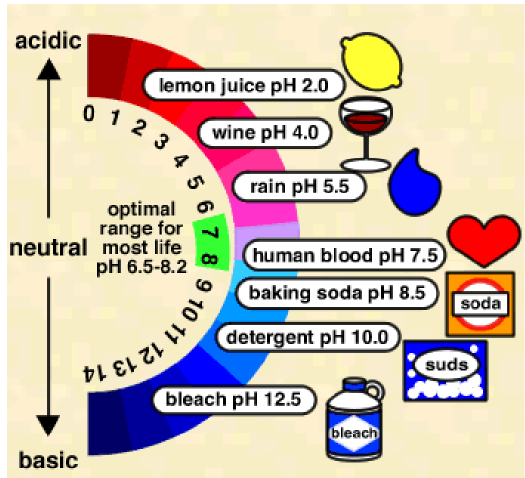
# pH




- Power of hydrogen
  - Measurement of the hydrogen ion concentration
  - Each decrease in pH unit equals a 10x increase in acid
- Indicates the intensity of its acidity or basicity
- Scale runs from 0 to 14, with 7 being neutral
- Probe measures millivolts, then converts into pH units
  - Temperature affects millivolts generated, therefore you need a Automatic Temperature Compensator (ATC)
- If the pH of the mixed liquor varies too far from neutral (pH = 7.0), microorganisms may become inhibited or may start to die.

## pH

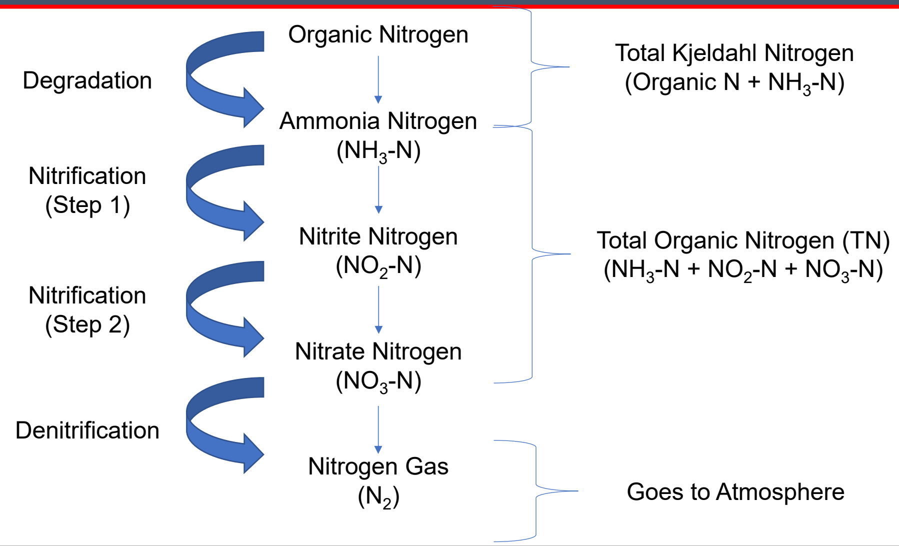
- Calibrate daily with fresh buffers
  - Use at least two buffers
  - 4.0, 7.0, 10.0
- Store probe in slightly acidic solution
- Replace probes yearly




## Dissolved Oxygen

- We must know the oxygen concentration in the aeration tanks to control it for optimum performance
  - Both BOD and nitrification are aerobic processes
- Two options for testing DO
  - DO probe and meter
  - Winkler method

## Nitrogen




## Chlorine Residual

- Two most common tests:
  1. Amperometric titration
     - Less interferences such as color and/or turbidity
  2. DPD ( N,N-diethyl-p-phenylenediamine )
- Analysis should be performed ASAP
- Exposure to sunlight or agitation of the sample will cause a reduction in the chlorine residual

## Chlorine Residual

- Approved Methods:
  - Amperometric titration
  - Iodometric titration – starch endpoint
  - Back titration
  - DPD - FAS
  - Spectrophotometric, DPD ("DPD colorimetric")
  - Electrode
- NOTE: DPD <u>color comparator</u> is NOT an approved method

## Chlorine Residual

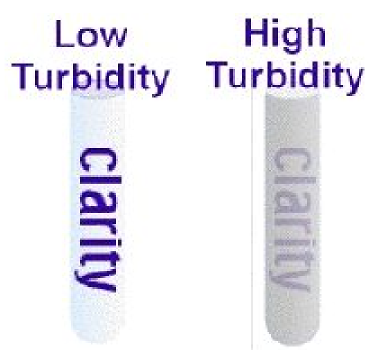
- DPD colorimetric method is the most commonly used
  - Add powder pillow
  - ***<u>Swirl sample for 20 seconds</u>*** to mix
  - Wait ***<u>three minutes</u>*** (Hach method)
  - Place it into colorimeter and take reading

## Alkalinity

- Capacity of water to neutralize acids
- Due to presence of hydroxides, carbonates and bicarbonates
- Many chemicals (alum, chlorine, lime) alters water alkalinity
  - Alum and chlorine destroy
  - Lime adds
  - Nitrification and denitrification also affect alkalinity
- Titration using $H_2SO_4$ (Sulfuric Acid) to pH endpoint
- Expressed as mg/L $CaCO_3$ (Calcium Carbonate)

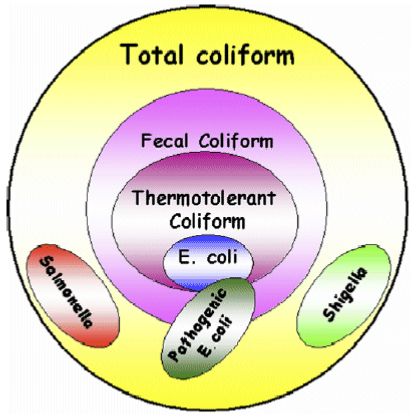
## Turbidity

- Turbidity is a quick (less than 30 minutes) control test that can be used to determine the quality of the treatment plant effluent.



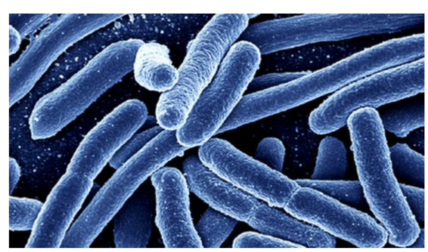
## Coliform Bacteria

- MPN of coliform bacteria are estimated to indicate the presence of bacteria originating from the intestines of warm-blooded animals
- Coliform bacteria are generally considered harmless
  - *But their presence may indicate the presence of pathogenic organisms*




## Coliform Bacteria

- Comprises all the aerobic and facultative anaerobic gram negative, nonspore-forming, rod-shaped bacteria that ferment lactose within 48 hours ~ 35ºC
- 2 groups Coliform bacteria:
  - Fecal
  - Non-fecal



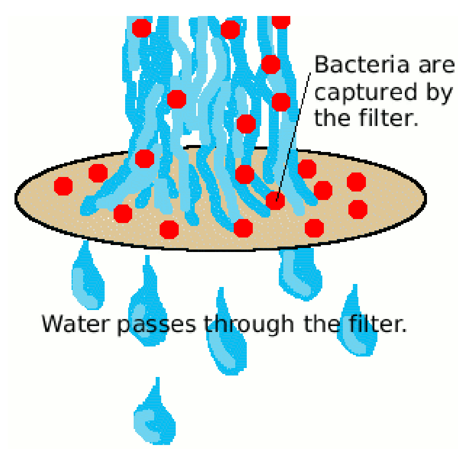
- The fecal group can grow at higher temperatures (45 ºC) than the non-fecal coliforms

# Sampling

- Clean, sterilized borosilicate glass or plastic bottles or sterile plastic bags
- Leave ample air space for mixing
- Collect samples representative of wastewater tested
- Use aseptic techniques; avoid sample contamination
- Test samples as soon as possible

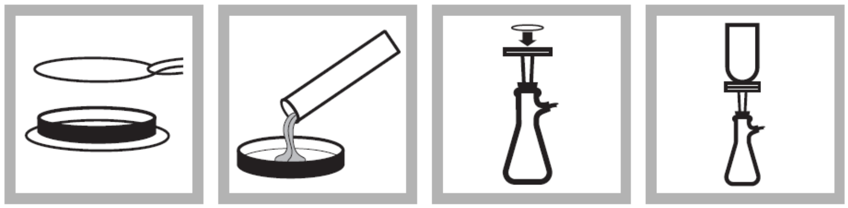
# Approved Methods

- Coliform (fecal)
  - Number per 100 mL
  - Membrane filtration (SM9222 D-2006)
- E. coli
  - Number per 100 mL
  - Membrane filtration
    - m-ColiBlue24®
    - Modified mTEC agar (EPA Method 1603)
  - Multiple tube/multiple well (Colilert®) (SM9223 B-2004)



## Membrane Filtration

**Simultaneous Total Coliform and E.coli Screening** **Method 10029**



1. Use sterilized forceps to place a sterile, absorbent pad in a sterile petri dish. Replace the lid on the dish.

   ***Note:** Do not touch the pad or the inside of the petri dish.*

   ***Note:** To sterilize the forceps, dip them in alcohol and flame in an alcohol or Bunsen burner. Let the forceps cool before use.*

2. Invert ampules two or three times to mix broth. Break open an ampule of m-ColiBlue24 Broth using an ampule breaker. Pour the contents evenly over the absorbent pad. Replace the petri dish lid.

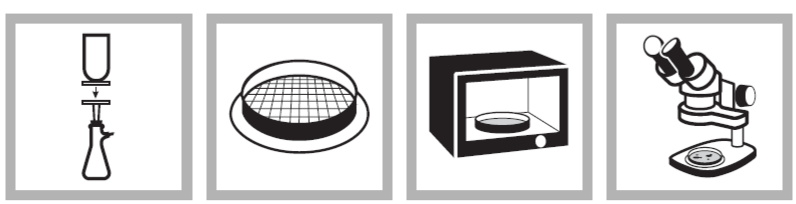
3. Set up the Membrane Filter Apparatus. With sterile forceps, place a membrane filter, grid side up, into the assembly.

4. Shake the sample vigorously to mix. Pour 100 mL of sample or diluted sample into the funnel. Apply vacuum and filter the sample. Rinse the funnel walls three times with 20 to 30 mL of sterile buffered dilution water.

***M-ColiBlue24® Membrane Filtration Method***, Hach Company, www.Hach.com

## Membrane Filtration

**Bacteria, Coliform**



5. Turn off the vacuum and lift off the funnel top. Using sterile forceps, transfer the filter to the previously prepared petri dish.

6. With a slight rolling motion, place the filter, grid side up, on the absorbent pad. Check for trapped air under the filter and make sure the filter touches the entire pad. Replace the petri dish lid.

7. Invert the petri dish and incubate at 35 ±0.5 °C for 24 hours.

8. Remove the petri dish from the incubator and examine the filters for colony growth. Colonies are typically readily visible; however, a stereoscopic microscope or other 10–15X magnifier may be useful. Red and blue colonies indicate total coliforms and blue colonies specifically indicate *E. coli*.

***M-ColiBlue24® Membrane Filtration Method***, Hach Company, www.Hach.com

## Membrane Filtration Equipment

- Water bath or air incubator operating at appropriate temperature
- Vacuum pump
- Alcohol burner
- UV sterilizer or boiling water bath
- 10-15 X dissecting microscope; should have fluorescent illuminator

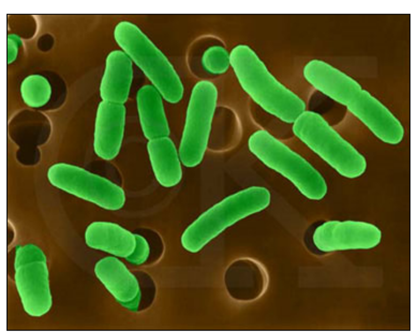
## Membrane Filtration Supplies and Glassware

- Sterile graduated cylinder
- Sterile pipets
- Sterile MF filtration flask
- Sterile dilution water
- Sterile sample vessels
- Samples containing chlorine must be treated with 3% sodium thiosulfate solution
- mFC Broth

## Membrane Filtration Supplies and Glassware

- The device used to sterilize laboratory equipment, DI water, or media is called an autoclave.
- 121°C for 15 minutes at 15 psi

## Fecal Coliform

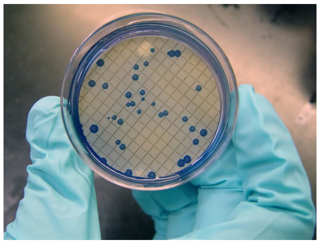


## Fecal Coliform

- A 100 mL volume of sample is filtered through a 47-mm membrane filter using standard techniques
- Filter is transferred to a 50-mm petri plate containing an absorbent pad saturated with mFC Broth
- Invert filter and incubate at 44.5±0.2°C for 24 ± 2 hrs
- Fecal coliform density reported as number of colonies per 100 mL of sample
  - Fecal coliforms appear blue
  - Colonies = colony forming unit = cfu
- NPDES permit limit: monthly average of 200 cfu/100 mL; daily maximum of 1000 cfu/100 mL

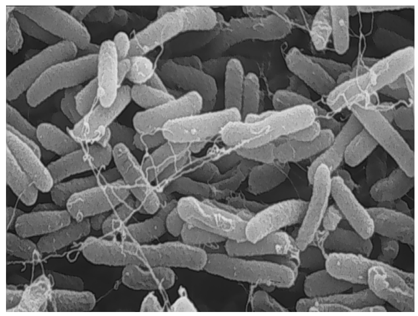
## Fecal Coliform

- Maximum hold time is 8 hrs at < 10°C
- Ideal sample volume yields 20-60 colonies
- Samples <20 mL, add 10 mL sterile dilution water to filter funnel before applying vacuum.
- Sanitize funnel between samples.
- Count colonies
- Verify using 10-15 X binocular wide-field microscope



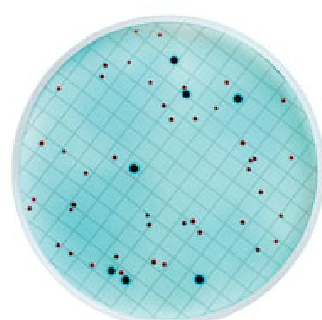
# *Escherichia coli (E.coli)* m-ColiBlue24®

m-ColiBlue24® with Membrane Filtration



# *E. coli* m-ColiBlue24®

- Incubation time is 24 ± 2 hrs at 35 ± 0.5°C
- *E. coli* density reported as number of colonies per 100 mL of sample.
- *E. coli* appear blue
- NPDES permit limit typically has a monthly average of 126 cfu/100 mL
- Samples and equipment known or suspected to have viable *E. coli* attached or contained must be sterilized prior to disposal.

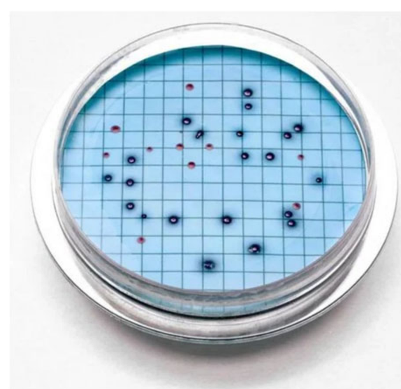


## *E. coli* m-ColiBlue24®

- Maximum hold time is 8 hrs at < 10°C
- Ideal sample volume yields 20-80 colonies
- Run a minimum of 3 dilutions
- Samples <20 mL, add 10 mL sterile dilution water to filter funnel before applying vacuum
- Sanitize funnel between samples
- Count colonies on membrane filters
- Verify using 10-15 X binocular wide-field microscope

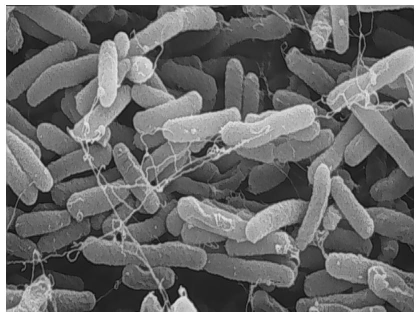
## Expected Reactions of Various Microorganisms

- Total coliforms will produce a red colony
  - Enterobacter species
    - *E. cloacae*
    - *E. aerogenes*
  - Klebsiella species
    - *K. pneumoniae*
  - Citrobacter species
    - *C. freundii*
- *Escherichia coli* will produce a blue colony
  - *E. coli* O157:H7 will not produce a blue colony, but will grow as a red colony



## *Escherichia coli (E.coli)* Modified mTEC agar (EPA Method 1603)

Modified mTEC Agar with Membrane Filtration

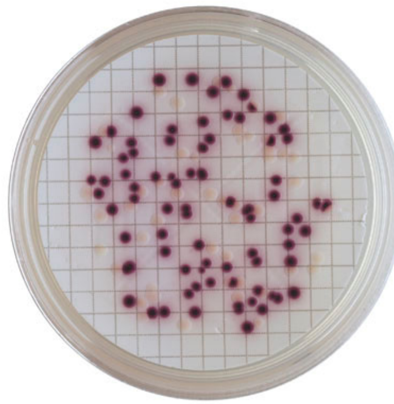


## EPA Method 1603

- Membrane Filter – modified mTEC agar
- Filter sample dilutions through a 47mm diameter sterile, white, grid marked filter (0.45µm pore size)
- Place sample in a petri dish with modified mTEC agar
- Invert dish and incubate for 35 ± 0.5°C for 2 hours
  - Resuscitates injured or stressed bacteria
- Then incubate at 44.5 ± 0.2°C for 22 hours
- After incubation, remove the plate from the water bath or dry air incubator

## Method 1603

- Count and record the number of red or magenta colonies (verify with stereoscopic microscope)
- See the USEPA microbiology methods manual, Part II, Section C, 3.5, for general counting rules



## Method 1603

- QC Tests:
  - Initial precision and recovery
  - Ongoing precision and recovery
  - Matrix spike
  - Negative control
  - Positive control
  - Filter sterility check
  - Method blank
  - Filtration blank
  - Media sterility check

## Method 1603

- Initial precision and recovery
  - Should be performed by each lab before the method is used for monitoring field samples
- Ongoing precision and recovery
  - Run after every 20 field and matrix spike samples or one per week that samples are analyzed
- Matrix spike
  - Run 1 per 20 samples
- Negative control
  - Analyze whenever a new batch of media or reagents is used
- Positive control
  - Analyze whenever a new batch of media or reagents is used

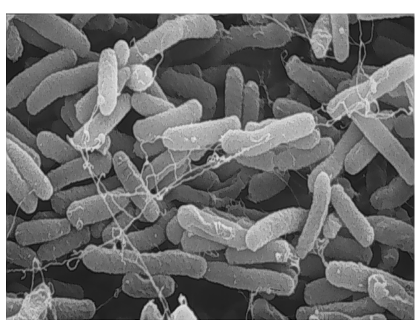
## Method 1603

- Filter sterility check
  - Place at least one membrane filter per lot of filters on a tryptic soy agar (TSA) plate and incubate for 24 ± 2 hours at 35ºC ± 0.5ºC.
  - Absence of growth indicates sterility of the filter
  - Run daily
- Method Blank
  - Filter a 50-mL volume of sterile buffered dilution water and place on a modified mTEC agar plate and incubate
  - Absence of growth indicates freedom of contamination from the target organism
  - Run daily
- Filtration Blank
  - Filter a 50-mL volume of sterile buffered dilution water and place on a TSA plate and incubate for 24 ± 2 hours at 35ºC ± 0.5ºC
  - Absence of growth indicates sterility of the buffer and filtration assembly
  - Run daily

# Method 1603

- Media sterility check
  - The lab should test media sterility by incubating one unit (tube or plate) from each batch of medium (TSA, modified mTEC and verification media) as appropriate and observing for growth
  - Absence of growth indicates media sterility
  - Run daily

# *Escherichia coli (E.coli)* Colilert® & Colilert-18®



## Colilert® & Colilert-18®

- MPN Method
  - Most Probable Number
- Add substrate to a 100 mL sample
- If making dilutions, use sterile DI water, not sterile buffered water.

## Colilert® & Colilert-18®

- Shake sample vigorously
- Wait for bubbles to dissipate
- Pour into QuantiTray

## Colilert® & Colilert-18®

- Seal sample in Quanti-Tray
- Incubate at 35±0.5°C for 18 hrs (Colilert-18) OR 24 hrs (Colilert)

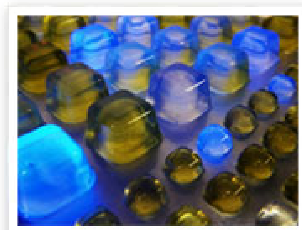
## Colilert® & Colilert-18®

- Examine tray for appropriate color change
- Yellow is an indicator of **total coliforms**

Left: The 97 well QuantiTray 2000 will count up to 2419 cfu without dilution.
Right: The 51 well QuantiTray will count up to 200 cfu without dilution.

## Colilert® & Colilert-18®

- Examine positive total coliform for fluorescence using a UV light in a dark environment
- Fluorescence is a positive indicator for ***E. coli***
- Calculate MPN value according to the table provided with the QuantiTray



## For more information

- For Colilert ®: IDEXX Laboratories, www.idexx.com
- For mTEC Agar and mColiBlue-24® media: Hach Company, www.Hach.com
- EPA Method 1603: E.coli In Water By Membrane Filtration Using Modified membrane-Thermotolerant *Escherichia coli* Agar (Modified mTEC), September 2002, EPA-821-R-09-007

## All Bacteriological Checks

- Temperatures are documented twice daily at least 4 hours apart, while samples are being incubated
- Thermometers are certified at least annually against NIST thermometers
- Reagents for storage requirements and expiration dates
- *E. coli* colonies identified correctly
- Calculations are correct
- Holding Times are met
  - Sample collection
  - Analysis start
  - End times

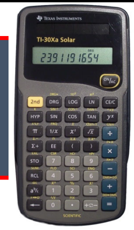
## Geometric Mean

$$\text{Geometric Mean} = (X_1)(X_2)(X_3)\ldots(X_n)^{1/n}$$

$$\text{Geometric Mean} = \sqrt[n]{(X_1)(X_2)(X_3)\ldots(X_n)}$$

- You have run your *E. coli* samples for the month and need to figure your geometric mean.
- Your results are as follows:
  - 60 cfu
  - 100 cfu
  - 0 cfu
  - 0 cfu

# Geometric Mean

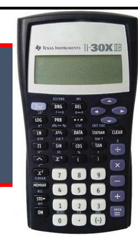


- Geometric Mean – $(X_1)(X_2)(X_3)\ldots(X_n)^{1/n}$
- Step 1: 1/n → 1 divided the number of test results. For our example above, there are four test results.
  - 1 ÷ 4 = 0.25 (write this number down, you will use it in Step 3)
- Step 2: Multiply all of the test results together and punch the = button on the calculator. **Remember to count 0 as a 1**.
  - 60 x 100 x 1 x 1 = 6000 (Do Not clear out your calculator)
- Step 3: Punch the $y^x$ button and then type in the number from Step 1, then punch =.
  - 6000 $y^x$ 0.25 = 8.8011



# Geometric Mean







- Geometric Mean – $(X_1)(X_2)(X_3)\ldots(X_n)^{1/n}$
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  - 60 x 100 x 1 x 1 = 6000 (Do Not clear out your calculator)



- Step 3: Punch the button, then type in the number from Step 1, & then punch =.
  - 6000 $y^x$ 0.25 = 8.8011

## Geometric Mean

- Now, try one on your own:
- 20, 20, 210, 350

- ¼ = 0.25
- (20)(20)(210)(350) = 29,400,000
- $(29{,}400{,}000)^{0.25} = 73.6$

- Geometric Mean = 73.6



Fleming Training Center Your Partner in Clean Water

TN Department of Environment & Conservation

Sampling and Laboratory Vocabulary

**Word Bank**

Composite

Precision

Membrane filtration

Process control tests

Biochemical Oxygen Demand (BOD)

Aseptic

Autoclave

Coliform

Turbidity

Chemical Oxygen Demand (COD)

pH

Samplers (Sampling devices)

Suspended Solids

Grab

Thirty-minute settleometer

1. A _____________________________ (aka proportional) sample is a collection of individual samples obtained at regular intervals, usually every 1 or 2 hours, during a 24 hour period.
2. A _______________________ sample is a single sample of water collected at a particular time and place that represents the composition of water only at that time and place.
3. Another word for sterile is _________________________. You use this type of technique when collecting samples for bacterial analysis.
4. ____________ is an expression of the intensity of the basic or acidic condition of a liquid. It is also described as the measurement of the hydrogen ion concentration, or the power of Hydrogen.
5. The purpose of the _________________________________________test is to indicate the solids – liquid separation capability of the sludge that is going to the secondary clarifiers.
6. The device used to sterilize laboratory equipment, DI water, or media: _______________________
7. _________________________________ can be automated or improvised devices, and may include weighted buckets, beakers, or other containers attached to a rod or chain.
8. Tests frequently performed by operators to quickly obtain the results and make any necessary process adjustments are known as ________________________________. Results of these tests are not reported each month, but the data should be documented in-house.
9. _______________________________ is a measure of the clarity or cloudiness of water, and is expressed in NTUs.

10. This test is used to determine a sample's organic strength by measuring the amount of oxygen required by a sample during a five day incubation period: ________________________________

11. The _________________________test is used for more rapid assessment of organic strength (results in 2 hours instead of 5 days with BOD).

12. Results from the _________________________________ measures the amount of solids in suspension that can be removed by filtration (and is a combination of settleable solids and those that will remain in suspension). The sample is filtered through a pre-weighed filter paper and dried in an oven at 103-105ºC.

13. The term ______________________________refers to all the aerobic and facultative anaerobic gram negative, nonspore-forming, rod-shaped bacteria that ferment lactose within 48 hours ~ 35ºC. There are 2 groups: Fecal and Non-fecal.

14. During ________________________________________, water passes through a filter, while bacteria are trapped or captured on the surface of the filter.

15. _____________________________ refers to the closeness of two or more measurements to each other. This is not to be confused with Accuracy, which refers to the closeness of a measured value to a standard or known value

# Section 4
# Microscopic Examination

# Section 4
# Microscopic Exam

## The First Light Microscopes

- Around 1590 Zaccharias and Hans Janssen experimented with lenses in a tube, leading to the forerunner of the microscope and the telescope
- In the late 1600's, Anton van Leeuwenhoek was the first to see bacteria, yeast, and many other microbes using a microscope

## Microscopes

- 2 types generally used
  1. Compound
     - High-magnification
     - 40x to 1000x
     - Monocular or binocular
  2. Stereoscopic or Dissecting
     - Lower magnification
     - 8x to 40x
     - Use for counting bacterial colonies (membrane filtration)
     - For objects too thick or large to be seen with higher magnifications, but too small for the naked eye

## Microscopes

- Compound Microscope

- Dissecting Microscope

## Microscopes

- Magnification usually written as a number followed by "x"
  - "x" stands for "times life size"
  - Ex: 10x means 10 times life size

- Magnification will be marked on the side of the objective lens


## Compound Microscopes

- All compound microscopes contain lens system consisting of:
  1. Objective lens
     - Produces the image (magnified)
     - Usually 4X, 10X, 40X
  2. Ocular (eyepiece)
     - Also magnifies the image (usually 10x)
     - May contain a pointer or counting grid
- Total magnification = magnification of ocular lens multiplied by magnification of objective lens
  - Ex: 40X (objective lens) x 10X (ocular lens) = 400X magnification

## Compound Microscopes

- Objective lenses:
  - 4x low power objective or "scanning objective"
  - 10x medium power objective
  - 40x high power objective
  - 100x "Oil immersion lens"
    - Use of immersion oil with this objective will increase resolving power (resolution)
    - Resolution = makes details clear and distinguishable

## Compound Microscopes

- Moveable Stage
  - With clips to hold the slide
- Course Adjustment Knob
  - Moves the stage in larger increments
  - Use with scanning objective (10x)
  - Never use this knob with 40x or 100x objectives
- Fine Adjustment Knob
  - Moves the stage in very small increments
  - Focusing

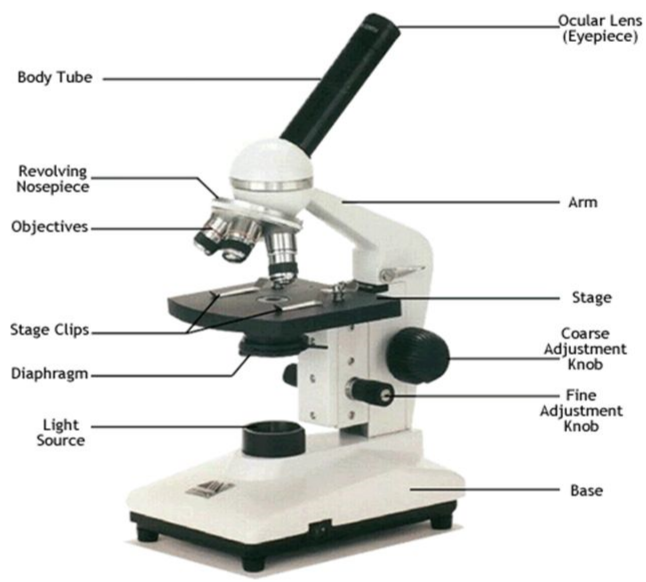
# Compound Microscopes

- Light source
  - "Illuminator" or lamp built into base
    - Adjustable light intensity
  - Mirror beneath stage, separate lamp required for illumination
  - Brightfield: light rays passed through a condenser that directs rays through specimen

- Diaphragm
  - Rotating disc diaphragm: different holes through which light passes
  - Iris diaphragm: aperture size is regulated by an

10

# Parts of the Microscope



# Procedure

1. Always carry microscope with 2 hands: one on the arm and one under the base for support
2. Clean ocular and objective
   - Only use lens paper!
3. Rotate 4x scanning objective into place
4. Open iris diaphragm fully
5. Use coarse adjustment knob to bring slide closer to lens
6. Once you can see the object, use fine adjustment knob to sharpen the focus

# Procedure (continued…)

7. While watching from the side, rotate to next higher objective
   - Only a minor adjustment with the fine adjustment knob should be needed to focus.
8. Repeat the above step until you get to the high power objective
   - Only use fine adjustment knob at this point!
9. If using immersion oil, move objectives until it is between 40x and 100x. Add one drop of oil onto slide, then slowly finish rotating 100x into position

## Procedure (continued…)

- When you are finished with your exam, clean oil off of objective!
- To store scope:
  - move to low power objective
  - raise stage, wrap cord around base
  - lower stage gently to secure cord
  - add protective cover

## Tips

- Always clean the lenses before beginning
- Always watch from the side when changing objectives
  - Never force the objective into place
- Watch from the side while making major adjustments with coarse knob to avoid ramming stage into objective lens
- Continually vary the light intensity to find the correct level
  - Excessive light eliminates color and contrast
  - You may need to increase light with higher objectives
- If you are seeing dark spiky things, it's probably your eyelashes – try moving a little closer

## Sample Collection

- Potential sampling areas
  - Aeration Basin
  - Suspect problematic areas
  - Mixed Liquor
  - WAS
  - RAS

## Sample Collection

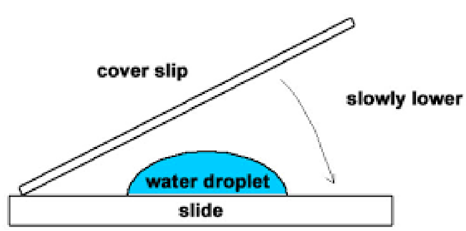
- 100 mL plastic bottles
- Select:
  - Mixed liquor from effluent side
  - Discharge from secondary clarifier center well
  - RAS pump discharge
- Foam samples (if suspect)
- Wastewater Inflent/Effluent samples

## How to Prepare a Wet Mount Slide

1. Clean slide & cover slip
2. Shake sample bottle, transfer 50 mL to beaker
3. Drop of sample to slide center
4. Hold cover slip at 45º above sample
5. Slide slip toward sample drop
6. Allow sample to spread to cover slip edge

## How to Prepare a Wet Mount Slide

7. Drop slip into place on sample
8. Press slip w/ pencil eraser to spread
9. Absorb excess sample with tissue
10. ID the slide with appropriate markings

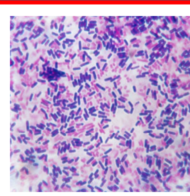


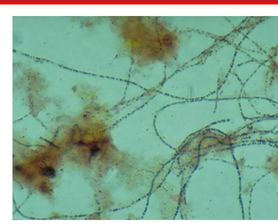
# Slide Prep, Staining

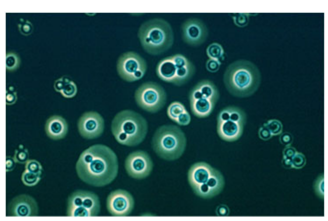
- Clean slide & cover glass
- Drop of sample in center of slide
- Spread/smear sample w/ glass rod
- Air-dry(do not use a heat source….hair-dryer)
- Stain per Standard Methods, following protocol, or manufacturer instructions

# Staining Types

- Gram stain
- Neisser stain
- India Ink reverse stain
- Polyhydroxybutyrate stain
- Crystal Violet Sheath stain

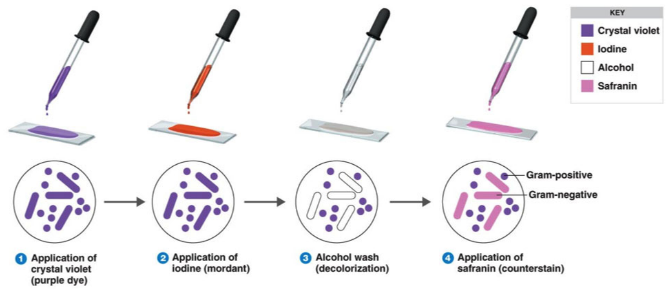






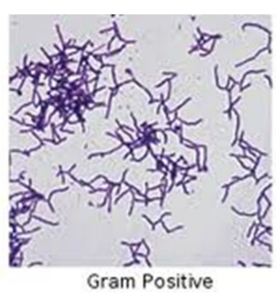
## Gram Stains, How-To

1. Prepare thin smear of sample-air dry
2. Stain 1 minute w/ Gentian Violet - rinse 1 sec in water
3. Stain 1 minute w/ Gram's Iodine solution, rinse well
4. Add Decolorizing agent drop-by-drop for 25 seconds, Blot dry



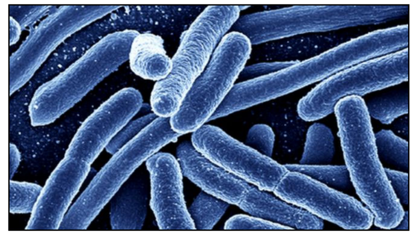

## Gram Stains, How-To

5. Stain w/ Safranin Solution for 1 minute
6. Examine using 1000X mag under oil immersion
   - Blue-Violet is Positive
   - Pink-Red is Negative

## Bacteria

- Convert dissolved organic material
  - Phosphates
  - Sugars
  - Proteins
  - Starches
- Comprise about 95% of activated sludge
  - Most are soil bacteria
- Aerobic, Anaerobic, Facultative
- Sphere (coccus), rod (bacillus), and spiral (spirillum)



*E. coli*

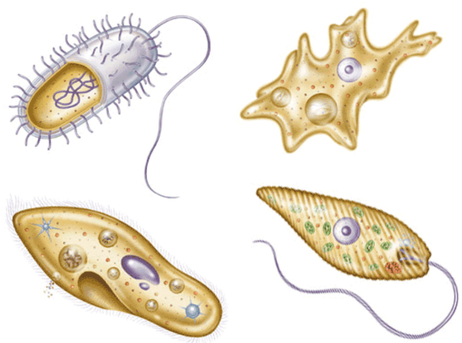
## Filaments (Filamentous Bacteria)

- Some filaments OK for floc formation
  - Forms a backbone of sorts
- Grow in long thread-like strands
- If you have excessive filaments:
  - Check DO levels > 1 PPM
  - Nutrients (N, P, FE)
  - pH
- No Filaments?
  - Check F/M ratio
  - Check DO, reduce if > 3.0 PPM

Source: http://www.environmentalleverage.com

# Protozoa

- Abundant & diverse in activated sludge process
- Inactive?
  - Toxic shocks?
- No Protozoa?
  - F/M too high:
    Reduce wasting, increase return
  - Low to normal F/M:
    Increase DO, toxic shock
- Healthy protozoa, but dispersed floc?
  - Reduce mixing, reduce aeration



http://www.scientific-art.com

# Amoebae

- Earliest organism that show-up in activated sludge process
- Associated with "young sludge"
- Feed by pseudopodia (false feet)
  - Engulf small of organic matter
- Often encyst themselves in wastewater

# Flagellates

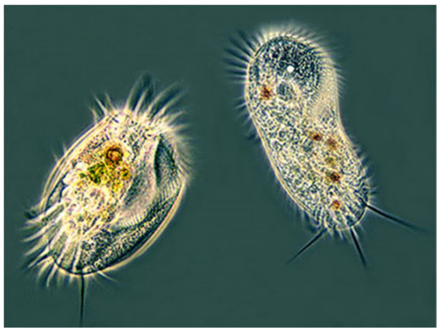
- Tail-like structure which whips back & forth for mobility
- Activated sludge activator
- Some feed on bacteria and small algae
- Others feed on soluble organic nutrients
  - Dominate early in treatment process when nutrients are high
  - Compete with bacteria

Source: http://www.environmentalleverage.com

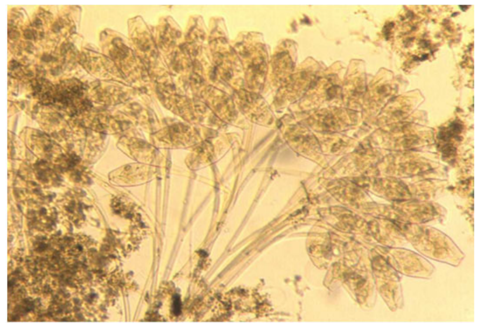
# Free & Stalked Ciliates

- Highly prized in wastewater activated sludge
- Associated w/ good settleability
- Low suspended solids
- Organism in sweeping motion
- Sweeping effect by ciliates gather small particles to form floc
- Settle rapidly
- Requires good bright microscopy to see these organisms
- Phase contrast may offer better visibility

# Free & Stalked Ciliates



Free Swimming Ciliates



Stalked Ciliates

# Rotifers

- Rotary sweeping organism that pull small particles into mouth
- Constant movement
- Wastewater plants may prefer larger numbers in activated sludge process
- Better settling
- In some wastewater, higher numbers mean old sludge and more wasting needs
- Best viewed with bright microscopy at 300X to 400x

# Nematodes

- Roundworms that feed on organic matter and bacteria
- Associated with old sludge
- Substantial numbers usually a sign to increase wasting rates
- Some are predators feeding upon protozoa, rotifers
- Best viewed upon Bright Microscopy at 300X

# Algae/Fungi

- Lagoon or pond type organisms
- Contribute to SS
- Add oxygen in sunlight
- Control or harvest is essential
- Best viewed with bright microscopy at <400X
- Phase contrast helps identify species

## Scope Care & Maintenance

- Never touch lens
- Never leave slide on stage when not in use
- Always remove oil from objective
- Stage should be clean
- Do not tilt microscope when using oil
- Keep microscope covered when not in use
- Store in cabinet when not in use
- Regular professional service

## Troubleshooting

- Image is too dark!
  - *Adjust the diaphragm, make sure your light is on*
- Only half of my viewing field is lit, it looks like there's a half-moon in there!
  - *You probably don't have your objective fully clicked into place*

## Troubleshooting (continued…)

- There's a spot in my viewing field, even when I move the slide the spot stays in the same place!
  - *Your lens is dirty.*
  - *Use lens paper, and only lens paper to carefully clean the objective and ocular lens.*
  - *The ocular lens can be removed to clean the inside*

## Troubleshooting (continued…)

- I can't see anything under high power!
  - *Remember the steps: if you can't focus under scanning and then low power, you won't be able to focus anything under high power*



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TN Department of Environment & Conservation

# Section 5
# Solids Treatment

# Section 5
# Sludge Thickening, Digestion, and Dewatering

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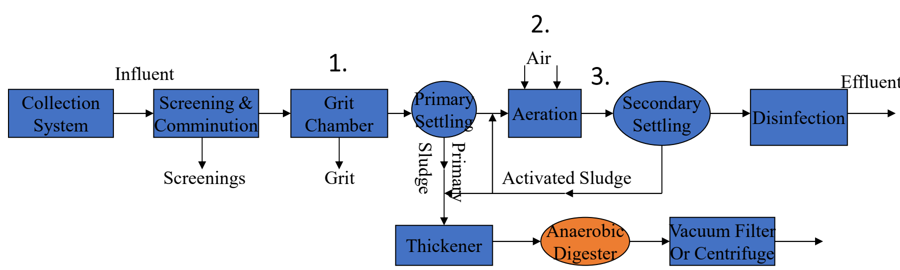


## Process Overview

1. Solids from preliminary treatment are sent to landfill
   - Screenings (coarse solids), grit, scum
2. Primary and secondary solids are most often treated onsite
   - Primary sludge usually is grey and slimy with an offensive odor
   - Sludge from activated sludge and trickling filter has brown, flocculant appearance, both digest readily
3. Sludge from chemical precipitation with metal salts
   - Usually dark in color and may be gelatinous
   - Decomposes slowly and may give off large amounts of gases

## Sludge Thickening, Digestion, and Dewatering

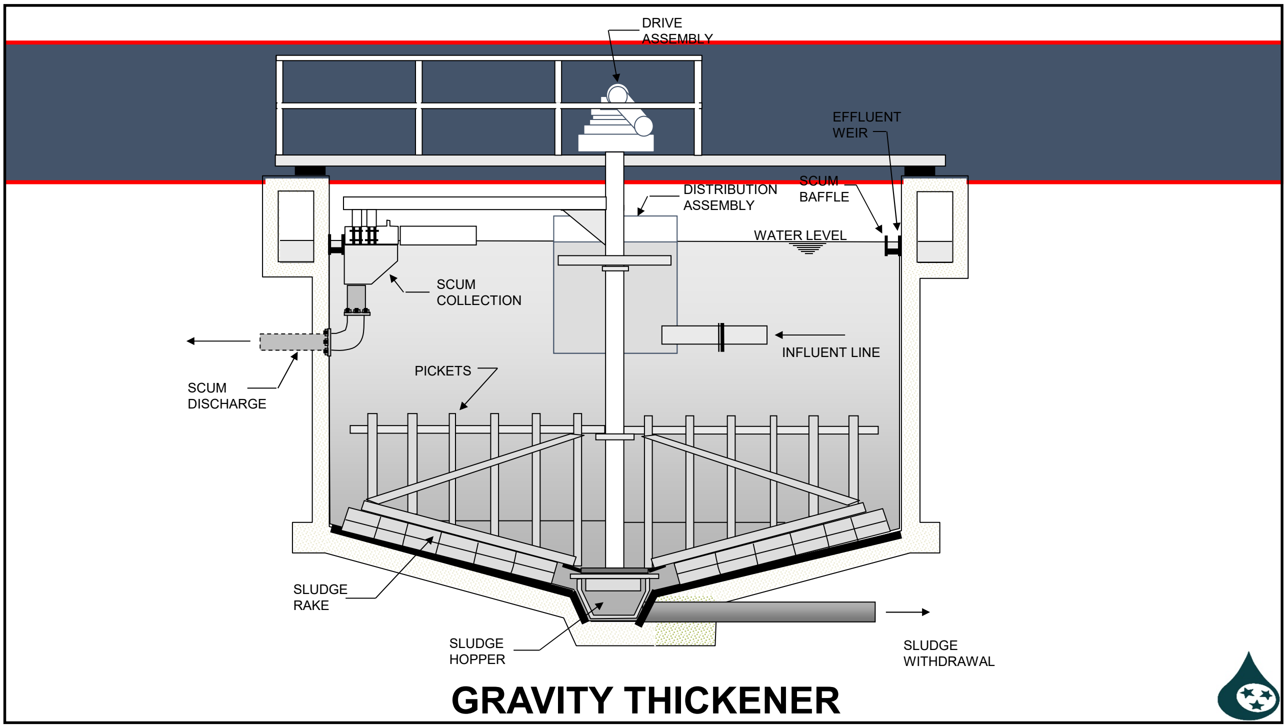
- Thickening
  - Gravity
  - Gravity belt
  - Dissolved Air Flotation (DAF)
- Stabilization
  - Anaerobic digestion
  - Aerobic digestion
- Dewatering
  - Centrifuge
  - Plate and frame
  - Belt filter press
  - Vacuum filter
  - Drying beds

# Sludge Thickening

Main component of sludge is water
~90% or more before treatment

# Gravity Thickening

- Most effective on primary sludge
- Detention time is around 24 hours
- Thickening tank looks like a primary circular clarifier
- Monitored for blanket depth and sludge concentration
- Affected by temperature of sludge
  - Increased temperature will increase biological activity and gas production

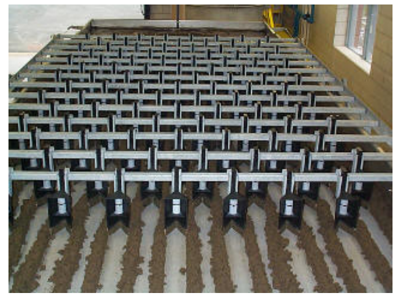



## Gravity Thickening

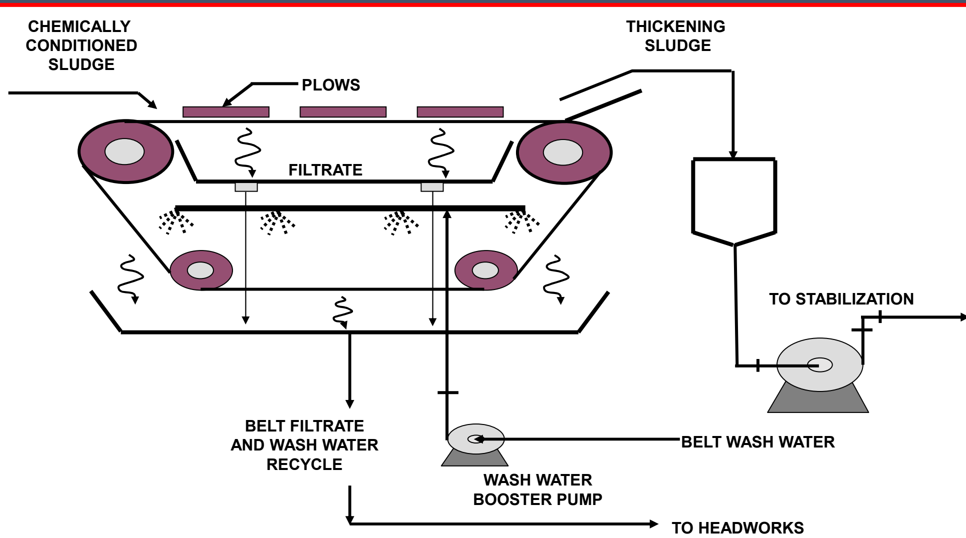
- Separates solids into three zones:
  1. Clear supernatant
  2. Sedimentation zone
  3. Thickening zone
- Dilute sludge is fed into center well
- Supernatant is returned to primary clarifier or plant headworks
- Thickened sludge is pumped to digester or dewatered

## Gravity Belt Thickener

- Concentrates solids on a porous horizontal belt
- Sludge usually preconditioned with polymer
- Water drawn by gravity through the belt
- Can thicken secondary sludge to 4 –7% solids



## Gravity Belt Filter Thickener



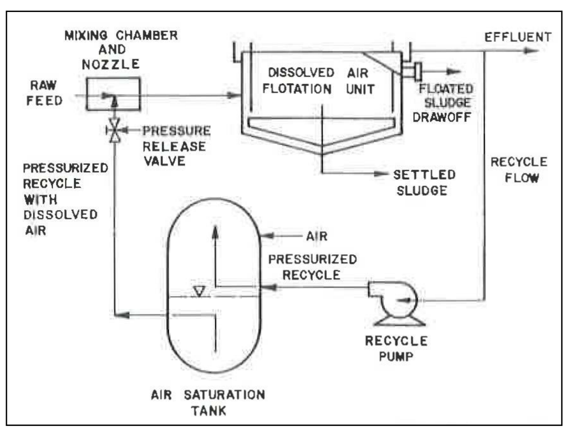
## Dissolved Air Flotation Thickening (DAF)

- Two components:
  1. Flotation unit- serves to separate the solid phase from the liquid phase
  2. Saturator- dissolves air into water under pressure
     - Pressure saturated water introduced to the flotation unit
- Air bubbles attach to the solids and carry them to the surface- they accumulate as a float ( This is the *separation of solids/liquids* stage)
- Solids ("Float cake") continuously removed by scraping
- Drainage of intestitial water from the float above the water level increases solids concentration (This is the *thickening* stage)

## Dissolved Air Flotation Thickening (DAF)

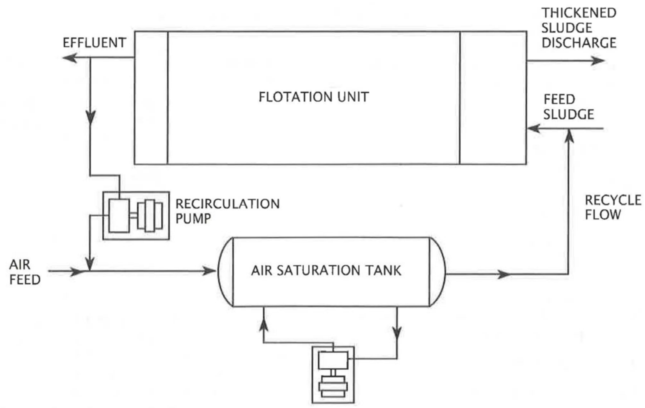
Principle factor affecting thickening during flotation =

**Drainage of float layers above the water level**

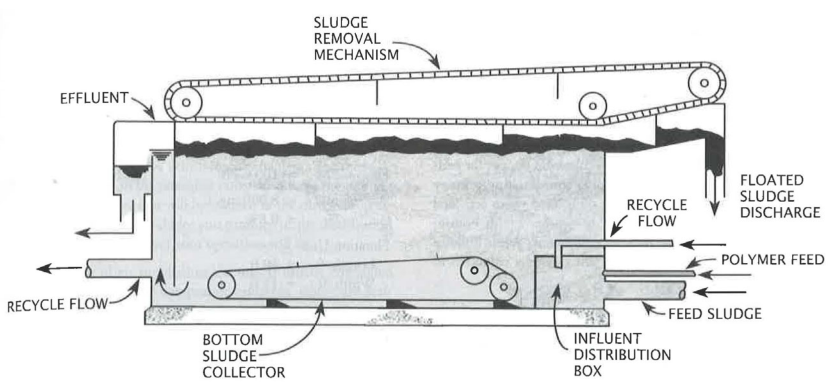



- Cake 2-4% solids vs 3-5% solids with polymer

# Dissolved Air Flotation Thickening (DAF)




# Dissolved Air Flotation Thickening (DAF)



# Biosolids Stabilization (Digestion)

Reduce volume

Stabilize organic matter

Eliminate pathogenic organisms

# Stabilization

- Helps to avoid odor problems
- Prevents breeding of insects
- Reduces the number of pathogenic organisms

- Sludges can be stabilized 2 ways:
  1. Anaerobically (in anaerobic digester, sludge heated and organics hydrolyzed into methane ($CH_4$), $CO_2$ and $H_2O$, and volatile solids reduced)
  2. Aerobically (in unheated digester, producing $CO_2$ and $H_2O$, and reducing volatile solids)

## General Overview

Before digestion of 100 pounds of sludge: 75% Volatile, 25% Fixed Solids

75 Lbs VS

25 Lbs Fixed

After a 65% reduction in Volatile Solids there is less sludge remaining to process

50 Lbs of $CH_4$, $CO_2$, $H_2O$

25 Lbs VS

25 Lbs Fixed

## Biosolids Stabilization

Anaerobic Digestion

## Anaerobic Digestion

- Removes 50-65% VS and 85-99% of pathogens
- Wastewater solids and water are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen.
- The purpose of sludge digestion is to decrease the bulk of sludge to facilitate handling, to decompose enough of the organic matter to avoid creating a nuisance and to separate the liquid from the solids to facilitate drying.
- At least two general groups of bacteria act in balance: Saprophytic Bacteria and Methane Producers break down the acids to methane, carbon dioxide, and water.

## Anaerobic Digestion

- Anaerobic Digestion reduces wastewater solids from a sticky, smelly mixture to a mixture that is relatively odor free, dewaterable and capable of being disposed of without causing a nuisance.
- In this process organic solids in the sludge are liquefied, the solids volume is reduced, and valuable methane gas is produced in the digester by the action of two different groups of bacteria living together in the same environment.

  1. Saprophytic organisms, commonly referred to as “acid formers.”
  2. “Methane producers” use the acid produced by the saprophytes

## Anaerobic Digestion

- 2-phase process:
  - Acid formers - Facultative bacteria convert organic matter to volatile acids, $CO_2$, and $H_2S$
  - Methane producers - Anaerobic bacteria convert acids to $CH_4$ and $CO_2$
    - The methane producers are not as abundant in raw wastewater as are the acid formers.
    - The methane producers desire a pH range of 6.6 to 7.6 and will reproduce only in that range.
- 28-40% carbon dioxide, 60-72% methane
  - Minimum methane for reuse is 62%
- Sludge retention time is 30-60 days

## Anaerobic Digestion

- The object of good digester operation is to maintain conditions in the digester for growing (reproducing) populations of both acid formers and methane fermenters.
- You must do this by controlling:
  - Loading rate of food supply (organic solids/cBOD)
  - **Volatile acid/Alkalinity ratio**
  - Mixing
  - Temperature

## Temperature Ranges

- Heated units operate ~ 90-95°F
- An anaerobic digester may be operated in one of three temperature zones or ranges, each of which has its own particular type of bacteria.
  - Cold temperature - Psychrophilic bacteria
  - Medium temperature - Mesophilic bacteria
  - Hot temperature - Thermophilic bacteria

## Psychrophilic Bacteria

- The lowest range (in an unheated digester) utilizes Psychrophilic (cold temperature loving) bacteria.
  - The psychrophilic upper range is around 68°F (20°C).
  - Digestion in this range requires from 50 to 180 days, depending upon the degree of treatment or solids reduction required.

## Mesophilic Bacteria

- Organisms in the middle temperature range are called the Mesophilic (medium temperature loving) bacteria
  - Thrive between about 68°F (20°C) and 113°F (45°C).
  - The optimum temperature range is 85°F (30°C) to 100°F (38°C), with temperatures being maintained at about 95°F (35°C) in most anaerobic digesters.
  - Digestion at 95°F may take from 5 to 50 days or more (normally around 25 to 30 days), depending upon the required degree of volatile solids reduction and adequacy of mixing.

## Thermophilic Bacteria

- Organisms in the third temperature range are called Thermophilic (hot temperature loving) bacteria and they thrive above 113 °F (45°C).
- The optimum temperature range is considered 120 °F (49°C).
- The time required for digestion in this range falls between 5 and 12 days, depending upon operational conditions and degree of volatile solids reduction.
  - However, the problems of maintaining temperature, sensitivity of the organisms to temperature change, and some reported problems of poor solids - liquid separation are reasons why only a few plants have actually been operated in the thermophilic range.

## Changing Temperatures

- You can't change temperature and expect a quick change in bacteria population and therefore a shorter digestion time
- An excellent rule for digestion is never change the temperature more than one degree a day to allow the bacterial culture to become acclimated (adjust to the temperature changes).

## Anaerobic Digestion

- Several products end up in the digester that are not desirable because the bacteria can't effectively use or digest them, and they can't be readily removed by the normal process
  - Petroleum products and mineral oils
  - Rubber goods
  - Plastics (back sheets to diapers)
  - Filter tips from cigarettes
  - Hair
  - Grit (sand and other inorganics)

## Anaerobic Digestion

- When wastewater solids are first added to a new digester, naturally occurring bacteria attack(eat) the most easily digestible food available, such as sugar, starches, and soluble nitrogen.
- The anaerobic acid producers change these foods into organic acids, alcohols, and carbon dioxide, along with some hydrogen sulfide.
- The pH of the sludge drops from 7.0 to about 6.0 or lower.
- An acid regression stage then starts and lasts as long as six to eight weeks.

## Anaerobic Digestion

- During this time ammonia and bicarbonate compounds are formed, and the pH gradually increases to around 6.8 again, establishing an environment for the methane fermentation or alkaline fermentation phase.
- Organic acids are available to feed the methane fermenters.
- Larger quantities of methane gas are produced as well as carbon dioxide, and the pH increases to 7.0 to 7.2.
- Once alkaline fermentation is well established, strive to keep the digesting sludge in the 7.0 to 7.2 range.

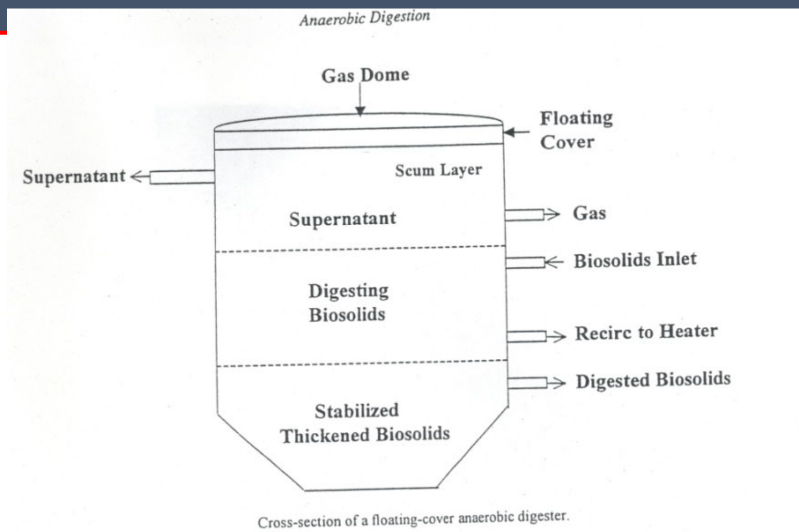
## Feeding Anaerobic Digester

- Better operational performance occurs when the digester is fed several times a day, rather than once a day because you are avoiding temporary overloads on the digester and you are using your available space more effectively.
- Several pumpings a day not only helps the digestion process, but maintains better conditions in the clarifiers, permits thicker sludge pumping, and prevents coning in the primary clarifier hopper.
- Never pump thin sludge or water to a digester.
- A sludge is considered thin if it contains less than 5% solids (too much water).
- Thick a sludge as possible = operating sludge pump for several minutes each hour (at a rate not to exceed 50 GPM)

## Feeding Anaerobic Digester

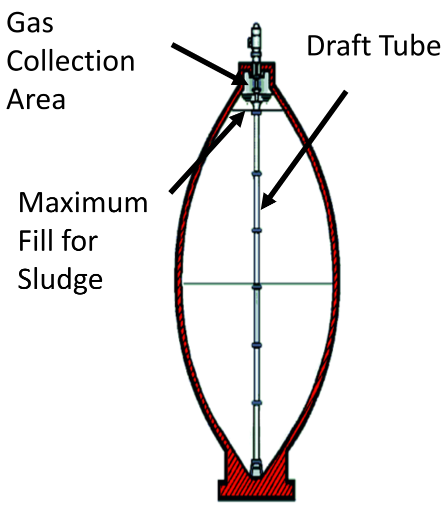
- Reasons for not pumping a thin sludge include:
  - Excess water requires more to heat than may be available
  - Excess water reduces holding time of the sludge in digester, and
  - Excess water forces seed and alkalinity from the digester, jeopardizing the system due to insufficient buffer capacity for the acids produced by digestion of the raw sludge.
- Feeding the digester must be regulated on the basis of laboratory test results in order to ensure that the volatile acid/alkalinity relationship does not start to increase and become too high.
  - Feeding too much = acid fermenters will predominate = pH drops = undesirable condition for the methane fermenters = digester will go sour or acid

# Anaerobic Digestion




Cross-section of a floating-cover anaerobic digester.

# Cross-Section of an Egg-Shaped Digester





Baltimore, Maryland

# Anaerobic Digesters

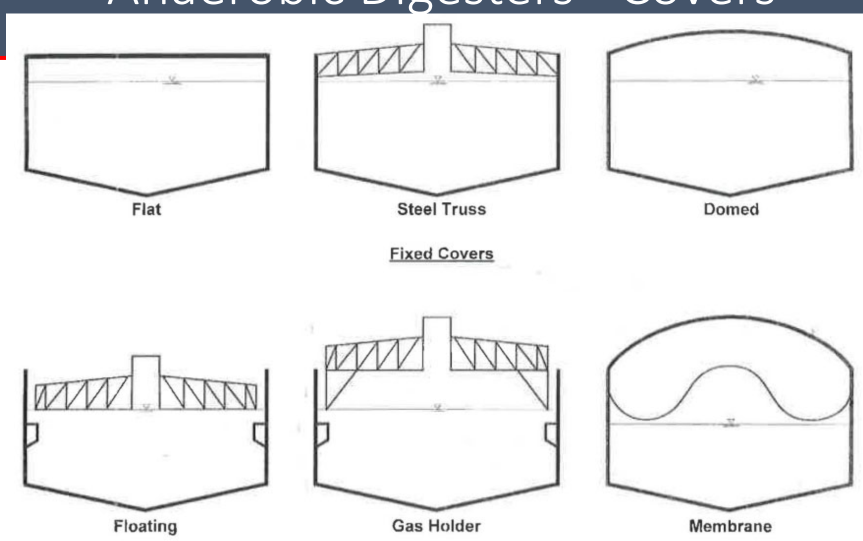
**Fixed Cover Tanks**

- Holds a larger volume of gas
- Must be equipped with pressure and vacuum relief valves to break the vacuum or bleed off excessive pressure to protect from structural damage
- If air is drawn into tank, explosive conditions could develop

**Floating Cover Tanks**

- Moves up and down with tank level and gas pressure
- Flotation chamber: in the roof of cover, prevents cover from sinking
- Less danger of explosives
- Better control of supernatant withdrawal
- Better control of scum blankets

# Anaerobic Digesters - Covers




Source: Operation of Municipal Wastewater Treatment Plants, Vol III, Sixth Ed., p. 30-14

## Anaerobic Digestion – Normal Ranges

| Parameter | Normal Ranges |
|---|---|
| Sludge retention time | 30 – 60 days (Heated) |
| Operating Temperature | 90 – 95 ºF (Heated) |
| Volatile Solids Loading | 0.04 – 0.1 lb VM/day/ft$^3$ |
| % Methane in gas | 60 – 72% |
| % Carbon Dioxide in gas | 28 – 40% |
| pH | 6.8 – 7.2 |
| Volatile acids: alkalinity ratio | ≤0.1 |
| Volatile solids reduction | 40 – 60% |

* For every 1 lb. of VM destroyed, 12-18 ft$^3$ of gas is produced.

## Anaerobic Digestion

- Volatile Acids to Alkalinity Ratio

$$\textbf{Ratio} = \frac{\textbf{volatile acids concentration, mg/L}}{\textbf{alkalinity concentration, mg/L}}$$

- *Most important factor to monitor*
- Can be used to control operation of anaerobic digester
- Very sensitive indicator of process condition
- One of the first indicators that the digester is going sour
- Must monitor alkalinity in lab
- Indication of the buffer capacity of the digester
  - High buffer capacity desired & achieved by a low ratio

## Acid-Alkalinity Relationship

- As long as volatile acids remain low and the alkalinity stays high, anaerobic sludge digestion will occur in digester
- Measure volatile acid/alkalinity relationship at least 2x/week
  - Plot the volatile acid/alkalinity relationship against time and watch for any adverse trends
- If ratio starts to rise = problem developing – your 1st sign!
- Action steps:
  1. Extend mixing time
  2. Control heat more evenly
  3. Decrease raw sludge feed rates
  4. Decrease digested sludge withdrawal rates

## Acid-Alkalinity Relationship

| | |
|---|---|
| Optimum | V.A./ALK = .05 - 0.1 |
| Stress | V.A./ALK = 0.3 - 0.4 |
| Deep Trouble | V.A./ALK = 0.5 - 0.7 |
| Failure | V.A./ALK = 0.8 and above |

- Once ratio reaches 0.5, serious decreases in the alkalinity usually occur
- Concentration of $CO_2$ will start to increase

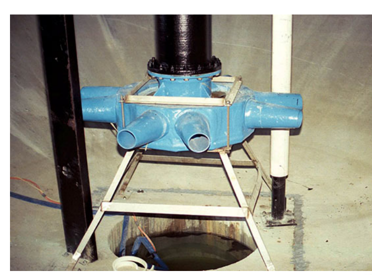
# Anaerobic Digestion

- Mixing
  - Puts microorganisms in contact with food
  - Controls pH, distributes buffering alkalinity
  - Distributes heat throughout the tank
  - Mixing combined with heating speeds up the digestion rate

# Anaerobic Digestion

**Mechanical mixing – most common method:**
- Shaft-driven propeller extended down into sludge
- Susceptible to wear
- Cleaning and replacement necessary

**Other methods:**
- Propeller with draft tube
- Bubble-gun type
- Jet mixing



# Anaerobic Digester

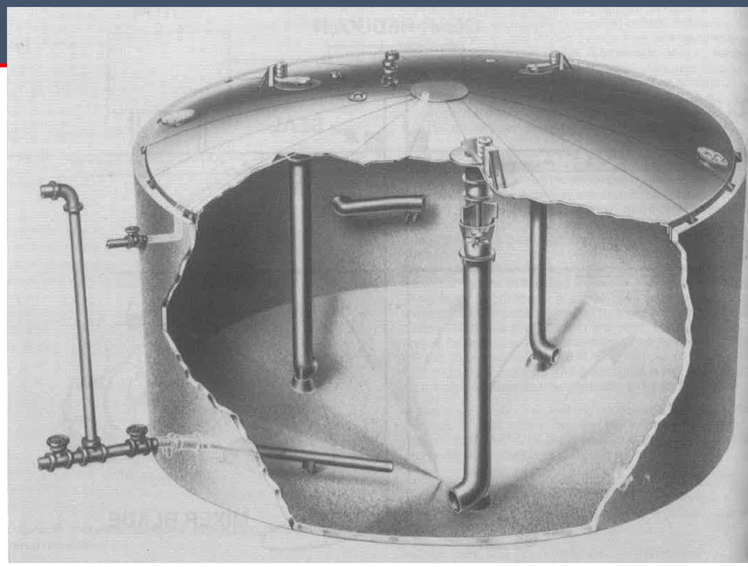


Fig. 12.22 Propeller mixer, draft tube, and digester
(Permission of Dorr-Oliver Incorporated)

Operation of Wastewater Treatment Plants, Vol II, seventh ed., p. 178

# Anaerobic Digestion

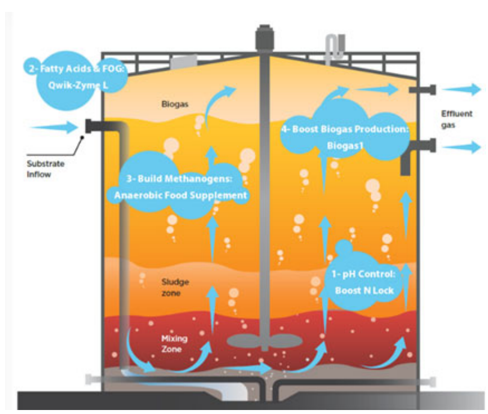
| Anaerobic Digestion – Sludge Parameters | |
|---|---|
| < 4% Solids | Loss of alkalinity<br>Decreased Sludge retention time<br>Increased heating requirements<br>Decreased volatile acid/alkalinity ratio |
| 4 – 8% Solids | Normal Operation |
| > 8% Solids | Poor mixing<br>Organic overloading<br>Decreased volatile acid/alkalinity ratio |

# Anaerobic Digestion: Neutralizing a Sour Digester

- A digester can be compared with your own body.
  - Both require food; but if fed too much will become upset.
  - Excess acid will upset both.
- Sour digester?
  - Lime
    - Lime is added at a 1:1 ratio, 1 lb of lime for every 1 lb or volatile acid
  - Soda ash
  - Transfer alkalinity from secondary digester to primary

# Anaerobic Digestion

- Foaming
  - Problems: odors, excess pressure on cover, plugs gas piping system
  - Cause: Gas production at startup with insufficient solids separation (Insufficient digestion)
  - Prevention: Adequate mixing before foaming starts



## Neutralizing a Sour Digester

- The recovery of a sour digester can be accelerated by neutralizing the acids with a caustic material such as anhydrous ammonia, soda ash, or lime, by transferring alkalinity in the form of digested sludge from the secondary digester.
- Such neutralization reduces the volatile acid/alkalinity to a level suitable from growth of the methane fermenters and provides buffering material which will help maintain the required volatile acid/alkalinity relationship and pH.
- If digestion capacity and available recovery time are great enough, it is probably preferable to simply reduce loading while heating and mixing so that natural recovery occurs.

## Neutralizing a Sour Digester

- When neutralizing a digester, the prescribed dose must be carefully calculated.
  - Too little will be ineffective, and too much is both toxic and wasteful. In considering dosage with lime, the small plant without laboratory facilities could use a rough guide a dosage of about **one pound of lime added for every 1000 gallons of sludge** to be treated.
- Stuck Digester - A stuck digester does not decompose organic matter properly.
  - The digester is characterized by low gas production, high VA/alk relationship, and poor liquid-solids separation.
  - A digester in a stuck condition is sometimes called a “sour” or “upset” digester.

## Gas Production

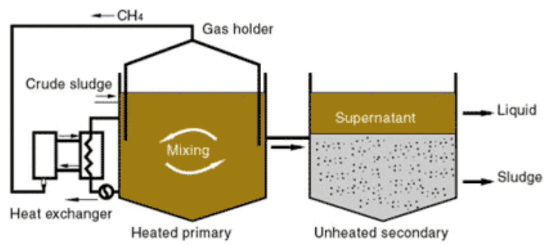
- The anaerobic digestion process (depending on the characteristics of the sludge) produces
  - 8-12 $ft^3$ of gas for every pound of volatile matter **added**
  - 12-18 $ft^3$ for every pound of volatile matter **destroyed**
- When methane fermentation starts and the methane content reaches around 60%, the gas will be capable of burning.
- Methane production eventually should predominate, generating a gas with 65-70% methane and 30-35% carbon dioxide by volume.
- Digester gas will burn when it contains 56% methane, but is not usable as a fuel until the methane content approaches 62%.

## Gas Production

- Digester gas is used in plants in various ways:
  - For heating and mixing the digesters
  - Heating the plant buildings
  - Running engines
  - Air blowers for the activated sludge process
  - Electrical power for the plant
- Note: It is dangerous to start a digester when it is only partially full due to explosive conditions created by the mixture of air and methane

## Supernatant and Solids

- Two separate digestion tanks or 1 tank with 2 divided sections
- Tank 1: Primary digester
  - Heating, mixing, breakdown of raw sludge
  - Binding property of sludge is broken = water released
- Tank 2: Secondary digester
  - Holding tank for separation of the solids from the liquor
  - Settled solids compact = minimal water in sludge dewatering system




## Biosolids Stabilization

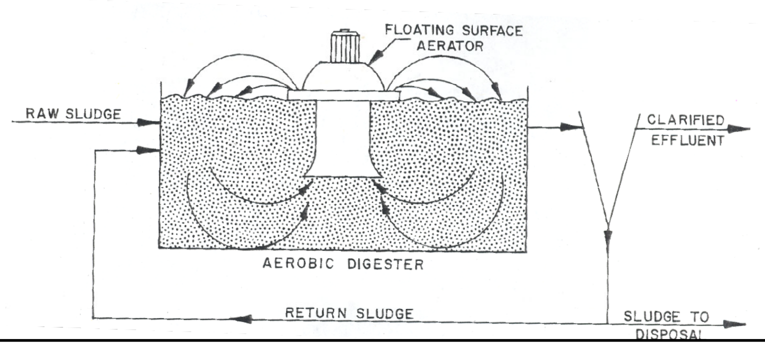
Aerobic Digestion

## Aerobic Digestion

- Purpose: to extend decomposition of solids and regrowth of organisms to a point where available energy in active cells and storage of waste materials are low enough and material is stable enough for ultimate disposal
- Extended aeration of wastewater
  - Wastes stabilized by long-term aeration of about 10-20 days
  - Check pH weekly and adjust if less than 6.5
  - Lower equipment costs than anaerobic (but higher energy costs)
  - Less noxious odors at DO ≥ 1 mg/L
  - Better on secondary sludge than primary sludge
  - Sludge has higher water content
  - By products: residual solids, $CO_2$, $H_2O$, $SO_4^-$, $NO_3^-$

## Aerobic Digestion

- Aerobic digesters are operated under the principle of extended aeration from the activated sludge process relying on the mode or region called **endogenous respiration**.
- Aerobic digestion consists of continuously aerating the sludge without the addition of new food, other than the sludge itself, so the sludge is always in the endogenous region.



## Comparison Between Anaerobic and Aerobic Digestion

| Anaerobic Digestion | Aerobic Digestion |
|---|---|
| Does not use aeration | Aeration equipment—oxygenation, mixing |
| Fresh wastes | Partially stabilized solids |
| Putrefaction | Produces fewer odors |
| Concentrates sludge | Higher water content sludge |
| Produces solids, water, etc. | Produces residual solids, water, etc |
| Liquids that are difficult to treat | Liquids that are easier to treat |

## Aerobic Digestion – Normal Ranges

| Parameter | Normal Levels |
|---|---|
| Detention time (days)* | >20 |
| Volatile Solids Loading ($lb/ft^3/day$) | 0.1 – 0.3 |
| DO (mg/L) | 1.0** to 2.0 |
| pH | 5.9 – 7.7 |
| Volatile Solids Reduction | 40 – 50% |

*To meet Class B standards for pathogen reduction, SRT ≥ 40 days at 20°C or ≥ 60 days at 15°C
**Strive to maintain DO level of 1.0 mg/L

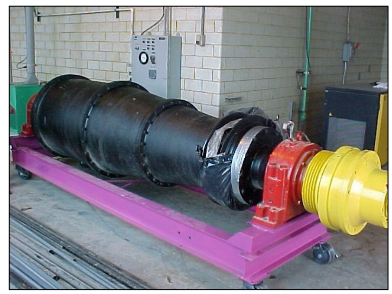
# Sludge Dewatering

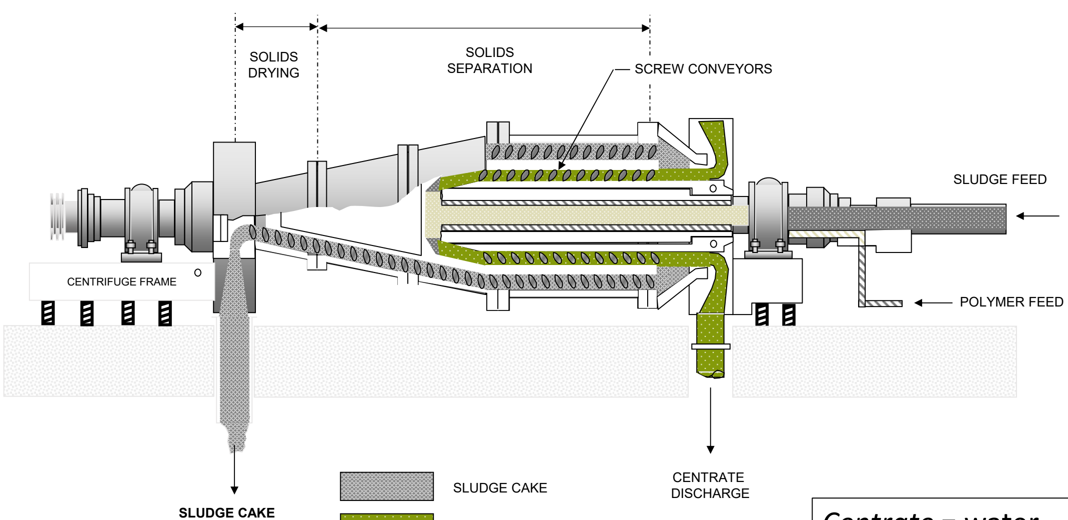
## Sludge Dewatering

- Dewatering reduces sludge moisture and volume to allow for more economical disposal
  1. Mechanical Dewatering:
     - Centrifuge*
     - Plate and Frame Press
     - Belt Press
     - Vacuum Filter*
  2. Drying Beds
  3. Blacktop Drying Beds
  4. Sludge Lagoon/Withdrawal to Land

# Centrifuge

- Used to thicken or dewater raw or secondary sludges
- Sludge fed at constant rate into rotating horizontal bowl
- Solids separated from liquid and compacted by centrifugal force (1000 – 2000 rpm)
- Condition of sludge cake and the quality of the *centrate* are regulated by:
  - Sludge feed rate
  - Bowl speed
  - Chemical conditioners
    - Dosage rates
    - Pool depth





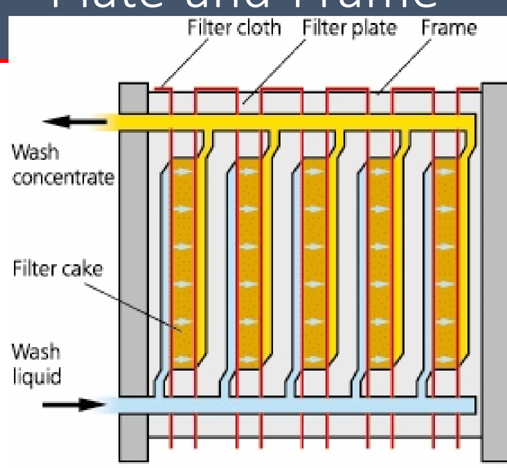

**SCROLL CENTRIFUGE**

*Centrate* = water leaving a centrifuge after most of the solids have been removed

## Plate-and-Frame

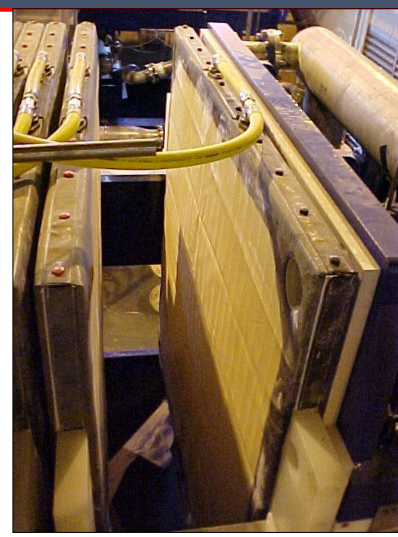
- Solids are pumped in batches into spaces between plates
- 200 – 250 psi pressure applied to squeeze out water
- At end of cycle (1.5 – 4 hours), plates are separated and solid drops out onto conveyor
- Pressure filtration that forces liquid through the filter media

## Plate-and-Frame




Filter cake washing in a plate and frame filter press

# Plate-and-Frame

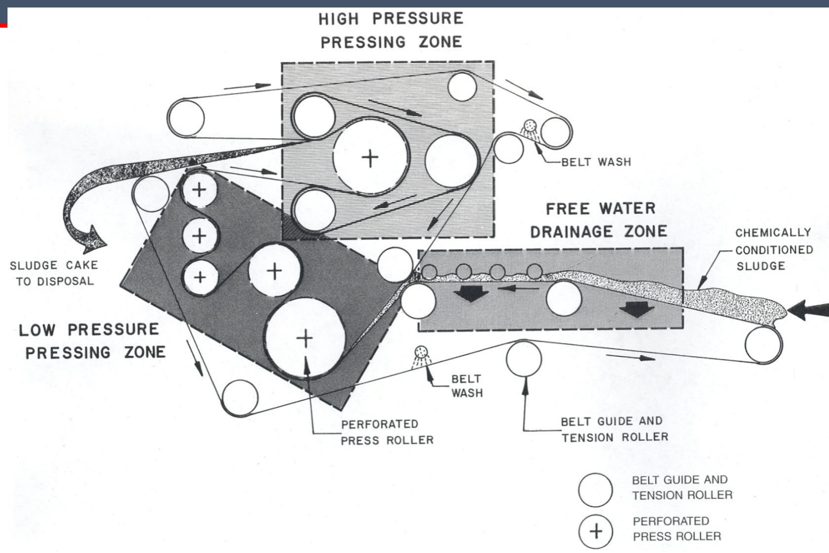


JVAP (US Filter) – Chattanooga
• Modified plate and frame that is vacuum assisted
•Steam heated at 163.4ºF for 30 min
•Entire process takes about 4 hours

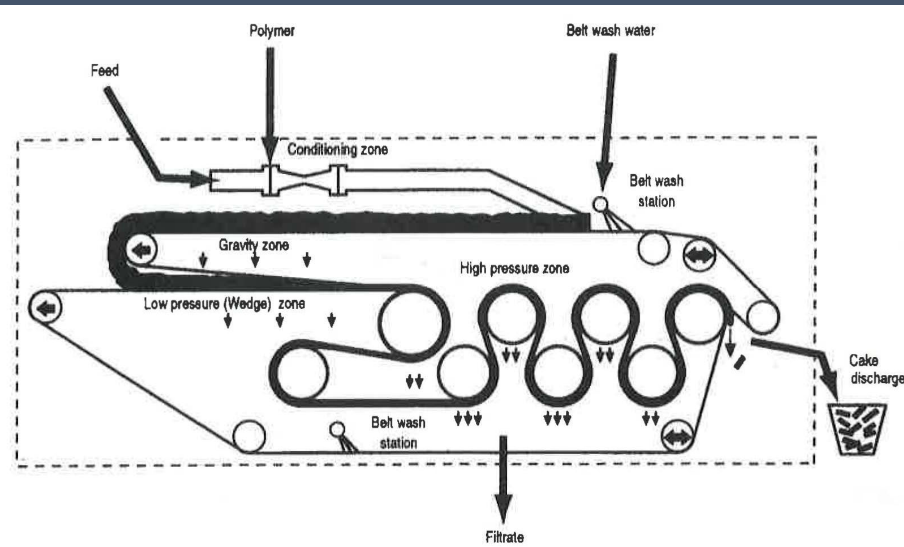
# Belt Filter Press

- Principle of filtration
- Low power use
- Reliable
- Continuous operation
- Two long belts that travel over a series of rollers
- Sludge applied to free water zone (much water will drain off here)
- Solids then squeezed between a series of rollers (and more water is removed)
- Remaining solids are scraped from the belt
- Belts are washed and the process repeats

# Belt Filter Press




# Belt Filter Press




Source: Operation of Municipal Wastewater Treatment Plants, Vol III, Sixth ed., p. 33-64

## Belt Filter Press

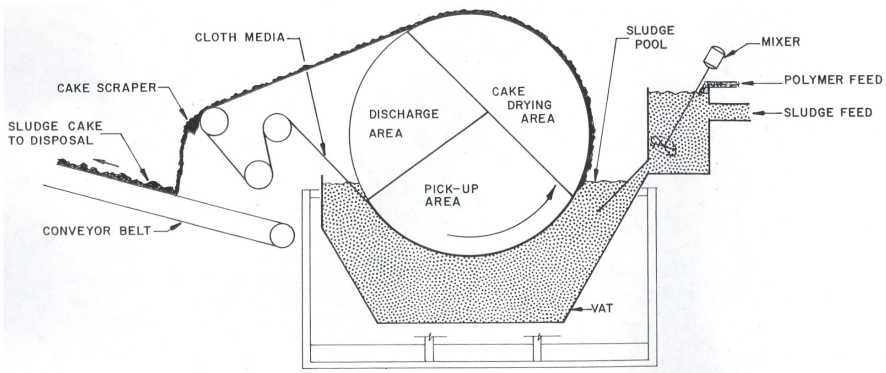
- Problem: Washout
  - "belt blinding" or "plugging"– result of inadequate belt washing or chemical blinding
    - Manually clean belts with high-pressure hose to restore at least some of the drainage
  - Polymer dose and belt speed too low
  - Hydraulic load too high

- Problem: Cake solids too wet
  - Belt speed too high
  - Belt tension too low

## Vacuum Filter

- Dewatering aerobically or anaerobically digested sludge requires washing the sludge first and then conditioning it with chemicals
- *Elutriation* = washing of digested sludge with either fresh water, plant effluent, or other wastewater
    - To remove fine particulates and/or alkalinity
    - Reduces demand for conditioning chemicals and improves settling/filtering
- Sludge pumped into a tank around a partially submerged rotating drum
- Drum rotates, vacuum collects solids on surface
- Vacuum removes excess water
- Vacuum is then released and solids are removed

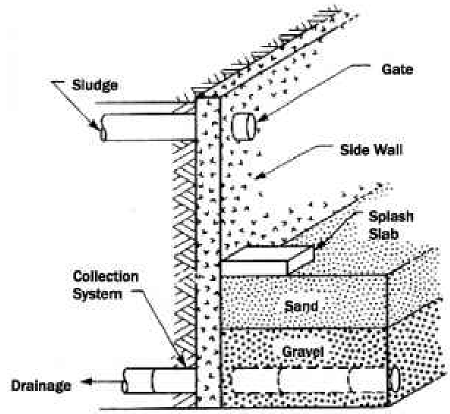
## Vacuum Filter

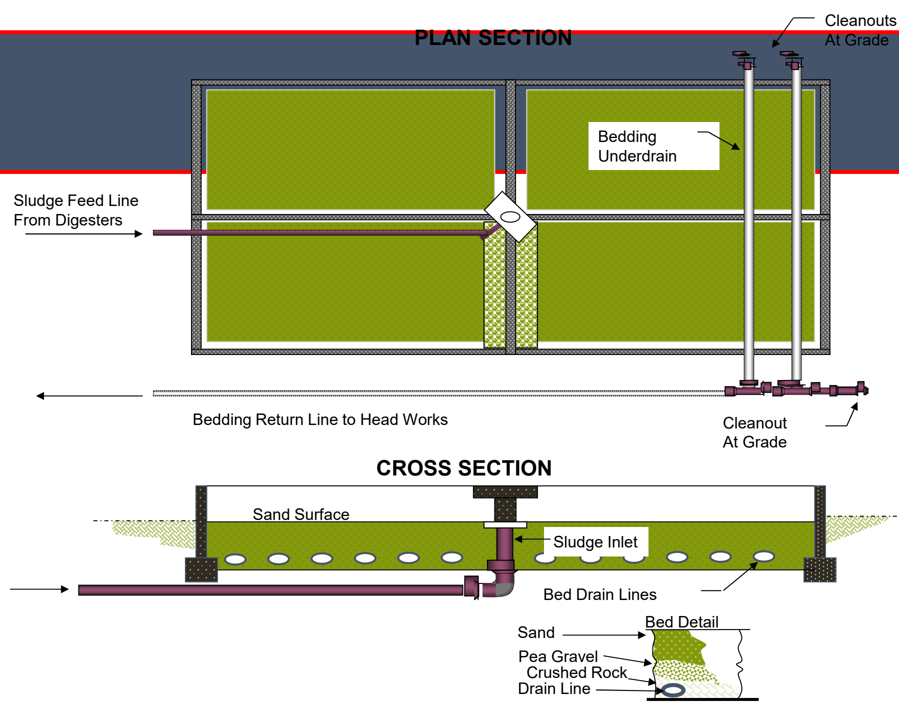



## Drying Bed

- Simplest of all methods
- Sludge deposited in layer on sand bed or other surface with drain
- Dewatering occurs by drainage and evaporation
- Drying bed constructed with underdrain system covered with coarse, crushed rock
  - Over rock is layer of gravel, then layer of pea gravel covered with 6-8 inches of sand
- Time required is affected by climate, depth of solids, and type of solids
- Sometimes drying beds are covered while others have vacuum assisted drainage
- Blacktop Drying Bed is a variation

# Drying Bed


Sludge
Gate
Side Wall
Splash Slab
Collection System
Sand
Gravel
Drainage


PLAN SECTION
Cleanouts At Grade
Bedding Underdrain
Sludge Feed Line From Digesters
Bedding Return Line to Head Works
Cleanout At Grade
CROSS SECTION
Sand Surface
Sludge Inlet
Bed Drain Lines
Bed Detail
Sand
Pea Gravel
Crushed Rock
Drain Line

# 40 CFR 503 Regs

- 40 CFR 503 requires the sludge be monitored for:

1. Pollutant Limits (Metals)
   - The first parameter of the three that must be assessed to determine overall sludge quality is the level of pollutants
2. Pathogen Reduction
   - The second parameter in determining sewage sludge quality is the presence or absence of pathogens (i.e., disease causing organisms), such as Salmonella bacteria, enteric viruses, and viable helminth ova.
3. Vector Attraction Reduction
   - The degree of attractiveness of sewage sludge to vectors is the third parameter of sewage sludge quality.

# 40 CFR 503 – Pollutant Limits

TABLE 3 OF §503.13.—POLLUTANT CONCENTRATIONS

| Pollutant | Monthly average concentration (milligrams per kilogram) [1] |
|---|---|
| Arsenic | 41 |
| Cadmium | 39 |
| Copper | 1500 |
| Lead | 300 |
| Mercury | 17 |
| Nickel | 420 |
| Selenium | 100 |
| Zinc | 2800 |

[1] Dry weight basis.

- Land applier is required to keep records of the amounts of each regulated pollutant applied to the site over time to ensure that the maximum allowable amounts are not exceeded.

## 40 CFR 503 – Pathogen Reduction

- If the Sludge is prepared for land application or surface disposal, it must comply with applicable pathogen reduction requirements.
- The part 503 regulation allows nine pathogen reduction alternatives, which are divided into two distinct classes :
  1. Class A
     - Class A pathogen reduction alternatives render the sewage sludge virtually pathogen free after treatment
  2. Class B
     - Class B pathogen reduction alternatives significantly reduce but do not eliminate all pathogens

## 40 CFR 503 - Pathogen Reduction

### Class A

- Six alternatives, each must meet following criteria:

1. Fecal coliform:

Fewer than 1000 MPN (most probable number) per gram of total dry solids

2. *Salmonella sp.*:

Fewer than 3 MPN per 4 grams of total dry solids

### Class B

- Three alternatives meet the criteria:

1. Fecal coliform:

Less than 2 million MPN or 2 million cfu per gram of total solids

Anaerobically digested: Minimum mean cell residence time of 15 days in anaerobic digester at 35-55°C

## 40 CFR 503 – Vector Attraction Reduction

- Vectors are animals and insects (e.g., rodents, flies, birds) that might be attracted to sewage sludge and, therefore, could transmit pathogenic organisms (if any are present) to humans.
- Vector attraction reduction is to reduce the attraction of vectors (flies, mosquitoes, and other potential disease - carrying organisms) to the biosolids or sludge.
- 1 of 10 options specified in part 503 to achieve vector attraction reduction must be met when biosolids are applied to land.

## 40 CFR 503 – Vector Attraction Reduction

1. Reduce the mass of volatile solids by a minimum of 38%
2. Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit
3. Meet a specific oxygen uptake rate for aerobically treated biosolids
4. Use aerobic processes at greater than 40ºC (avg. temp 45ºC) for 14 days or longer (during biosolids composting)
5. Add alkaline materials to raise the pH under specified conditions

## 40 CFR 503 – Vector Attraction Reduction (continued)

5. Reduce the moisture content of biosolids that do not contain unstabilized solids from other than primary treatment to at least 75% solids
6. Reduce the moisture content of biosolids with unstabilized solids to at least 90%
7. Inject biosolids beneath the soil surface within a specified time, depending on the level of pathogen treatment
8. Incorporate biosolids applied to or placed on the land surface within specified time periods after application to or placement on the land surface

## 40 CFR 503 Regs

- If your wastewater plant has a design influent flow rate equal to or greater than 1 million gallons per day, or serves a population of 10,000 or more, or Class I Sludge management facilities (State of Tennessee Industrial Pretreatment Program) you must report annually to the permitting authority.
- Annual reports cover information and data collected during the calendar year (January 1 to December 31) and are due February 19, every year and submitted to the permitting authority, which is the EPA Regional IV Office for Tennessee.



Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

# Section 6
# Safety

# Section 6
# Safety

## Safety

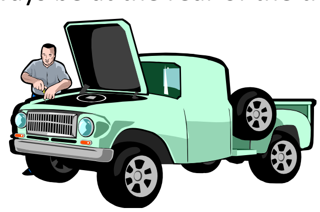
- An accident is caused by either an unsafe act or an unsafe environment.
- Personal cleanliness is the best means of protection against infection

## General Duty Clause

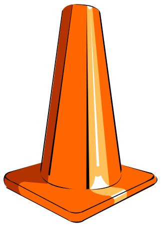
- FEDERAL - 29 CFR 1903.1
- Worker Right to Know:
  - EMPLOYERS MUST: Furnish a place of employment free of recognized hazards that are causing or are likely to cause death or serious physical harm to employees. Employers must comply with occupational safety and health standards promulgated under the Williams-Steiger Occupational Safety and Health Act of 1970.

## Before Leaving the Yard

- Work assignments
- Equipment needs
- Equipment inspection
- Vehicle inspection
  - When backing up a truck, one person should always be at the rear of the truck in view of the driver
  - Mirrors and windows
  - Lights and horn
  - Brakes
  - Tires
  - Trailer hitch/safety chain

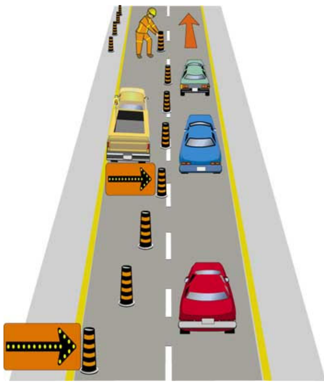


# Traffic Safety

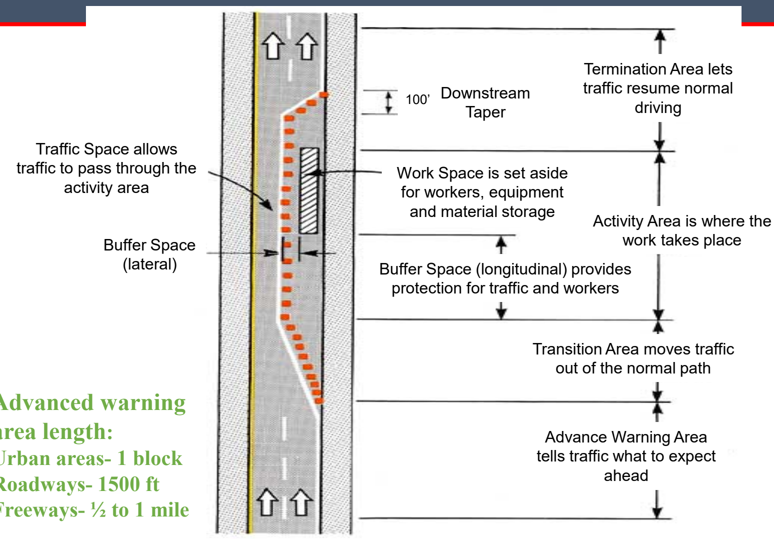


# Traffic Control Zones

- Advanced warning area
- Transition area
- Buffer space
- Work area
- Termination area



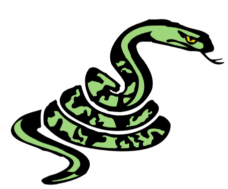
# Traffic Control Zones




**Advanced warning area length:**
**Urban areas- 1 block**
**Roadways- 1500 ft**
**Freeways- ½ to 1 mile**

# Manhole Hazards

- Atmospheric
- Physical injury
- Infection and disease
- Insects and biting animals
- Toxic exposure
- Drowning



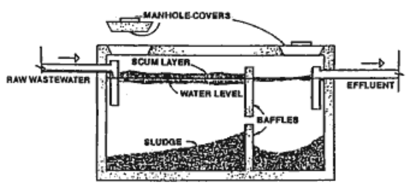
## Confined Space


## Confined Space Conditions

- Large enough and so configured that an employee can bodily enter and perform assigned work
- Limited or restricted means of entry or exit
- Not designed for continuous employee occupancy

## Confined Space Examples

- Storage tanks
- Manholes
- Hoppers
- Vaults
- Septic tanks
- Inside filters
- Basins
- Sewers



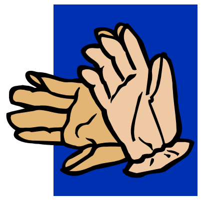
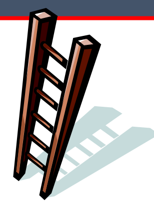

Submersible lift stations are designed to blend readily with natural surroundings, since there is no pump house and there is a minimum of above-ground equipment. Other advantages to below-ground installations are noise reductions and less safety-hazard concerns.

## Equipment Needed for Confined Spaces

- Safety harness with lifeline, tripod and winch
- Electrochemical sensors
- Ventilation blower with hose
  - Should have a capacity of no less than 750-850 cfm

## Equipment Needed for Confined Spaces

- PPE
- Ladder
- Rope
- Breathing Apparatus


## Permit Required Confined Space

- Contains or has potential to contain hazardous atmosphere
- Contains material with potential to engulf an entrant
- Entrant could be trapped or asphyxiated
- Positions required for entrance into a permit required confined space
  - Supervisor
  - Attendant – at least one person much be outside a permit required space
  - Entrant

# Atmospheric Hazards

- Need to have atmosphere monitored!!!
  - Explosive or flammable gas or vapor
    - These can develop in the collection system or sewer plant duel to legal, illegal or accidental sources
  - Toxic or suffocating gases
    - Comes from natural breakdown of organic matter in wastewater or toxic discharges
  - Depletion or elimination of breathable oxygen
    - Oxygen deficient atmosphere
    - Minimum oxygen level is 19.5%

# Hydrogen Sulfide – $H_2S$

- Detected by the smell of rotten eggs
- Loss of ability to detect short exposures
  - Olfactory fatigue
- Not noticeable at high concentrations
- Poisonous, colorless, flammable, explosive and corrosive
- Exposures to .07% to 0.1% will cause acute poisoning and paralyze the respiratory center of the body
- At the above levels, death and/or rapid loss of consciousness occur
- S.G. = 1.19
- Alarm set point = 10 ppm (0.001%)

# Hydrogen Sulfide – $H_2S$

| % | PPM | Hazard |
|---|---|---|
| 46 | 460,000 | Upper Explosive Limit (UEL) |
| 4.3 | 43,000 | Lower Explosive (LEL) |
| 0.1 | 1,000 | DEAD |
| 0.07 | 700 | Rapid loss of consciousness |
| 0.01 | 100 | IDLH |
| 0.005 | 50 | Eye tissue damage |
| 0.002 | 20 | Eye, nose irritant |
| 0.001 | 10 | Alarm set point |

# Methane Gas – $CH_4$

- Product of anaerobic waste decomposition
- Leaks in natural gas pipelines
  - Odorless unless natural gas supplied through pipeline, has mercaptans added, but soil can strip the odor
- Explosive at a concentration of 5% or 50,000 ppm
- Spaces may contain concentrations above the Lower Explosive Limits (LEL) and still have oxygen above the 19.5% allowable
- Colorless, odorless, tasteless
- Does not decrease oxygen content
- Acts as an asphyxiant
- Coal miners used canaries as early alarms; if bird died, it was time to get out
- S.G.= 0.55
- Alarm set point is 10% LEL = 5000 ppm

## Methane Gas – $CH_4$

| % | PPM | Hazard |
|---|---|---|
| 85 | 850,000 | Amount in natural gas |
| 65 | 650,000 | Amount in digester gas |
| 15 | 150,000 | Upper Explosive Limit (UEL) |
| 5 | 50,000 | Lower Explosive Limit (LEL) |
| 0.5 | 5,000 | Alarm set point (10% of LEL) |

## Carbon Monoxide - CO

- Decreases amount oxygen present
  - Hazardous because it readily binds with hemoglobin in blood, starving the person's body of oxygen
- ALWAYS VENTILATE
- 0.15% (1500 ppm) DEAD
- Will cause headaches at .02% in two hour period
- Maximum amount that can be tolerated is 0.04% in 60 minute period
- Colorless, odorless, tasteless, flammable and poisonous
- Manufactured fuel gas
- S. G. = 0.97
- Alarm set point at 35 ppm

# Carbon Monoxide - CO

| % | PPM | Hazard |
|---|---|---|
| 74 | 740,000 | Upper Explosive Limit (UEL) |
| 12.5 | 125,000 | Lower Explosive (LEL) |
| 0.2 | 2,000 | Unconscious in 30 minutes |
| 0.15 | 1,500 | IDLH |
| 0.05 | 500 | Sever headache |
| 0.02 | 200 | Headache after 2-3 hours |
| 0.0035 | 35 | 8-hour exposure limit |
| 0.0035 | 35 | Alarm set point |

# Oxygen – $O_2$

- ALWAYS ventilate – normal air contains ~ 21%
- Oxygen deficient atmosphere if less than **19.5%**
- Oxygen enriched at greater than **23.5%**
  - Speeds combustion
  - Could be from pure oxygen being used to oxidize hydrogen sulfide
- Leave area if oxygen concentrations approach 22%
- Early warning signs that an operator is not getting enough oxygen:
  - Shortness of breath
  - Chest heaving
  - Change from usual responses

## Oxygen – $O_2$

| % | PPM | Hazard |
|---|---|---|
| 23.5 | 235,000 | Accelerates combustion |
| 20.9 | 209,000 | Oxygen content of normal air |
| 19.5 | 195,000 | Minimum permissible level |
| 8 | 8,000 | **DEAD** in 6 minutes |
| 6 | 6,000 | Coma in 40 seconds, then **DEAD** |

## Oxygen – $O_2$

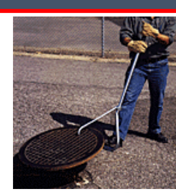
- When $O_2$ levels drop below 16%, a person experiences
  - Rapid fatigue
  - Inability to think clearly
  - Poor coordination
  - Difficulty breathing
  - Ringing in the ears
  - Also, a false sense of well-being may develop

## Oxygen – $O_2$

- In a confined space, the amount of oxygen in the atmosphere may be reduced by several factors
  - Oxygen consumption
    - During combustion of flammable substances
    - Welding, heating, cutting or even rust formation
  - Oxygen displacement
    - Carbon dioxide can displace oxygen
  - Bacterial action

## Atmospheric Alarm Units

- Continuously sample the atmosphere
- Test atmospheres from manhole areas prior to removing the cover if pick holes available
- Remove manhole covers with non sparking tools



1. **Test for oxygen first**
2. **Combustible gases second (methane at 5000 ppm)**
   - Atmospheric alarms with a catalytic element are used to test for explosive conditions.
3. **Test for toxic gases third**

## Atmospheric Alarm Units

- Alarms set to read:
  - Flammable gasses exceeding 10% of the LEL
  - $H_2S$ exceeds 10 ppm and/or
  - $O_2$ percentage drops below 19.5%
  - CO alarm set point is 35 ppm
- Calibrate unit before using
- Most desirable units: simultaneously sample, analyze and alarm all three atmospheric conditions

## Atmospheric Alarm Units

- Some physical and environmental conditions that could affect the accuracy of gas detection instruments include:
  - Caustic gases
  - Temperature
  - Dirty air
  - Humidity
  - Air velocity
  - Vibration

## Safety Procedures if Explosive Atmosphere Discovered

- Immediately notify supervisor
- Do not remove manhole cover
- Turn off running engines in area
- Route vehicles around area
- Inspect up and downstream of manhole
- Route traffic off the street
- Notify waste and or pretreatment facility
- Cautiously ventilate
- NO SMOKING IN AREA

## Ventilation

- Blowers need to be placed upwind of manhole and at least 10 feet from opening
- Gas driven engine – exhaust must be downwind of manhole
- Air intake should be 2-5 feet above ground service

# Infectious Disease Hazards

- Many diseases may be transmitted by wastewater: hepatitis A, cholera, bacterial dysentery, polio, typhoid, amoebic dysentery
- Ingestion (splashes); inhalation (aerosols); contact (cuts or burns)
- Wash hands frequently
- Avoid touching face
- Never eat, drink or smoke without first washing hands

***Best method of protection is person cleanliness!***

# Lockout / Tagout


## LOTO General Requirements

- Written program
- Utilize tagout system if energy isolating device not capable of being locked out
- Lockout/tagout hardware provided
- Devices used only for intended purposes
- Tagout shall warn **DO NOT START, DO NOT ENERGIZE, DO NOT OPERATE**
- Only trained employees shall perform lockout/tagout

## Requirements for Lockout of Equipment

- Before beginning work on any pump, the first thing to be done is to lock it out.
  - The person doing the work should have the key
- Notify employees
- Employees notified after completion of work and equipment re-energized

## Recommend Steps for Lockout/Tagout

- Notify employees that device locked and tagged out
- Turn off machine normally
- De-activate energy
- Use appropriate lockout/tagout equipment
- Release any stored energy
- Try to start machine by normal means

## Steps for Restoring Equipment

- Check area for equipment or tools
- Notify all employees in the area
- Verify controls are in neutral
- Remove lockout/tagout devices and re-energize device
- Notify employees maintenance and/or repairs are complete and equipment is operationally

## Training Requirements

- Employer shall train all employees
- All new employees trained
- Recognition of applicable hazardous energy
- Purpose of program
- Procedures
- Consequences
- ANNUAL REQUIREMENT

## Inspections

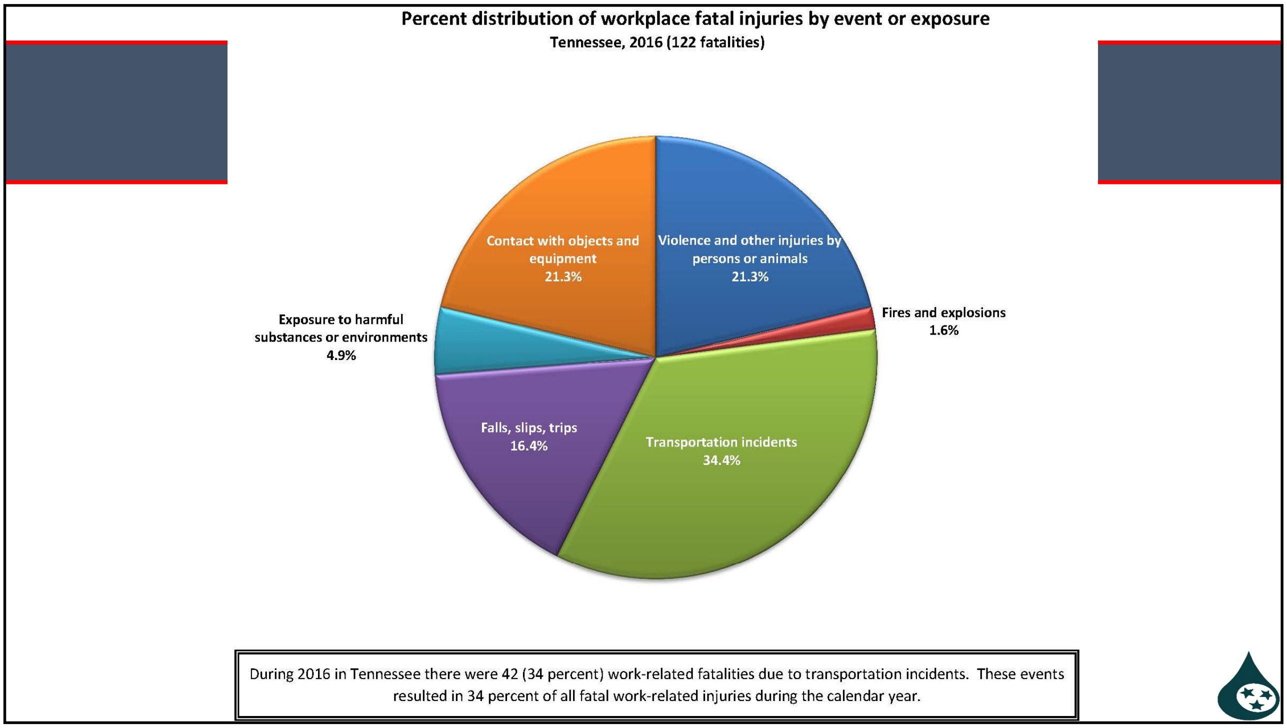
- Conduct periodic inspection at least annually
- Shall include review between the inspector and each authorized employee
- Recommendation: Frequent walk through of work areas and observation of Maintenance and Operation area

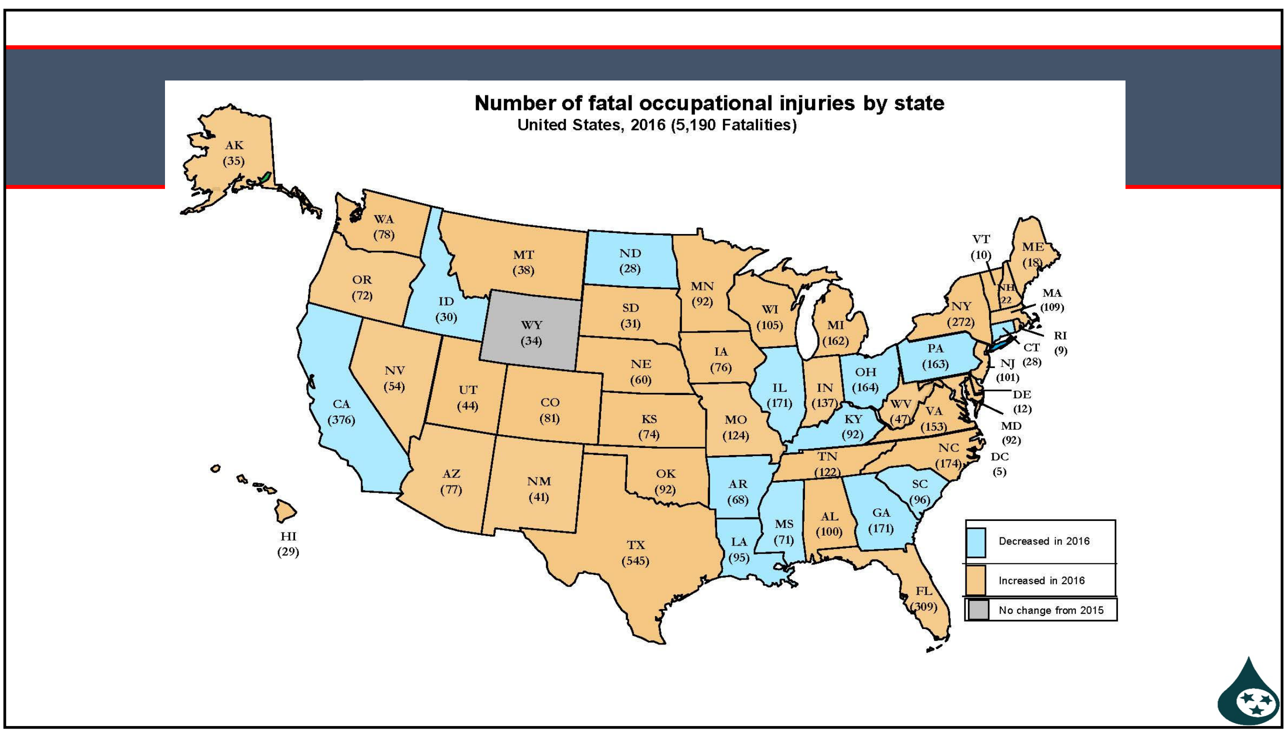
## Required Record Keeping

- Written Lockout/Tagout Program
- Training:  Annual and New Employees
- Inspections: Annual including new equipment, inspection of devices, and procedures

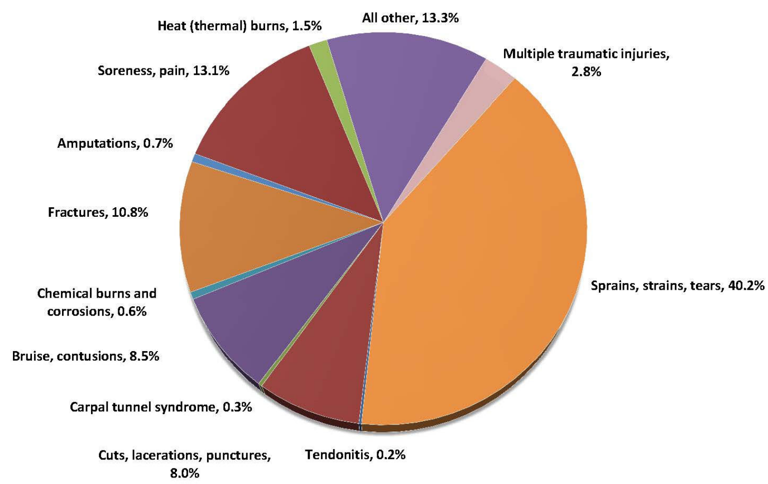
## Most Cited Industry Standards By TOSHA

- No written Hazard Communication Program
- Inadequate Hazard Communication Training
- PPE Hazard Assessment not Done
- No Energy Control Program - Lockout/Tagout
- No MSDS on Site
- No one Trained in First Aid
- No Emergency Action Plan
- Metal Parts of Cord and Plug Equipment Not Grounded
- Unlabeled Containers of Hazardous Chemicals


Percent distribution of workplace fatal injuries by event or exposure
Tennessee, 2016 (122 fatalities)
Contact with objects and equipment 21.3%
Violence and other injuries by persons or animals 21.3%
Fires and explosions 1.6%
Exposure to harmful substances or environments 4.9%
Falls, slips, trips 16.4%
Transportation incidents 34.4%
During 2016 in Tennessee there were 42 (34 percent) work-related fatalities due to transportation incidents. These events resulted in 34 percent of all fatal work-related injuries during the calendar year.

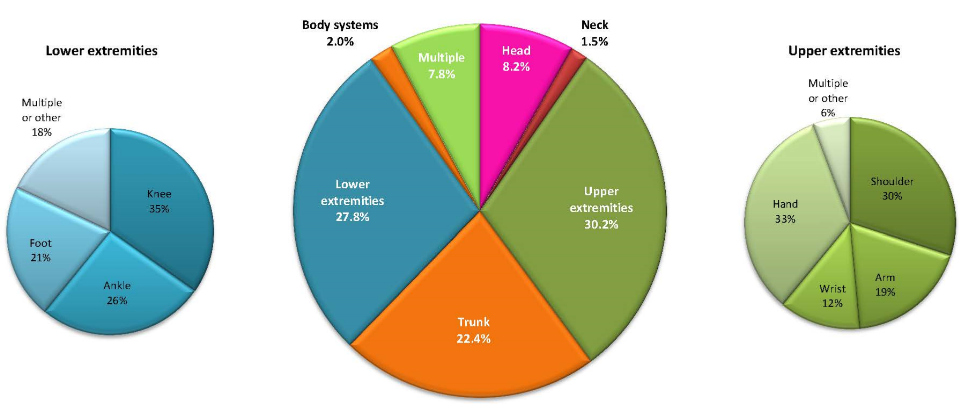

Number of fatal occupational injuries by state
United States, 2016 (5,190 Fatalities)
Decreased in 2016
Increased in 2016
No change from 2015

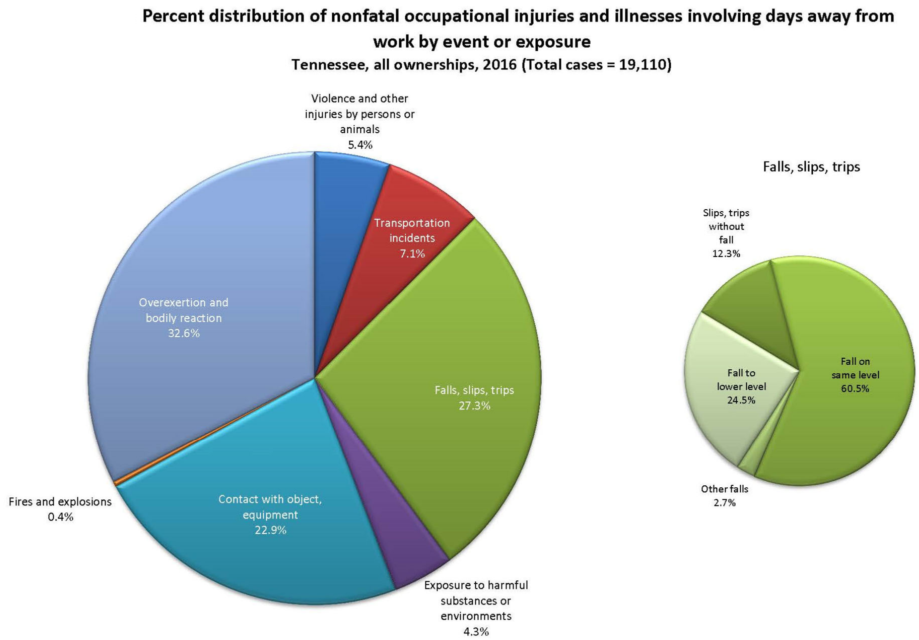
**Percent distribution of nonfatal occupational injuries and illnesses involving days away from work by nature of injury or illness**
**Tennessee, all ownerships, 2016 (Total cases = 19,110)**



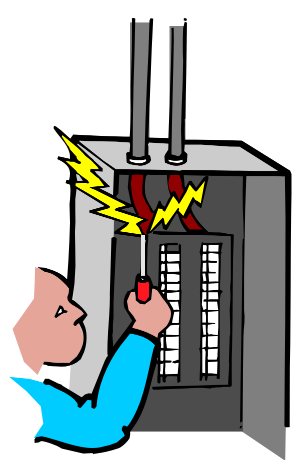

Forty percent of all nonfatal occupational injuries and illnesses resulting in days away from work in Tennessee during 2016 were due to sprains, strains, or tears.

**Percent distribution of nonfatal occupational injuries and illnesses involving days away from work by part of body affected**
**Tennessee, all ownerships, 2016 (Total cases = 19,110)**






# Electrical Safety



## OSHA Says

- Any electrical installations shall be done by a professionally trained electrician.
- Any employee who is in a work area where there is a danger of electric shock shall be trained.
- Employees working on electrical machinery shall be trained in lockout/tagout procedures

## Fire Protection

## Fire Protection Equipment

- Fire extinguishers shall be located where they are readily accessible.
- Shall be fully charged and operable at all times.
  - Charged after each use.
- All fire fighting equipment is to be inspected at least annually.
- Portable fire extinguishers inspected at least monthly and records kept.
- Hydrostatic testing on each extinguisher every five years.
- Fire detection systems tested monthly if batter operated.

## Types of Fire Extinguishers

- Class A 
  - Used on combustible materials such as wood, paper or trash
  - Can be water based.
- Class B 
  - Used in areas where there is a presence of a flammable or combustible liquid
  - Shall not be water based
  - Example is dry chemical extinguisher
  - An existing system can be used but not refilled.

## Types of Fire Extinguishers

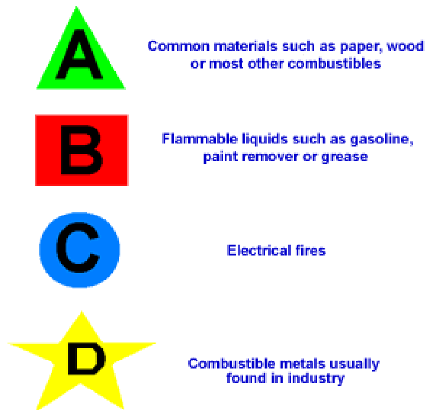
- Class C 
  - Use for areas electrical
  - Best is carbon dioxide extinguisher.
  - Using water to extinguish a class C fire risks electrical shock
- Class D
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire.

## Types of Fire Extinguishers

| Class | Material | Method |
|---|---|---|
| A | Wood, paper | Water |
| B | Flammable liquids (oil, grease, paint) | Carbon dioxide, foam, dry chemical or Halon |
| C | Live electricity | Carbon dioxide, dry chemical, Halon |
| D | Metals | Carbon dioxide |

# Types of Fire Extinguishers

- Combination ABC are most common
- Have the types of extinguishers available depending upon analyses performed in each area

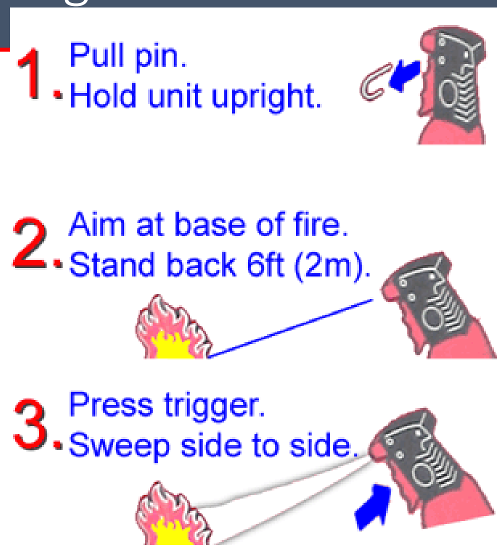



# Fire Extinguishers

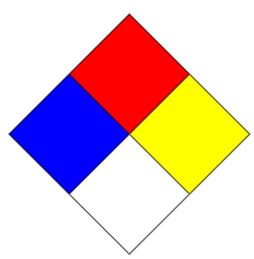
- To operate a fire extinguisher, remember the word PASS
  - **P**ull the pin. Hold the extinguisher with the nozzle pointing away from you
  - **A**im low. Point the extinguisher at the base of the fire.
  - **S**queeze the lever slowly and evenly.
  - **S**weep the nozzle from side-to-side.

## Fire Extinguishers

Combo Extinguisher

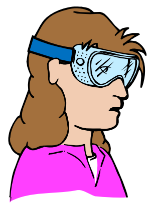
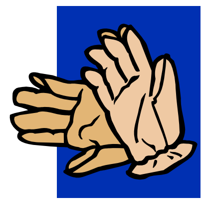
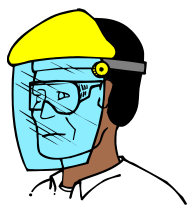



## Chemical Safety



# Personal Protective Equipment

- Gloves
- Coveralls / Overalls
- Face Shield / Goggles
- Respirator / SCBA
- Boots
- Ear Plugs / Muffs


# Safety Data Sheets

- Also called SDS
  - Previously called MSDS
- Lists:
  - Common and chemical name
  - Manufacturer info
  - Hazardous ingredients
  - Health hazard data
  - Physical data
  - Fire and explosive data
  - Spill or leak procedures
  - PPE
  - Special precautions

# MSDS to SDS

- What is the difference between a MSDS and the new SDS?
- SDSs are in use globally
- The Safety Data Sheets (formerly MSDSs) will now have a specified 16-section format

# Minimum Info for SDS

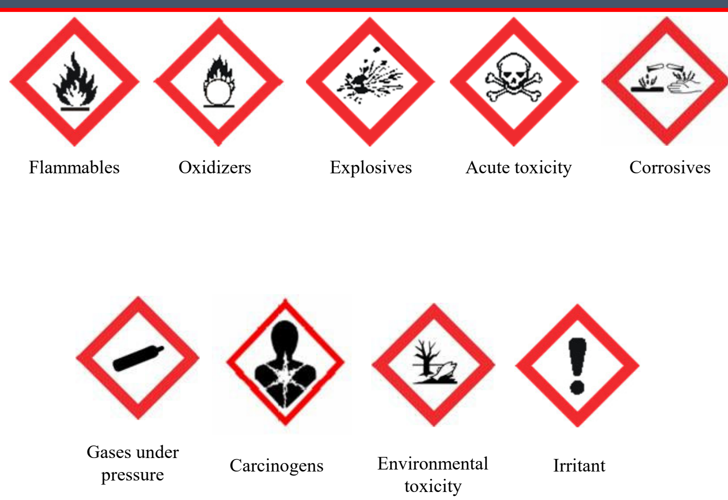
- Product identification
- Hazard Identification
- Composition/info on ingredients
- First-aid measures
- Fire-fighting measures
- Accidental release measures
- Handling and storage
- Exposure controls
- Physical/chemical properties
- Stability & reactivity
- Toxicological information
- Ecological information*
- Disposal considerations*
- Transport information*
- Regulatory information*
- Other information (including date of SDS or last revision)*

* Non mandatory

## MSDS to SDS

- In addition, chemical manufacturers and importers will be required to provide a label that includes a harmonized signal word, pictogram, and hazard statement for each hazard class and category
  - The use of pictograms will enable workers, employers, and chemical users worldwide to understand the most basic chemical information without language barriers

## OSHA Pictograms



## NFPA

- National Fire Protection Association
- Chemical hazard label
  - Color coded
  - Numerical system
    - Health
    - Flammability
    - Reactivity
  - Special precautions
- Labels are required on all chemicals in the lab

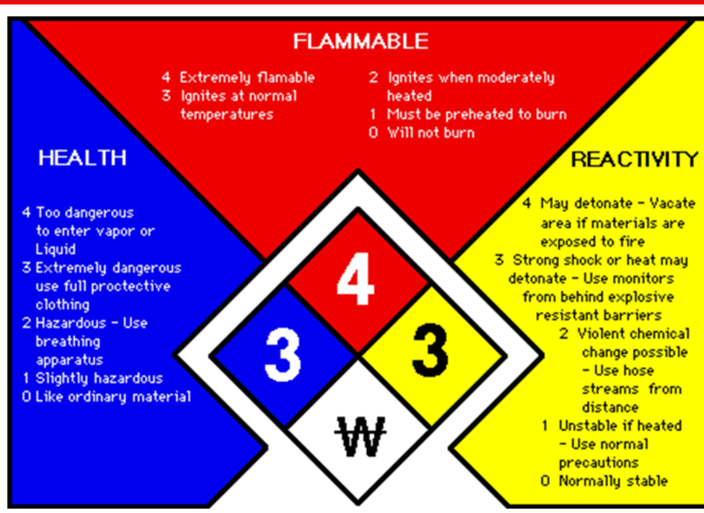
## RTK Labels


- "Right to Know"
  - In 1983, OSHA instituted Hazard Communication Standard 1910-1200, a rule that gives employees the right to know the hazards of chemicals to which they may be exposed in the workplace.

## Degrees of Hazard

- Each of the colored areas has a number in it regarding the degree of hazard
  - 4 → extreme
  - 3 → serious
  - 2 → moderate
  - 1 → slight
  - 0 → minimal

## Chemical Label



## Terms

- ***Lower Explosive Level (LEL)*** – minimum concentration of flammable gas or vapor in air that supports combustion
- ***Upper Explosive Limit (UEL)*** – maximum concentration of flammable gas or vapor in air that will support combustion
- Teratogen – causes structural abnormality following fetal exposure during pregnancy
- Mutagen – capable of altering a cell's genetic makeup

## Trenching

## Trenching Basics

- Provide stairways, ladders, ramps or other safe means of access in all trenches **4 feet** or deeper
  - These devices must be located within **25 feet** of all workers
  - Ladders used in trenches shall protrude at least **3 feet** above the trench edge
  - Minimum diameter of rungs on a fixed steel ladder is **¾-inch**
  - Minimum clear length of rungs on a fixed steel ladder is **16 inches**

## Trenching Basics

- Trenches **5 feet** deep or greater require a protective system, which can be shielding, shoring or sloping
  - A registered engineer must approve all shielding and shoring
- Trenches **20 feet** deep or greater require that the protective system be designed by a registered professional engineer
- Keep excavated soil (spoils) and other materials at least **2 feet** from trench edges.
- The support or shield system must extend at least **18 inches** above the top of the vertical side.

# Cross-Connection Control

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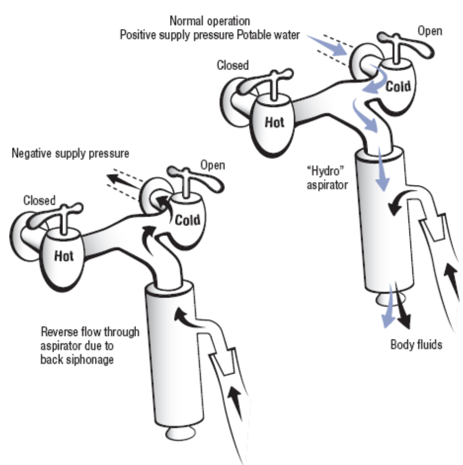
TN Department of Environment & Conservation

## Backflow Case Study
### Human Blood in the Water System

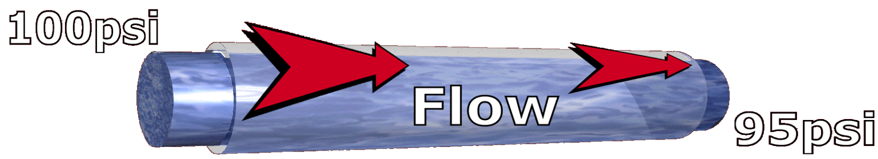
Blood observed in drinking fountains at a funeral home

Hydraulic aspirator used to drain body fluids during embalming

Contamination caused by low water pressure while aspirator was in use

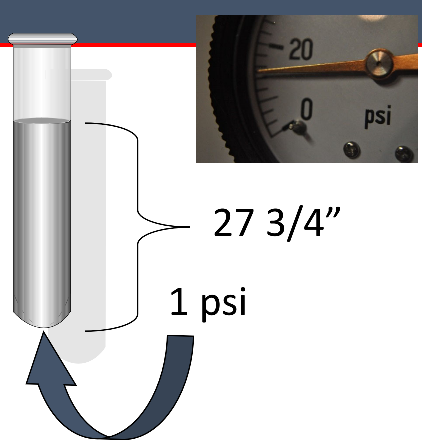


## Hydraulics and Pressure




- Water can flow through a pipe in either direction
- The direction of flow will depend on the forces (pressures) acting on the water
- Water pressure naturally tends to equalize
- Therefore, water flows down a gradient from high pressure regions to low pressure regions

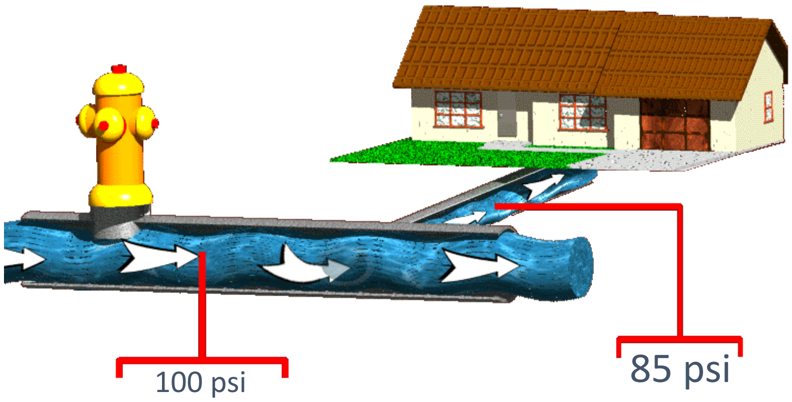
## Head Pressure



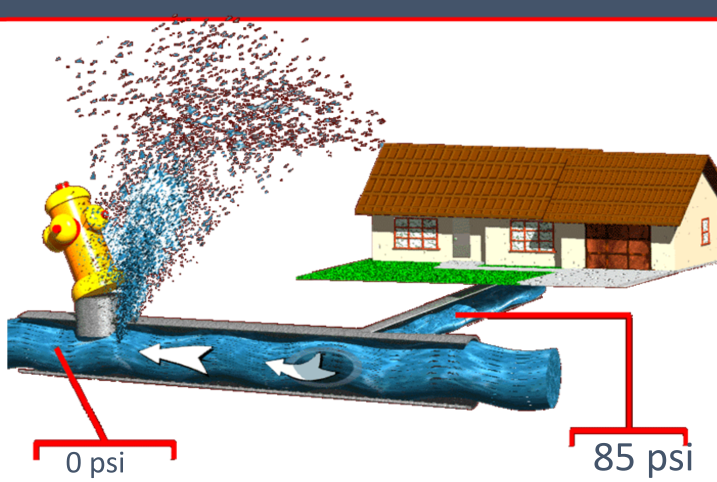

- 27 3/4” of water generates a pressure of one pound per square inch (psi)
- The pressure on the bottom of the container is generated by the weight of the water above it

27 ¾” = 2.31 Feet of Head

# Normal Flow




# Reverse Flow - Backflow



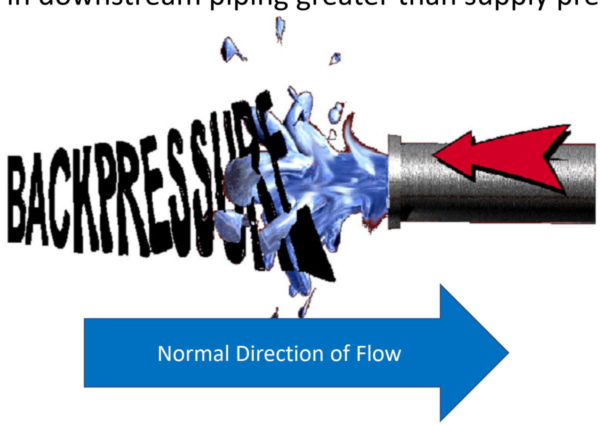
## Backflow

- The undesirable reversal of flow of water or other substances into the potable water distribution supply

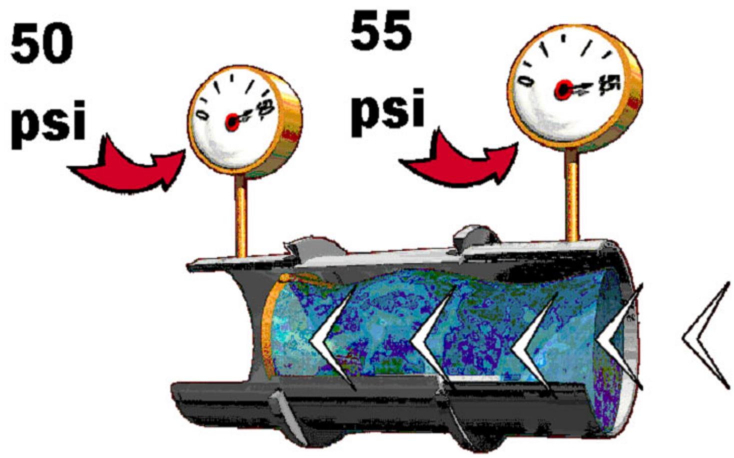
- Occurs due to:
  - Backpressure
  - Backsiphonage

## Backpressure

- Pressure in downstream piping greater than supply pressure

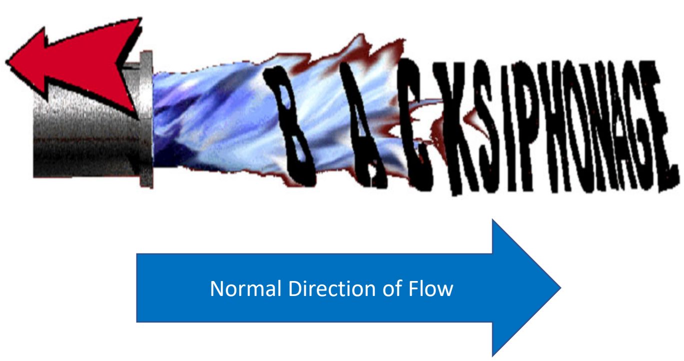


## Backpressure

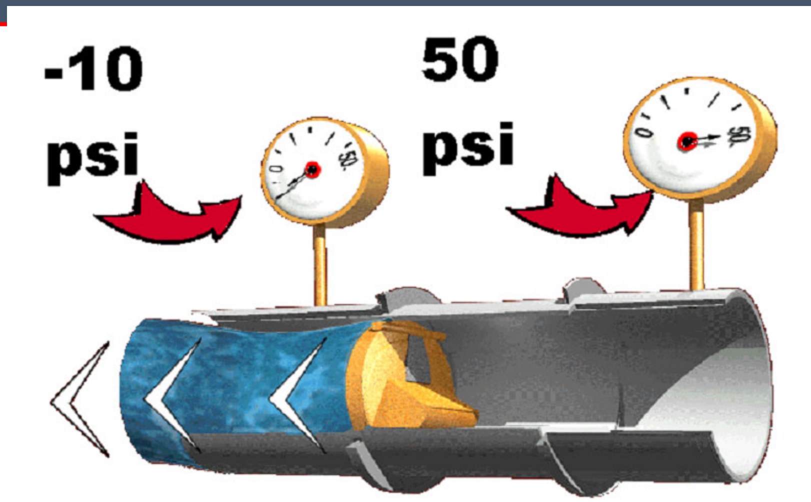



## Backsiphonage

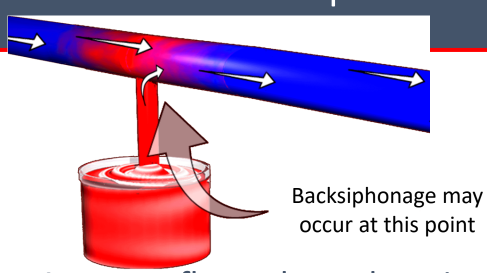
- Sub-atmospheric pressure in the water system



## Backsiphonage




## Aspirator Effect




- As water flows through a pipe, the pressure against the walls of the pipe decreases as the speed of the water increases
- If a second pipe is attached there could be a low pressure area created at the point of connection which could siphon water from the attached pipe into the flowing pipe - Backsiphonage

## Five Means of Preventing Backflow

- Air Gap Separation (AG) **Best Method**
- Reduced Pressure Principle Assembly (RPZ/RPBP/RP) **Best Device**
- Double Check Valve Assembly (DCVA)
- Pressure Vacuum Breaker (PVB)/
  Spill-Resistant Vacuum Breaker
- Atmospheric Vacuum Breaker (AVB)

## Air Gap


- An air gap is the vertical separation between the water supply line outlet and the overflow rim of the non-pressurized receiving fixture or tank

## Air Gap

2 X ID,
not <1 inch

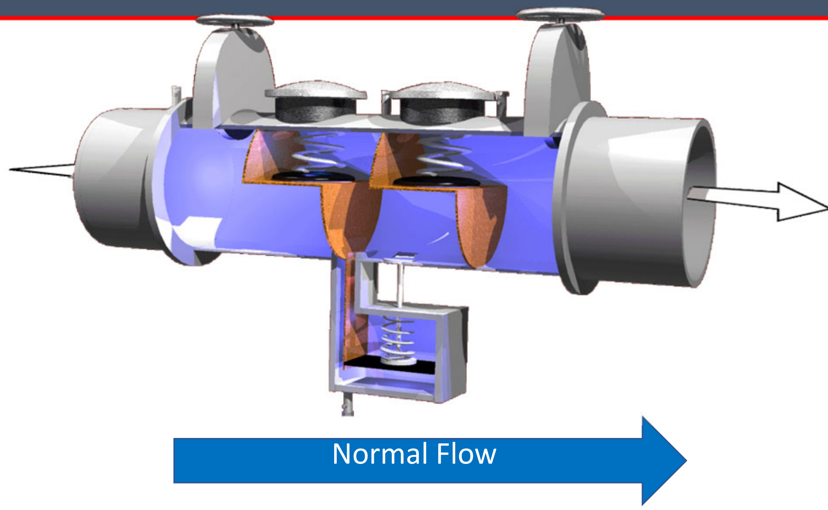
- An air gap is the *BEST* method of protection against backflow
- Approved air gap separation must have a vertical unobstructed distance of at least twice the internal diameter of the outlet pipe, but never less than 1 inch

## Air Gap Separation Limitations

- The air gap is the best method of backflow prevention, but it is easily defeated through modifications or being bypassed
- The air gap separation causes a loss of pressure in the system

- Sanitary control is lost - cannot be installed in an environment containing airborne contamination

## Reduced Pressure Principle Assembly

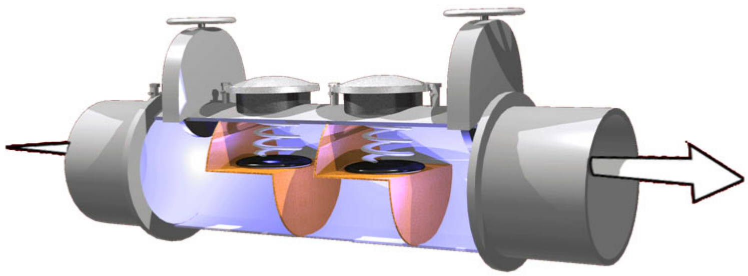




## Reduced Pressure Principle Assembly

- The reduced pressure principle backflow prevention assembly (RP) consists of two independently operating check valves together with a hydraulically operating, mechanically independent, pressure differential relief valve located between the check valves, all located between two resilient seated shutoff valves and four properly located test cocks.
- *BEST* device to protect against backflow

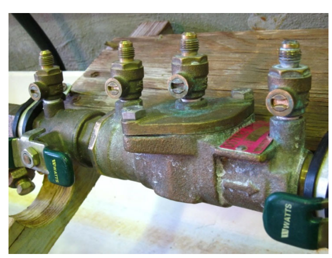
## Double Check Valve Assembly (DC)



Normal Flow

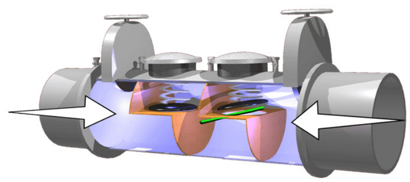
## Double Check Valve Assembly (DC)

- The double check valve backflow prevention assembly (DC) consists of two independently operating check valves installed between two tightly closing resilient seated shutoff valves and fitted with four properly located test cocks
- Similar to the RP, but has no relief port so it cannot maintain a lower pressure in the zone between the checks and nowhere for the water to go during a backflow incident or failure



# Double Check Valve Assembly (DC)

- Since the water in a DC cannot leave the system during a backflow event or assembly failure then it is a higher risk and therefore cannot be used in a high hazard (contaminant) application
- If one check fails the other will continue to protect, but given enough time the second check will fail and backflow will occur



Second check fouled during backpressure

| | Indirect | | Direct |
|---|---|---|---|
| | Backsiphonage Only | | Backpressure and Backsiphonage |
| | Continuous Use | Non-Continuous Use | |
| **Health Hazard** | Air Gap | Air Gap | Air Gap |
| | RP | RP | RP |
| | PVB | PVB | |
| | | AVB | |
| **Non – Health Hazard** | Air Gap | Air Gap | Air Gap |
| | RP | RP | RP |
| | DC | DC | DC |
| | PVB | PVB | |
| | | AVB | |

## Testing of Assemblies

- Assemblies must be tested when installed, after repair, and at least annually
- Assembly testing must be conducted by certified personnel
  - TDEC issues a certification for all assembly testers
  - Backflow tester certification courses are offered through the Fleming Training Center

## Cross Connection Control

*The ultimate goal of cross connection control is to protect the public drinking water supply*



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Safety Vocabulary

1. A _______________________________ is defined by OSHA as a person capable of identifying existing and predictable hazards in the surroundings, or working conditions that are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate the hazards.
2. The ___________________ is the unit for expressing the relative intensity of sounds on a scale of zero to the average least perceptible sound to about 130 for the average level at which sound causes pain to humans. It is abbreviated dB.
3. The ______________________________ is the lowest concentration of a gas or vapor that explodes if an ignition source is present at ambient temperature.
4. __________________________ is the condition in which a person's nose, after exposure to certain odors, is no longer able to detect the odor.
5. The condition in which an atmosphere contains oxygen at a concentration of more than 23.5 percent by volume is called ____________________________________.
6. An _________________ health effect is an adverse effect on a human or animal body, with symptoms developing rapidly. In contrast, a _____________________ health effect is one that develops slowly over a long period of time or one that recurs frequently.
7. The atmospheric concentration of any toxic, corrosive, or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere is classified as __________________________________________.
8. _____________________________________ occurs when the atmosphere contains oxygen at a concentration of less than 19.5 percent by volume.
9. Gas present in the collection system is called ______________________ even if it is from such sources as gas mains, gasoline, and cleaning fluid. It usually results from the decomposition of organic matter in the wastewater.
10. The excavated material, such as soil, from the trench of a water main or sewer.
11. A ______________________________ is defined as a space that:
    - Is large enough and so configured that an employee can bodily enter and perform assigned work; and
    - Has limited or restricted means of entry or exit; and
    - Is not designed for continuous employee occupancy
12. Any substance that tends to produce cancer in an organism is called a _________________________.
13. A tool that is made of a nonferrous material, usually a copper-beryllium alloy is a __________________________________.
14. _____________________________ means the surrounding and effective capture of a person by a liquid or finely divided (flowable) solid substance that can be aspirated to cause death by filling or plugging the respiratory system or that can exert enough force on the body to cause death by strangulation, constriction, or crushing.

15. This type of confined space has one or more of the following characteristics:
    - Contains or has a potential to contain a hazardous atmosphere
    - Contains a material that has the potential for engulfing an entrant
    - Has an internal configuration such that an entrant could be trapped or asphyxiated by inwardly converging walls or by a floor that slopes downward and tapers to a smaller cross section
    - Contains any other recognized serious safety or health hazard
16. This type of confined space does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm:________________________.
17. A collection system is considered _____________________ is the wastewater has produced hydrogen sulfide, turned black, is giving off foul odors, and contains little or no dissolved oxygen.
18. _____________________ are sulfur-containing compounds that have an offensive skunk-like odor; but can sometimes be described as smelling like garlic or onions.

<u>Word Bank</u>

Competent person

Permit-required

IDLH (Immediately Dangerous to Life or Health

Chronic

Septic

Spoil

Nonsparking tool

Oxygen enrichment

Confined space

Non-permit

Sewer gas

Lower explosive limit (LEL)

Decibel

Acute

Olfactory fatigue

Carcinogen

Mercaptans

Oxygen deficiency

Engulfment

## <u>Cross Connection Vocabulary Words</u>

<u>Absolute Pressure</u> – The total pressure; gauge pressure plus atmospheric pressure. Absolute pressure is generally measured in pounds per square inch (psi).

<u>Air Gap</u> – A physical separation between the free flowing discharge end of a potable water supply line and an open or non-pressurized receiving vessel. An air gap acts as a physical, unobstructed separation between the water distribution system and the wastewater collections system. An “approved air gap” must be twice the internal diameter of the supply pipe measured vertically above the overflow rim of the receiving vessel, but never less than 1 inch.

*The air gap is the most effective method for preventing backflow.*

<u>Air Inlet</u> – The opening in the body of a device (usually a vacuum breaker) which will allow free atmosphere into the liquid passageway of the device body, which will prevent downstream siphoning. (backsiphonage) -

<u>Approved Backflow Prevention Assembly</u> – An assembly that has been evaluated/tested and approved according to the authority having jurisdiction for use within the water system.

<u>Aspirator Effect</u> – The hydraulic effect of suction created by an aspirator or restricted area of flow. At this restricted area of flow the pressure drops to sub-atmospheric, creating suction. The effect can be increased with the use of a Venturi apparatus.

<u>Atmospheric Pressure</u> – The pressure exerted by the weight of the atmosphere (14.7 psi at sea level). As the elevation above sea increases, the atmospheric pressure decreases.

<u>Atmospheric Vacuum Breaker (AVB)</u> – A non-testable backflow device consisting of a body, a checking member (float), and an atmospheric opening. An AVB protects against backsiphonage only, not backpressure.

<u>Auxiliary Water Supply</u> – Any water supply on or available to the premises other than water supplied by the public water purveyor. These waters may be polluted or contaminated and constitute an unacceptable water source over which the water purveyor does not have sanitary control.

<u>Backflow</u> – The undesirable reversal of flow of contaminated water, other liquids or gases into the distribution system of a potable water supply.

<u>Backflow Prevention Device (Backflow Preventer)</u> – Any device, method or construction used to prevent the backward flow of liquids into a potable water supply.

<u>Backpressure (Superior Pressure)</u> – The hydraulic condition of increased pressure in a system above the supply pressure which results in backflow into the potable water supply.

<u>Backsiphonage</u> – The hydraulic condition resulting in backflow due to a reduction in system pressure, which causes a sub-atmospheric pressure (vacuum) to exist in the water system.

<u>Bypass</u> – Any arrangement of pipes, plumbing or hoses designed to divert the flow around an installed backflow device or assembly through which the flow normally passes.

<u>Check Valve</u> – A mechanical device designed to allow flow in one direction only.

Containment – A water purveyor's backflow prevention policy of installing a backflow prevention device commensurate with the degree of hazard after the termination of the distribution system (water meter) and prior to any branches in the system.

Contaminant – Any substance introduced into the public water system that will cause illness or death. (high hazard)

Continuous Pressure – A condition in which upstream pressure is applied for more than 12 hours in a 24-hour period to a device or assembly. Continuous pressure can cause mechanical parts within a device to freeze.

Cross Connection – Any physical arrangement whereby a public water system is connected, directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture or other device which contains or may contain contaminated water, sewage, or other waste or liquid of unknown or unsafe quality which may be capable of contaminating the public water supply as a result of backflow.

Cross Connection Control – The use of assemblies, methods and procedures to prevent contamination of a potable water supply through cross connections.

Degree of Hazard – The danger posed by a particular substance or set of circumstances. Generally, a low degree of hazard (pollutant) is one that does not affect health, but may be aesthetically objectionable. A high degree of hazard (contaminant) is one that could cause serious illness or death.

Differential Pressure – The relative difference in pressure between two pressure sources.

Direct Cross-Connection – A continuous, enclosed interconnection to allow the flow of fluid from ones system to the other. A direct cross connection is subject to both backsiphonage and backpressure.

Distribution System – A system of conduits (pipes, laterals, fixtures) by which a potable water supply is distributed to consumers.

Double Check Detector Assembly – A specially designed assembly composed of line size approved double check valve assembly, with a bypass containing a water meter and approved double check valve assembly specifically designed for such application. The meter shall register accurately for very low rates of flow up to 2 gallons per minute and shall show a registration for all rates of flow. This assembly shall only be used to protect against non-health hazards and is designed primarily for uses on fire sprinkler systems.

Double Check Valve Assembly – A backflow prevention assembly consisting of two independently acting internally loaded check valves, four properly located test cocks, and two shutoff valves. Used to protect against non-health hazards (pollutants) only.

Dual Check – An untestable backflow prevention device consisting of two independently operating check valves, without any test cocks or shut-off valves.

Failed – The status of a backflow prevention assembly determined by a performance evaluation based on the failure to meet all minimums set forth by the approved testing procedure.

Feed Water – Water that is added to a commercial or industrial system and subsequently used by the system, such as water that is fed to a boiler to produce steam.

Flood-Level Rim – The top edge of a receptor from which water overflows.

Gauge Pressure – Pounds per square inch (psi) that are registered on a test gauge. Gauge pressure measures only the amount of pressure above (or below) atmospheric pressure.

Indirect Cross-Connection – A potential cross connection where the interconnection is not continuously enclosed and is subject to backsiphonage only.

Isolation – A water purveyor's backflow prevention policy of installing a backflow prevention device commensurate with the degree of hazard at each fixture or appliance outlet.

Liability – Legally responsible for or being obligated by law for the protection of the potable water supply.

Negative Pressure – Pressure that is less than atmospheric; negative pressure in a pipe can induce a partial vacuum that can siphon nonpotable liquids into the potable distribution system.

Nonpotable – Any liquid that is not considered safe for human consumption.

Parallel Installation (Dual Installation) – The installation of two or more backflow prevention assemblies of the same type having a common inlet, outlet, and direction of flow.

Passed – The status of a backflow prevention assembly determined by a performance evaluation in which the assembly meets all minimums set forth by the approved testing procedure.

Pathogen – A disease producing organism, such as a virus, bacterium, or other microorganism. Associated with high hazard (contaminant) conditions.

Performance Evaluation – An evaluation of an approved backflow prevention assembly using the latest approved testing procedures in determining the status of the assembly.

Plumbing – Any arrangement of pipes, fittings, fixtures or other devices for the purpose of moving liquids from one point to another, generally within a single structure.

Poison – A substance that can kill, injure or impair a living organism.

Pollutant – A substance that would constitute a non-health hazard and would be aesthetically objectionable if introduced into the potable water system.

Potable – Water (or other liquids) that are safe for human consumption.

Pressure – The weight (of air, water, etc.) exerted on a surface, generally expressed as pounds per square inch (psi).

Pressure Vacuum Breaker (PVB) – A backflow prevention assembly consisting of one or two independently operating spring loaded check valves and an independently operating spring loaded air inlet valve located on the discharge side of the check valve(s), with properly located test cocks, and tightly closing shutoff valves on each side of the check valves.  A PVB is testable and protects against backsiphonage only, not backpressure.

Reduced Pressure Principle Assembly (RP) – A backflow prevention assembly consisting of two independently operating spring-loaded check valves together with a hydraulically operating, mechanically independent, pressure differential relief valve located between the check valves and below the first check valve.  These units shall be located between two tightly closing shutoff valves with four properly located test cocks.

*The RP is the best device for preventing backflow.*

Reduced Pressure Principle Detector Assembly – A specially designed assembly composed of a line size approved reduced pressure principle backflow prevention assembly with a bypass containing a water meter and an approved reduced pressure principle backflow prevention assembly specifically designed for such application. The meter shall register accurately for very low flow rates of flows up to 2 gallons per minute and shall show registration of all flow rates.  This assembly shall only be used to protect against non-health and health hazards and is designed primarily for uses on fire sprinkler systems.

Refusal of Service (Shutoff Policy) – A formal policy adopted by a governing board to enable a utility to refuse or discontinue service where a known hazard exists and corrective measures are not undertaken.

Regulating Agency – Any local, state or federal authority given the power to issue rules or regulations having the force of law for the purpose of providing uniformity in details and procedures.

Relief Valve – A device designed to release air from a pipeline, or introduce air into a line if the internal pressure drops below atmospheric pressure.

Submerged Inlet – The discharge of a piping system that is located below the flood level rim of a tank or vessel. This can result in an indirect cross connection with a potable drinking water supply.

Test Cock – An appurtenance on a device or valve used for testing the device.

Venturi – A specifically designed hydraulic structure designed to increase the velocity and thus decrease the pressure of a fluid through a constricted region creating suction.

Venturi Effect – A hydraulic principle that states that as the flow path is restricted, a fluid will exhibit a greater velocity and a reduced system pressure through the restriction.  The Venturi effect can induce a vacuum in a distribution system.

Waterborne Disease – Any disease that is capable of being transmitted through water.  Examples include typhoid, cholera, giardiasis.

Water Purveyor – An organization that is engaged in producing and/or distributing potable water for domestic use.

Cross-Connections Examples and Potential Hazards

| Connected System | Hazard Level |
|---|---|
| Sewage pumps | High |
| Boilers | High |
| Cooling towers | High |
| Flush valve toilets | High |
| Garden hose (sil cocks) | Low to high |
| Auxiliary water supply | Low to high |
| Aspirators | High |
| Dishwashers | Moderate |
| Car wash | Moderate to high |
| Photographic developers | Moderate to high |
| Commercial food processors | Low to moderate |
| Sinks | High |
| Chlorinators | High |
| Solar energy systems | Low to high |
| Sterilizers | High |
| Sprinkler systems | High |
| Water systems | Low to high |
| Swimming pools | Moderate |
| Plating vats | High |
| Laboratory glassware or washing equipment | High |
| Pump primers | Moderate to high |
| Baptismal founts | Moderate |
| Access hole flush | High |
| Agricultural pesticide mixing tanks | High |
| Irrigation systems | Low to high |
| Watering troughs | Moderate |
| Autopsy tables | High |

# Section 7 Administration and Management

# Section 7 Administration and Management

## Need for utility management

- Public or private, large or small, it's a complex and challenging job
- Protection from environmental disasters with a minimum investment of money
- External concerns (public citizens) vs. challenges within the utility
  - Ethical and responsible decisions
  - Personnel
  - Resources
  - Equipment
  - Preparing for the future

## Functions of a manager

- Planning
- Organizing
- Staffing
- Directing
- Controlling

- In small communities, the utility manager may be the only one who has all these responsibilities

## Planning

- One of the most important functions
- Building the resources and financial capability to provide for future needs
  - Future growth
  - Industrial development
  - Plant capacity
  - Level of treatment
- Short term and long term goals
- Should include input from: operational personnel, local officials, and the public

## Planning (O & M)

- Operational Standpoint
- To maintain design functionality (capacity)
  - Does the system perform as designed?
- Proactive or reactive?

1. Corrective Maintenance
2. Preventative Maintenance
3. Predictive Maintenance

- Proactive can be scheduled and long-term Capital Improvement Programs (CIP) planned/budgeted

## Planning (O&M)

- Corrective Maintenance (Reactive)
  - Emergency
  - Reliance on reactive maintenance will always result in poor system performance
- 2 types of emergencies:
  1. Normal
     - Sewer blockages
     - Can be reduced by effective maintenance program
  2. Extraordinary
     - High-intensity rainstorm, floods, earthquakes
     - Can be minimized by planned maintenance program and development of comprehensive emergency response plan

## Planning (O&M)

- Preventative Maintenance (Proactive)
  - Programmed, systematic approach
  - Will always result in improved system performance
  - Ex: lubrication of motors is frequently based on running time
- Major elements of good PM program:
  - Planning and scheduling
  - Records management
    - Spare parts management
  - Cost and Budget control
  - Emergency repair procedures
  - Training program

## Planning (O&M)

- Predictive Maintenance (Proactive)
  - Method of establishing baseline performance data, monitoring performance over time, observing changes so failure can be predicted
  - Goal: reduce Corrective and Emergency maintenance, thereby reducing system failures that result in stoppages and overflows
- Goal of managing maintenance: minimize investments of labor, materials, money, and equipment
  - Major capital investments
  - Reliability is critical

# Planning

- Emergency Response Plan (aka Emergency Operating Plan or EOP)
  - Natural or human disasters
  - Contingency planning

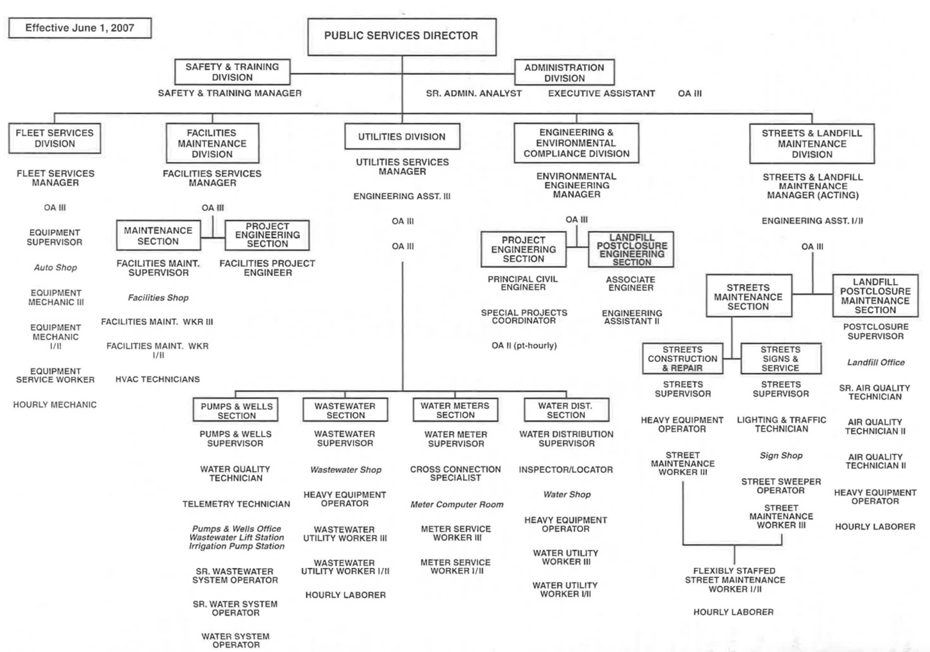

1. Vulnerability Assessment
2. Inventory organizational personnel
3. Provide for a recovery operation (plan)
4. Training programs for operators
5. Coordinate with local agencies
6. Establish communications procedure
7. Provide protection for staff, equip, records, maps

# Back-up requirements

- TN Design Criteria:
  - 14.3.1.2
    - All treatment facilities greater than 100,000 gpd shall be equipped with an emergency generator to provide an alternate power source
  - 2.7.4
    - An emergency power source or auxiliary power is required for all pumping stations larger than 1 MGD to ensure continuous operability unless experience has shown the frequency and duration of outages to be low and the pumping station and/or sewers provide storage sufficient for expected interruptions in power service.

# Organizing

- Deciding who does what work and delegating authority to appropriate persons
- Utility should have a written organizational plan and written policies
  - Show who reports to whom
  - Job descriptions
- *Authority* = the power and resources to do a specific job or to get that job done
- *Responsibility* = answering to those above in the chain of command to explain how and why you used your authority
- *Delegation* = the act in which power is given to another person
- *Accountable* = employee must ensure the manager is informed of results or events



## Organizing

- Employees should not be asked to accept responsibilities beyond their level of authority
- Authority and responsibility must be delegated properly to be effective
- 3 components present = successful delegation
  1. Proper job assignments
  2. Authority
  3. Responsibility
- Follow-up is important

## Staffing

- Should have established procedures for:
  - Hiring
    - Analyzing staffing needs
    - Qualifications profile, Advertising, Interviewing
  - Training
    - New employee and ongoing
    - Safety is extremely important, but not sole benefit
      - Protection of public's investment
      - Employee pride and recognition
    - Certification
    - Supervisor training
  - Evaluating job performance
    - Written evaluation strongly recommended for documentation
    - Set goals

## Staffing

- 68-221-909. Certification of operators Responsibilities Multiple functions.
- (a) All operators of water and wastewater systems are encouraged to become certified, although this part requires only that a person in direct charge of a water treatment plant, wastewater treatment plant, water distribution system or wastewater collection system be certified.
- (c) It is permissible for one (1) certified operator to have the responsibility for more than one (1) water and/or wastewater system where two (2) or more systems are involved in reasonable proximity to one another, and where the duties of operation are such that the work time of one (1) person may properly be divided among two (2) or more systems, or where a certified operator may adequately supervise the work of others in more than one (1) system.

[Acts 1984, ch. 812, § 8; T.C.A., § 68-13-909.]

## Communication

- Both written and oral communication skills are needed to effectively organize and direct the operation of wastewater plant
- 2 part process:
  - Info must be given
  - Info must be understood (good listening skills)
- Communicating with employees, your governing body, and the public
- Annual report
  - One of the most involved writing projects
  - Review of what and how the utility operated the past year
  - Include goals for next year

# Communication

- Conducting Meetings
- Public Relations
  - Utility Operations
    - Public image
    - Open communication
  - Mass Media
  - Being Interviewed
  - Public Speaking
  - Consumer Inquiries
    - Customer calls are frequently your first indication that something may be wrong
    - Education can be a valuable tool
      - Franklin videos: flushable wipes, grease
  - Plant Tours

# Financial management

- **Budgeting is perhaps the most challenging task for many managers**
- Must understand how the money was spent over the last year, the needs of the utility, and how the needs should be prioritized
- Must have a Repair/Replacement Fund
- Wastewater treatment rates
- Capital Investments and funding in the future
- Financial Assistance

## Safety

- Regardless of size, utility must have a safety program
  - Basic elements include: safety policy statement, safety training and promotion, accident investigation and reporting
- Regulatory agencies
  - OSHA (TOSHA)
- First Aid
- Hazard Communication/Right To Know Laws
  - 29 CFR 1910.1200
  - SDS
- Confined Space Entry Procedures
- Reporting
- Training

## Security Measures

- Investing in security and infrastructure improvements
- Security of critical wastewater infrastructure
  - Sanitary and Storm sewers is one of America's most valuable resources
  - **Vulnerabilities** include:
    - Pumping and Lift Stations
    - Manholes
    - Chemical and fuel storage areas
    - Outfall pipes

Vulnerability Analysis Worksheet

Treatment System Capital City Wastewater Treatment Plant

Assumed Emergency Flood (100 years)

Description of Emergency The flood will cause considerable damage to low lying areas. Bridges will be closed, utility poles downed and electrical power interrupted.

| System component | Effects of emergency<br>Type and extent | Prevention recommendations |
|---|---|---|
| Collection lines | 60" interceptor could be washed out at Back Creek crossing | 1. Encase line in concrete<br>2. Maintain pipe and fitting to repair damaged section.<br>3. Provide portable pumps to bypass break.<br>4. Contract for major emergency repair services |

FIGURE 3.12 Example of a vulnerability analysis.

# Ethics

- Performing illegal acts is always unethical. However, unethical acts are not always illegal.
- What is ethics?
  - **Moral principles and rules of conduct**
  - The point of ethics is to benefit people
  - Correct ethical actions are those that one does out of consideration for others
  - How people ought to treat each other
  - Ethical concepts are based on the assumption that everyone acts with consideration of all
  - Everyone benefits when we act ethically towards others

## Ethics

- Examples of illegal and unethical activities:
  - Providing false information on an application for a job or certification exam
  - Cheating on your certification exam
  - Copying certification exam questions
  - Dry-labbing (writing down results without actually performing the test)
  - Falsifying results and reports
  - Intentionally discharging toxic wastes to receiving waters
  - Harassing other employees
  - Requiring operators to use unsafe equipment, work under unsafe conditions, or occupy confined space with an unsafe atmosphere

## Ethics

- Ask yourself: "Would I be uncomfortable with my actions if they were reported in the newspaper?"

- Other areas where operators will encounter ethical situations:
  - Collecting samples
  - Preparation of reports
  - Sabotaging someone else's work
  - Recommending a vendor or consulting engineer
  - Employee performance evaluations
  - Cheating on an exam

## Ethics

- Whistleblowing = the act of reporting illegal activity to an authority

- Codes of Ethics
  - Trustworthiness
  - Respect
  - Responsibility
  - Caring
  - Justice
  - Civic virtue and citizenship

- Interactions between operators and the public
- Interactions among operators
- Approved professional conduct
- Service by operators to protect the public and the environment

## Ethics

- 0400-49-01-.11 Rules Governing Water and Wastewater Operator Certification
- An operator's certificate may be revoked when:
  - Operator has not used reasonable care, judgement, or application of his/her knowledge in performance of their duties
    - Intentional or negligent
  - Operator is incompetent to perform those duties
  - Operator has practiced fraud or deception
    - Obtained certificate through fraud, deceit, or submission of inaccurate data regarding qualifications
    - False, inaccurate data on reports or lab analysis



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TN Department of Environment & Conservation

Administration and Management Vocabulary

1. __________________ is the power and resources to do a specific job or to get that job done.
2. The act of _______________________ is defined as deciding who does what work and delegating authority to the appropriate persons.
3. Answering to those above in the chain of command to explain how and why you have used your authority is defined as ________________________.
4. A ______________________________ is a brief (10-20 minutes) safety meeting held every 7 – 10 working days.
5. Moral principles and rules of conduct define the concept of ___________________. An operator's certification may be revoked if they do not act with this concept in mind.
6. When a manager gives power/responsibility to an employee, and the employee ensures that the manager is informed of results or events, that employee is demonstrating _____________________.
7. ________________________ is the act in which power is given to another person in the organization to accomplish a specific job.
8. ______________________ maintenance is proactive and is defined as a programmed, systematic approach to maintenance activities.
9. The nation's _________________________ provides the essential services that underpin American society and serve as the backbone of our nation's economy, security, and health. This includes the Water and Wastewater Systems Sector, which includes water distribution and sewage collection systems.
10. Identifying system components, estimating disaster effects on those components, estimating customer demand for service following a disaster, and identifying key system components that would be primarily responsible for a system failure are all key steps that should be taken when conducting a ____________________ analysis.
11. The act of reporting illegal activity to an authority is called _______________________.
12. ______________________ maintenance is a method of establishing baseline performance data, monitoring performance criteria over a period of time, and observing changes in performance so that failure can be predicted and maintenance can be performed on a planned, scheduled basis.

Word Bank:

| | |
|---|---|
| Accountability | Ethics |
| Organizing | Accountability |
| Preventative | Responsibility |
| Whistleblowing | Tailgate Safety Meeting |
| Critical Infrastructure | Authority |
| Predictive | Vulnerability |

# Section 8
# NPDES Permit

# STATE of TENNESSEE

## NPDES PERMIT

## Authorization to Discharge Under the National Pollutant Discharge Elimination System (NPDES) Permit Number TN0022586

Issued by

**Department of Environment and Conservation**
**Division of Water Resources**
**William R. Snodgrass - Tennessee Tower**
**312 Rosa L. Parks Avenue, 11th Floor**
**Nashville, Tennessee 37243-1102**

Under authority of the Tennessee Water Quality Control Act of 1977 (T.C.A. 69-3-101 et seq.) and the delegation of authority from the United States Environmental Protection Agency under the Federal Water Pollution Control Act, as amended by the Clean Water Act of 1977 (33 U.S.C. 1251, et seq.)

| | |
|---|---|
| Discharger: | **City of Murfreesboro**<br>**Sinking Creek STP** |
| is authorized to: | treated municipal wastewater from Outfall 001and distribution of treated municipal wastewater for non-potable reuse in irrigation |
| from a facility located at: | 2032 Blanton Drive, Murfreesboro, Rutherford County, Tennessee |
| to receiving waters named: | West Fork of the Stones River at mile 10.5 |

in accordance with effluent limitations, monitoring requirements and other conditions set forth herein.

| | |
|---|---|
| This permit shall become effective on: | **July 01, 2022 (minor modification September 1, 2022)** |
| This permit shall expire on: | **June 30, 2027** |
| Issuance date: | **June 27, 2022** |

for Jennifer Dodd
Director

# Table of Contents

WDM
TN0022586.DOC

# PART 1

## 1. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

### 1.1. NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS

#### 1.1.1. Numeric Limitations

The City of Murfreesboro is authorized to discharge treated municipal wastewater from Outfall 001 to the West Fork of the Stones River at mile 10.5. It is also authorized to distribute treated municipal wastewater for non-potable reuse. This permit authorizes discharges of 20 MGD to the West Fork Stones with 16 MGD routinely discharging during summer in conjunction with up to 4.0 MGD disposed via reuse and the discharge of up to 20 MGD during winter. The current treatment facility has the capacity to discharge 24 MGD in the winter. The permit may be expanded in the future to 24 MGD when the facility has sufficient disposal means in the summer for an additional 4 MGD. Discharge 001 shall be limited and monitored by the permittee as specified in the below tables.

**Year round:**

| External Outfall, Number : 001, Monitoring : Effluent Gross, Season : All Year | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Code** | **Parameter** | **Qualifier** | **Value** | **Unit** | **Sample Type** | **Monitoring Frequency** | **Statistical Base** |
| 00300 | Oxygen, dissolved (DO) | >= | 6.0 | mg/L | Grab | Daily | Instantaneous Minimum |
| 00400 | pH | >= | 6.0 | SU | Grab | Daily | Daily Minimum |
| 00400 | pH | <= | 9.0 | SU | Grab | Daily | Maximum |
| 00530 | Total Suspended Solids (TSS) | <= | 24 | mg/L | Composite | Weekly | Monthly Average |
| 00530 | Total Suspended Solids (TSS) | <= | 32 | mg/L | Composite | Weekly | Weekly Average |
| 00530 | Total Suspended Solids (TSS) | <= | 36 | mg/L | Composite | Weekly | Daily Maximum |
| 00530 | Total Suspended Solids (TSS) | <= | 4003 | lb/d | Composite | Weekly | Monthly Average |
| 00530 | Total Suspended Solids (TSS) | <= | 5338 | lb/d | Composite | Weekly | Weekly Average |
| 00545 | Settleable Solids | <= | 1.0 | mL/L | Grab | Annually | Daily Maximum |
| 00600 | Nitrogen, total (as N) – ALERT See Notes | <= | 9.0 | mg/L | Composite | Twice Per Month | Monthly Average |
| 00600 | Nitrogen, total (as N) | Report | | lb/d | Composite | Twice Per Month | Monthly Average |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 00600 | Nitrogen, total (as N) | Report | | mg/L | Composite | Twice Per Month | Daily Maximum |
| 00600 | Nitrogen, total (as N) | Report | | lb/d | Composite | Twice Per Month | Daily Maximum |
| 00600 | Nitrogen, total (as N) – ALERT – See Notes | <= | 1201 | lb/d | Composite | Annual | Annual Average |
| 00665 | Phosphorus, total (as P) | Report | - | mg/L | Composite | Twice Per Month | Monthly Average |
| 00665 | Phosphorus, total (as P) | Report | - | lb/d | Composite | Twice Per Month | Monthly Average |
| 00665 | Phosphorus, total (as P) | Report | - | mg/L | Composite | Twice Per Month | Daily Maximum |
| 00665 | Phosphorus, total (as P) | Report | - | lb/d | Composite | Twice Per Month | Daily Maximum |
| 00665 | Phosphorus, total (as P) – ALERT – See | <= | 307 | lb/d | Calculated | Annual | Annual Average |
| 50050 | Flow | Report | - | MGD | Continuous | Daily | Monthly Average |
| 50050 | Flow | Report | - | MGD | Continuous | Daily | Daily Maximum |
| 51040 | E. coli | <= | 126 | #/100mL | Grab | Daily | Monthly Geometric Mean |
| 51040 | E. coli | <= | 941 | #/100mL | Grab | Daily | Daily Maximum |
| 51504 | UV Light Working | Report | - | pass=0/fail=1 | Visual | Daily When Discharging | Value |
| **Description : External Outfall, Number : 001, Monitoring : Effluent Gross, Season : Summer** | | | | | | | |
| **Code** | **Parameter** | **Qualifier** | **Value** | **Unit** | **Sample Type** | **Monitoring Frequency** | **Statistical Base** |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 0.5 | mg/L | Composite | Two Per Week | Monthly Average |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 1.2 | mg/L | Composite | Two Per Week | Weekly Average |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 1.6 | mg/L | Composite | Two Per Week | Daily Maximum |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 83 | lb/d | Composite | Two Per Week | Monthly Average |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 200 | lb/d | Composite | Two Per Week | Weekly Average |
| 80082 | CBOD, 5-day, 20 C | <= | 4 | mg/L | Composite | Two Per Week | Monthly Average |
| 80082 | CBOD, 5-day, 20 C | <= | 6 | mg/L | Composite | Two Per Week | Weekly Average |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 80082 | CBOD, 5-day, 20 C | <= | 8 | mg/L | Composite | Two Per Week | Daily Maximum |
| 80082 | CBOD, 5-day, 20 C | <= | 667 | lb/d | Composite | Two Per Week | Monthly Average |
| 80082 | CBOD, 5-day, 20 C | <= | 1001 | lb/d | Composite | Two Per Week | Weekly Average |
| TRP3B | IC25 Static Renewal 7 Day Chronic Ceriodaphnia | > | 98 | % | Composite | Semiannual | Minimum |
| TRP6C | IC25 Static Renewal 7 Day Chronic Pimephales promelas | > | 98 | % | Composite | Semiannual | Minimum |

**Description : External Outfall, Number : 001, Monitoring : Effluent Gross, Season : Winter**

| Code | Parameter | Qualifier | Value | Unit | Sample Type | Monitoring Frequency | Statistical Base |
|---|---|---|---|---|---|---|---|
| 00610 | Nitrogen, Ammonia total (as N) | <= | 1.2 | mg/L | Composite | Two Per Week | Monthly Average |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 2.6 | mg/L | Composite | Two Per Week | Weekly Average |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 3.5 | mg/L | Composite | Two Per Week | Daily Maximum |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 200 | lb/d | Composite | Two Per Week | Monthly Average |
| 00610 | Nitrogen, Ammonia total (as N) | <= | 440 | lb/d | Composite | Two Per Week | Weekly Average |
| 80082 | CBOD, 5-day, 20 C | <= | 8 | mg/L | Composite | Two Per Week | Monthly Average |
| 80082 | CBOD, 5-day, 20 C | <= | 12 | mg/L | Composite | Two Per Week | Weekly Average |
| 80082 | CBOD, 5-day, 20 C | <= | 16 | mg/L | Composite | Two Per Week | Daily Maximum |
| 80082 | CBOD, 5-day, 20 C | <= | 1334 | lb/d | Composite | Two Per Week | Monthly Average |
| 80082 | CBOD, 5-day, 20 C | <= | 2002 | lb/d | Composite | Two Per Week | Weekly Average |
| TRP3B | IC25 Static Renewal 7 Day Chronic Ceriodaphnia | > | 77 | % | Composite | Semiannual | Minimum |
| TRB6C | IC25 Static Renewal 7 Day Chronic Pimephales promelas | > | 77 | % | Composite | Semiannual | Minimum |

| Description : External Outfall, Number : 001, Monitoring : Percent Removal, Season : All Year | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Code** | **Parameter** | **Qualifier** | **Value** | **Unit** | **Sample Type** | **Monitoring Frequency** | **Statistical Base** |
| 80358 | CBOD, 5-day, 20 C, % removal | >= | 85 | % | Calculated | Two Per Week | Monthly Average Minimum |
| 80358 | CBOD, 5-day, 20 C, % removal | >= | 40 | % | Calculated | Two Per Week | Daily Minimum |
| 81011 | TSS, % removal | >= | 85 | % | Calculated | Weekly | Monthly Average Minimum |
| 81011 | TSS, % removal | >= | 40 | % | Calculated | Weekly | Daily Minimum |

| Description : External Outfall, Number : 001, Monitoring : Raw Sewage Influent, Season : All Year | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Code** | **Parameter** | **Qualifier** | **Value** | **Unit** | **Sample Type** | **Monitoring Frequency** | **Statistical Base** |
| 00530 | Total Suspended Solids (TSS) | Report | - | mg/L | Composite | Weekly | Monthly Average |
| 00530 | Total Suspended Solids (TSS) | Report | - | mg/L | Composite | Weekly | Daily Maximum |
| 50050 | Flow | Report | - | MGD | Continuous | Daily | Monthly Average |
| 50050 | Flow | Report | - | MGD | Continuous | Daily | Daily Maximum |
| 80082 | CBOD, 5-day, 20 C | Report | - | mg/L | Composite | Two Per Week | Monthly Average |
| 80082 | CBOD, 5-day, 20 C | Report | - | mg/L | Composite | Two Per Week | Daily Maximum |

| **General MyTDEC Forms Report Requirements*** | |
|---|---|
| Bypass of Treatment Facility | See Section 1.3.5.1. and 2.3.5. |
| Anticipated Bypass of Treatment Facility | See Section 1.3.5.1. and 2.3.5. |
| Five-day Follow-up Noncompliance Report | See Sections 1.3.5.1. and 2.3.1.a. |
| Scheduled Reporting | See Section 2.3.1.b. |

* Each event shall be reported via MyTDEC Forms.

Notes:

The permittee shall achieve 85 % removal of $CBOD_5$ and TSS on a monthly average basis. The permittee shall report all instances of releases, overflows and/or bypasses. See **Part 2.3.2(a)** for the definition of overflow and **Part 1.3.5** for reporting requirements.

Calculations for all limitations which require averaging of measurements shall utilize an arithmetic mean unless otherwise specified in the permit.

Unless elsewhere specified, summer months are May through October; winter months are November through April.

See **Part 1.2.3** for test procedures.

See **Part 3.4** for biomonitoring test and reporting requirements.

See below for percent removal calculations.

The permittee may collect more samples than specified as the monitoring frequency in the permit. Samples may not be collected at intervals of less than 12 hours. For the purpose of determining the geometric mean, individual samples having an *E. coli* group concentration of less than 1 per 100 mL shall be considered as having a concentration of 1 per 100 mL. In addition, the concentration of the *E. coli* group in any individual sample shall not exceed a specified maximum amount.

Total residual chlorine (TRC) monitoring shall be applicable when chlorine, bromine, or any other oxidants are added. The acceptable methods for analysis of TRC are any methods specified in Title 40 CFR § 136 as amended, so long as the requirements of Tennessee Rule 0400-40-03-.05(8) are met. The method detection limit (MDL) should be determined in accordance with 40 CFR § 136 as amended, Appendix B. The MDL for TRC shall not exceed 0.05 mg/l unless the permittee demonstrates that its MDL is higher. The permittee shall retain the documentation that justifies the MDL and have it available for review upon request. In cases where the permit limit is less that the MDL, the reporting of TRC at less than the MDL shall be interpreted to constitute compliance with the permit.

The total nitrogen and total phosphorus numeric values are “ALERT” values. Exceeding these values will not trigger a numeric permit violation. If exceeded, the permittee shall investigate the cause(s) and make the process adjustments necessary to return to optimized biological nutrient removal. The permittee shall submit an attachment to the Discharge Monitoring Report (DMR) for the month acknowledging the value(s) exceeding the alert value and providing a status of the investigation of the occurrence and if known, the plan to return to optimized biological nutrient removal. Failure to submit an attachment will be a narrative violation.

Each daily load is calculated by multiplying the day’s sample concentration (mg/L) by the effluent flow rate (MGD) for the day the sample was collected and the conversion factor 8.34 lbs/gal.

$$Load = \begin{pmatrix} Effluent \\ Concentration \end{pmatrix} * \begin{pmatrix} Effluent\ flow\ for\ the\ day\ the \\ day\ the\ sample\ was\ collected \end{pmatrix} * (8.34)$$

The average pound per year is the mathematical average where the sum of all the calculated loads during the current year and is divided by the number of calculated loads.

$$Annual\ Average\ Pounds\ per\ Day = \left( \frac{Sum\ of\ All\ Loads\ in\ \frac{lbs}{day}\ During\ the \\ Current\ Year}{Total\ Number\ of\ Loads\ Calculated\ During \\ the\ Current\ Year} \right)$$

### 1.1.2. Collection System Requirements

City of Murfreesboro is authorized to operate a sewage collection system. Operation and discharges from the collection system shall be limited and monitored by the permittee as specified below:

| Code | Monitoring | Parameter | Qualifier | Value | Unit | Sample Type | Monitoring Frequency | Statistical Base |
|---|---|---|---|---|---|---|---|---|
| 51925 | Dry Weather | SSO, Dry Weather | <= | 0 | occur/mo | Occurrences | Continuous | Monthly Total |
| 51926 | Wet Weather | SSO, Wet Weather | <= | 0 | occur/mo | Occurrences | Continuous | Monthly Total |

Report via NetDMR. See sections **1.3.1.** and **1.3.5.2.**

| Collection System MyTDEC Forms Report Requirements* | |
|---|---|
| Sanitary Sewer Overflow (SSO, Dry Weather) | See Section 1.3.5.1. |
| Sanitary Sewer Overflow (SSO, Wet Weather) | See Section 1.3.5.1. |
| Release (Dry Weather) | See Section 1.3.5.1. |
| Release (Wet Weather) | See Section 1.3.5.1. |
| Five-day Follow-up Noncompliance Report | See Sections 1.3.5.1. and 2.3.1. |

* Each event shall be reported via MyTDEC Forms.

### 1.1.3. Reuse Conditions

The City of Murfreesboro is authorized to distribute treated municipal wastewater for non-potable reuse. The reuse water shall be limited and monitored by the permittee as specified below:

**Description : External Outfall, Number : 01T, Monitoring : Effluent Gross, Season : All Year**

| Code | Parameter | Qualifier | Value | Unit | Sample Type | Frequency | Statistical Base |
|---|---|---|---|---|---|---|---|
| 50050 | Flow | Report | - | Mgal/d | Composite | Continuous | Daily Maximum |
| 50050 | Flow | Report | - | Mgal/d | Composite | Continuous | Monthly Average |
| 50060 | Chlorine, total residual (TRC)(after 30 minutes) | >= | 1.0 | mg/L | Grab | Daily | Daily Minimum |
| 51040 | E. coli | <= | 23 | #/100mL | Grab | Daily | Daily Maximum |

(1) Daily *E.coli* and residual chlorine samples should be collected at the point of release from the treatment system. Quarterly *E.coli*, as 23 #/100 ml daily maximum, and residual chlorine, as 1.0 mg/L quarterly average, samples should be collected for analysis at two points within the distribution system: one that is representative of the system's average residence time and one that is representative of the system's maximum residence time.

(2) Total residual chlorine (TRC) monitoring shall be applicable when chlorine, bromine, or any other oxidants are added. The acceptable methods for analysis of TRC are any methods specified in Title 40 CFR, Part 136 as amended. The method detection level (MDL) for TRC shall not exceed 0.05 mg/l unless

the permittee demonstrates that its MDL is higher. The permittee shall retain the documentation that justifies the higher MDL and have it available for review upon request. In cases where the permit limit is less that the MDL, the reporting of TRC at less than the MDL shall be interpreted to constitute compliance with the permit.

This permit allows treated wastewater effluent to be distributed for land application reuse by industrial customers, commercial developments, golf courses, recreational areas, residential developments and other non-potable uses. The reuse water must receive all treatment steps applied to the discharged wastewater and must comply with all effluent limitations applied to the discharge wastewater. In addition, the reuse wastewater must comply with the numeric limitations in this section and the following requirements:

Reuse activities are restricted to use of the water in a manner that results in its disposal by land application (spray irrigation or drip irrigation). No discharge of the reuse water is allowed. The application rate when spray or drip irrigation is employed shall be restricted such that there shall be no ponding or runoff of the reuse water. Dedicated irrigation sites shall be owned by the permittee (or covered by a perpetual easement for use as a land application site) and approved by the division prior to their use for irrigation purposes.

In order to protect public health, this permit requires that the permittee meet a daily maximum E. coli concentration of 23 colonies per 100 ml and a daily minimum chlorine residual of 1.0 mg/l in the distribution system.

The permittee shall take appropriate measures, including signs, tags, permanently imprinted warnings, etc., to insure that all points where water can be accessed from the reuse distribution system are clearly marked to indicate that the reuse water is unfit for drinking or other potable purposes.

Any runoff due to improper operation must be reported in writing to the Division of Water Resources, Environmental Field Office - Nashville within 5 days of the incident. In addition, the reuse irrigation system must be operated in a manner preventing the creation of a public health hazard or a public/private nuisance.

The permittee shall maintain service agreements with the end users governing, at a minimum, the quality and quantity of the treated municipal wastewater made available for reuse.

Nothing in this permit prohibits the reuse agreement from containing and imposing additional conditions, limits or monitoring and reporting requirements.

The permittee shall maintain a copy of the reuse agreements at the treatment facility address and make them available for inspection upon request.

The permittee shall comply with applicable provisions of rules of the Board of Water Quality, Oil and Gas governing non-potable reuse.

### 1.1.4. Narrative Conditions

| | |
|---|---|
| Active - Permit Requirement | The permittee shall submit a written technical evaluation of the need to revise local limits within 120 days of the effective date of this permit to the state pretreatment program coordinator. The evaluation shall include the most recent pass-through limits proposed by the Division and should be submitted to the following email address: DWRWaterCompliance@tn.gov. |
| Active - Permit Requirement | The permittee shall submit the results of an Industrial Waste Survey (IWS) to the Division of Water Resources, Pretreatment Section within 120 days of the effective date of this permit, unless such a survey has been submitted within 3 years of the effective date. If an IWS has been submitted within the past 3 years, the permittee shall notify the Division of the date when the IWS was previously submitted to the Division. The IWS shall be submitted to the following email address: DWRWater.Compliance@tn.gov. |
| Active - Permit Requirement | Submit a Reclaimed Wastewater Management Plan (RWMP) and the form of end user service agreements pursuant to Rule §0400-40-06-.10 no later than submission of the application for permit renewal for 2027. |

The authorized discharge shall not:

- Result in distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits, or sludge banks of such size or character as may be detrimental to fish and aquatic life.
- Result in total suspended solids, turbidity, or color in such amounts or character that will result in any objectionable appearance to the receiving water, considering the nature and location of the water.
- Contain pollutants in quantities that will be hazardous or otherwise detrimental to humans, livestock, wildlife, plant life, or fish and aquatic life in the receiving stream.

Sludge or any other material removed by any treatment works must be disposed of in a manner that prevents its entrance into or pollution of any surface or subsurface waters. Additionally, the disposal of such sludge or other material must be in compliance with the Tennessee Solid Waste Disposal Act, Tennessee Code Annotated (Tenn. Code Ann.) §68-31-101 et seq. and the Tennessee Hazardous Waste Management Act, Tenn. Code Ann. §68-46-101 et. seq.

## 1.2. MONITORING PROCEDURES

### 1.2.1. Representative Sampling

Samples and measurements taken in compliance with the monitoring requirements specified herein shall be representative of the volume and nature of the monitored discharge and shall be taken after treatment and prior to mixing with uncontaminated stormwater runoff or the receiving stream. Appropriate flow measurement devices and methods consistent with accepted scientific practices shall be selected and used to ensure the accuracy and reliability of measurements of the volume of monitored discharges. The devices shall be installed and calibrated by a qualified source at least once every 12 months[1], and maintained to ensure that the accuracy of the measurements is consistent with accepted capability of that type of device. Devices selected shall be capable of measuring flows with a maximum deviation of plus or minus 10% from the true discharge rates throughout the range of expected discharge volumes.

Composite samples must be proportioned by flow at the time of sampling. Aliquots may be collected manually or automatically. The sample aliquots must be maintained at ≤ 6°C during the compositing period, or as otherwise specified in 40 CFR §136 or in the method.

Samples and measurements taken in compliance with the monitoring requirements specified above shall be representative of the volume and nature of the monitored discharge, and shall be taken at the following location(s):

**Influent samples** must be collected prior to mixing with any other wastewater being returned to the head of the plant, such as sludge return. Those systems with more than one influent line must collect samples from each and proportion the results by the flow from each line.

**Effluent samples** must be representative of the wastewater being discharged and collected prior to mixing with any other discharge or the receiving stream. This can be a different point for different parameters but must be after all treatment for that parameter or all expected changes. Specifically:

a) The chlorine residual must be measured after the chlorine contact chamber and any dechlorination. It may be to the advantage of the permittee to measure at the end of any long outfall lines.

[1] The Division expects for permittees to meet EPA's guidance on proper operation and maintenance of flow measurement devices, as stated in the NPDES Compliance Inspection Manual.

b) Samples for *E. coli* can be collected at any point between completion of disinfection and the actual discharge.

c) The dissolved oxygen (DO) can drop in the outfall line; therefore, DO measurements are required at the discharge end of outfall lines greater than one mile long. Systems with outfall lines less than one mile may measure dissolved oxygen as the wastewater leaves the treatment facility. For systems with dechlorination, DO must be measured after this step and as close to the end of the outfall line as possible.

d) Total suspended solids (TSS) and settleable solids can be collected at any point after the final clarifier.

e) Biomonitoring tests (if required) shall be conducted on final effluent.

### 1.2.2. Sampling Frequency

The permittee should report “No Discharge” on Discharge Monitoring Reports (DMRs) only if a permitted outfall does not discharge at any time during the monitoring period. If the outfall discharges effluent at any time during the monitoring period, the permittee must provide at least one sampling result from the effluent of that outfall.

If the required monitoring frequency is once per month or 1/month, the monitoring period is one month. If the discharge occurs during only one day in that period, the permittee must sample on that day and report the results of analyses accordingly.

### 1.2.3. Test Procedures

a) Test procedures for the analysis of pollutants shall conform to regulations published pursuant to Section 304 (h) of the Clean Water Act (the "Act"), as amended, under which such procedures may be required.

b) Unless otherwise noted in the permit, all pollutant parameters shall be determined using sufficiently sensitive methods in Title 40 CFR § 136, as amended, and promulgated pursuant to Section 304 (h) of the Act. The chosen methods must be sufficiently sensitive as required in state rule 0400-40-03-.05(8).

c) If the minimum level of quantification (ML) for all methods available in accordance with 40 CFR § 136 are above the stated permit limit or applicable water quality criteria for that parameter, then the method with the lowest ML shall be used.

d) Where the analytical results are below the method detection limit (MDL), the permittee shall report the actual laboratory MDL and ML values. See **Section 1.3.6.** for instructions regarding reporting less than detection.

e) When there is no analytical method that has been approved under 40 CFR §136 or required under 40 CFR chapter I, subchapter N or O, and a specific method is not otherwise required by the Director, the permittee may use any suitable method but shall provide a description of the method. When selecting a suitable method, factors such as a method's precision, accuracy, or resolution must be considered when assessing the performance of the method.

f) All sampling for total mercury at the municipal wastewater plant (including application, pretreatment, etc.) shall use Methods 1631, 245.7, or any additional method in 40 CFR § 136 with a maximum detection limit of 5 ng/L.

**1.2.4. Recording of Results**

For each measurement or sample taken pursuant to the requirements of this permit, the permittee shall record the following information:

i. The date, exact place, and time of sampling or measurements;
ii. The individual(s) who performed the sampling or measurements;
iii. The date analyses were performed;
iv. The individual(s) who performed the analyses;
v. The laboratory where the analyses were performed;
vi. The analytical techniques or methods used; and
vii. The results of such analyses.

**1.2.5. Records Retention**

The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this permit, and records of all data used to complete the application for this permit, for a period of at least 3 years from the date of the sample, measurement, report or application. This period may be extended by request of the Director at any time.

## 1.3. REPORTING

### 1.3.1. Monitoring Results

Monitoring results shall be recorded monthly and submitted monthly on Discharge Monitoring Reports (DMRs) using EPA's NetDMR website. The first DMR is due on the 15th of the month following permit effectiveness. Subsequent DMRs shall be submitted through NetDMR no later than 15 days after the completion of the reporting period. In compliance with the Federal NPDES Electronic Reporting Rule, DMRs may not be submitted via email under any circumstances.

Discharge Monitoring Reports and any other information or report must be signed and certified by a responsible corporate officer as defined in Tennessee Rules, Chapter 0400-40-05-.07(2)(i), a general partner or proprietor, a principal municipal executive officer or ranking elected official, or his or her duly authorized representative. Such authorization must be submitted in writing and must explain the duties and responsibilities of the authorized representative.

In the event that electronic reporting is unavailable, the permittee shall comply with reporting conditions provided in **Section 1.7**.

### 1.3.2. Additional Monitoring by Permittee

If the permittee monitors any pollutant more frequently than required by the permit using test procedures approved under 40 CFR § 136, or as specified in the permit, the results of this monitoring shall be included in the calculation and reporting of the data submitted in the DMR or other reporting form specified by the Commissioner. Such increased frequency shall also be indicated.

### 1.3.3. Falsifying Results and/or Reports

Knowingly making any false statement on any report required by this permit or falsifying any result may result in the imposition of criminal penalties as provided for in Section 309 of the Federal Water Pollution Control Act, as amended, and in § 69-3-115 of the Tennessee Water Quality Control Act.

### 1.3.4. Monthly Report of Operation

Monthly Operational Reports (MORs) shall be submitted by the 15th day of the month following data collection. Reports shall be submitted by one of the following methods, presented below in order of preference:

1) Using MyTDEC Forms, if available.

2) Submitting both a signed and certified copy in pdf format, uploaded as an attachment to NetDMR, *and* a copy of the native format spreadsheet file emailed to DWRWW.Report@tn.gov and TDEC.Nashville.EFO@tn.gov.

3) Submitting signed and certified forms to the EFO at the following address:

*STATE OF TENNESSEE*
*DEPARTMENT OF ENVIRONMENT AND CONSERVATION*
*DIVISION OF WATER RESOURCES*
*Nashville Environmental Field Office*
*711 R.S. Gass Boulevard*
*Nashville, Tennessee 37216*

### 1.3.5. Overflow, Release, and Bypass Reporting

#### 1.3.5.1. Event Report Requirements

For the purpose of this section, "events" are known as instances of sanitary sewer overflows, releases, upsets, and bypasses. These events shall be reported through MyTDEC Forms according to the following conditions:

a) Events that are not a threat to human health and the environment shall be reported using MyTDEC Forms no later than 15 days following the completion of the DMR reporting period.

b) Events that could cause a threat to human health or the environment, as defined in **Section 2.3.1.a.**, shall be reported using MyTDEC Forms no later than 5 days after becoming aware of the non-compliance.

In both cases, the event report must contain the following:

i. Start date;
ii. Estimated duration in hours;
iii. Estimated volume in gallons;
iv. Type of event;
v. Type of structure (e.g., manhole);
vi. Types of human health and environmental impacts~~;~~
vii. Location (i.e., latitude and longitude);
viii. The name of receiving water (if applicable);
ix. Description of the cause;
x. The steps being taken to correct, reduce, eliminate, and prevent recurrence of the noncompliance; and
xi. The next downstream pump/lift station using the permittee's naming conventions.

In the event that MyTDEC Forms is not functioning, the permittee shall comply with reporting conditions provided in **Section 1.7**.

#### 1.3.5.2. DMR Report Requirements

On the DMR, the permittee must separately report:

i. The total number of sanitary sewer overflows for the reporting month; and
ii. The total number of dry-weather sanitary sewer overflows for the reporting month.

On the DMR, sanitary sewer overflows are coded “SSO, Dry Weather” and “SSO, Wet Weather”. Each discrete location of a sanitary sewer overflow shall be reported as a separate value.

### 1.3.6. Reporting Less Than Detection; Reporting Significant Figures

For the purpose of evaluating compliance with the permit limits established herein, where certain limits are below the minimum level (ML) of 40 CFR § 136 approved analytical methods, compliance will be demonstrated when a non-detect result is obtained using the most sensitive method available. The results of non-detect analyses, in this case, shall be reported as Below Detection Limit (BDL) or “NODI = B” in NetDMR. Reporting examples are provided below.

> Reporting Example 1: If the permit limit is 0.02 mg/L with a method detection limit (MDL) of 0.05 mg/L and no detection is shown, the permittee must report “BDL” or “NODI = B” on DMRs in NetDMR. Whenever “BDL” or “NODI = B” is reported, the actual MDL must be reported in the DMR comments or in an attachment submitted in NetDMR.
>
> Reporting Example 2: If the permit limit is 0.02 mg/L with an MDL of 0.05 mg/L and detection is shown, the actual detected value must be reported.
>
> Reporting Example 3: If the permit limit is 0.02 mg/L with an MDL of 0.01 mg/L and no detection is shown, the permittee must report less than MDL (<0.01 mg/L in this case).

For purposes of calculating averages, zero may be assigned for values less than the MDL, the numeric value of the MDL may be assigned for values between the MDL and the ML. If the average value is less than the MDL, the permittee must report “less than {numeric value of the MDL}" and if the average value is less than the ML, the permittee must report "less than {numeric value of the ML}.” If a value is equal to or greater than the ML, the permittee must report and use the actual value. The resulting average value must be compared to the compliance level, the ML, in assessing compliance.

Reported results are to correspond to the number of significant figures (decimal places) set forth in the permit conditions. The permittee shall round values, if allowed by the method of sample analysis, using a uniform rounding convention adopted by the permittee.

### 1.3.7. Outlier Data

Outlier data include analytical results that are probably false. The validity of results is based on operational knowledge and a properly implemented quality assurance program. False results may include laboratory artifacts, potential sample tampering, broken or suspect sample containers, sample contamination or similar demonstrated quality control flaw.

Outlier data are identified through a properly implemented quality assurance program, and according to ASTM standards (e.g. Grubbs Test, 'h' and 'k' statistics). Furthermore, outliers should be verified, corrected, or removed based on further inquiries into the matter. If an outlier was verified (through repeated testing and/or analysis), it should remain in the preliminary data set. If an outlier resulted from a transcription or similar clerical error, it should be corrected and subsequently reported.

Therefore, only if an outlier was associated with problems in the collection or analysis of the samples and as such does not conform with the Guidelines Establishing Test Procedures for the Analysis of Pollutants (40 CFR §136), can it be removed from the data set and not reported on DMRs. Otherwise, all results (including monitoring of pollutants more frequently than required at the location(s) designated, using approved analytical methods as specified in the permit) should be included in the calculation and reporting of the values required in the DMR form. The permittee should use the "comment" section in NetDMR to explain any potential outliers or dubious results.

## 1.4. COMPLIANCE WITH SECTION 208

The limits and conditions in this permit shall require compliance with an area-wide waste treatment plan (208 Water Quality Management Plan) where such approved plan is applicable.

## 1.5. REOPENER CLAUSE

This permit shall be modified, or alternatively revoked and reissued, to comply with any applicable effluent standard or limitation issued or approved under Sections 301(b)(2)(C) and (D), 307(a)(2), and 405(d)(2)(D) of the Clean Water Act, as amended, if the effluent standard, limitation, or sludge disposal requirement so issued or approved:

a) Contains different conditions or is otherwise more stringent than any condition in the permit; or

b) Controls any pollutant or disposal method not addressed in the permit.

The permit as modified or reissued under this paragraph shall also contain any other requirements of the Act then applicable.

## 1.6. SCHEDULE OF COMPLIANCE

Full compliance and operational levels shall be attained from the effective date of this permit, except for conditions under compliance schedules. See **Section 1.1.** for numeric and narrative requirements.

## 1.7. ELECTRONIC REPORTING

This permit requires the submission of forms developed by the Director in order for a person to comply with certain requirements, including, but not limited to, making reports, submitting monitoring results, and applying for permits. The Director may make these forms available electronically and, if submitted electronically, then that electronic submission shall comply with the requirements of Chapter 0400-01-40. Electronic submission is required when available unless waived by the Commissioner in accordance with 40 C.F.R. § 127.15.

In the event of large-scale emergencies and/or prolonged electronic reporting system outages, an episodic electronic reporting waiver may be granted by the Commissioner in accordance with 40 CFR § 127.15. A request for a deadline extension or episodic electronic reporting waiver should be submitted to DWRWater.Compliance@tn.gov, in compliance with the Federal NPDES Electronic Reporting Rule.

If an episodic electronic reporting waiver is granted, reports with wet-ink original signatures shall be mailed to the following address:

*STATE OF TENNESSEE*
*DEPARTMENT OF ENVIRONMENT AND CONSERVATION*
*DIVISION OF WATER RESOURCES*
*COMPLIANCE & ENFORCEMENT UNIT*
*William R. Snodgrass - Tennessee Tower*
*312 Rosa L. Parks Avenue, 11th Floor*
*Nashville, Tennessee 37243-1102*

For purposes of determining compliance with this permit, data provided to the Division electronically is legally equivalent to data submitted on signed and certified forms. A copy must be retained for the permittee's files.

# PART 2

## 2. GENERAL PERMIT REQUIREMENTS

### 2.1. GENERAL PROVISIONS

### 2.1.1. Duty to Comply

The permittee shall comply with all conditions of this permit. Any permit noncompliance constitutes a violation of the Act and is grounds for enforcement action; for permit termination, revocation and reissuance, or modification; or denial of a permit renewal application.

### 2.1.2. Duty to Reapply

The permittee is not authorized to discharge after the expiration date of this permit. In order to receive authorization to discharge beyond the expiration date, the permittee shall submit such information and forms as are required to the Division Director no later than 180 days prior to the expiration date. Such forms shall be properly signed and certified.

### 2.1.3. Proper Operation and Maintenance

a) The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances, including but not limited to collection and conveyance systems) which are installed or used by the permittee to achieve compliance with the conditions of this permit. Low pressure pumps, low pressure tanks, septic tank effluent pumps (STEP), STEP tanks, and septic tank effluent gravity tanks are integral to the treatment and conveyance of sewage in a low-pressure system design, and shall be owned or under control of the municipality, other body of government, public utility district, or a privately-owned public utility demonstrating lawful jurisdiction over the service area. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. This provision requires the operation of backup or auxiliary facilities or similar systems, which are installed by a permittee only when the operation is necessary to achieve compliance with the conditions of the permit.

b) Dilution water shall not be added to comply with effluent requirements to achieve BCT, BPT, BAT, or other technology based effluent limitations such as those established in Tennessee Rule 0400-40-05-.09.

### 2.1.4. Duty to Provide Information

The permittee shall also furnish to the Director, upon request, copies of records required to be kept by this permit.

### 2.1.5. Right of Entry

The permittee shall allow the Director, the Regional Administrator of the U.S. Environmental Protection Agency, or their authorized representatives, upon the presentation of credentials, to:

a) Enter upon the permittee's premises where a regulated facility or activity is located or conducted, or where records shall be kept under the conditions of this permit;

b) Have access to and copy, at reasonable times, any records that shall be kept under the conditions of this permit;

c) Inspect at reasonable times any facilities, equipment (including monitoring and control equipment), practices, or operations regulated or required under this permit; and

d) Sample or monitor at reasonable times for the purposes of assuring permit compliance or as otherwise authorized by the Director.

### 2.1.6. Availability of Reports

Except for data determined to be confidential under Section 308 of the Federal Water Pollution Control Act, as amended, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the Division's offices or via the Department's dataviewer webpage. As required by the Federal Act, effluent data shall not be considered confidential.

### 2.1.7. Treatment Facility Failure (Industrial Sources)

The permittee, in order to maintain compliance with this permit, shall control production, all discharges, or both, upon reduction, loss, or failure of the treatment facility until the facility is restored or an alternative method of treatment is provided. This requirement applies in such situations as the reduction, loss, or failure of the primary source of power.

### 2.1.8. Property Rights

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of federal, state, or local laws or regulations.

**2.1.9. Severability**

The provisions of this permit are severable. If any provision of this permit due to any circumstance is held invalid, then the application of such provision to other circumstances and to the remainder of this permit shall not be affected thereby.

**2.1.10. Other Information**

If the permittee becomes aware of failure to submit any relevant facts in a permit application, or of submission of incorrect information in a permit application or in any report to the Director, then the permittee shall promptly submit such facts or information.

**2.2. CHANGES AFFECTING THE PERMIT**

**2.2.1. Planned Changes**

The permittee shall give notice to the Director as soon as possible of any planned physical alterations or additions to the permitted facility. Notice is required only when:

a) The alteration or addition to a permitted facility may meet one of the criteria for determining whether a facility is a new source as defined in Rule 0400-40-05-.02;

b) The alteration or addition could significantly change the nature or increase the quantity of pollutants discharged. This notification applies to pollutants which are subject neither to effluent limitations in the permit nor to notification requirements under 40 CFR § 122.42(a)(1); or

c) The alteration or addition results in a significant change in the permittee's sludge use or disposal practices.

**2.2.2. Permit Modification, Revocation, or Termination**

a) This permit may be modified, revoked and reissued, or terminated for cause as described in 40 CFR § 122.62 and § 122.64, Federal Register, Volume 49, No. 188 (Wednesday, September 26, 1984), as amended. Causes for such permit action include but are not limited to the following:

   i. Violation of any terms or conditions of the permit;

ii. Obtaining a permit by misrepresentation or failure to disclose fully all relevant facts; and

iii. A change in any condition that requires either a temporary or permanent reduction or elimination of the permitted discharge.

b) The permittee shall furnish to the Director, within a reasonable time, any information which the Director may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit.

c) If any applicable effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established for any toxic pollutant under Section 307(a) of the Federal Water Pollution Control Act, as amended, the Director shall modify or revoke and reissue the permit to conform to the prohibition or to the effluent standard, providing that the effluent standard is more stringent than the limitation in the permit for the toxic pollutant. The permittee shall comply with these effluent standards or prohibitions within the time provided in the regulations that establish these standards or prohibitions, even if the permit has not yet been modified or revoked and reissued to incorporate the requirement.

d) The filing of a request by the permittee for a modification, revocation, reissuance, termination, or notification of planned changes or anticipated noncompliance does not halt any permit condition.

### 2.2.3. Change of Ownership

Except as provided in Tennessee Rule Chapter 0400-40-05-.06(5)(a) or (b), this permit may be transferred to another party (provided there are neither modifications to the facility or its operations, nor any other changes which might affect permit limits and conditions contained in the permit) by the permittee if:

a) The permittee notifies the Director of the proposed transfer at least 30 days in advance of the proposed transfer date;

b) The notice includes a written agreement between the existing and new permittees containing a specified date for transfer of permit responsibility, coverage, and liability between them; and

c) The permittee shall provide the following information to the Director in the permittee's formal notice of intent to transfer ownership:

i. The permit number of the subject permit;
ii. The effective date of the proposed transfer;
iii. The name, address, and contact information of the transferor;
iv. The name, address, and contact information of the transferee;
v. The names of the responsible parties for both the transferor and transferee;
vi. A statement that the transferee assumes responsibility for the subject permit;
vii. A statement that the transferor relinquishes responsibility for the subject permit;
viii. The signatures of the responsible parties for both the transferor and transferee pursuant to the signatory requirements of subparagraph (i) of Rule 0400-40-05-.07(2); and
ix. A statement regarding any proposed modifications to the facility, its operations, or any other changes, which might affect the permit, limits and conditions contained in the permit.

**2.2.4. Change of Mailing Address**

The permittee shall promptly provide to the Director written notice of any change of mailing address. In the absence of such notice, the original address of the permittee will be assumed to be correct.

## 2.3. NONCOMPLIANCE

**2.3.1. Reporting of Noncompliance**

a) 24-hour Reporting:

In the case of any noncompliance, or any release (whether or not caused by improper operation and maintenance), which could cause a threat to human health or the environment, the permittee shall:

i. Report the noncompliance or release to the Commissioner within 24 hours from the time the permittee becomes aware of the circumstances. Such noncompliance or release includes, but is not limited to, any unanticipated bypass exceeding any effluent limitation, any upset exceeding any effluent limitation, and violations of any maximum daily effluent limitation identified in the permit as requiring 24-hour reporting. (The EFO should be contacted for names and phone numbers of the environmental response team.)

ii. Submit a written report within five days of the time the permittee becomes aware of the noncompliance. The permittee shall provide the following information:

1. A description of and the cause of the noncompliance or release;

2. The period of noncompliance or release, including start and end dates and times i.e. duration or, if not corrected, the anticipated time the noncompliance or release is expected to continue;

3. The steps being taken to reduce, eliminate, and prevent recurrence of the noncompliance or release; and

4. For POTWs or domestic wastewater treatment plants, reporting any dry weather overflow, wet weather overflow, dry weather release, wet weather release, combined sewer overflow, or bypass, this written report must also include the following:

I. Type of event;
II. Type of sewer overflow, release, or bypass structure (e.g., manhole, combined sewer overflow outfall);
III. Estimated volume (gallons);
IV. Types of human health and environmental impacts;
V. Location (latitude and longitude);
VI. Estimated duration (hours);
VII. The next downstream pump station (for overflows and releases only); and
VIII. The name of receiving water (if applicable).

iii. Industrial dischargers that do not treat domestic waste shall comply with subpart a) ii. 4. of this subparagraph with respect to bypasses only.

iv. For overflows, releases, bypasses, upsets and washouts, the report required by a) ii. Shall be submitted electronically via MyTDEC Forms.

b) Other Noncompliance.

i. All permittees shall report each instance of noncompliance or any release (whether or not caused by improper operation and maintenance), not reported under sub-part a) at the time of submitting the next routine monitoring report, including all information required by sub-parts a) ii. 1-3.

ii. In addition to the information required by part i of this sub-part, POTWs and domestic wastewater treatment plants shall submit a written report containing the information required by sub-part a) i. 4. If these events are caused by an extreme weather event, the Commissioner may provide a written waiver of some or all of these reporting requirements.

iii. In addition to the information required by sub-part i, industrial dischargers shall submit a written report of bypasses containing the information required by sub-part a) i. 4. This part does not relieve industrial dischargers from any applicable reporting requirements of 40 C.F.R. Part 117 (2021) and 40 C.F.R. Part 302 (2021).

**2.3.2. Overflows and Releases**

a) For publicly owned treatment works (POTW) or domestic wastewater treatment plants, sanitary sewer overflows, including dry-weather overflows and wet weather overflows, are prohibited.

b) Releases caused by improper operation and maintenance, which is to be determined by the Commissioner based on the totality of the circumstances, are prohibited.

c) The permittee shall operate the collection, transmission, and treatment system so as to avoid sanitary sewer overflows and releases due to improper operation or maintenance. A "release" may be due to improper operation or maintenance of the collection system or may be due to other cause(s).

d) The permittee shall take all reasonable steps to minimize any adverse impact associated with overflows and releases.

e) No new or additional flows shall be added upstream of any point in the collection, transmission, or treatment system that experiences greater than 5 sanitary sewer overflows and/or releases per year[2] or would otherwise overload any portion of the system. Unless there is specific enforcement action to the contrary, the permittee is relieved of this requirement after:

1) An authorized representative of the Commissioner of the Department of Environment and Conservation has approved an engineering report

[2] This includes dry weather overflows, wet weather overflows, dry weather releases and wet weather releases.

and construction plans and specifications prepared in accordance with accepted engineering practices for correction of the problem;

2) The correction work is underway; and
3) The cumulative, peak-design flows potentially added from new connections and line extensions upstream of any chronic overflow or release point are less than or proportional to the amount of inflow and infiltration removal documented upstream from that point.

The inflow and infiltration reduction must be measured by the permittee using practices that are customary in the environmental engineering field and reported in an attachment to the permittee's DMR and uploaded to NetDMR. The data measurement period shall be sufficient to account for seasonal rainfall patterns and seasonal groundwater table elevations.

f) In the event that chronic sanitary sewer overflows or releases have occurred from a single point in the collection system for reasons that may not warrant the self-imposed moratorium of the actions identified in this paragraph, the permittee may request a meeting with Division EFO staff to petition for a waiver based on mitigating evidence.

g) For industrial dischargers, the discharge of pollutants from any location other than a permitted outfall is prohibited.

### 2.3.3. Upset

a) An upset shall constitute an affirmative defense to an action brought for noncompliance with technology-based permit effluent limitations if the permittee demonstrates, through properly signed, contemporaneous operating logs, or other relevant evidence that:

   i. An upset occurred and that the permittee can identify the cause(s) of the upset;
   ii. The permitted facility was at the time being operated in a prudent and workman-like manner and in compliance with proper operation and maintenance procedures;
   iii. The permittee submitted information required under "Reporting of Noncompliance" within 24 hours of becoming aware of the upset (if this information is provided orally, a written submission must be provided within five days); and
   iv. The permittee complied with any remedial measures required under "Adverse Impact".

b) In any enforcement proceeding, the permittee seeking to establish the affirmative defense of an upset has the burden of proof.

### 2.3.4. Adverse Impact

The permittee shall take all reasonable steps to minimize any adverse impact to the waters of Tennessee resulting from noncompliance with this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge. It shall not be a defense for the permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

### 2.3.5. Bypass

a) Bypasses (see subpart 4.1) are prohibited unless all the following conditions are met:

   i. The bypass is unavoidable to prevent loss of life, personal injury, or severe property damage;
   ii. There are no feasible alternatives to bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventative maintenance; and
      a. For anticipated bypass, the permittee submits prior notice, if possible at least ten days before the date of the bypass, or
      b. For unanticipated bypass, the permittee submits notice of an unanticipated bypass within 24 hours from the time that the permittee becomes aware of the bypass.

b) Bypasses that do not cause effluent limitations to be exceeded may be allowed only if the bypass is necessary for essential maintenance to assure efficient operation. The permittee must sample and report the discharge during each bypass to demonstrate that the bypass does not cause effluent limitations to be exceeded.

### 2.3.6. Washout

a) For domestic wastewater plants only, a "*washout*" shall be defined as loss of Mixed Liquor Suspended Solids (MLSS) of 30.00% or more. This refers to the MLSS in the aeration basin(s) only. This does not include MLSS decreases due to solids wasting to the sludge disposal system. A washout can be caused by improper operation or from peak flows due to inflow and infiltration.

b) A washout is prohibited. If a washout occurs the permittee must report the incident to the Division in the appropriate EFO within 24 hours by telephone. A written submission must be provided within five days. The washout must be noted on that month's DMR. Each day of a washout is a separate violation.

## 2.4. LIABILITIES

### 2.4.1. Civil and Criminal Liability

Except as provided in permit conditions for "*Bypass*" (**Section 2.3.5**), "*Overflows and Releases*" (**Section 2.3.2**), and "*Upset*" (**Section 2.3.3**), nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for noncompliance. Notwithstanding this permit, the permittee shall remain liable for any damages sustained by the State of Tennessee, including, but not limited to, fish kills and losses of aquatic life and/or wildlife as a result of the discharge of wastewater to any surface or subsurface waters. Additionally, notwithstanding this permit, it shall be the responsibility of the permittee to conduct its wastewater treatment and/or discharge activities in a manner such that public or private nuisances or health hazards will not be created.

### 2.4.2. Liability Under State Law

Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable state law or the Federal Water Pollution Control Act, as amended.

# PART 3

## 3. PERMIT SPECIFIC REQUIREMENTS

### 3.1. CERTIFIED OPERATOR

The waste treatment facilities shall be operated under the supervision of a certified wastewater treatment operator, and the collection system shall be operated under the supervision of a certified collection system operator in accordance with the Water Environmental Health Act of 1984.

### 3.2. POTW PRETREATMENT PROGRAM GENERAL PROVISIONS

As an update of information previously submitted to the Division, the permittee will undertake the following activity:

a) The permittee has been delegated the primary responsibility and therefore becomes the "Control Authority" for enforcing the 40 CFR § 403 General Pretreatment Regulations. Where multiple plants are concerned the permittee is responsible for the Pretreatment Program for all plants within its jurisdiction. The permittee shall implement and enforce the Industrial Pretreatment Program in accordance with the Tennessee Water Quality Control Act § 69-3-123 through 69-3-128, Rule 0400-40-14, and the legal authorities, policies, procedures, and financial provisions contained in its approved Pretreatment Program, except to the extent this permit imposed stricter requirements. Such implementation shall require but not limit the permittee to do the following:

   i. Carry out inspection, surveillance, and monitoring procedures which will determine, independent of information supplied by the industrial user (IU), whether the IU is in compliance with the pretreatment standards;
   ii. Require development, as necessary, of compliance schedules for each IU for the installation of control technologies to meet applicable pretreatment standards;
   iii. Require all industrial users to comply with all applicable monitoring and reporting requirements outlined in the approved pretreatment program and IU permit;
   iv. Maintain and update, as necessary, records identifying the nature and character of industrial user discharges, and retain such records for a minimum of three (3) years;

v. Obtain appropriate remedies for noncompliance by an IU with any pretreatment standard and/or requirement;

vi. Publish annually, pursuant to Rule 0400-40-14-.08(6)(b)8, a list of industrial users that have significantly violated pretreatment requirements and standards during the previous twelve-month period;

vii. Maintain an adequate revenue structure for continued operation of the pretreatment program;

viii. Update its Industrial Waste Survey at least once every five years. Results of this update shall be submitted to the Division of Water Resources, Pretreatment Section within 120 days of the effective date of this permit, unless such a survey has been submitted within 3 years of the effective date; and

ix. Submit a written technical evaluation of the need to revise local limits within 120 days of the effective date of this permit to the state pretreatment program coordinator. The evaluation shall include the most recent pass-through limits proposed by the Division. The technical evaluation shall be based on practical and specialized knowledge of the local program and not be limited by a specified written format.

b) The permittee shall enforce Rule 0400-40-14-.05, "prohibited discharges". Pollutants introduced into the POTW by a non-domestic source shall not cause pass through or interference as defined in Rule 0400-40-14-.03. These general prohibitions and the specific prohibitions in this section apply to all non-domestic sources introducing pollutants into the POTW whether the source is subject to other National Pretreatment Standards or any state or local pretreatment requirements.

*Specific prohibitions*: Under no circumstances shall the permittee allow introduction of the following wastes into the POTW:

i. Pollutants which create a fire or explosion hazard in the POTW, including, but not limited to, wastestreams with a closed cup flashpoint of less than 140°F or 60°C using the test methods specified in 40 CFR § 261.21;

ii. Pollutants which will cause corrosive structural damage to the POTW, but in no case discharges with pH lower than 5.0 unless the system is specifically designed to accommodate such discharges;

iii. Solid or viscous pollutants in amounts which will cause obstruction to the flow in the POTW resulting in interference;

- iv. Any pollutant, including oxygen-demanding pollutants (BOD, etc.) released in a discharge at a flow rate and/or pollutant concentration which will cause interference with the POTW;
- v. Heat in amounts which will inhibit biological activity in the POTW resulting in interference, but in no case heat in such quantities that the temperature at the POTW Treatment Plant exceeds 40°C (104°F) unless the Division, upon request of the POTW, approves alternate temperature limits;
- vi. Any priority pollutant in amounts that will contaminate the treatment works sludge;
- vii. Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;
- viii. Pollutants which result in the presence of toxic gases, vapors or fumes within the POTW in a quantity that may cause acute worker health and safety problems; or
- ix. Any trucked or hauled pollutants, except at discharge points designated by the POTW.

c) The permittee shall notify the Division of any of the following changes in user discharge to the system no later than 30 days prior to change of discharge:

- i. New introductions into such works of pollutants from any source which would be a new source as defined in Section 306 of the Act if such source were discharging pollutants;
- ii. New introductions of pollutants into such works from a source which would be subject to Section 301 of the "Federal Water Quality Act as Amended" if it were discharging such pollutants; or
- iii. A substantial change in volume or character of pollutants being introduced into such works by a source already discharging pollutants into such works at the time this permit is issued.

This notice will include information on the quantity and quality of the wastewater introduced by the new source into the POTW, and on any anticipated impact on the effluent discharged from such works. If this discharge necessitates a revision of the current NPDES permit or pass-through guidelines, discharge by this source is prohibited until the Tennessee Division of Water Resources gives final authorization.

d) Reporting Requirements:

Upon notification, all semi-annual must be submitted electronically through MyTDEC Forms portal. Prior to electronic reporting approval, the report shall be submitted to the Division's Central Office and a copy to the appropriate EFO no later than the 28th day of the month following each reporting period. Large programs with more than 20 SIUs will be granted an additional 15 days for report submittal.

The permittee shall provide a semiannual report briefly describing the permittee's pretreatment program activities over the previous six-month period. Reporting periods shall end on the last day of the months of March and September. For Control Authorities with multiple STPs, one report should be submitted with a separate Form 1 for each STP. Prior to approval of electronic reporting, each report shall conform to the format set forth in the State POTW Pretreatment Semiannual (or Annual) Report Package which contains information regarding:

i. An updated listing of the permittee's industrial users;

ii. Results of sampling of the influent and effluent of the wastewater treatment plant. At least once each reporting period, the permittee shall analyze the wastewater treatment plant influent and effluent for the following pollutants, using the prescribed sample types:

| Pollutant | Sample Type |
|---|---|
| chromium (III) | 24-hour composite |
| chromium (VI) | Per method requirements [3] |
| copper | 24-hour composite |
| lead | 24-hour composite |
| nickel | 24-hour composite |
| zinc | 24-hour composite |
| cadmium | 24-hour composite |
| mercury | Per method requirements [3] |
| silver | 24-hour composite |
| total phenols | grab |
| cyanide | grab |

If any particular pollutant is analyzed more frequently than is required, the permittee shall report the maximum and average values on the semiannual or annual report. All upsets, interferences, and pass-through violations must also be reported on the semiannual or annual report, along with the actions that were taken to determine the causes

[3] When a composite sample would compromise sample integrity, refer to 40 CFR § 136.3 Table II, including footnotes.

of the incidents and the steps that have been taken to prevent the incidents from recurring.

At least once during the term of this permit, the permittee shall analyze the effluent from the STP (and report the results in the next regularly scheduled report) for the following pollutants:

| | | |
|---|---|---|
| chromium III | cyanide | phthalates, sum of the following: |
| chromium VI | silver | bis (2-ethylhexyl) phthalate |
| copper | benzene | butyl benzylphthalate |
| lead | carbon tetrachloride | di-n-butylphthalate |
| nickel | chloroform | diethyl phthalate |
| zinc | ethylbenzene | 1,2 trans-dichloroethylene |
| cadmium | methylene chloride | tetrachloroethylene |
| mercury | naphthalene | toluene |
| phenols, total | 1,1,1 trichloroethane | trichloroethylene |

iii. Compliance with categorical and local standards, and review of industrial compliance, which includes a summary of the compliance status for all permitted industries. Also included is information on the number and type of major violations of pretreatment regulations, and the actions taken by the POTW to obtain compliance. The effluent from all significant industrial users must be analyzed for the appropriate pollutants at least once every 12 months;

iv. A list of industries in significant non-compliance as published in local newspapers in accordance with the requirements set forth in Rule 0400-40-14-.08(6)(b)8;

v. A description of all substantive changes made to the permittee's pretreatment program. Any such changes shall receive prior approval. Substantive changes include, but are not limited to, any change in any ordinance, major modification in the program's administrative structure, local limits, or a change in the method of funding the program; and

vi. A summary of the permittee's industrial user inspections, which includes information on the number and type of industry inspected. All significant industrial users must be inspected at least once every twelve months.

## 3.3. BIOSOLIDS MANAGEMENT PRACTICES

All sludge and/or biosolids use or disposal must comply with 40 CFR § 503 *et seq*. Biosolids shall be sampled and analyzed at a frequency dependent on the amount used annually.

Any facility that land applies non-exceptional quality biosolids must obtain an appropriate permit from the Division in accordance with Chapter 0400-40-15.

a) Reopener: If an applicable "acceptable management practice" or numerical limitation for pollutants in sewage sludge promulgated under Section 405(d)(2) of the Clean Water Act, as amended by the Water Quality Act of 1987, is more stringent than the sludge pollutant limit or acceptable management practice in this permit, or controls a pollutant not limited in this permit, this permit shall be promptly modified or revoked and reissued to conform to the requirements promulgated under Section 405(d)(2). The permittee shall comply with the limitations by no later than the compliance deadline specified in the applicable regulations as required by Section 405(d)(2) of the Clean Water Act.

b) Notice of change in sludge disposal practice: The permittee shall give prior notice to the Director of any change planned in the permittee's sludge disposal practice.

*STATE OF TENNESSEE*
*DEPARTMENT OF ENVIRONMENT AND CONSERVATION*
*DIVISION OF SOLID WASTE MANAGEMENT*
*Nashville Environmental Field Office*
*711 R.S. Gass Boulevard*
*Nashville, Tennessee 37216*
*(615)687-7000*

The current method of sludge disposal is to a municipal solid waste landfill (or co-composting facility). This method of disposal is controlled by the rules of the Tennessee Division of Solid Waste Management (DSWM) and Federal Regulations at 40 CFR § 258. If the permittee anticipates changing its disposal practices to either land application or surface disposal, the Division of Water Resources shall be notified prior to the change. A copy of any results of pollutant analyses required by the Tennessee Division of Solid Waste Management (DSWM) and/or 40 CFR § 258 shall be submitted to the Division of Water Resources.

## 3.4. BIOMONITORING REQUIREMENTS, CHRONIC

The permittee shall conduct a 3-Brood *Ceriodaphnia dubia* Survival and Reproduction Test and a 7-Day Fathead Minnow *(Pimephales promelas)* Larval Survival and Growth Test on samples of final effluent from Outfall 001.

The measured endpoint for toxicity will be the inhibition concentration causing 25% reduction in survival, reproduction and growth ($IC_{25}$) of the test organisms. The $IC_{25}$ shall be determined based on a 25% reduction as compared to the controls, and as derived from linear interpolation. The average reproduction and growth responses will be determined based on the number of *Ceriodaphnia dubia* or *Pimephales promelas* larvae used to initiate the test.

Tests shall be conducted and results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

**Summer:**

| Serial Dilutions for Whole Effluent Toxicity (WET) Testing | | | | | |
|---|---|---|---|---|---|
| 100% Effluent | Permit Limit (PL) | 0.50 X PL | 0.25 X PL | 0.125 X PL | Control |
| % effluent | | | | | |
| 100 | 98 | 49 | 24.5 | 12.25 | 0 |

**Winter:**

| Serial Dilutions for Whole Effluent Toxicity (WET) Testing | | | | | |
|---|---|---|---|---|---|
| 100% Effluent | Permit Limit (PL) | 0.50 X PL | 0.25 X PL | 0.125 X PL | Control |
| % effluent | | | | | |
| 100 | 77 | 38.5 | 19.25 | 9.625 | 0 |

The dilution/control water used will be moderately hard water as described in *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms*, EPA-821-R-02-013 (or the most current edition). A chronic standard reference toxicant quality assurance test shall be conducted with each species used in the toxicity tests and the results submitted with the discharge monitoring report. Additionally, the analysis of this multi-concentration test shall include review of the concentration-response relationship to ensure that calculated test results are interpreted appropriately.

Toxicity will be demonstrated if the $IC_{25}$ is less than or equal to the permit limit indicated for each outfall in the above table(s).

All tests will be conducted using a minimum of three 24-hour, flow-proportionate composite samples of final effluent (*e.g.*, collected on days 1, 3, and 5). If, in any control more than 20% of the test organisms die in 7 days, the test (control and effluent) is considered invalid and the test shall be repeated within two (2) weeks. Furthermore, if the results do not meet the acceptability criteria in the above-referenced *Short-term Methods* document, or if the required concentration-response review fails to yield a valid relationship per guidance contained in *Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing*, EPA-821-B-00-004 (or the most current edition), that test shall be repeated. Any test initiated but terminated before completion must also be reported along with a complete explanation for the termination.

The toxicity tests specified herein shall be conducted semiannually (1/6 months) for Outfall 001 and begin no later than 180 days from the effective date of this permit.

In the event of a test failure, the permittee must start a follow-up test within 2 weeks and submit results from a follow-up test within 30 days from obtaining initial WET testing results. The follow-up test must be conducted using the same serial dilutions as presented in the corresponding table(s) above. The follow-up test will not negate an initial failed test. In addition, the failure of a follow-up test will constitute a separate permit violation.

In the event of 2 consecutive test failures or 3 test failures within a 12-month period for the same outfall, the permittee must initiate a Toxicity Identification Evaluation/Toxicity Reduction Evaluation (TIE/TRE) study within 30 days and so notify the Division by letter. This notification shall include a schedule of activities for the initial investigation of that outfall. During the term of the TIE/TRE study, the frequency of biomonitoring shall be once every three months. Additionally, the permittee shall submit progress reports once every three months throughout the term of the TIE/TRE study. The toxicity must be reduced to allowable limits for that outfall within 2 years of initiation of the TIE/TRE study. Subsequent to the results obtained from the TIE/TRE studies, the permittee may request an extension of the TIE/TRE study period if necessary, to conduct further analyses. The final determination of any extension period will be made at the discretion of the Division.

The TIE/TRE study may be terminated at any time upon the completion and submission of 2 consecutive tests (for the same outfall) demonstrating compliance. Following the completion of TIE/TRE study, the frequency of monitoring will return to a regular schedule, as defined previously in this section as well in Part I of the permit. During the course of the TIE/TRE study, the permittee will continue to conduct toxicity testing of the outfall being investigated at the frequency of once every three months but will not be required to perform follow-up tests for that outfall during the period of TIE/TRE study.

Test procedures, quality assurance practices, determinations of effluent survival/reproduction and survival/growth values, and report formats will be made in accordance with *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms*, EPA-821-R-02-013, or the most current edition. Results of tests, reference toxicant information, copies of raw data sheets, statistical analysis, and chemical analyses shall be compiled in a report also written in accordance with the *Short-term Methods* document above.

A copy of the biomonitoring report (including any follow-up reports) shall be submitted to the Division as an attachment to the monthly DMR in NetDMR.

## 3.5. PLACEMENT OF SIGNS

Within 60 days of the effective date of this permit, the permittee shall place and maintain a sign at each outfall and any overflow/release point in the collection system or the nearest publicly accessible location. For the purposes of this requirement, any point that has had a total of 5 or more overflows plus releases in the previous 12 months must be so posted. The sign(s) should be clearly visible to the public from the bank and the receiving stream. The *minimum* sign size should be two feet by two feet (2' x 2') with one-inch (1") letters. The sign should be made of durable material and have a white background with black letters.

The sign(s) are to provide notice to the public as to the nature of the discharge and, in the case of the permitted outfalls, that the discharge is regulated by the Tennessee Department of Environment and Conservation, Division of Water Resources. The following are given as examples of the minimal amount of information that must be included on the signs:

**NPDES Permitted Municipal/Sanitary Outfall:**

| |
|---|
| **TREATED MUNICIPAL/SANITARY WASTEWATER** |
| **City of Murfreesboro** |
| **Sinking Creek STP** |
| **(615) 890-0862** |
| **NPDES Permit NO. TN0022586** |
| **TENNESSEE DIVISION OF WATER RESOURCES** |
| **1-888-891-8332 ENVIRONMENTAL FIELD OFFICE - Nashville** |

**Unpermitted release/overflow point:**

| |
|---|
| **UNTREATED WASTEWATER DISCHARGE POINT** |
| **City of Murfreesboro** |
| **Sinking Creek STP** |
| **(615) 890-0862** |
| **NPDES Permit No. TN0022586** |
| **TENNESSEE DIVISION OF WATER RESOURCES** |
| **1-888-891-8332 ENVIRONMENTAL FIELD OFFICE - Nashville** |

The permittee may request the removal of signs for unpermitted release/overflows points only. This request should be sent to Division EFO staff detailing the work that has been completed to rectify the cause(s) contributing to overflows and releases at that location. In no case will approval to remove the signs be granted if either an overflow or release has occurred at that location in the previous 12 months.

# PART 4

## 4. DEFINITIONS AND ACRONYMS

All terminology not specifically defined herein shall be defined in accordance with the Water Quality Control Act of 1977, T.C.A. Title 69, Chapter 3, Part 1 and Tennessee Rule 0400-40-05. The following terms have the meanings given below unless otherwise specified.

### 4.1. DEFINITIONS

For the purposes of this permit, ***annually*** is defined as a monitoring frequency of once every 12 months beginning with the effective date of this permit, so long as the following set of measurements for a given 12 month period are made approximately 12 months subsequent to that time.

***Biosolids*** are treated sewage sludge that have contaminant concentrations less than or equal to the contaminant concentrations listed in Table 1 of subparagraph (3)(b) of Rule 0400-40-15-.02, meet any one of the ten vector attraction reduction options listed in part (4)(b)1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 of Rule 0400-40-15-.04, and meet either one of the six pathogen reduction alternatives for Class A listed in part (3)(a)3, 4, 5, 6, 7, or 8, or one of the three pathogen reduction alternatives for Class B listed in part (3)(b)2, 3, or 4 of Rule 0400- 40-15-.04.

***Bypass*** means the intentional diversion of waste streams from any portion of a treatment facility.

A ***calendar day*** means the 24-hour period from midnight to midnight or any other 24-hour period that reasonably approximates the midnight to midnight time period.

***Combined sewer overflow*** or "CSO" means a discharge from a combined sewer system (CSS) at a point prior to the publicly owned treatment works (POTW) treatment plant headworks.

***Combined sewer system*** or "CSS" means a wastewater collection system owned by a State or municipality which was originally designed to convey sanitary wastewaters (domestic, commercial, and industrial wastewaters) and stormwater through a single-pipe system into a publicly owned treatment works (POTW) treatment plant headworks.

A ***composite sample*** means a combination of not less than eight influent or effluent portions (aliquots), collected over a 24-hour period. Under certain circumstances a lesser time period may be allowed, but in no case less than eight hours. A sufficient volume of sample to perform all required analyses plus any additional amount for quality control must be obtained. For automatic samplers that use a peristaltic pump, a minimum 100 ml aliquot must be obtained.

The ***daily maximum amount*** means the total amount of any pollutant in the discharge by weight during any calendar day.

The ***daily maximum concentration*** is a limitation on the average concentration in units of mass per volume (*e.g.* milligrams per liter) of the discharge during any calendar day. When a proportional-to-flow composite sampling device is used, the daily maximum concentration is the concentration of that 24-hour composite; when other sampling means are used, the daily maximum concentration is the arithmetic mean of the concentrations of equal volume samples collected during any calendar day or sampling period.

***Degradation*** means the alteration of the properties of waters by the addition of pollutants, withdrawal of water, or removal of habitat, except those alterations of a short duration.

***De Minimis*** is degradation of a small magnitude, as provided in this paragraph:

(a) Discharges and withdrawals:

1. Subject to the limitation in part 3 of this subparagraph, a single discharge other than those from new domestic wastewater sources will be considered de minimis if it uses less than five percent of the available assimilative capacity for the substance being discharged.
2. Subject to the limitation in part 3 of this subparagraph, a single water withdrawal will be considered de minimis if it removes less than five percent of the 7Q10 flow of the stream.
3. If more than one activity described in part 1 or 2 of this subparagraph has been authorized in a segment and the total of the authorized and proposed impacts uses no more than 10% of the assimilative capacity, or 7Q10 low flow, they are presumed to be de minimis. Where the total of the authorized and proposed impacts uses 10% of the assimilative capacity, or 7Q10 low flow, additional degradation may only be treated as de minimis if the Division finds on a scientific basis that the additional degradation has an insignificant effect on the resource.

(b) Habitat alterations authorized by an Aquatic Resource Alteration Permit (ARAP) are de minimis if the Division finds that the impacts, individually and cumulatively, are offset by impact minimization and/or in-system mitigation, provided however, in Outstanding National Resource Waters (ONRWs) the mitigation must occur within the ONRW.

***Discharge*** or ***discharge of a pollutant*** refers to the addition of pollutants to waters from a source.

A ***dry weather overflow*** means a sanitary sewer overflow that is not directly related to a rainfall event.

An ***ecoregion*** is a relatively homogeneous area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

The ***geometric mean*** of any set of values means the $n^{th}$ root of the product of the individual values where n is equal to the number of individual values. The geometric mean is equivalent to the antilog of the arithmetic mean of the logarithms of the individual values. For the purposes of calculating the geometric mean, values of zero shall be considered to be one.

A ***grab sample*** means a single sample collected at a particular time.

$\boldsymbol{IC_{25}}$ means the inhibition concentration in which at least a 25% reduction in reproduction and/or growth in test organisms occurs.

***Industrial discharger*** means those industries identified in the standard industrial classification manual, Bureau of the Budget, 1987, as amended and supplemented, under the category "Division D - Manufacturing" and such other classes of significant waste producers as the Board or Commissioner deems appropriate.

***Industrial wastes*** means any liquid, solid, or gaseous substance, or combination thereof, or form of energy including heat, resulting from any process of industry, manufacture, trade, or business or from the development of any natural resource.

The ***instantaneous maximum concentration*** means the concentration, in units of mass per volume, of any pollutant parameter in a grab sample taken at any point in time.

The ***instantaneous minimum concentration*** means the minimum concentration, in units of mass per volume, of a pollutant parameter in a grab sample taken at any point in time.

***$LC_{50}$*** means the concentration that causes at least 50% lethality of the test organisms.

***Major facility*** means a municipal or domestic wastewater treatment plant with a design capacity of one million gallons per day or greater; or any other facility or activity classified as such by the Commissioner.

***Minor facility*** means any facility that is not a major facility.

The ***monthly average amount*** means the arithmetic mean of all the measured daily discharges by weight during the calendar month when the measurements were made.

The ***monthly average concentration***, means the arithmetic mean of all samples collected in a one calendar-month period, expressed in units of mass per volume of any pollutant other than bacteria.

***National Pollutant Discharge Elimination System*** or ***NPDES*** means the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the federal CWA. The term includes an "approved program."

***New or increased discharge*** is a new discharge of pollutants to waters of the state or an increase in the authorized loading of a pollutant above either (1) numeric effluent limitations established in a National Pollutant Discharge Elimination System permit for that discharge, or (2) if no such limitations exist, the actual discharges of that pollutant.

***New source*** means any building, structure, facility, area, or installation from which there is or may be a "discharge of pollutants," the construction of which commenced after the publication of state or federal regulations prescribing a standard of performance.

***Nitrate (as N)*** means nitrate reported as nitrogen.

A ***one-week period*** (or ***calendar-week***) means the period from Sunday through Saturday. For weekly average reporting purposes, a calendar week that contains a change of month shall be considered part of the latter month.

***Owner*** or ***operator*** means any person who owns, leases, operates, controls, or supervises a source.

***Person*** means an individual, association, partnership, corporation, municipality, state or federal agency, or an agent or employee thereof.

***Point source*** means any discernible, confined, and discrete conveyance, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff.

***Pollutant*** means sewage, industrial wastes, or other wastes.

***Pollution*** means such alteration of the physical, chemical, biological, bacteriological, or radiological properties of the waters of this state including, but not limited to, changes in temperature, taste, color, turbidity, or odor of the waters that will:

(a) Result or will likely result in harm, potential harm, or detriment to the public health, safety, or welfare;

(b) Result or will likely result in harm, potential harm, or detriment to the health of animals, birds, fish, or aquatic life;

(c) Render or will likely render the waters substantially less useful for domestic, municipal, industrial, agricultural, recreational, or other reasonable uses; or

(d) Leave or likely leave the waters in such condition as to violate any standards of water quality established by the Board.

***Quarter*** means any one of the following three-month periods: January 1 through March 31, April 1 through June 30, July 1 through September 30, and/or October 1 through December 31.

***Rainfall event*** means any occurrence of rain, preceded by 10 hours without precipitation that results in an accumulation of 0.01 inches or more. Instances of rainfall occurring within 10 hours of each other will be considered a single rainfall event.

***Rationale*** or ***fact sheet*** means a document that is prepared when drafting an NPDES permit or permit action. It provides the technical, regulatory and administrative basis for an agency's permit decision.

A ***reference site*** means the least impacted waters within an ecoregion that have been monitored to establish a baseline to which alterations of other waters can be compared.

A ***reference condition*** is a parameter-specific set of data from regional reference sites that establish the statistical range of values for that particular substance at least-impacted streams.

***Release*** means the flow of sewage from any portion of the collection or transmission system owned or operated by a publicly owned treatment works (POTW) or a domestic wastewater treatment plant, other than through permitted outfalls, that does not reach waters. In addition, a "release" includes a backup into a building or private property that is caused by blockages, flow conditions, or other malfunctions originating in the collection or transmission system owned or operated by the permittee. A "release" does not include:

(a) Backups into a building or private property caused by blockages or other malfunctions originating in a private lateral;

(b) Events caused by vandalism;

(c) Events caused by lightning strike;

(d) Events caused by damage due to third parties working on other utilities in the right of way, e.g., cross bore from telecommunications line; or

(e) Events that are directly incidental to planned, preventative, or predictive maintenance provided the site is under the direct control of a certified operator or contractor, public access is restricted, and the site is disinfected.

***Sanitary sewer overflow*** or ***SSO*** means an unpermitted discharge of wastewater from the collection, transmission, or treatment system other than through the permitted outfall.

***Schedule of compliance*** means a schedule of remedial measures including an enforceable sequence of actions or operations leading to compliance with an effluent limitation, condition of a permit, other limitation, prohibition, standard, or regulation. This term includes, but is not limited to, schedules authorized by national effluent limitations guidelines or by Tennessee's water quality standards.

The term ***semi-annually,*** for the purposes of this permit, means the same as once every 6 months. Measurements of the limited effluent parameters may be made any time during a 6 month period beginning from the effective date of this permit, so long as the second set of measurements for a given 12 month period are made approximately 6 months subsequent to that time, if feasible.

***Severe property damage,*** when used to consider the allowance of a bypass, means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

***Sewage*** means water-carried waste or discharges from human beings or animals, from residences, public or private buildings, or industrial establishments, or boats, together with such other wastes and ground, surface, storm, or other water as may be present

***Sewerage system*** means the conduits, sewers, and all devices and appurtenances by means of which sewage and other waste is collected, pumped, treated, or disposed.

***Sludge*** or ***sewage sludge*** is solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works. Sewage sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and a material derived from sewage sludge. Sewage sludge does not include ash generated during the firing of sewage sludge in a sewage sludge incinerator or grit and screenings generated during preliminary treatment of domestic sewage in a treatment works.

***Source*** means any activity, operation, construction, building, structure, facility, or installation from which there is or may be the discharge of pollutants.

***Standard of performance*** means a standard for the control of the discharge of pollutants that reflects the greatest degree of effluent reduction that the

Commissioner determines to be achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

***Stream*** means a surface water that is not a wet weather conveyance.

***Subecoregion*** is a smaller, more homogenous area that has been delineated within an ecoregion.

***Total dissolved solids*** or ***TDS*** means nonfilterable residue.

***Upset*** means an exceptional incident in which there is unintentional and temporary noncompliance with technology-based effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

The term ***washout*** is applicable to domestic wastewater activated sludge plants and means a loss of mixed liquor suspended solids (MLSS) of 30.00% or more from the aeration basin(s).

***Waters*** means any and all water, public or private, on or beneath the surface of the ground, which are contained within, flow through, or border upon Tennessee or any portion thereof, except those bodies of water confined to and retained within the limits of private property in single ownership which do not combine or effect a junction with natural surface or underground waters.

***Watercourse*** means a man-made or natural hydrologic feature with a defined linear channel that discretely conveys flowing water, as opposed to sheet-flow.

***Weekly average amount*** means the arithmetic mean of all the measured daily discharges by weight during the calendar week when the measurements were made.

***Weekly average concentration*** means the arithmetic mean of all the concentrations expressed in units of mass per volume of any pollutant measured in a calendar week.

***Wet weather conveyance*** means, notwithstanding any other law or rule to the contrary, man-made or natural watercourses, including natural watercourses that have been modified by channelization:

(a) That flow only in direct response to precipitation runoff in their immediate locality;

(b) Whose channels are at all times above the groundwater table;

(c) That are not suitable for drinking water supplies; and

(d) In which hydrological and biological analyses indicate that, under normal weather conditions, due to naturally occurring ephemeral or low flow there is not sufficient water to support fish, or multiple populations of obligate lotic aquatic organisms whose life cycle includes an aquatic phase of at least two months.

***Wet weather overflow*** means a sanitary sewer overflow that is directly related to a specific rainfall event.

***Wet weather release*** means a release that is directly related to a specific rainfall event.

## 4.2. ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| 1Q10 – | 1-day minimum, 10-year recurrence interval |
| 30Q5 – | 30-day minimum, 5-year recurrence interval |
| 7Q10 – | 7-day minimum, 10-year recurrence interval |
| BAT – | best available technology economically achievable |
| BCT – | best conventional pollutant control technology |
| BDL – | below detection limit |
| $BOD_5$ – | five-day biochemical oxygen demand |
| BPT – | best practicable control technology currently available |
| $CBOD_5$ – | five-day carbonaceous biochemical oxygen demand |
| CEI – | compliance evaluation inspection |
| CFR – | code of federal regulations |
| CFS – | cubic feet per second |
| CFU – | colony forming units |
| CIU – | categorical industrial user |
| CSO – | combined sewer overflow |
| DMR – | discharge monitoring report |
| D.O. – | dissolved oxygen |

| | |
|---|---|
| *E. coli* – | *Escherichia coli* |
| EPA – | Environmental Protection Agency |
| EFO – | environmental field office |
| GPM – | gallons per minute |
| $IC_{25}$ – | inhibition concentration causing 25% reduction in survival, reproduction, and growth of the test organisms |
| IU – | industrial user |
| IWS – | industrial waste survey |
| LB (lb) – | pound |
| $LC_{50}$ – | acute test causing 50% lethality |
| MDL – | method detection limit |
| MGD – | million gallons per day |
| mg/L – | milligrams per liter |
| ML – | minimum level of quantification |
| mL – | milliliter |
| MLSS – | mixed liquor suspended solids |
| MOR – | monthly operating report |
| NODI – | no discharge code in NetDMR |
| NPDES – | national pollutant discharge elimination system |
| PL – | permit limit |
| POTW – | publicly owned treatment works |
| SAR – | semi-annual report [pretreatment program] |
| SIU – | significant industrial user |
| SSO – | sanitary sewer overflow |
| STP – | sewage treatment plant |
| TBEL – | technology-based effluent limit |
| TCA – | Tennessee code annotated |
| TDEC – | Tennessee Department of Environment and Conservation |
| TIE/TRE – | toxicity identification evaluation/toxicity reduction evaluation |
| TMDL – | total maximum daily load |
| TRC – | total residual chlorine |
| TSS – | total suspended solids |
| WQBEL – | water quality-based effluent limit |

## 4.3. RESOURCES, HYPERLINKS, AND WEB PAGES

Clean Water Act NPDES Electronic Reporting (eReporting) Information
*https://www.epa.gov/compliance/npdes-ereporting*

Electronic Code of Federal Regulations (eCFR), Title 40 (40 CFR § 1 through § 1099)
*https://www.ecfr.gov/cgi-bin/text-idx?SID=75202eb5d09974cab585afeea981220b&mc=true&tpl=/ecfrbrowse/Title40/40chapterI.tpl*

Electronic Reporting (NetDMR) Waiver Request
*https://www.tn.gov/content/dam/tn/environment/water/documents/wr_ereporting_waiver.pdf*

Low Flow Statistics Tools: A How-To Handbook for NPDES Permit Writers (EPA)
*https://www.epa.gov/sites/production/files/2018-11/documents/low_flow_stats_tools_handbook.pdf*

Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms (EPA)
*https://www.epa.gov/sites/production/files/2015-08/documents/acute-freshwater-and-marine-wet-manual_2002.pdf*

NetDMR Login
*https://cdxnodengn.epa.gov/net-netdmr/*

NetDMR, MyTDEC Forms, & Electronic Reporting Information
*https://www.tn.gov/environment/program-areas/wr-water-resources/netdmr-and-electronic-reporting.html*

NPDES Compliance Inspection Manual (EPA)
*https://www.epa.gov/sites/production/files/2017-01/documents/npdesinspect.pdf*

NPDES Electronic Reporting Rule
*https://www.federalregister.gov/documents/2015/10/22/2015-24954/national-pollutant-discharge-elimination-system-npdes-electronic-reporting-rule*

Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (QSSOP)
*https://www.tn.gov/content/dam/tn/environment/water/documents/DWR-PAS-P-01-Quality_System_SOP_for_Macroinvertebrate_Stream_Surveys-081117.pdf*

Rules of the TN Department of Environment and Conservation, Chapter 0400-40
*https://publications.tnsosfiles.com/rules/0400/0400-40/0400-40.htm*

Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms (EPA)
*https://www.epa.gov/sites/production/files/2015-08/documents/short-term-chronic-freshwater-wet-manual_2002.pdf*

TDEC Water Quality Rules, Reports, and Publications
*https://www.tn.gov/environment/program-areas/wr-water-resources/water-quality/water-quality-reports---publications.html*

Technical Support Document for Water Quality-based Toxics Control (EPA)
*https://www3.epa.gov/npdes/pubs/owm0264.pdf*

Tennessee Nutrient Reduction Framework
*https://www.tn.gov/content/dam/tn/environment/water/tmdl-program/wr-ws_tennessee-draft-nutrient-reduction-framework_030315.pdf*

Tennessee Plant Optimization Program (TNPOP)
*https://www.tn.gov/environment/program-areas/wr-water-resources/tn-plant-optimization-programs/tnpop.html*

Tennessee Water Resources Data and Map Viewers
*https://www.tn.gov/environment/program-areas/wr-water-resources/water-quality/water-resources-data-map-viewers.html*

USGS StreamStats
*https://www.usgs.gov/mission-areas/water-resources/science/streamstats-streamflow-statistics-and-spatial-analysis-tools?qt-science_center_objects=0#qt-science_center_objects*

USGS SWToolbox
*https://www.usgs.gov/software/swtoolbox-software-information*

State of Tennessee NPDES Permit Vocabulary

**Word Bank:**

| | |
|---|---|
| Degradation | Rainfall event |
| Washout | Dry weather overflow |
| Biosolids | Quarter |
| Sewage | Upset |
| Sludge or sewage sludge | One week period or Calendar week |
| Discharge | Bypass |
| DMR | Grab sample |
| Sanitary Sewer Overflow (SSO) | Composite sample |
| Pollutants | Monthly average concentration |
| Geometric mean | Daily maximum concentration |
| Calendar day | Monthly average amount |

1. Treated sewage sludge: __________________________
2. An intentional diversion of waste streams from any portion of a treatment facility: _________________
3. An exceptional incident in which there is unintentional and temporary noncompliance with technology-based effluent limitations because of factors beyond the reasonable control of the permittee: ____________________
4. The 24-hour period from midnight to midnight: ____________________________
5. A combination of not less than 8 influent or effluent portions, of at least 100 mL, collected over a 24-hour period: _________________________________
6. A loss of mixed liquor suspended solids (MLSS) of 30% or more from the aeration basin(s): _____________________________________
7. A limitation on the average concentration in units of mass per volume of the discharge during any calendar day: _______________________________
8. The addition of pollutants to waters from a source: ____________________________ (Also referred to as "discharge of a pollutant.")

9. A type of sanitary sewer overflow defined as one day or any portion of a day in which unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall occurs and is not directly related to a rainfall event: ________________________________

10. The alteration of the properties of waters by the addition of pollutants, withdrawal of water, or removal of habitat, except those alterations of a short duration: ___________________________

11. The $n^{th}$ root of the product of the individual values where "n" is equal to the number of individual values: ____________________________. For calculating purposes, values of zero shall be considered to be one.

12. A single influent or effluent sample collected at a particular time: ___________________________

13. An unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall: ______________________________

14. The summation of all the measured daily discharges by weight divided by the number of days during the calendar month when the measurements were made: ______________________________

15. Discharge Monitoring Report, the first of which is due on the $15^{th}$ of the month: __________________

16. The arithmetic mean of all the composite or grab samples collected in a one-calendar month period (other than for *E.coli*): __________________________________

17. Water-carried waste or discharges from human beings or animals, from residences, public or private buildings, or industrial establishments, or boats, together with such other wastes and ground, surface, storm, or other water as may be present: ________________________________

18. The period from Sunday through Saturday: _____________________________. For reporting purposes, a calendar week that contains a change of month shall be considered part of the latter month.

19. Sewage, industrial wastes, or other wastes are all considered: ___________________________

20. Solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works: ___________________________________. It includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and a material derived from sewage sludge.

21. One of the following three-month periods: January 1 - March 31, April 1 - June 30, July 1 - September 30, and/or October 1 - December 31 ______________________________

22. Any occurrence of rain, preceded by 10 hours without precipitation that result in an accumulation of 0.01 inches or more: ______________________________. Instances of rainfall occurring within 10 hours of each other will be considered a single rainfall event.

# Section 9
# Pumps and Maintenance

# Section 9
# Pumps and Equipment Maintenance

Fleming Training Center
Your Partner in Clean Water

TN Department of Environment & Conservation

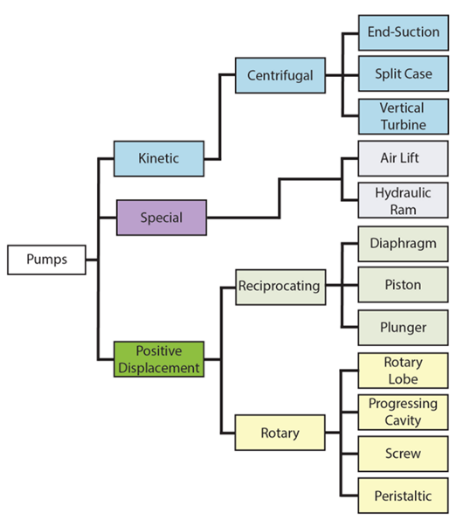
## Purpose

- A ***pump*** is merely a device used to move water from one place to another or to increase the pressure in the water.
- Pumps are the workhorses that make every aspect of water resource recovery happen.
- Many different types of pumps are used to move water, wastewater, treatment chemicals, and solids from one location to another.
- Pumps move wastewater through the collection system to the water resource recovery facility (WRRF).

# Function

- They increase the elevation of water in a tank or distribution box so it can flow by gravity to downstream processes.
- They meter chemicals into tanks or processes.
- They regulate recycle streams.
- They are critical mechanical tools that help operators reclaim water every day.

# Common Types



## Note

- ***Kinetic*** or dynamic pumps operate by increasing the velocity of the water and/or solids as they move through the pump.
- Velocity is then converted to pressure at the pump discharge.
- Kinetic pumps include centrifugal and turbine pumps.

## Note

- ***Positive displacement pumps*** operate by taking a fixed volume of fluid or sludge from the inlet, through the pump body, and then pushing it out the pump discharge.
  - These pumps push the fluid or sludge along similarly to the way toothpaste is pushed out of a tube by squeezing.
- Positive displacement pumps include reciprocating types (diaphragm, piston, and plunger) and rotary types (lobe, progressing cavity, screw, and peristaltic).

## Pump Operation – Start Up

- The following checklist contains items that are good to check any time you are starting a pump that has been out of service.
  – Inspect the base and make sure that the bolts are all tight and the base appears to be level.
  – Check that the pump shaft spins freely.
  – Check the seal. If using packing, make sure the seal water is on and dripping at the correct rate. If using a mechanical seal, check to see if there is any leakage.

## Pump Operation – Start Up

– Verify that the pump and driver are both properly lubricated.
– Check the condition of the coupling.
– Verify that all suction and discharge valves are in the correct position.
– Make sure that the pump is fully primed and air has been vented.
– Immediately after startup, check to make sure there are no abnormal noises or vibration coming from the pump.

## Pump Operation – Start Up

- Verify that the pump and driver are both properly lubricated.
- Check the condition of the coupling.
- Verify that all suction and discharge valves are in the correct position.
- Make sure that the pump is fully primed and air has been vented.
- Immediately after startup, check to make sure there are no abnormal noises or vibration coming from the pump.

## Pump Operation – Shut Down

- Push or click on the "Off" button to stop the pump from pumping.
- Flip the local disconnect switch to "Off" to ensure that the pump is not accidentally started.
- Turn off the seal flushing water, if present.
- Close the isolation valves on the suction and the discharge sides of the pump. Please note that if a wastewater or solids pump will be out of service for more than 24 hours, it is possible that gases can build up in the isolated section of pipe and cause damage. If a flushing connection is available, flush the wastewater or solids out of the pump before closing the discharge valve. If a flushing connection is not available, it may be necessary to leave one of the valves cracked slightly open to allow pressure to escape out of the pipe or install a pressure relief valve.

## Pump Operation – Shut Down

- If the pump is going to remain out of service for a month or more, check the manufacturer's operations and maintenance (O&M) instructions to see if additional measures should be taken to protect the pump.

## Pump Operation – Daily Operation

- When a pump is operating under normal conditions, it is still advisable to regularly verify proper operation. On a daily basis, the following things should be checked:
  - Listen to the pump while it is operating. If you notice any strange noise, you should investigate to determine the source of the new noise.
  - Are there any new or different smells near the pump? Components that are rubbing or becoming overheated often have a distinctive "burnt" odor.

## Pump Operation – Daily Operation

– Some operators will place their hand on a pump while it is operating to tell whether it is warmer than usual or if it is vibrating. This practice can be dangerous because pump components can become so hot that they will cause serious burns. It is a better practice to use an infrared temperature gun to measure the exact temperature of the pump. Good quality infrared guns are now available at reasonable prices. First, this will protect you from a burn injury. Second, it provides an exact temperature measurement that can be recorded and trended to see when changes are occurring. After you know the temperature is safe, then you can place your hand on the pump to check for new vibration.

## Pump Operation – Daily Operation

– Check for new water or lubricant leaks. If you find something, always try to trace it back to the source and document your findings. Schedule a repair or put in a work order, if appropriate.

– On pumps with stuffing boxes and packing, check to make sure you see the correct amount of leakage. Adjust the gland nuts if necessary.

## Maintenance

- It is very important for preventive maintenance outlined in a pump O&M manual to be performed.

1. Those instructions typically consist of
   1. a maintenance schedule (run time or calendar time),
   2. maintenance activities at each maintenance interval, and
   3. instructions on how to perform that maintenance.

- Examples of routine and preventive maintenance include:
  - For pumps with stuffing boxes and packing: If the seal water drip rate can no longer be adjusted properly and pumped liquid is leaking through, replace the packing.
  - For pumps with mechanical seals: If pumped liquid is leaking from the seal, it is likely time to replace the seal. Follow the manufacturer's recommendations.

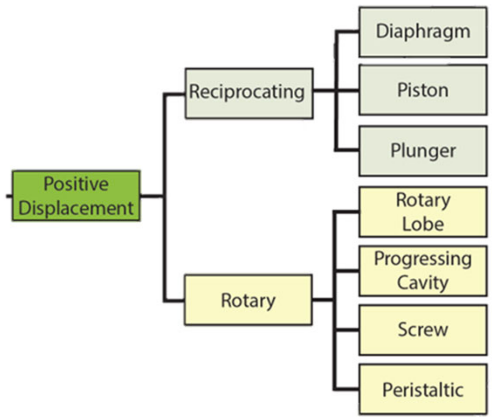
## Maintenance

- Motors may or may not need to be greased. Refer to the manufacturer's recommendations for your motors included in the O&M manual.
- For belt- and sheave-driven pumps, the belts will stretch over time and the tension will need to be adjusted. Regularly check the belt for wear.
- Pump bearings may or may not need grease or oil. Check the O&M manual and change as recommended. Also, ALWAYS pay attention to what type of oil or grease is required. A motor bearing may require a different grease than a pump bearing (and catastrophic results may occur if the wrong grease is applied or the greases are mixed).

- See the O&M sections and troubleshooting guides at the end of each pump section for more information.

## Positive Displacement Pumps

There are 2 types/categories of positive displacement:




## Positive-Displacement Pumps

- Pumps work well to transport sludge & chemical feed pumps
- Less efficient than centrifugal pumps
  - But much more accurate
- **Cannot operate against a closed discharge valve**

# Positive-Displacement Pumps

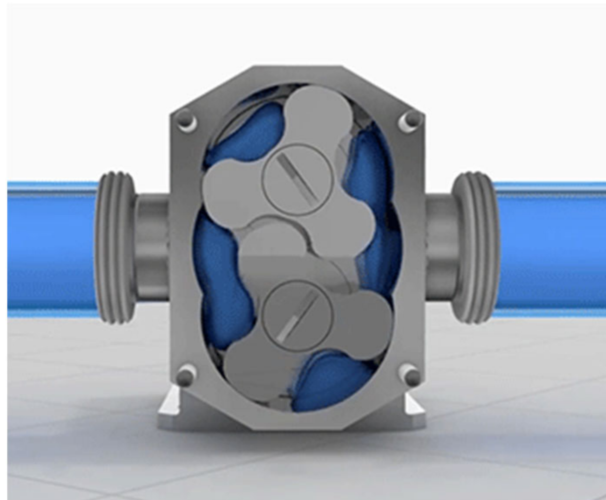
- ***Reciprocating (piston) pump*** - piston moves back and forth in cylinder, liquid enters and leaves through check valves

# Piston Pump

- The first example of positive displacement pump we have is the piston pump. This is similar to what you would find in your car engine. It works on a very similar principle. The piston arm pulls back the piston. As it does this, liquid is pulled in on the suction side of the pump (flow in). When the pump reaches its set stroke length, the piston will then move forward and expel the liquid out the discharge side of the pump (flow out). You can set how far the piston is pulled back and control how much chemical is being fed.
- A check valve is installed on the suction and discharge side to prevent backflow and keep liquid flowing in one direction
- We can demonstrate with this type of pump why a positive displacement pump cannot be operated against a closed discharge valve. If the cavity fills with liquid, then cannot expel it, the motor will burn itself up trying to move the piston. So the discharge valve always needs to be open on a positive discharge pump.

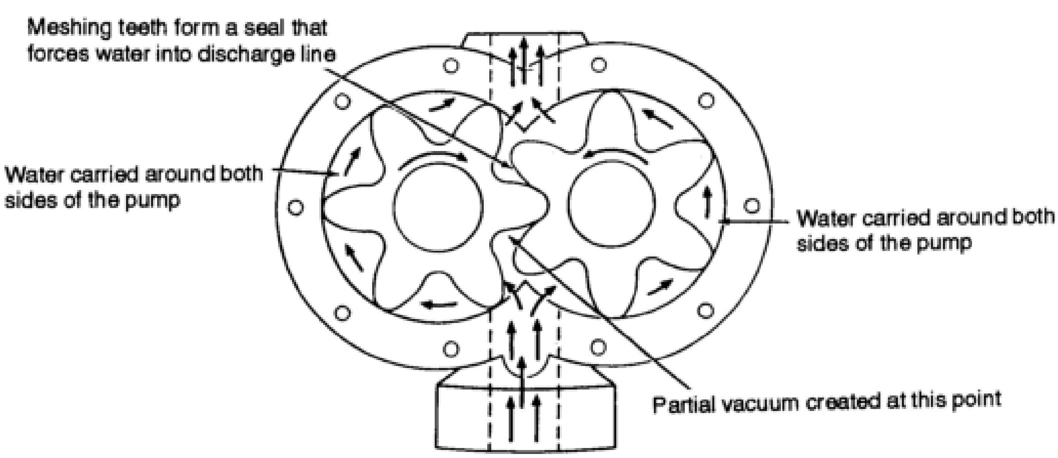
## Positive-Displacement Pumps

- ***Rotary pump*** - Use lobes or gears to move liquid through pump
- As the lobes or gears rotate in opposite directions, a low pressure area is created in the center pulling in the liquid. The liquid is then moved around the outside of the pump by the gears. It will then be pushed out the discharge side of the pump.
- If you know the volume/size of the space, it allows you to find the volume of liquid being moved through



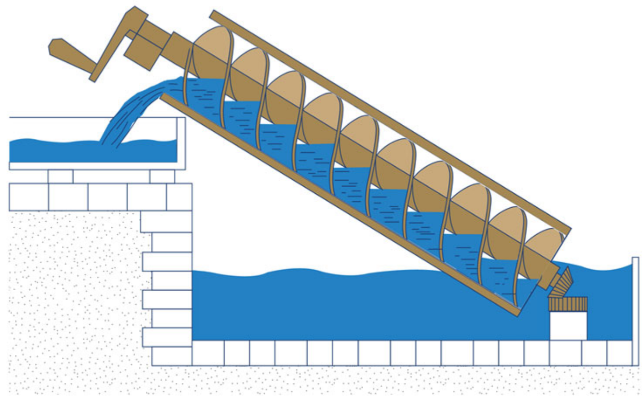
## Positive-Displacement Pumps

- ***Rotary pump*** - Use lobes or gears to move liquid through pump



## Positive-Displacement Pumps

- ***Screw pumps*** are used to lift wastewater to a higher elevation
- This pump consists of a screw operating at a constant speed within a housing or trough
- The screw has a pitch and is set at a specific angle
- When revolving, it carries wastewater up the trough to a discharge point

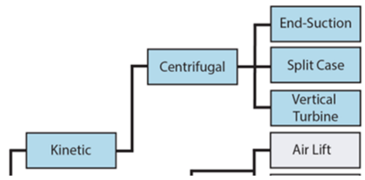


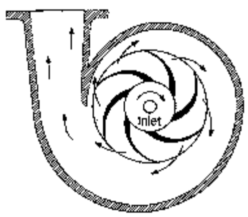
## Positive-Displacement Pumps

- Screw pumps are also known as progressive cavity pumps.
- They consist of a screw shaped rotor snugly enclosed in a nonmoving stator or housing.
- As the rotor turns, the material is moved along until it leaves the conveyor at the discharge end of the pump.
- Incline screw pumps handle large solids without plugging
- Screw pumps are supported by 2 bearings, a ball or roller bearing above the flights & a sleeve bearing in the WW

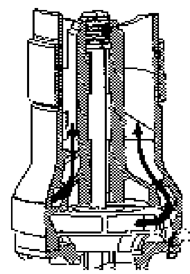
# Velocity (Kinetic) Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)
- High velocity, low pressure water is converted to low velocity, high pressure water




Volute



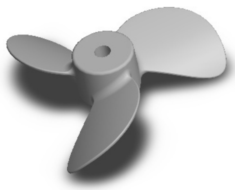
Diffuser

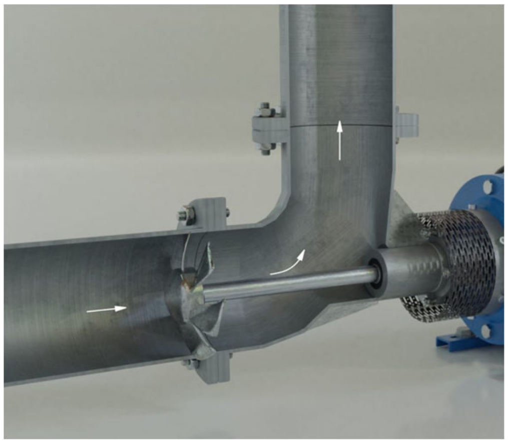
# Vertical Wet Well Pumps

- Has a vertical shaft, diffuser-type centrifugal pump with the pumping element suspended from the discharge piping.
- The needs of a given installation determines the length of discharge column
- The pumping bowl assembly may connect directly to the discharge head for shallow sumps, or may be suspended several hundred feet for raising water from wells
- Vertical turbine pumps are used to pump water from deep wells and may be of the single-stage or multistage type

## Velocity Pump Design Characteristics

- Axial - flow designs
  - Propeller shaped impeller adds head by lifting action on vanes
  - Water moves parallel to pump instead of being thrown outward
  - High volume, but limited head
  - Not self-priming

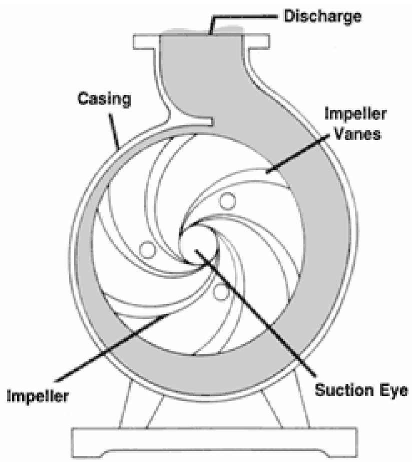




Prime= to replace air w/ water

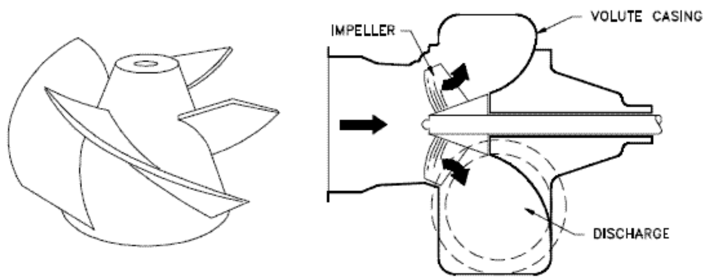
## Velocity Pump Design Characteristics

- Radial flow designs
  - Water comes in through center (eye) of impeller
  - Water thrown outward from impeller to diffusers that convert velocity to pressure
  - The discharge is perpendicular to the pump shaft



## Velocity Pump Design Characteristics

- Mixed - flow designs
  - Has features of axial and radial flow
  - Works well for water with solids




## Centrifugal Pump

- Basically a very simple device: an impeller rotating in a casing
- The impeller is supported on a shaft, which in turn, is supported by bearings
- Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge

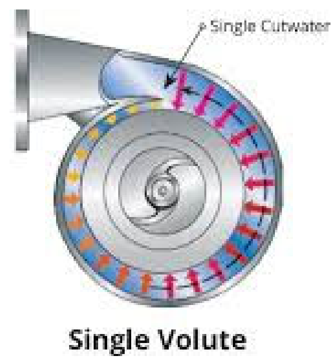
## Centrifugal Pump

## Most Common Centrifugal Pumps

- Horizontal non-clog type
- Vertical ball bearing type
- Propeller type

## Advantages of Centrifugal Pumps

- Wide range of capacities
- Uniform flow at a constant speed and head
- Low cost
- Ability to be adapted to various types of drivers
- Moderate to high efficiency
- No need for internal lubrication




## Disadvantages of Centrifugal Pumps

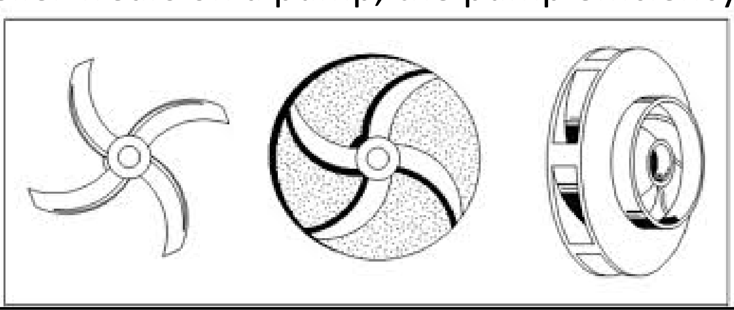
- Efficiency is limited to very narrow ranges of flow and head
- Flow capacity greatly depends on discharge pressure
- Generally no self-priming ability
- Can run backwards if check valve fails and sticks open
- Potential impeller damage if pumping abrasive water

## Parts of Centrifugal Pump: Impellers

- ***Impeller***
  - This is the heart of our pump
  - As the impeller spins, liquid between the blades is impelled outward by centrifugal force
  - As liquid in the impeller moves outward, it will suck more liquid behind it through this eye, provided it is not clogged.
    - Pump creates a low pressure zone
  - If there is any danger that foreign material may be sucked into the pump, clogging or wearing of the impeller unduly, provide the intake end of the suction piping with a suitable screen

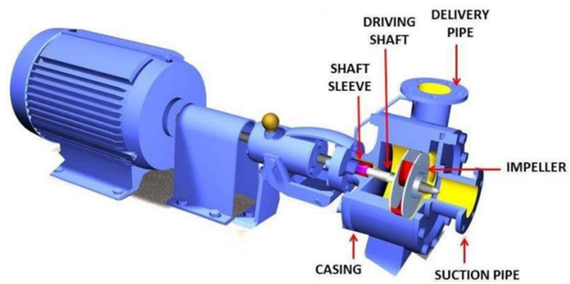
## Parts of Centrifugal Pump: Impellers

- Bronze or stainless steel
- Closed; some single-suction have semi-open; open designs
- Inspect regularly
- As the impeller wears on a pump, the pump efficiency will decrease



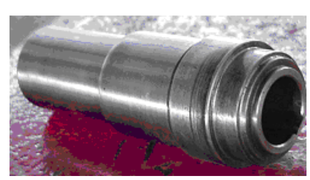
# Parts of Centrifugal Pump: Shaft

- ***Shaft***
  - supports and turns the impeller
  - It must maintain the impeller in precisely the right place
  - But that ruggedness does not protect the shaft from the corrosive or abrasive effects of the liquid pumped, so we must protect it with sleeves slid on from either end.
    - Cheaper than replacing entire shaft




# Parts of Centrifugal Pump: Shaft

- Shaft
  - Connects impeller to pump; steel or stainless steel
  - Should be repaired/replaced if grooves or scores appear on the shaft
- Shaft Sleeves
  - Protect shaft from wear from ***packing rings***
  - Generally they are bronze, but various other alloys, ceramics, glass or even rubber-coating are sometimes required.



## Parts of Centrifugal Pump: Shaft

- We mount the shaft on sleeve, ball or roller ***bearings***
  - If bearings supporting the turning shaft and impeller are allowed to wear excessively and lower the turning units within a pump's closely fitted mechanism, the life and efficiency of that pump will be seriously threatened.
  - 2 types:
    - Oil-lubricated
    - Grease lubricated

## Note

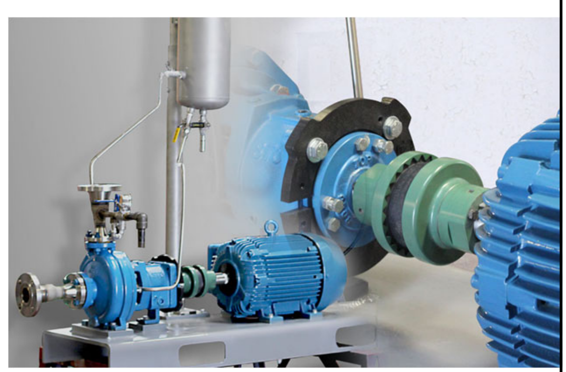
- ***Bearings***
  - Anti-friction devices for supporting and guiding pump and motor shafts
  - Get noisy as they wear out
  - If pump bearings are over lubricated, the bearings will overheat and can be damaged or fail
    - Tiny indentations high on the shoulder of a bearing or race is called brinelling
    - When greasing a bearing on an electric motor, the relief plug should be removed and replaced after the motor has run for a few minutes. This prevents you from damaging the seals of the bearing.
  - Types: ball, roller, sleeve

## Note

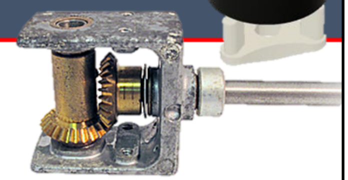
- Inspect and lubricate bearings-grease
  - If possible, remove bearing cover and visually inspect grease.
  - When greasing, remove relief plug and cautiously add 5 or 6 strokes of the grease gun.
  - Afterward, check bearing temperature with thermometer.
    - If over 220°F (104°C), remove some grease.
- It is vital to **maintain the right amount of the right lubricant in the bearings at all times**.
  - Too much grease in antifriction type bearings (ball or roller) will promote friction and heat. The main job of grease in antifriction bearings is to protect steel elements against corrosion, not friction.
  - Too much bearing lubricant is just as bad as not enough.

## Parts of Centrifugal Pump: Coupling flange

- ***Coupling flange***
  - Our pump is driven by a separate motor, and we attach a flange to one end of the shaft through which bolts will connect with the motor flange
  - This transfers the energy of the motor, or driver, to the pump shaft allowing it to turn the impeller.
  - If shafts are met at an angle, every rotation throws tremendous extra load on bearings of both pump and the motor
    - Flexible couplings will not correct this condition if excessive

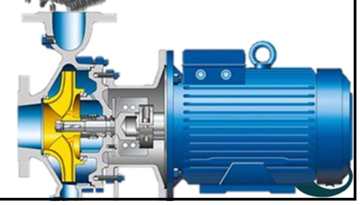


## Parts of Centrifugal Pump: Coupling

- Direct coupling
  - . It is a direct connection between the driver and the pump
- Angle drive
  - drive uses gears to transfer the energy from the motor to the pump
- Belt or chain
  - a belt or chain connects the motor and pump shafts
- Flexible coupling
  - allow for slight misalignment between the motor and pump shafts
- Close-coupled
  - characterized by a common motor and pump shaft or by their motor shaft and pump shaft being rigidly connected in a pump casing





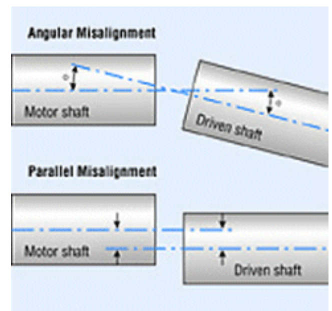
## Parts of Centrifugal Pump: Coupling

- Connect pump and motor shafts
- If lubricated coupling: require greasing at 6 month intervals
- Dry has rubber or elastomeric membrane (does not require lubricant)

- Calipers and thickness gauges can be used to check alignment on all couplings as part of the regular preventive maintenance program.
  - Especially flexible couplings

## Note

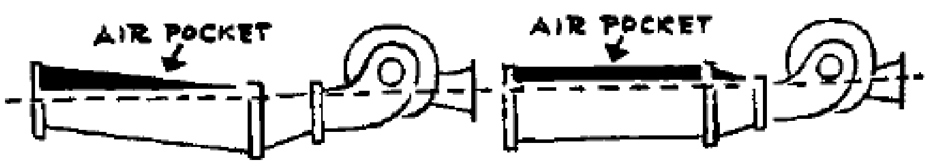
- Unless couplings between the driving and driven elements of a pump are kept in proper alignment wear can result:
  - Excessive bearing loading
  - Shaft bending
  - Premature bearing failure
  - Shaft damage




- Checking alignment should be a regular procedure in pump maintenance.
  - Foundations can settle unevenly
  - Piping can change pump position
  - Bolts can loosen
  - ***Misalignment*** is a major cause of pump and coupling wear.

## Parts of Centrifugal Pump: Pipe

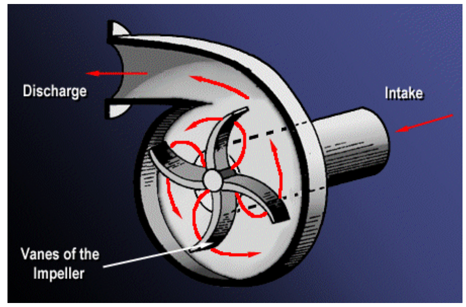
- Now we need a "straw" through which liquid can be sucked
  - Insure that the pipe does not put strain on the pump's casing
- Notice two things about the suction piping:
  - 1. the horizontal piping slopes upward toward the pump; and
  - 2. any reducer that connects between the pipe and pump intake nozzle should be horizontal at the top.
- This upsloping prevents air pocketing in the top of the pipe where trapped air might be drawn into the pump. This will lead to a loss of suction as the pump pulls in air instead of water.




This rule is very important. Loss of suction greatly endangers a pump.

## Parts of Centrifugal Pump: Volute

- We contain and direct the spinning liquid with a casing
  - Housing surrounding the impeller; also called the ***volute***
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape
  - See that piping puts absolutely no strain on the pump casing.
    - the casing is apt to be cracked or sprung enough to allow closely fitted pump parts to rub.



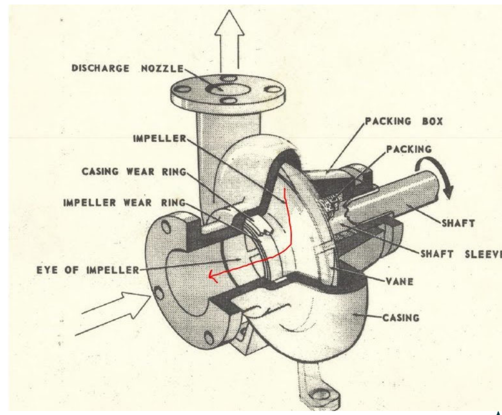

It is good practice to check the piping supports regularly to see that loosening or settling has not put strains on the casing.

## Parts of Centrifugal Pump

- If we were to build a pump off the parts discussed, it would leak like a sieve
  - As water is drawn into the spinning impeller, centrifugal force causes it to flow outward, building up high pressure at the outside of the pump (which will force water out) and creating low pressure at the center of the pump (which will draw water in)
    - Water tends to be drawn back from pressure to suction through the space between the impeller and casing – this needs to be plugged

## Parts of Centrifugal Pump: Wear Rings

- So we add wearing rings (aka ***wear rings***) to plug internal liquid leakage (between pump casing and the impeller)
  - Restrict flow between impeller discharge and suction
  - Leakage reduces pump efficiency
  - Installed to protect the impeller and pump casing from excessive wear
  - Provides a replaceable wearing surface
  - Inspect regularly




## Parts of Centrifugal Pump: Stuffing Box

- To keep air from being drawn in, we use ***stuffing boxes***
  - We have two good reasons for wanting to keep air out of our pump
    - We want to pump water, not air
    - Air leakage is apt to cause our pump to lose suction
  - Each stuffing box we use consists of a casing, rings of packing and a gland at the outside end
    - A mechanical seal may be used instead
- Parts include:
  - Packing
  - ***Lantern ring***
  - Gland follower

## Note

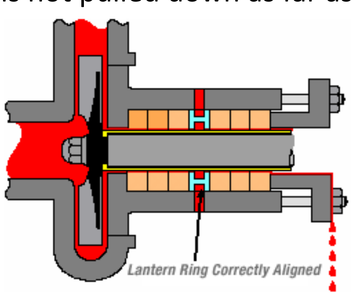
***Lantern rings*** (also called **seal cages**)

- Perforated ring placed in stuffing box
  - These are placed in the center of each stuffing box (that has packing rings).
  - This allows water under pressure into the stuffing box.
  - This liquid acts both to block out air intake and to lubricate the packing.
  - It makes both packing and shaft sleeves wear longer, providing it is clean liquid.

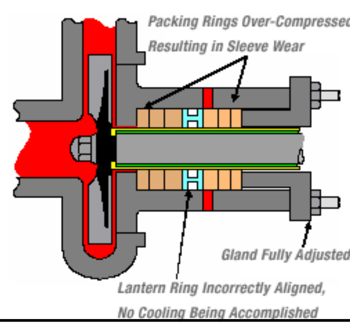
- A spacer ring in the stuffing box that forms seal around shaft, helps keep air from entering the pump and lubricates packing

## Note

The stuffing box is set up correctly. The packing rings (tan) are placed evenly and symmetrically around the lantern ring (blue). The water (red) travels along the pump shaft to fill the seal cage and lubricate the packing. Notice that the packing gland (gray at the end) is not pulled down as far as it can go.




The packing gland has over tightened. As a result, the packing rings have been compacted and the lantern ring dislodged. The necessary lubrication cannot be provided. This will lead to friction, heat, and damage to the equipment.



## Parts of Centrifugal Pump: Packing Rings

- Provides a seal where the shaft passes through the pump casing in order to keep air form being drawn or sucked into the pump and/or the water being pumped from coming out


## Parts of Centrifugal Pump: Packing Rings

- If new packing leaks, stop the motor and repack the pump
- Pumps need new packing when the gland or follower is pulled all the way down
- The packing around the shaft should be tightened slowly, over a period of **several hours** to just enough to allow an occasional drop of liquid (**20-60 drops per minute** is desired)
  - Leakage acts as a lubricant
- Stagger joints 180º if only 2 rings are in stuffing box, space at 120º for 3 rings or **90º if 4 rings or more are in set**

## Parts of Centrifugal Pump: Packing Rings

- If packing is not maintained properly, the following troubles can arise:
  - **Loss of suction** due to air being allowed to enter pump
  - **Shaft or shaft sleeve damage**
  - Water or wastewater **contaminating bearings**
  - **Flooding** of pump station
  - Rust corrosion and unsightliness of pump and area

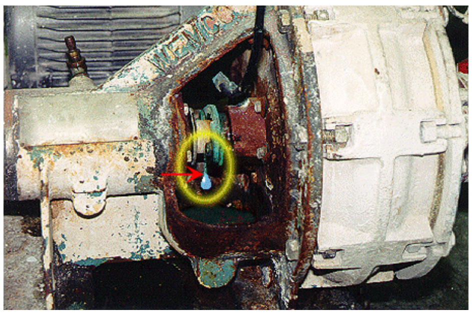
## Packing vs. Mechanical Seals

If a pump has **packing, water should drip slowly**

If it has a **mechanical seal, no leakage should occur**

# Packing Rings vs. Mechanical Seal

- Advantages
  - Less expensive, short term
  - Can accommodate some looseness



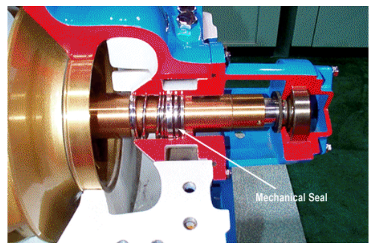
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement
    - Recommended that you repack the pump once a year.
    - One student said they will do it every 3 months on some pumps

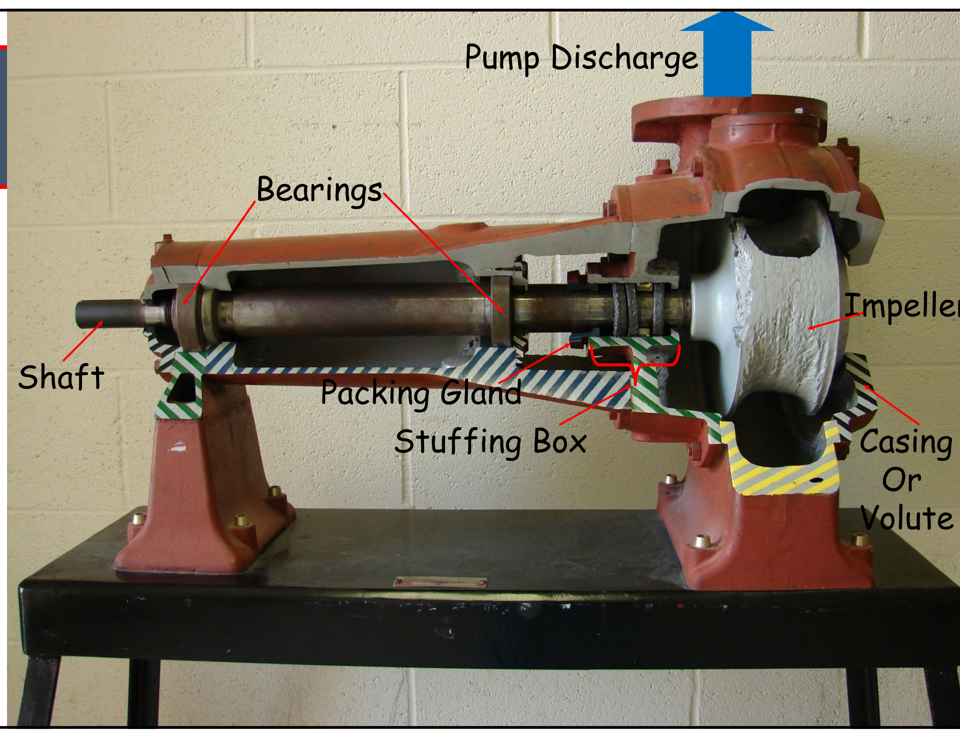
# Parts of Centrifugal Pump: Mechanical Seals

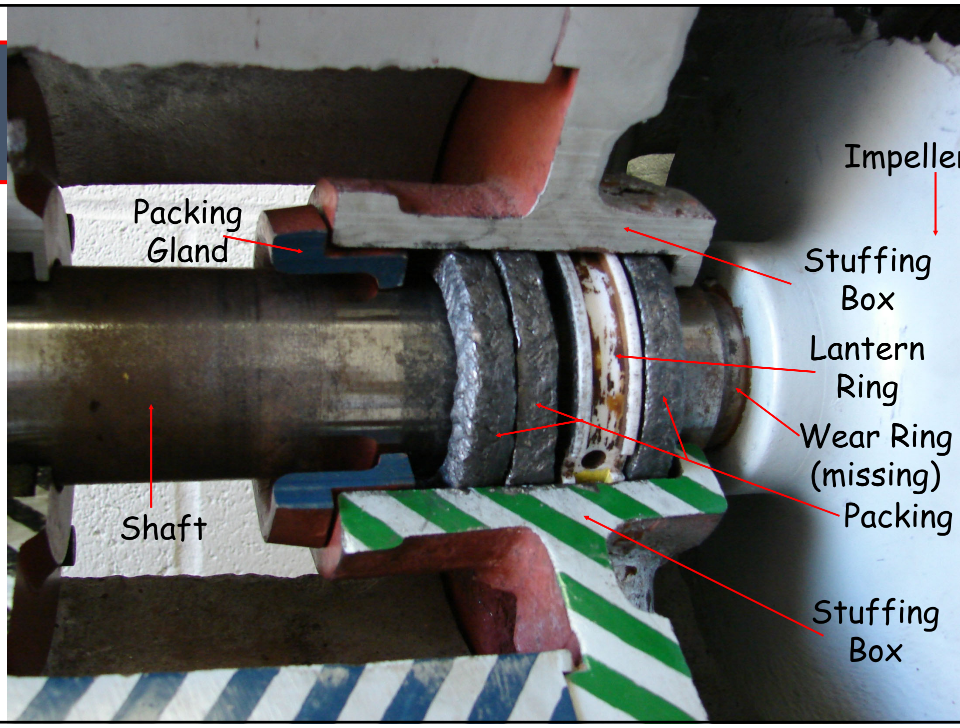
- Located in stuffing box
- Prevents water from leaking along shaft; keeps air out of pump
- **Should not leak**
- Consists of a rotating ring and stationary element
- **The operating temperature on a mechanical seal should never exceed 160$^{o}$F (71$^{o}$C)**
- Mechanical seals are always flushed in some manner to lubricate the seal faces and minimize wear
  - The flushing water pressure in a water-lubricated wastewater pump should be **3-5 psi higher** than the pump discharge pressure.

## Mechanical Seal vs. Packing Rings

- Advantages
  - **Last 3-4 years**, which can be a savings in labor
  - Usually there is **no damage to shaft sleeve**
  - **Continual adjusting, cleaning or repacking is not required**
  - Possibility of flooding lift station because a pump has thrown its packing is eliminated; however mechanical seals can fail and lift stations can be flooded
- Disadvantages
  - **High initial cost**
  - **Great skill and care needed to replace**
  - When they fail, the pump must be shut down
  - **Pump must be dismantled to repair**






## Centrifugal Pump: Start Up

- Pump Starting -
  - Impeller must be submerged for a pump to start
    - Should never be run empty, except momentarily, because parts lubricated by water would be damaged
  - **Foot valve helps hold prime**
  - Discharge valve should open slowly to control water hammer
  - In small pumps, a check valve closes immediately when pump stops to prevent flow reversal
  - In large pumps, discharge valve may close before pump stops

## Centrifugal Pump: Shut down

- Pump shut down for extended period of time -
  - Close the valve in the suction line
  - Close the valve in the discharge line
  - Drain the pump casing

## Flow Control

- Flow usually controlled by starting and stopping pumps
- Throttling flow should be avoided - wastes energy
- Variable speed drives or motor are best way to vary flow
  - Variable speed pumping equipment can be adjusted to match the inflow rate

## Monitoring Operational Variables

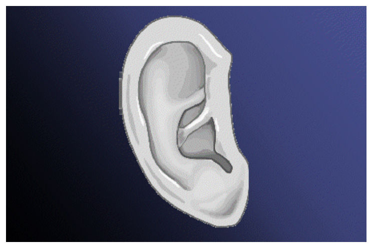
- Pump and motor should be tested and complete test results recorded as a baseline for the measurement of performance within the first 30 days of operation

## Monitoring Operational Variables

- Suction and Discharge Heads
  - Pressure gauges
- Bearing and Motor Temperature
  - Temp indicators can shut down pump if temp gets too high
  - Check temp of pump by feel

## Monitoring Operational Variables

- Vibration
  - Detectors can sense malfunctions causing excess vibration
  - Operators can learn to distinguish between normal and abnormal sounds



## Monitoring Operational Variables

- Likely causes of vibration
  - Bad bearings or bearing failure
  - Imbalance of rotating elements, damage to impeller
  - Misalignment from shifts in underlying foundation
  - Improper motor to pump alignment

## Monitoring Operational Variables

- Speed
  - Cavitation can occur at low and high speeds
  - Creation of vapor bubbles due to partial vacuum created by incomplete filling of the pump

## Monitoring Operational Variables

- Cavitation is a noise coming from a centrifugal pump that sounds like marbles trapped in the volute
- A condition where small bubbles of vapor form and explode against the impeller, causing a **pinging sound**
- Best method to prevent it from occurring is to reduce the suction lift

# Inspection and Maintenance

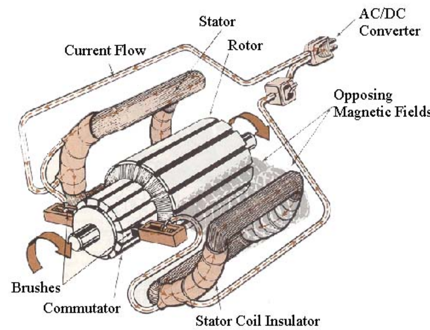
- Inspection and maintenance prolongs life of pumps
  - Checking operating temperature of bearings
  - Checking packing glands
  - Operating two or more pumps of the same size alternatively to equalize wear
  - Check parallel and angular alignment of the coupling on the pump and motor
    - A feeler gauge, dial indicator  calipers are tools that can be used to check proper alignment
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

# Inspection: Impellers

- Wear on impeller and volute
- Cavitation marks
- Chips, broken tips, corrosion, unusual wear
- Tightness on shaft
- Clearances
- Tears or bubbles (if rubber coated)

## Pump Won't Start?

- Incorrect power supply
- No power supply
- Incorrectly connected
- Fuse out, loose or open connection
- Rotating parts of motor jammed mechanically
- Internal circuitry open




## Pump Safety

- Machinery should always be turned off and locked out/tagged out before any work is performed on it
- Make sure all moving parts are free to move and all guards in place before restarting
- Machinery creating excessive noise shall be equipped with mufflers.

## Pump Safety: Wet Wells

- Confined spaces
- Corrosion of ladder rungs
- Explosive atmospheres
- Hydrogen sulfide accumulation
- Slippery surfaces


## Pump Facts

- Sewer pumps used in a lift station shall be capable of passing at least a 3 inch diameter sphere
- Pump suction and discharge opening shall be no less 4 inches in diameter
- Each pump must have its own intake line
- Wet wells should be designed to avoid turbulence near the intakes
- The velocity in the suction line of a pump should not exceed 6 fps
- The velocity in the discharge line of a pump should not exceed 8 fps

## Pump Facts

- Ventilation in wet wells shall provide for at least 12 complete air changes per hour if continuous and 30 changes per hour if intermittent
- Ventilation in dry wells shall provide for at least 6 complete air changes per hour if continuous and 30 changes per hour if intermittent

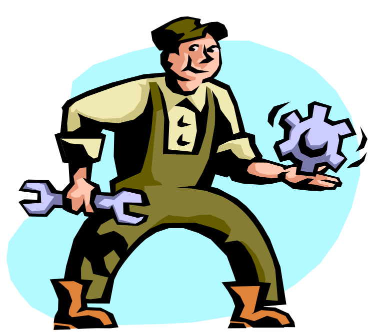
## Pump Facts

- The maximum recommended suction lift for a pump in a pumping station is 15 feet
- Minimum force main size is 4 inches
- A gasoline powered centrifugal pump in good condition can lift water (suction lift) up to 18 inches of mercury
    - 20 feet of possible suction lift
- Head is the amount of energy possessed by water at any point in a hydraulic system
    - Feet divided by 2.31 equals psi (pounds per square inch) in head

## Types of Pumps Found in Collection Systems

- Incline screw pump
- Centrifugal
- Pneumatic ejectors
- Piston
- Close-coupled
- Submersible
- Progress cavity
- Flexible stator and rotor

## Equipment Maintenance



## Beware of Electricity

- Be careful around electrical panels, circuits, wiring, & equipment
  - Serious injury
  - Damage costly equipment
- Basic working knowledge is key

## Tools, Meters & Testers

- Ammeter: records the current or amps in circuit
  - Most are clamp on type


- Megger: checks insulation resistance on motors, feeders, grounds, and branch circuit wiring
  - Motors should be megged at least once a year

## Tools, Meters & Testers

- Ohmmeter: measures resistance in a circuit.
  - An ohmmeter is used only when the electric circuit is off or de-energized
  - Tests fuses, relays, resistors and switches.

- Multimeter: checks for voltage
  - By holding one lead on ground and the other on a power lead, you can determine if power is available
  - You can also tell if it is AC or DC and the intensity or voltage (110, 220, 480 or whatever) by testing the different leads

## Need for Maintenance

- Performance and life of pumps and other equipment affected by:
  - Water
  - Dust
  - Humidity
  - Heat and cold
  - Vibration
  - Corrosive atmosphere

## Need for Maintenance

- Inspect & maintain electrical equipment annually.
- Inspection should include:
  - Thorough examination
  - Replacement of worn & expendable parts
  - Operational checks & tests
- Fuses and circuit breakers are protective devices used to protect operators, main circuits, branch circuits, heater, motors and various other electrical equipment.

## Electrical Protective Devices: Fuses


- Protect control panel from excess voltage or amperage
- Fusible metal strip melts and breaks circuit
- One-time use devices
  - Should never be jumped or bypassed
  - When removing any fuse, a fuse puller should be used

# Electrical Protective Devices: Circuit Breaker


- Protect electrical systems from short circuiting
- Switch opens when current or voltage out of range
- Unlike fuse, can be reset

# Transformer

- Allows energy to be transferred in an AC system for one circuit to another
- Used to convert high voltage to low voltage
  - **High voltage is 440 volts or higher**
- Standby engines should be run weekly to ensure that it is working properly
- Relays are used to protect electric motors

- Converters
  - Sometimes used to change the frequency in an AC power system
- Rectifiers
  - Changes AC to DC by allowing the current to flow in one direction only
- Inverters
  - Changes DC to AC

## Note

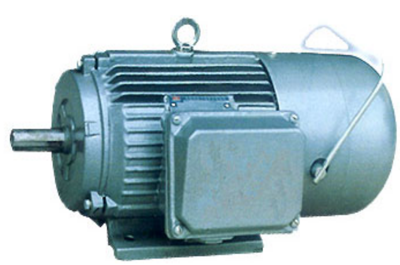
- ***Direct current (D.C.)*** is flowing in one direction only and is essentially free from pulsation
  - DC is seldom used in lift stations and wastewater treatment plants except in motor-generated sets, some control components of pump drives and standby lighting
  - DC is used exclusively in automotive equipment, certain types of welding equipment, and a variety of portable equipment
  - All batteries are DC
- ***Alternating current (A.C.)*** is periodic current that has alternating positive and negative values
  - AC are classified as:
    - Single phase
    - Two phase
    - Three phase or polyphase

## Batteries

- An ***electric battery*** is a device for the transformation of chemical energy into electric energy
- A ***primary battery*** is a battery that the chemical action is irreversible, like a flashlight battery
- A ***storage battery*** is one that the chemical action is almost completely reversible, like a car battery
  - The most common battery is the lead-acid type
  - Another common type of battery is the nickel-cadmium type

## A.C. Induction Motor

- Most common pump driver in wastewater pump stations
- **Motors pull the most current on start up**.
- Malfunction due to:
  - Thermal overload (40°C max.)
  - Contaminants
  - Single phasing
  - Old age
  - Rotor failure



# Single-phase vs Three-phase

- Single-phase power is found in lighting systems, small pump motors, variable portable tools and throughout our homes.
  - It is usually 120 volts or 240 volts
  - Single phase means only one phase of power is supplied to the main electrical panel at 240 volts and the power supply has three wires or leads
    - 2 of these leads have 120 volts each, the other lead is neutral and usually coded white, which is grounded
- Three-phase power is generally used with motors and transformers found in lift stations and wastewater treatment plants
  - Generally all motors above 2 horsepower are three-phase
  - If runs backwards on start up: shut down and swap 2 leads

# Motors

- In order to prevent damage, turn the circuit off immediately if the fuse on one of the legs of a three-phase circuit blows.
- An electric motor changes electrical energy into mechanical energy
- Power factors can be improved by:
  - Changing motor loading
  - Changing the motor type
  - Using capacitors
    - Also referred to as a condenser and it will also store electricity when it is charged

# Motors

- Routine cleaning of pump motors includes:
  - Checking alignment and balance
  - Checking brushes
  - Removing dirt and moisture
  - Removal of obstructions that prevent air circulation
- Cool air extends the useful life of motors
- A motor (electrical or internal combustion) used to drive a pump is called a prime mover
- The speed at which the magnetic field rotates is called the motor synchronous speed and is expressed in rpm

# Motors

- If a variable speed belt drive is not used for 30 days or more, shift the unit to minimum speed setting
- Emory cloth should not be used on electric motor components because it is electronically conductive and may contaminate parts
- Ohmmeters used to test a fuse in a motor starter circuit
- The most likely cause of a three-phase motor not coming to speed after starting – the motor has lost power to one or more phases

## Compressors

- Used to increase the pressure of air or gas
- Common uses:
  - Wastewater ejectors
  - Pump control systems (bubblers)
  - Water pressure systems
  - Portable pneumatic tools

## Compressors

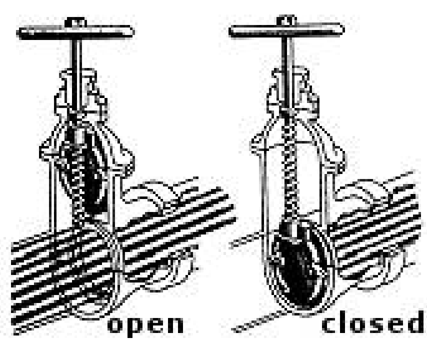
- Inspect suction filter at least monthly
  - Daily in dusty areas such as construction zones
- Inspect safety valves weekly
- Lubrication
  - Oil bearings
  - Oil cup, grease fittings, crankcase reservoir
  - Change oil every 3 months (unless otherwise specified)
- Inspect belt tension
- Clean dirt, oil & grease at least monthly
- Drain condensate daily using valve on air receiver
- Examine operating controls

# Valves

- Controlling device in piping systems to stop, regulate, check, or divert flow of liquids or gases
- Types of valves found in a pumping station
  - Butterfly – used on suction and discharge
  - Gate – used on suction and discharge
  - Plug – used on suction and discharge
  - Swing or ball check – used on discharge
  - Knife – used on suction and discharge
  - Wafer – used on discharge

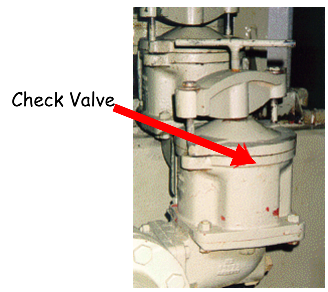
# Valves

- Gate valve:
  - Open valve fully; reverse & close one-half turn
  - Operate all large valves at least yearly
  - Inspect valve stem packing for leaks; tighten if needed
  - Close valves slowly in pressure lines to prevent water hammer



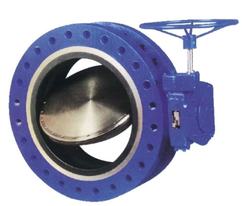
## Valves

- Check valves: discharge of pump to provide positive shut off from force main pressure & prevent force main from draining back into wet well




## Valves

- Butterfly valves: often clog on sewer lines when installed to carry stormwater or wastewater



- Plug valves: less susceptible to plugging; sludge pumping

## Lubrication

- Purposes:
  - Reduce friction between two surfaces
  - Remove heat due to friction
- Oils in service becomes acidic & may cause corrosion, deposits, sludging, etc.
- Oils & greases:
  - Can create fire hazard
  - Clean up spills immediately
  - Don’t contaminate

## Bearings

- Usually last for years if serviced properly
- Failures:
  - Fatigue – excessive load
  - Contamination
  - Brinelling – improper mounting
  - Electric arching – leakage; short circuiting
  - Misalignment
  - Cam failure
  - Lubrication failure – dirty; too much; not enough; wrong kind

## Building Maintenance

- Only one person should be in charge on any maintenance program.
- Keep facility clean, store tools in proper place
- Type of maintenance needed influenced by age, type & use of building
- Maintenance program includes:
  - Floors & roofs
  - Heating, cooling & ventilation
  - Lighting
  - Plumbing
  - Windows



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Pumps, Motors, and Equipment Maintenance Vocabulary

**Word Bank**

| | | |
|---|---|---|
| Amperage | Foot Valve | Positive Displacement |
| Brinelling | Fuse | Resistance |
| Bearing | Impeller | Velocity |
| Cavitation | Jogging | Voltage |
| Centrifugal | Lantern Ring | Volute |
| Circuit | Mechanical | Water Hammer |
| Circuit Breaker | Megger | Wear |
| Current | Packing | |

1. A ________________________ is a safety device in an electric circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.
2. ______________________ describes the tiny indentations (dents) that occur high on the shoulder of the bearing race or bearing. A type of bearing failure.
3. A ____________________ is a protective device having a strip or wire of fusible metal that, when placed in a circuit, will melt and break the electric circuit if heated too much. High temperatures will develop in the fuse when a current flows through the fuse in excess of that which the circuit will carry safely.
4. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve is known as ______________________. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. This is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer.
5. _____________________ is the electrical pressure available to cause a flow of current (amperage) when an electric circuit is closed.
6. The frequent starting and stopping of an electric motor is called ______________________.
7. The term_________________ describes the movement or flow of electricity.
8. A ________________________ is an instrument used for checking the insulation resistance on motors, feeders, bus bar systems, grounds, and branch circuit wiring.
9. ________________________ is the strength of an electric current measured in amperes. The amount of electric current flow, similar to the flow of water in gallons per minute.
10. ______________________ is that property of a conductor or wire that opposes the passage of a current, thus causing electrical energy to be transformed into heat.

11. A ______________________ is the complete path of an electric current, including the generating apparatus or other source; or a specific segment or section of the complete path.

12. A _______________________ is an anti-friction device that is used to support and guide a pump and motor shaft.

13. The__________________________ is a check valve placed in the bottom of the suction pipe of a pump, which opens to allow water to enter the suction pipe, but closes to prevent water from passing out of it at the bottom end. It keeps the prime.

14. The rotating set of vanes that force water through the pump are known as the ____________________.

15. The ___________________________ is a perforated ring placed around the pump shaft in the stuffing box. Water from the pump discharge is piped to this ring. The water forms a liquid seal around the shaft and lubricates the packing.

16. A _____________________ seal is placed on the pump shaft to prevent water from leaking from thepump along the shaft; the seal also prevents air from entering the pump.

17. Rings of graphite-impregnated cotton, flax, or synthetic materials that are used to control leakage along a valve stem or a pump shaft are called _________________________.

18. A _________________________ pump consists of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at a high velocity, and the casing shape concerts this velocity into pressure.

19. The expanding section of a pump casing which converts velocity head to pressure head is the ________________.

20. A ______________________________ pump delivers a precise volume of liquid with each stroke of the piston or rotation of the shaft

21. The term _____________________________ describes the potentially damaging slam that occurs ina pipe when a sudden change in water velocity (usually the result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.

22. _______________ rings are made of brass or bronze and placed on the impeller and/or casing of a centrifugal pump to control the amount of water that is allowed to leak from the discharge to the suction side of the pump.

# Section 10
# Answers to Vocabulary

Activated Sludge Part II

1. Bulking
2. Denitrification
3. F:M (or F/M)
4. Biochemical Oxygen Demand (BOD)
5. Mixed Liquor Suspended Solids (MLSS)
6. Diffuser
7. Sludge Age
8. Coagulation
9. Mixed Liquor Volatile Suspended Solids (MLVSS)
10. Mean Cell Residence Time (MCRT)
11. Supernatant
12. Nitrification
13. Rising Sludge
14. Sludge Volume Index (SVI)

Sludge Thickening, Digestion, and Dewatering

1. Biosolids
2. Saprophytic
3. Endogenous Respiration
4. Dewatering
5. Elutriation
6. Centrate
7. Anaerobic Digestion
8. Methane Fermenters
9. Buffering Capacity
10. Aerobic Digestion
11. Psychrophilic, Mesophilic, Thermophilic
12. Volatile Acid/Alkalinity Ratio
13. 40 CFR 503

Introduction to Laboratory and Sampling

1. Composite
2. Grab
3. Aseptic
4. pH
5. Thirty Minute Settleometer
6. Autoclave
7. Samplers
8. Process Control Tests
9. Turbidity
10. BOD
11. COD
12. Suspended Solids Test
13. Coliform
14. Membrane Filtration
15. Precision

Safety

1. Competent Person
2. Decibel
3. Lower Explosive Limit
4. Olfactory Fatigue
5. Oxygen Enrichment
6. Acute, Chronic
7. IDLH
8. Oxygen Deficiency
9. Sewer gas
10. Spoil
11. Confined Space
12. Carcinogen
13. Non-sparking tool
14. Engulfment
15. Permit-required
16. Non-permit
17. Septic
18. Mercaptans

Administration and Management

1. Authority
2. Organizing
3. Responsibility
4. Tailgate Safety Meeting
5. Ethics
6. Accountability
7. Delegation
8. Preventative
9. Critical Infrastructure
10. Vulnerability
11. Whistleblowing
12. Predictive

Pumps and Equipment Maintenance

1. Circuit Breaker
2. Brinelling
3. Fuse
4. Cavitation
5. Voltage
6. Jogging
7. Current
8. Megger
9. Amperage
10. Resistance
11. Circuit
12. Bearing
13. Foot Valve
14. Impeller
15. Lantern Ring
16. Mechanical
17. Packing
18. Velocity
19. Volute
20. Positive Displacement
21. Water Hammer
22. Wear

NPDES Permits

1. Biosolids
2. Bypass
3. Upset
4. Calendar day
5. Composite sample
6. Washout
7. Daily maximum concentration
8. Discharge
9. Dry weather overflow
10. Degradation
11. Geometric mean
12. Grab sample
13. Sanitary Sewer Overflow (SSO)
14. Monthly average amount
15. DMR
16. Monthly average concentration
17. Sewage
18. Calendar week or One week period
19. Pollutants
20. Sludge or Sewage sludge
21. Quarter
22. Rainfall event

# Section 11
# Handouts

# Section 12
# Lined Paper