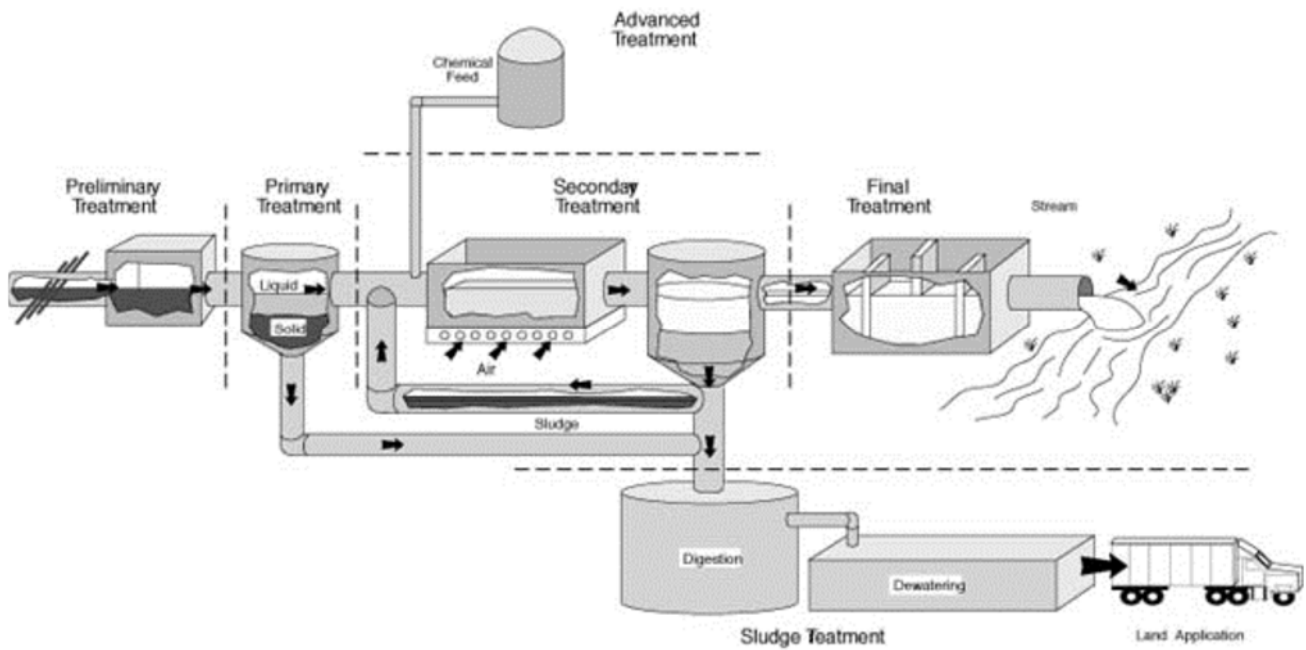


Introduction to Wastewater Treatment

Week # 2

Grades 1 - 4, Course #2201



Fleming Training Center
January 24-28, 2022



INTRODUCTION TO WASTEWATER TREATMENT WEEK#2

Course #2201

Grades 1-4

Monday

8:30 Review Exam 1
9:00 Activated Sludge Part II
11:00 Lunch
12:00 Activated Sludge Part II cont.
1:30 Intro to Wastewater Math

Tuesday

8:30 Intro to Lab and Sampling
10:00 Intro to QA/QC, Standard Methods, and SOPs
12:00 Lunch
1:00 Microscopic Exam

Wednesday

8:30 Sludge Thickening, Digestion, and Dewatering
11:00 Lunch
12:00 Safety
1:30 Cross Connections

Thursday

8:30 Plant Tour—Murfreesboro
11:00 Lunch
12:30 Pumps and Equipment Maintenance
2:00 NPDES

Friday

8:30 End of Course Review
11:00 Lunch
12:00 Exam

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State of Tennessee
Dept. of Environment & Conservation
Bureau of Environment
Fleming Training Center
2022 Blanton Dr.
Murfreesboro, TN 37129



Introduction to Wastewater Treatment

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Section 1

Activated Sludge

Part II

Activated Sludge: Part II

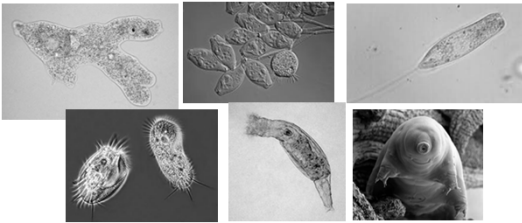
Introduction to Wastewater

Recap from Part I

- Activated Sludge:
 - Mixture of influent (primary clarifier effluent) and microorganisms; bacteria, protozoa, metazoan, insects, fungi
 - This fundamental process is the heart of activated sludge treatment
- Organics + O₂ + nutrients + inert matter → CO₂ + H₂O + new microorganisms + additional inert matter

Components of all Activated Sludge

1. Flocculent Slurry of Microorganisms Solids in the Aerator



2. Quiescent Settling of Solids in Clarifier
3. Return of Settled Solids to the Aerator (RAS)
4. Excess Solids Wasted from the System (WAS)

Activated Sludge Process Design

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

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)

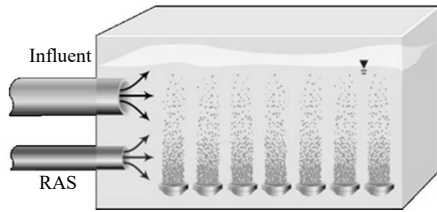
$$10 \text{ MG} * 2500 \text{ mg/L} * 8.34 = 208,500 \text{ lbs}$$



Aeration

Biological Reactors

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



Biological Reactors

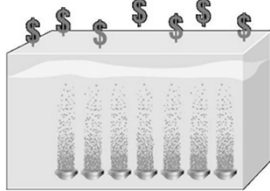
- In biological reactors, adequate DO must be maintained. The typical concentration range for most reactors is: "1.0 to 4.0 mg/L, with 2.0 being optimum"



Test Material, BUT, there is a lot of off/on Aeration.

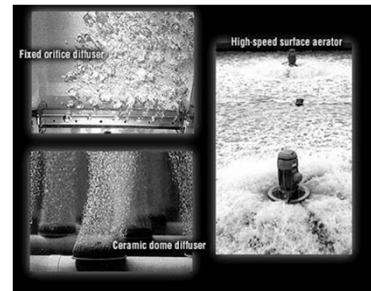
Over Aeration

- 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.



Aeration Systems

- Surface aerators
- Diffused aeration systems
- Hybrid devices



Pure Oxygen System

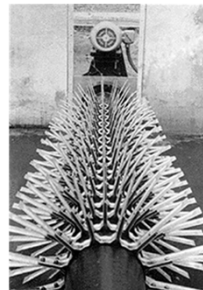
- Chattanooga, TN



- Pure oxygen systems use mechanical mixers similar to a complete mix plant but in a covered tank

Surface Aerators

Horizontal Rotor Surface Aerator



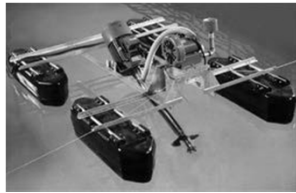
Surface Aerator



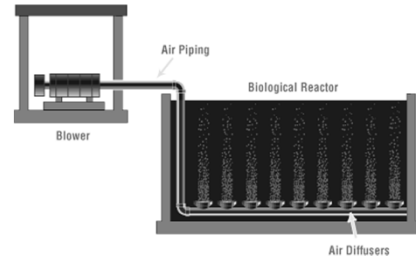
(Also subsurface mixers)

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

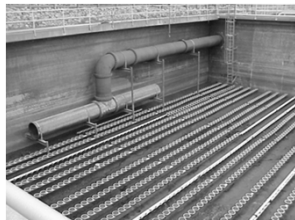


Diffused Aeration System



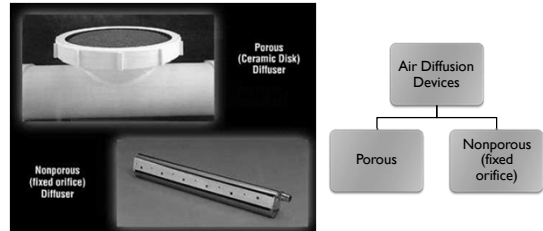
Diffused Aeration Systems

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



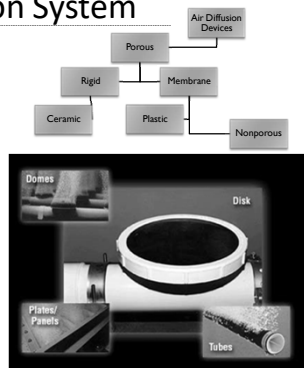
Diffused Aeration System

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

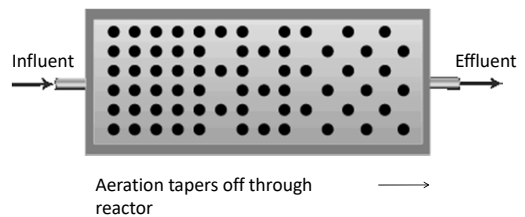


Diffused Aeration System

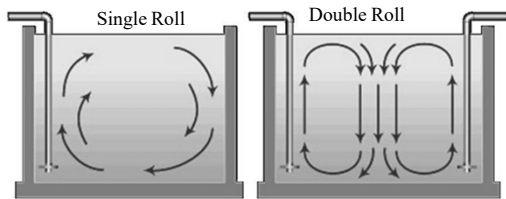
- Membrane Diffuser



Biological Reactor



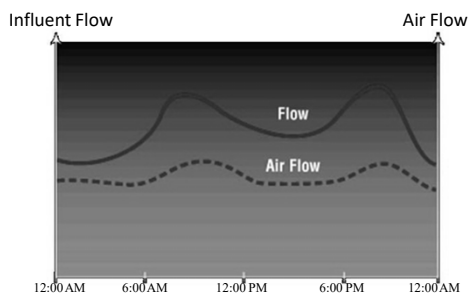
Mixing with Aeration, Conventional



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

Influent Flow vs. Air Flow



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- free oxygen is present, used for CBOD removal and a must for ammonia & phosphorus removal
- Anoxic- no free oxygen, but there is the combined 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

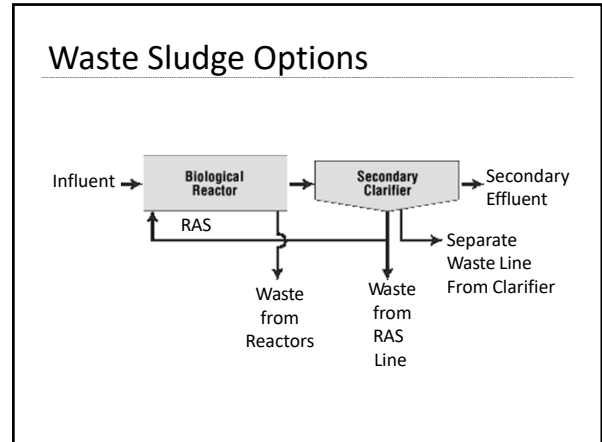


Return Activated Sludge Systems

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

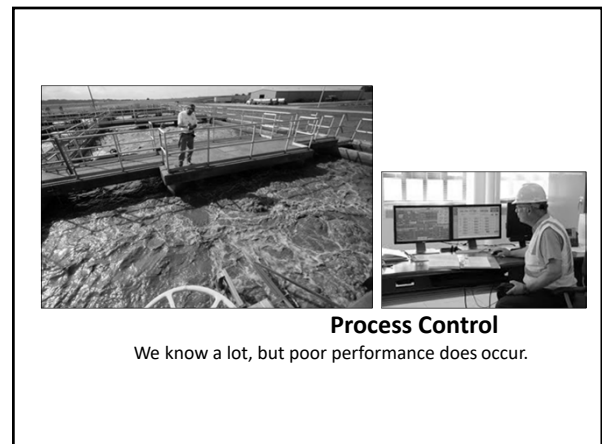




- ### Waste Sludge Options
- The amount of sludge wasted from the process affects all the following:
 - Growth rate of microorganisms
 - Oxygen consumption
 - Mixed liquor settleability
 - Nutrient quantities needed
 - Occurrence of foaming/frothing
 - Possibility of nitrification
 - Effluent quality

- ### 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.
 - If the WAS is not adequate, the microorganisms may starve, 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.

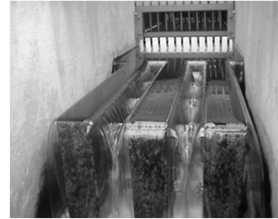


How do you control your activated sludge process?

- 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



Note supernatant clarity

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

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 clarifiers, selectors, filters, recycle, RAS, WAS, manual or automatic control and adjustment
 - Number of treatment units

Process Control Tools

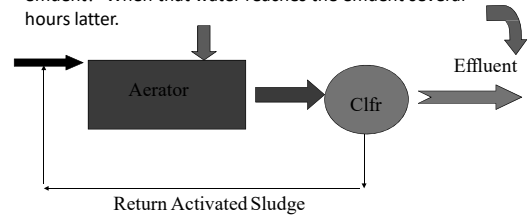
- Adjust
 - Air: flow(cfm), Dissolved Oxygen(DO), concentration (mg/L)
 - Return rate: percent of influent flow, gallons, lbs
 - Waste rate: gallons, lbs
 - Mode of operation: most powerful operator tool but most plants are not designed for this change
 - Number of units used: clarifiers, aeration tanks, 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

- Humansenses
 - Visual appearance, odors, noise, mixing
- Process tests
 - Flow, D.O., pH, temp., alkalinity, ORP, turbidity
 - Settrometer, 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 later.



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



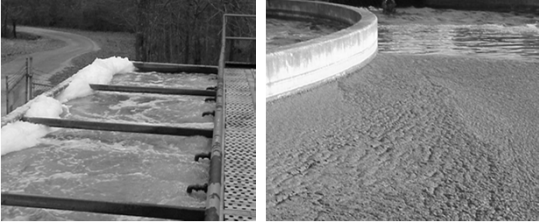
- Clarifier Issues
 - Bulking, sludge quality
 - Billowing, hydraulic overload
 - Clumping, denitrification
 - Ashing/Pin Floc, old sludge
 - Straggler Floc, young sludge

Observations- Influent/Effluent Odors, color, solids




Foam

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”

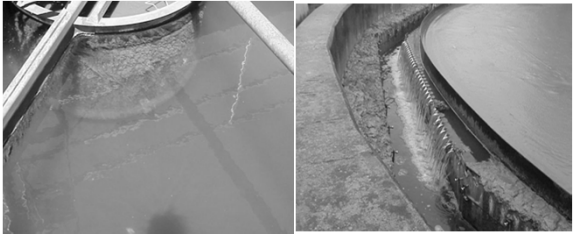
Observations, Clarifier

Rising clumps – Denitrification **Solids Wash Out- High Flow**



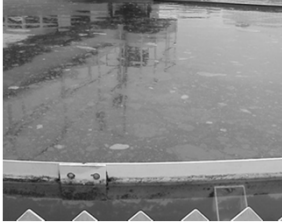
Observations, Clarifier

Bulking- Filaments **Filamentous Scum, M. Parvicella**



Observations, Clarifier

Ashing- Old Sludge
Age/Denitrification

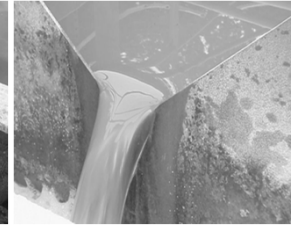
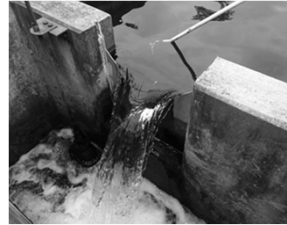


Pristine Effluent



Observations, Effluent

Clear Mountain Stream vs. Ooops, not a good day



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
 - Settrometer, Sludge judge
 - MLSS, MLVSS
 - Centrifuge spins, TSS meter
 - Oxygen Uptake Rate, Specific Oxygen Uptake Rate
 - Microscopic evaluation

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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
 - OUR/SOUR

Process Control, continued

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

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

Process Control, continued

- **Settlimeter**
 - Use settlometer not graduated cylinder
 - 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
- **Microbiological Exam**

Sludge Judge, Core Taker

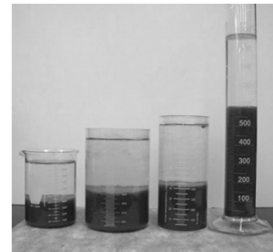


- **Sludge Judge**
 - Depth of blanket- from bottom of clarifier to the top of the sludge layer
 - Depth to blanket - from the top water level down to the top of the sludge blanket
 - Core Sample – the entire contents of the sampler into a bucket

Settlimeter- 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.

Settlimeter – Use a wide mouth container



- (Photo of a settlometer comparison)
- 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



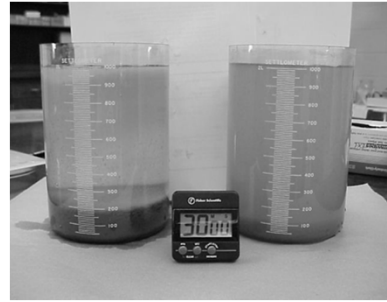
10 min.



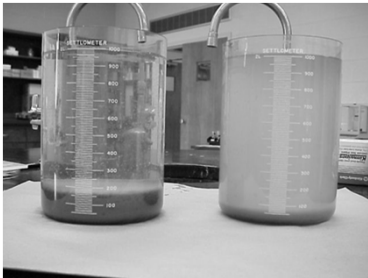
15 min.



30 min.



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

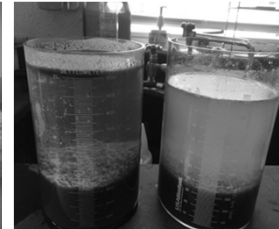


Clarity of Supernatant

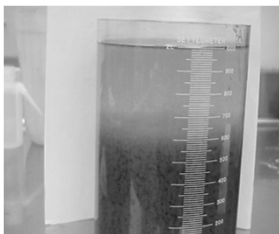
Clear Supernatant = Good effluent



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



Settler, Blanket Observation



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

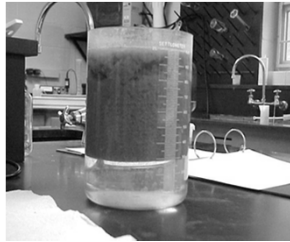
Settler, Blanket Observation



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



- Rise Time
 - 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



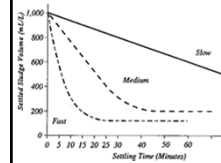
Settleometer



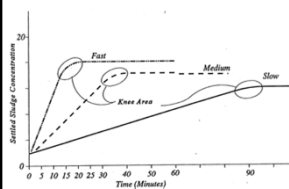
- Reasons for fast Settling
 - Old over oxidized sludge, with turbid supernatant
 - But wasting is not always the correct reaction, check color, history & SOUR

Settlometer, Graphs

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

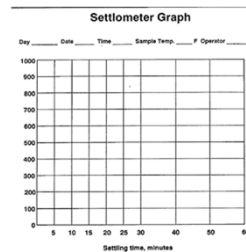


Settled Sludge Concentration



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

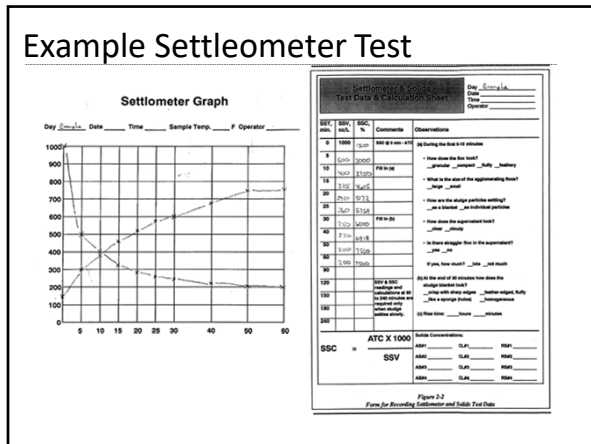
Settlometer, Worksheets



Settling Time (min)	Settled Sludge Volume (mL)	Settling Time (min)	Settled Sludge Volume (mL)	Comments	Observations
5		15			
10		20			
15		25			
20		30			
25		35			
30		40			
35		45			
40		50			
45		55			
50		60			

Day	Date	Time	Sample Temp	F	Operator
SSC = $\frac{ATC \times 1000}{SSV}$					
ATC	SSV	SSC	MLSS	MLSS	MLSS

Form for Recording Settlometer and Sludge Test Data

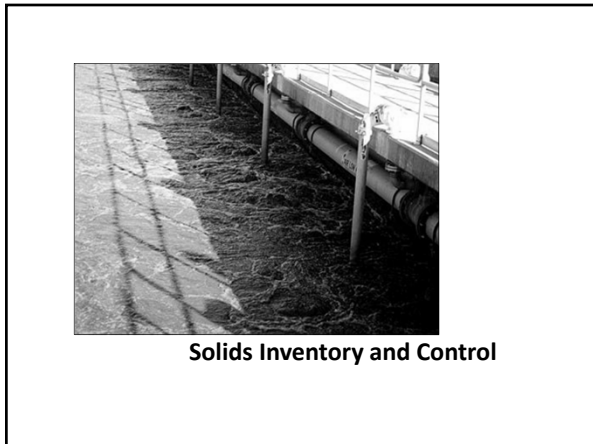


- ### More Process Control Tests – Biomass Solids
- MLSS, MLVSS - Mixed Liquor Suspended Solids and Mixed Liquor Volatile Suspended Solids - needed for Solids Inventory, Mean Cell Residence Time, and Food to Microorganism calculations.
 - Quicker Tests to do MCRT calculations.
 - Centrifuge- Al West
 - 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

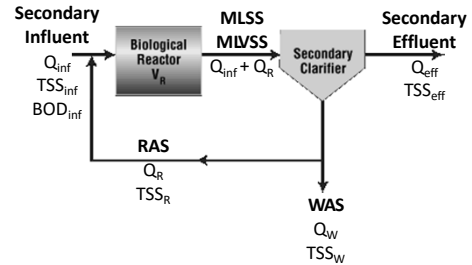
- ### Biomass Inventory/MCRT
- Inventory of Biomass should answer three questions:
 1. How much sludge is in the system?
 2. Where is it located?
 3. How long has it been there?
 - Experience has shown us certain mean cell residence times will give us certain effluent qualities.
 - With these answers,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



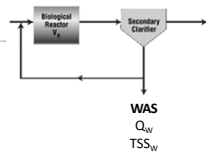
Solids

- 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

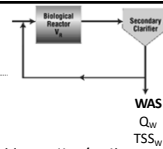


Solids Wasted



- $WAS, \text{ lbs/day} = (TSS_w, \text{ mg/L})(Q_w, \text{ MGD})(8.34 \text{ lbs/gal})$
- Example: WAS flow of 200 gpm with a WAS TSS of 8050 mg/L
- How many pounds of WAS are wasted per day?

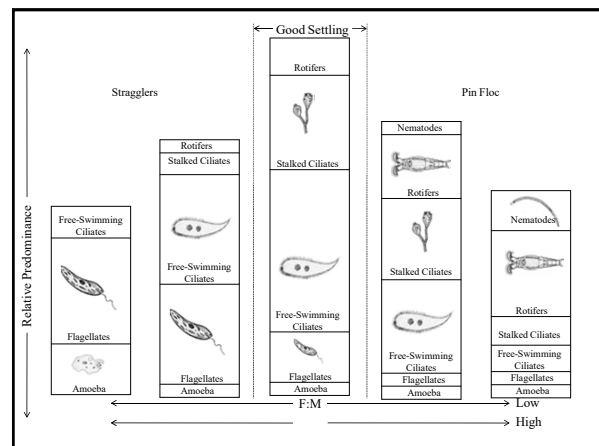
Solids Wasted



- $WAS, \text{ lbs/day} = (TSS_w, \text{ mg/L})(Q_w, \text{ MGD})(8.34 \text{ lbs/gal})$
- Example: WAS flow of 200 gpm with a WAS TSS of 8050 mg/L
 $(200 \text{ gpm})(1440 \text{ min/day}) / 1,000,000 = 0.288 \text{ MGD}$
- $WAS, \text{ lbs/day} = (8050 \text{ mg/L})(0.288 \text{ MGD})(8.34 \text{ lbs/gal})$
- = 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

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

F:M Ratio

- Target F:M values
 - Conventional = 0.2 – 0.5
 - Nitrifying less than or equal to 0.10
 - Extended Aeration = 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
 - 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

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

F:M Ratio

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 = Current M – $\frac{F(\text{Food})}{F:M \text{ Target}}$ (Microorganisms)

F:M Ratio

- Excess sludge to waste:
 - Excess M to waste = Current M – $\frac{F(\text{Food})}{F:M \text{ Target}}$ (Microorganisms)
- 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 = 1,300,000 gal MLSS = 2980 mg/L
 - Q_{inf} = 3,190,000 gpd %VS = 70%
 - BOD = 115 mg/L
- Desired F:M = 0.15 lbs BOD/day/lb MLVSS
- Desired MLVSS, lbs = $\frac{\text{BOD, lbs}}{\text{Desired F:M ratio}}$

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

$$= 20,396.86 \text{ lbs desired MLVSS}$$

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	MLSS = 2980 mg/L
Q _{inf} = 3,190,000 gpd	%VS = 70%
BOD = 115 mg/L	Desired MLVSS = 20,396.86 lbs
Desired F:M = 0.15	

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

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

$$= 29,138.37 \text{ lbs desired MLSS}$$

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 = 1,300,000gal	MLSS = 2980 mg/L
Q _{inf} = 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

$$= (2980 \text{ mg/L})(1.3 \text{ MG})(8.34) - 29,138.37 \text{ lbs}$$

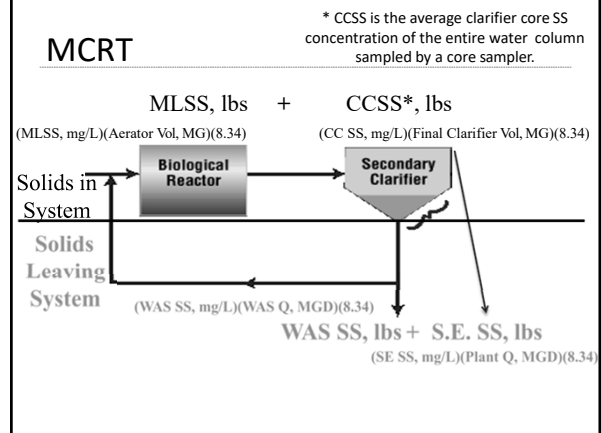
$$= 32,309.16 \text{ lbs} - 29,138.37 \text{ lbs}$$

$$= 3170.79 \text{ lbs to waste}$$

MCRT

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

MCRT



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

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

$$= 7.2 \text{ days}$$

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 CCSS sample:

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

$$\text{MCRT} = \frac{(2460 \text{ mg/L})(1.5 \text{ MG}) + (0.11 \text{ MG})(834)}{(8040 \text{ mg/L})(0.06 \text{ MGD})(8.34) + (18 \text{ mg/L})(3.4 \text{ MGD})(8.34)}$$

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

= 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



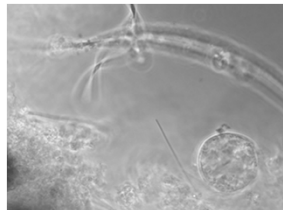
DO Requirements

- 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,

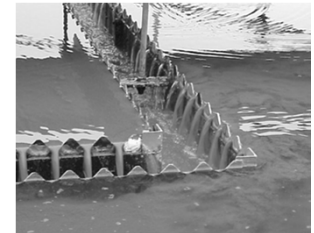


Trouble Shooting

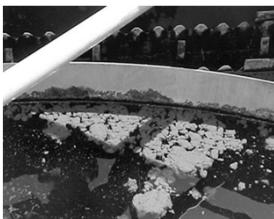
- Trouble shooting observations and data
 - Influent, In the Plant, Effluent
- Trouble shooting steps:
 - Check operational data and logs ~ three weeks of data
 - Talk to other operators and on other shifts
 - Review recent adjustments and tests
 - Check for variation in:
 - Influent
 - Plant equipment
 - 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 recommend:
 - SSV₆₀ blanket stays down
 - SSV₁₂₀ 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

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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

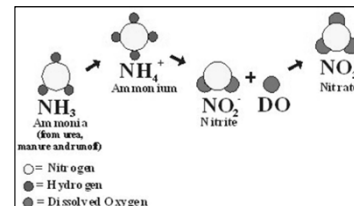
Temperature Impacts



- "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

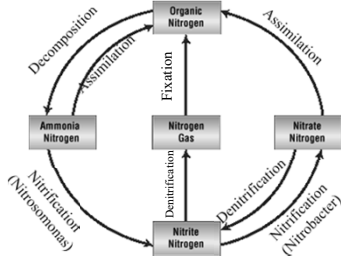


Nitrification

Biological conversion of ammonia to nitrate

Nitrogen Cycle

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



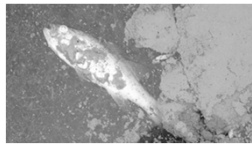
Nutrients

- ▶ 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



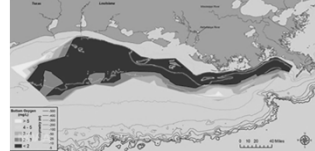
Eutrophication

- ▶ 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.

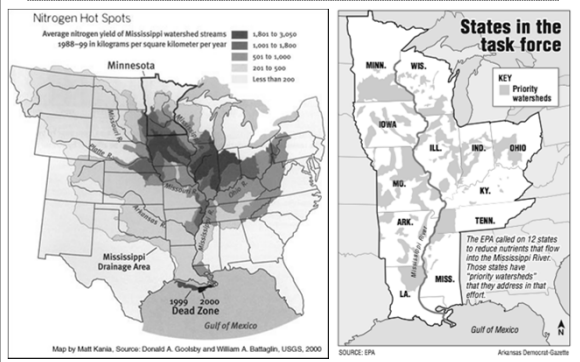


Eutrophication

- ▶ 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

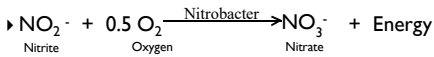
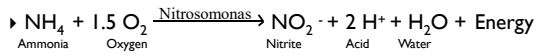


Reversal of Dead Zones

- ▶ 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.

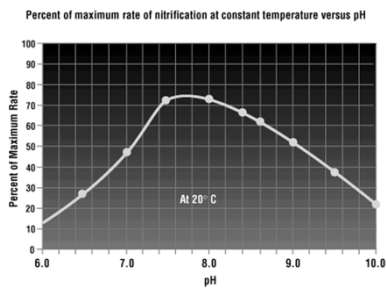


Process Modes for Nitrification

- ▶ 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.

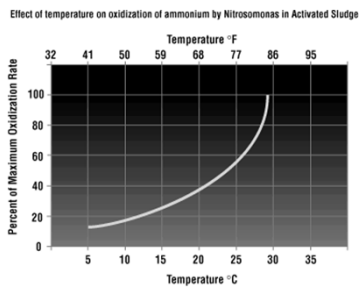


Alkalinity and pH

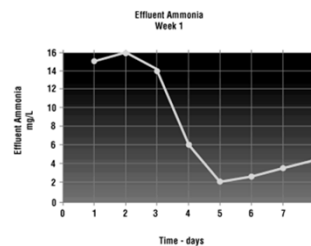
- ▶ Alkalinity is a key parameter in nitrifying systems.
- ▶ To adequately control pH
 - ▶ Calculate the total amount of alkalinity required
 - ▶ Calculate the additional alkalinity that must be added

Nitrification vs. Temperature

▶ The optimum wastewater temperature range is 60-95°F (15-35°C) for good nitrification.



Nitrification



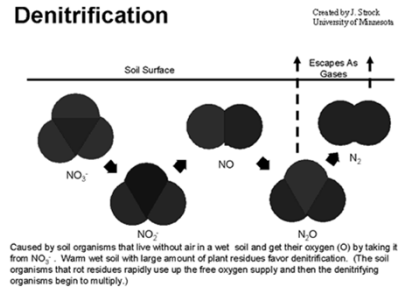
- ▶ Most processes will require an MCRT of 4 days or more to nitrify.
- ▶ If a plant has to recover from a toxic shock load, killing the nitrifying bacteria, allow several weeks for a full recovery

Nitrification

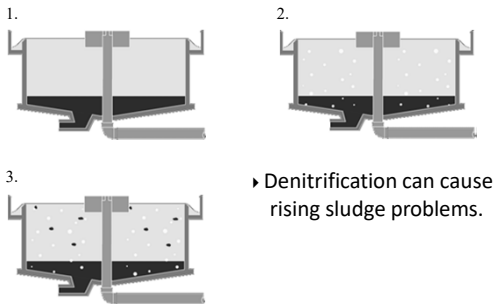
- Nitrification typically requires 25% more oxygen than conventional processes.
- Factors influencing nitrification:
 - DO
 - Alkalinity/pH
 - MCRT
 - Temperature

Denitrification

- Denitrification can occur unintentionally causing operational difficulties.



Denitrification

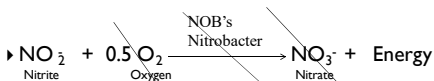
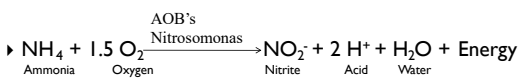


Denitrification

- 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.



- Nitrite, 5:1 chlorine demand! Loss of disinfection so elevated e-coli.
- 5parts chlorine: one part Nitrite

Any Questions?



Excerpt from *TN Design Criteria for Sewage Works***CHAPTER 8****Nitrification**8.1 General

8.1.1 Applications

8.1.2 Process Selection

8.2 Suspended Growth Systems

8.2.1 Single - Stage Activated Sludge

8.2.2 Two - Stage with Activated Sludge Nitrification

8.3 Fixed - Film Systems

8.3.1 Trickling Filters

8.3.2 Activated Biofilter (ABF) Process

8.3.3 Submerged Media

8.3.4 Rotating Biological Contactors

NITRIFICATION

8.1 General

8.1.1 Applications

Nitrogen exists in treated wastewater primarily in the form of ammonia which is oxidized to nitrate by bacteria. This process requires oxygen and can exert a significant oxygen demand on the receiving water.

Nitrification shall be considered when ammonia concentrations in the effluent would cause the receiving water to exceed the limitations established to prevent ammonia toxicity to aquatic life, or when the effluent ammonia quantity would cause the dissolved oxygen level of the receiving stream to deplete below allowable limits. The degree of treatment required will be determined by the NPDES permit limit.

8.1.2 Process Selection

Calculations shall be submitted to support the basis of design. The following factors should be considered in the evaluations of alternative nitrification processes:

- a. Ability to meet effluent requirements under all environmental conditions to be encountered, with special emphasis on temperature, pH, alkalinity, and dissolved oxygen.
- b. Cost (total present worth)
- c. Operational considerations, including process stability, flexibility, operator skill required, and compatibility with other plant processes.
- d. Land requirements.

8.2 Suspended Growth Systems

8.2.1 Single - Stage Activated Sludge

This section details the requirements for activated sludge systems designed to both remove carbonaceous matter and oxidize ammonia.

8.2.1.1 Process Design

Design must provide adequate solids retention time in the activated sludge system for sufficient growth of nitrifying bacteria. A safety factor of 2.5 or greater should be used to calculate the design mean cell residence time or sludge age. This safety factor must be large enough to provide enough operational flexibility to handle diurnal, peak, and transient loadings. The calculation of the solids retention time shall consider influent BOD, TSS, BOD₅/TKN (Total Kjeldahl Nitrogen) ratio and kinetic parameters. The kinetic parameters can be taken from the literature, similar installations, or pilot plant studies. The effect of temperature on the kinetics must be considered since nitrification will not proceed as rapidly during winter months.

8.2.1.2 Special Details

The following requirements are in addition to those included in Chapter 5, "Clarifiers", and Chapter 7, "Activated Sludge":

- a. Sufficient oxygen must be provided for both carbonaceous BOD oxidation and ammonia oxidation. Use 4.6 pounds O₂ per pound total Kjeldahl nitrogen to calculate the oxygen requirements for nitrification, in addition to the oxygen needed for BOD removal.
- b. Aeration basin design dissolved oxygen shall be greater than or equal to 2.0 mg/l.
- c. Diurnal peak mass flow rates of BOD and total Kjeldahl nitrogen must be considered in the aeration system design.
- d. The pH levels must be controlled within the range of 6.5 to 8.4. Nitrification is optimized in the upper portion of this range (7.9 to 8.4) but pH levels in the range of 7.6 to 7.8 are recommended since CO₂ produced will be released from the wastewater.
- e. Nitrification requires alkalinity, 7.1 pounds as CaCO₃ per pound NH₃-N oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.
- f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times. Flexibility should be provided to prevent denitrification in the clarifier from low D.O. levels in the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.2.2 Two-Stage with Activated Sludge Nitrification

This section details the requirements for systems in which carbonaceous BOD is removed in the first stage and ammonia is oxidized by activated sludge in the second stage. BOD removal in the first stage could be by activated sludge, trickling filters, or physical - chemical treatment.

8.2.2.1 Process Design

The first stage shall be designed using the requirements of the appropriate chapters, such as activated sludge, trickling filters, and clarifiers. To promote a sludge with good settling characteristics in the second stage clarifier, some carbonaceous BOD shall enter the second stage aeration basin. This allows a less conservative design of the first stage as long as total BOD removal is sufficient. The requirements for the process design of the second stage are the same as those presented previously for the single-stage nitrification system.

8.2.2.2 Special Details

The following details are in addition to those in Chapter 5, "Clarifiers," Chapter 6, "Fixed Film Reactors," and Chapter 7, "Activated Sludge."

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- e. Nitrification requires alkalinity, 7.1 pounds as $CaCO_3$ per pound NH_3-N oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.

- f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times.
Flexibility should be provided to prevent denitrification in the clarifier from low D.O. levels in the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.3 Fixed - Film Systems

8.3.1 Trickling Filters

8.3.1.1 Process Design

Recirculation is required to provide a constant hydraulic loading on the medium.

- a. Single - Stage

This section details the requirements for a trickling filter that is designed for both carbonaceous BOD removal and ammonia oxidation. Design shall be based on the organic loading expressed as pounds BOD per 1,000 cubic feet. The design loading rate shall be justified from literature, similar installations, or pilot plant data for a particular depth and type of filter medium. Design shall consider temperature effects on ammonia removal and organic loading rates, and any proposal to attain nitrification in a single-stage rock media trickling filter will be more closely scrutinized than with other types of media.

- b. Two - Stage

This section details the requirements of using a trickling filter for nitrification which is preceded by a trickling filter, activated sludge system, or physical - chemical treatment for carbonaceous BOD removal. Design must be based on either a surface area loading expressed as square feet per pound $\text{NH}_4\text{-N}$ oxidized per day or a volumetric loading expressed as pounds $\text{NH}_4\text{-N}$ per 1,000 cubic feet per day. Loading rates must be justified from literature, similar plants, or pilot plant data. The effects of temperature on loading rates and ammonia oxidation must be considered in the design.

8.3.1.2 Special Details

The following requirements are in addition to those in Chapter 5, "Clarifiers," and Chapter 6, "Fixed Film Reactors."

- a. Clarifiers will be required for second-stage trickling filters for nitrification.

- b. Higher specific surface area and lower void ratio media may be used for second-stage trickling filters providing nitrification.

8.3.2 Activated Biofilter (ABF) Process

8.3.2.1 Process Design

Process design shall be based on the literature, similar installations, or pilot plant data. The design shall consider the effects of temperature, pH, and aeration basins.

8.3.2.2 Special Details

- a. Sufficient oxygen must be provided for both carbonaceous BOD oxidation and ammonia oxidation. Use 4.6 pounds O_2 per pound total Kjeldahl nitrogen to calculate the oxygen requirement for nitrification, in addition to the oxygen needed for BOD removal.
- b. Aeration basin design dissolved oxygen shall be greater than or equal to 2.0 mg/l.
- c. Diurnal peak mass flow rates of BOD and total Kjeldahl nitrogen must be considered in the aeration system design.
- d. The pH levels must be controlled within the range of 6.5 to 8.4. Nitrification is optimized in the upper portion of this range (7.9 to 8.4) but pH levels in the range of 7.6 to 7.8 are recommended since CO_2 produced will be released from the wastewater.
- e. Nitrification requires alkalinity, 7.1 pounds as $CaCO_3$ per pound NH_3-N oxidized. The wastewater must be shown to have sufficient alkalinity or chemical treatment must be considered to provide adequate alkalinity.
- f. Clarifier and return sludge pumping must be designed with the capability to allow operation over a range of solids retention times. Flexibility should be provided to prevent denitrification in the clarifier from low D.O. in the sludge blanket. This could cause violations of other effluent limits (i.e., suspended solids).

8.3.3 Submerged Media

8.3.3.1 General

This section includes all designs for fixed-film reactors using stones, gravel, sand, anthracite coal, or plastic media or combinations thereof in which the medium is submerged and air or oxygen is used to maintain aerobic conditions.

Pilot plant testing or a similar full-scale installation with a minimum of 1 year of operation is required before consideration will be given to a submerged design. No design will be considered unless the following can be demonstrated:

- a. Reliable operation
- b. Ability to transfer sufficient oxygen
- c. Ability to handle peak flows without washout of medium
- d. Methods of separating suspended solids from effluent, removing waste sludge, and stabilization and dewatering of waste sludge
- e. Media resistance to plugging

8.3.3.2 Process Design

Data for design and calculations shall be submitted upon request to justify the basis of design.

8.3.4 Rotating Biological Contactors

8.3.4.1 Process Design

Process design shall be based on the surface area loading expressed as gallons per day per square foot. Design surface area loading shall consider the number of stages, temperature, BOD concentration entering and leaving each stage, and ammonia concentration entering and leaving each stage. Calculations shall be submitted upon request to justify the basis of design.

8.3.4.2 Special Details

The following requirements are in addition to those set forth in Chapter 5, "Clarifiers," and Chapter 6, "Fixed Film Reactors."

- a. Standard media (100,000 square feet per shaft or less) shall be used until influent BOD concentration is less than manufacturer's recommendation for high-density media (150,000 square feet per shaft or more). High-density media may be used for influent BOD concentrations less than manufacturer's recommendation for high-density media.
- b. Clarifiers will be required following rotating biological contactors that follow a secondary process.

Activated Sludge Vocabulary – Part 2

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.

Word Bank:

Nitrification

Sludge age

Mean Cell Residence Time (MCRT)

Diffuser

Biochemical Oxygen Demand (BOD)

Mixed Liquor Volatile Suspended Solids (MLVSS)

Sludge Volume Index (SVI)

Coagulation

Denitrification

F:M ratio (or F/M ratio)

Supernatant

Mixed Liquor Suspended Solids (MLSS)

Bulking

Rising Sludge

Activated Sludge Review Questions – Part 2

1. The amount of time that microorganisms spend in the activated sludge process before they are wasted is called the _____.
 - a. Total residual chlorine
 - b. MLSS
 - c. MCRT
 - d. WAS

2. Conventional activated sludge processes are designed to remove soluble carbonaceous BOD from wastewater.
 - a. True
 - b. False

3. Return activated sludge is typically pumped back to which of the following?
 - a. The headworks
 - b. Primary clarifier
 - c. Influent side of a biological reactor
 - d. Effluent side of a biological reactor

4. The measure of biochemical or organic strength of wastewater is referred to as _____.
 - a. Total residual chlorine
 - b. TSS
 - c. BOD
 - d. F:M

5. The mean cell residence time for most conventional activated sludge processes is typically _____.
 - a. 5 – 15 days
 - b. 5 – 15 hours
 - c. 20 – 30 days
 - d. 20 – 30 hours

6. Billowy, white foam is usually a sign of old, over-oxidized sludge in the aeration basin. True or False?
 - a. True
 - b. False

7. Nitrification is a two-step process. At the end of the second and final step, to what has ammonia been oxidized?
 - a. Nitrite
 - b. Nitrate
 - c. Ammonium hydroxide
 - d. Nitric acid

8. Which of the following is one of the most important process control parameters used to maintain the optimum amount of solids to remove BOD from influent wastewater, and which incorporates both the amount of BOD and the quantity of microorganisms in the water?
 - a. MCRT
 - b. F:M Ratio
 - c. Biomass Inventory
 - d. Settleometer

9. The settleometer “rise time” is the time it takes for the sludge blanket to float to the surface. What is the most likely cause of a rising sludge blanket in the settleometer?
 - a. Gasification
 - b. Denitrification
 - c. Bulking
 - d. Excessive aeration

10. Off/On aeration is increasingly being used for nutrient removal. True or False?
 - a. True
 - b. False

11. The amount of sludge wasted (WAS) from the activated sludge process affects all of the following *except*:
 - a. Growth rate of microorganisms
 - b. Mixed liquor settleability
 - c. Effluent quality
 - d. Influent quality

12. Which of the following statements is *not* true?
 - a. Increasing the wasting rate will decrease the MLSS concentration
 - b. Increasing the wasting rate will decrease the MCRT
 - c. Increasing the wasting rate will decrease the F:M ratio
 - d. Decreasing the wasting rate will increase the MLSS concentration

13. Thick, scummy, dark tan foam and a “hog pen” odor in the aeration basin are signs that the activated sludge process is working effectively. True or False?
 - a. True
 - b. False

14. In the winter, activated sludge systems commonly require lower DO levels and higher MLSS concentrations due to the decreased temperature. True or False?
 - a. True
 - b. False


15. Which of the following statements is *not* true regarding nitrification in an activated sludge system?
 - a. A pH of 6.5 – 7.5 is considered optimal
 - b. Alkalinity is a key parameter
 - c. The optimum wastewater temperature range is 60 – 95°F (15 – 35°C)
 - d. Most processes require an MCRT of 4 days or more to nitrify

Section 2

Introduction to

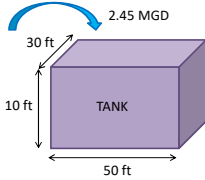
Wastewater Math

Introduction to Sedimentation Math



Detention Time

Example 1
The flow to a sedimentation tank 50 ft long, 30 ft wide, and 10 ft deep is 2.45 MGD. What is the detention time in the tank, in hours?



TANK

Tank Volume:
Volume (ft³) = (L,ft)(W,ft)(d,ft)
Vol. = (50ft)(30ft)(10ft) = 15,000 ft³
Vol. = (15,000 ft³)(7.48 gal/ft³) = 112,200 gal

Flow Rate:
Flow = MGD → gph
= (2.45 MG/day)(1 day/24 hrs)(1000000 gal/1 MG)
= 102083.3333 gph

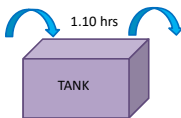
Detention Time, hrs = $\frac{\text{Volume of Tank, gal}}{\text{Flow, gph}}$

Detention Time

Detention Time, hrs = $\frac{\text{Volume of Tank, gal}}{\text{Flow Rate, gph}}$

$$= \frac{112200 \text{ gal}}{102083.3333 \text{ gph}}$$


$$= 1.10 \text{ hrs}$$

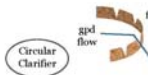


TANK

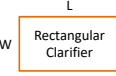
Weir Overflow Rate

- Weir overflow rate (WOR) is a measure of the gallons per day flowing over each foot of weir






- If you are not given a total weir length in a problem then you must calculate it
- The shape of the clarifier will need to be known to calculate either a perimeter or a circumference



Rectangular Clarifier

Perimeter = 2(L) + 2(W)



Circular Clarifier

Circumference = 3.14(Diameter)

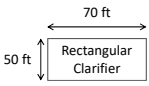
Weir Overflow Rate

$$\text{Weir Overflow Rate, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$$

Weir Overflow Rate is commonly expressed in gpd/ft

Weir Overflow Rate

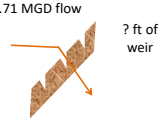
Example 2
A rectangular clarifier has a length of 70 ft and a width of 50 ft. What is the weir overflow rate in gpd/ft when the flow is 2.71 MGD?



Rectangular Clarifier

Flow Rate:
Flow = MGD → gpd
= (2.71 MG/Day)(1000000 gal/1 MG)
= 2710000 gpd

Weir Length:
Perimeter = 2(L) + 2(W)
= 2(70ft) + 2(50ft) = 140ft + 100ft
= 240ft



? ft of weir

Weir Overflow Rate, gpd/ft = $\frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$


Weir Overflow Rate

Example 2
 A rectangular clarifier has a length of 70 ft and a width of 50 ft. What is the weir overflow rate in gpd/ft when the flow is 2.71 MGD?

Rectangular Clarifier

2.71 MGD flow

240 ft of weir



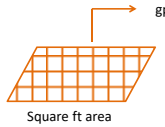
$$\text{Weir Overflow Rate, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$$

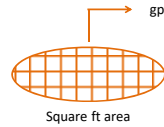
$$= \frac{2,710,000 \text{ gpd}}{240 \text{ ft}}$$

$$= 11291.67 \text{ gpd/ft}$$

Surface Overflow Rate

$$\text{Surface Overflow Rate, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Area, ft}^2}$$



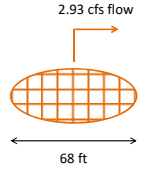


Surface Overflow Rate

Example 1
 A circular clarifier has a diameter of 68 ft. What is the surface overflow rate in gpd/ft² if the primary effluent flow is 2.93 cfs?

2.93 cfs flow

Flow Rate:
 Flow = cfs → gpd
 = (2.93 ft³/sec)(60 sec/1 min)(1440 min/1 day)(7.48 gal/ft³)
 = 1893576.96 gpd



Area:
 Area = (0.785)(D²)
 = (0.785)(68 ft)(68 ft)
 = 3629.84 ft²

$$\text{Surface Overflow Rate, gpd/ft}^2 = \frac{\text{Flow, gpd}}{\text{Area, ft}^2}$$

Surface Overflow Rate

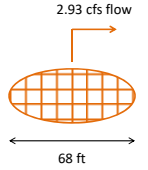
Example 1
 A circular clarifier has a diameter of 68 ft. What is the surface overflow rate in gpd/ft² if the primary effluent flow is 2.93 cfs?

2.93 cfs flow

Surface Overflow Rate, gpd/ft² = $\frac{\text{Flow, gpd}}{\text{Area, ft}^2}$

$$= \frac{1,893,576.96 \text{ gpd}}{3629.84 \text{ ft}^2}$$

$$= 521.67 \text{ gpd/ft}^2$$



Wastewater Sedimentation Math

1. The flow to a circular clarifier is 3,940,000 gpd. If the clarifier is 75 ft in diameter and 12 feet deep, what is the clarifier detention time in hours?
2. A circular clarifier has a diameter of 50 feet. If the primary clarifier influent flow is 2,260,000 gpd, what is the surface overflow rate in gpd/sq.ft.?
3. A rectangular clarifier has a total of 210 ft. of weir. What is the weir overflow rate in gpd/ft when the flow 3,728,000 gpd?
4. The flow to a secondary clarifier is 5.1 MGD. If the influent BOD concentration is 216 mg/L and the effluent BOD concentration is 103, how many lbs/day BOD are removed daily?

Introduction to Chemical Dosage Math

Feed Rate, Mass, Loading Rate
aka "Pounds Formulas"

Chemical Application

- * Different chemicals are added to locations of wastewater system to maintain the system
- * The amount of chemicals needed is determined by dosage level desired and the purity of the chemicals used
 - * If the purity of the chemical is not mentioned then it is assumed to be 100% available or 1.0 in decimal form for use in formulas

Chemical Application

- * There are three possible formulas to calculate dosage rates:
 - * Feed Rate, lbs/day
 - * Mass, lbs
 - * Loading Rate, lbs/day
- * All three calculate pounds, but feed rate is the only one that factors in the percent purity of the chemical being applied

Chemical Application

- * Chlorine application is achieved by applying one of two types of hypochlorite
 - * Sodium hypochlorite
 - * NaOCl
 - * Bleach
 - * 5-15% concentration
 - * Calcium hypochlorite
 - * Ca(OCl)₂
 - * High test hypochlorite (HTH)
 - * 65% concentration
- Different percent purity

Feed Rate

- * When dosing a volume of wastewater, a measured amount of chemical is required

$$\text{Feed rate, } \frac{\text{lb}}{\text{day}} = \frac{(\text{dose})(\text{flow})(8.34 \text{ lb/gal})}{\% \text{ purity}}$$

Example 1

- * A collections system wants to feed calcium hypochlorite with a purity of 65%. The required dose is 8 mg/L for a flow of 3 MGD. How many pounds per day of disinfectant must be fed?

$$\begin{aligned} \text{Feed rate, } \frac{\text{lb}}{\text{day}} &= \frac{(\text{dose})(\text{flow})(8.34 \text{ lb/gal})}{\% \text{ purity}} \\ \frac{\text{lb}}{\text{day}} &= \frac{(8 \text{ mg/L})(3 \text{ MGD})(8.34 \text{ lb/gal})}{0.65} \\ \frac{\text{lb}}{\text{day}} &= 307.94 \text{ lb/day} \end{aligned}$$

Mass and Loading Rate

- * Same as feed rate without the % purity
- * If percent purity of a chemical is not provided, it assumed to be 100% pure

$$\text{Mass, lbs} = (\text{volume, MGD})(\text{conc., } \frac{\text{mg}}{\text{L}}) \left(8.34 \frac{\text{lb}}{\text{gal}}\right)$$

$$\text{Loading rate, } \frac{\text{lb}}{\text{day}} = (\text{flow, MGD})(\text{conc., } \frac{\text{mg}}{\text{L}}) \left(8.34 \frac{\text{lb}}{\text{gal}}\right)$$

Dose

- * To determine dose, we will need to rearrange the Feed Rate or Mass formula

$$\frac{\text{lb}}{\text{day}} = \frac{(\text{dose})(\text{flow})(8.34)}{\% \text{ purity}}$$

$$(\% \text{ purity}) \left(\frac{\text{lb}}{\text{day}}\right) = (\text{dose})(\text{flow})(8.34)$$

$$\frac{(\% \text{ purity}) \left(\frac{\text{lb}}{\text{day}}\right)}{(\text{flow})(8.34)} = \text{dose}$$

Example 2

- * A collection system feeds 65 lb/day of 65% calcium hypochlorite. If the flow is 1.6 MGD, what dose, in mg/L, of disinfectant will result?

$$\text{Dose} = \frac{(\% \text{ purity}) \left(\frac{\text{lb}}{\text{day}}\right)}{(\text{flow})(8.34 \frac{\text{lb}}{\text{gal}})}$$

$$\text{Dose} = \frac{(0.65)(65 \frac{\text{lb}}{\text{day}})}{(1.6 \text{ MGD})(8.34 \frac{\text{lb}}{\text{gal}})}$$

$$\text{dose} = 3.17 \frac{\text{mg}}{\text{L}}$$

Two Normal equation

- * $N = \text{normality}$
- * Can be replaced with concentration
- * $V = \text{volume or flow}$

$$N_1 \times V_1 = N_2 \times V_2$$

OR

$$C_1 \times V_1 = C_2 \times V_2$$

Example 3

- * An operator needs to make 10 gallons of a bleach dilution with a concentration 25 mg/L. The bleach on hand has a concentration of 100 mg/L. How many gallons of the concentrate must be used to achieve the dilution?

$$C_1 \times V_1 = C_2 \times V_2$$

$$(25 \text{ mg/L})(10 \text{ gal}) = (100 \text{ mg/L})(V)$$

$$\frac{(25 \text{ mg/L})(10 \text{ gal})}{100 \text{ mg/L}} = V$$

$$2.5 \text{ gal} = V$$

Chemical Dosage/Wastewater Disinfection Math

1. Calculate the chlorine feed rate in lbs/day for a chlorine dosage of 6 mg/L at a flow of 100,000 gal/day.
2. Determine the chlorinator setting (lbs/day) needed to treat a flow of 8.2 MGD with a chlorine dose of 4.5 mg/L.
3. What is the chlorinator feed rate in lbs/day if the chlorine dosage is 8 mg/L and the flow is 500,000 gal/day?
4. A total chlorine dose of 6.8 mg/L is required to treat a particular wastewater. If the flow is 1.3 MGD and the calcium hypochlorite has 65% available chlorine, calculate the lbs/day of hypochlorite required.
5. To neutralize a sour digester, one pound of lime is added for every pound of volatile acids in the digester sludge. If the digester contains 195,000 gallons of sludge with a volatile acid level of 2,100 mg/L, how many pounds of lime should be added?

6. The chlorinator is set to feed 26.5 lbs of chlorine per 24 hours for a plant flow of 1.2 MGD. Calculate the chlorine residual for a chlorine demand of 1.85 mg/L.

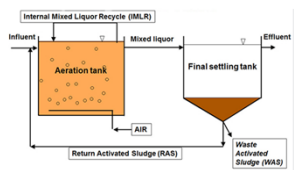
7. What is the demand of your wastewater if you are feeding 133 lbs/day of chlorine and the flowrate is 2 MGD? The chlorine residual after a 30 minutes contact time is 1.5 mg/L.

8. A chlorine contact tank with a volume of 20,000 gallons receives an average flow of 1000gal/min. If the minimum contact time is 15 minutes, is this tank above or below the minimum time?

9. How many pounds of HTH (65% available chlorine) are required to make 35 gallons of 5% available chlorine bleach? (Assume bleach is 8.34 lbs/gal.)

10. How many pounds of 65% HTH are used to make 10 gallons of 5% solution?

Introduction to Activated Sludge Math



Loading Rate (“Pounds”) Formula

- BOD, COD, or SS Loading
- The BOD concentration of the wastewater entering an aerator is 215 mg/L. If the flow to the aerator is 1,440,000 gpd, what is the lbs/day of BOD loading?
- $(\text{Concentration, mg/L})(\text{Flow, MGD})(8.34 \text{ lbs/gal}) = \text{lbs/day}$
- $(215 \text{ mg/L})(1.44 \text{ MGD})(8.34) = 2582 \text{ lbs/day}$

Pounds

Mass (“Pounds”) Formula

- Solids Inventory in the Aeration Tank
- If the MLSS concentration is 1100 mg/L, and the aeration tank has a volume of 525,000 gallons, how many pounds of suspended solids are in the aeration tank?
- $(\text{Concentration, mg/L})(\text{Volume, MG})(8.34 \text{ lb/gal}) = \text{Mass, lbs}$
- $(1100 \text{ mg/L})(0.525 \text{ MG})(8.34 \text{ lb/gal}) = 4816 \text{ lbs MLSS}$

Pounds

Wasting Rate

- An operator calculates that 15,000 lbs MLSS are desired in the aeration tank. If the aeration tank vol is 800,000 gal and the MLSS conc is 2720 mg/L, how many lbs MLSS should be wasted?
- $(\text{MLSS, mg/L})(\text{Aer.Vol, MG})(8.34) = \text{lbs MLSS}$
- $(2720 \text{ mg/L})(0.8 \text{ MG})(8.34) = 18,148 \text{ lbs MLSS}$
- Now compare actual versus desired lbs MLSS:
18,148 lbs actual – 15,000 lbs desired =
3148 lbs MLSS to be wasted

F:M Ratio

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

Expanded formula:

- $$\text{F:M Ratio} = \frac{(\text{BOD, mg/L})(\text{Flow, MGD})(8.34 \text{ lbs/gal})}{(\text{MLVSS, mg/L})(\text{Aer Vol, MG})(8.34 \text{ lbs/gal})}$$

- Note: The expanded formula is not included in the ABC formula book.

F:M Ratio

- An activated sludge aeration tank receives a primary effluent flow of 2.42 MGD with a BOD of 170 mg/L. The MLVSS is 1980 mg/L and the aeration tank volume is 350,000 gallons. What is the current F:M ratio?
- $$\text{F:M Ratio} = \frac{(\text{BOD, mg/L})(\text{Flow, MGD})(8.34 \text{ lbs/gal})}{(\text{MLVSS, mg/L})(\text{Aer Vol, MG})(8.34 \text{ lbs/gal})}$$
- $$\text{F:M Ratio} = \frac{(170 \text{ mg/L})(2.42 \text{ MGD})(8.34 \text{ lbs/gal})}{(1980 \text{ mg/L})(0.35 \text{ MG})(8.34 \text{ lbs/gal})}$$
- F:M Ratio = 0.59

Mean Cell Residence Time

- Also called Solids Retention Time (SRT)
- Represents the average length of time an activated biosolids particle stays in the activated biosolids system.
- MCRT/SRT is based on suspended solids leaving the system
- When calculating the lbs MLSS, both the aeration tank and final clarifier volumes are normally used.
- Basically 4 *Pounds Formulas*

Mean Cell Residence Time

- In ABC Formula Book:

$$\text{MCRT or SRT, days} = \frac{(\text{Aeration Tank TSS,lb}) + (\text{Clarifier TSS,lb})}{(\text{TSS Wasted,lb/day}) + (\text{Effluent TSS,lb/day})}$$

$$\text{MCRT, days} = \frac{\text{Solids in the System}}{\text{Solids Leaving the System}}$$

$$\text{MCRT, days} = \frac{\left(\frac{\text{MLSS, mg}}{\text{L}}\right)(\text{Aer.Vol,MG})\left(8.34\frac{\text{lbs}}{\text{gal}}\right) + \left(\frac{\text{CCSS, mg}}{\text{L}}\right)(\text{Fin.Clar.Vol,MG})\left(8.34\frac{\text{lbs}}{\text{gal}}\right)}{\left(\frac{\text{WAS SS, mg}}{\text{L}}\right)(\text{WAS,MGD})\left(8.34\frac{\text{lbs}}{\text{gal}}\right) + \left(\frac{\text{S.E.SS, mg}}{\text{L}}\right)(\text{Plant Flow,MGD})\left(8.34\frac{\text{lbs}}{\text{gal}}\right)}$$

Note: CCSS = Average Clarifier Core SS Concentration

Mean Cell Residence Time

- Determine the MCRT given the following data:
 - Aer. Vol. = 1.5 MG
 - Fin. Clar. Vol. = 0.11 MG
 - P.E. Flow = 3.4 MG
 - WAS Pumping Rate = 60,000 gpd
 - MLSS = 2460 mg/L
 - WAS SS = 8040 mg/L
 - S.E. SS = 18 mg/L
 - CCSS = 1850 mg/L

Mean Cell Residence Time

- Determine the MCRT given the following data:
 - Aer. Vol. = 1.5 MG
 - Fin. Clar. Vol. = 0.11 MG
 - P.E. Flow = 3.4 MG
 - WAS Pumping Rate = 60,000 gpd
 - MLSS = 2460 mg/L
 - WAS SS = 8040 mg/L
 - S.E. SS = 18 mg/L
 - CCSS = 1850 mg/L

$$\text{MCRT} = \frac{\left(\frac{\text{MLSS, mg}}{\text{L}}\right)(\text{Aer.Vol,MG})\left(8.34\frac{\text{lbs}}{\text{gal}}\right) + \left(\frac{\text{CCSS, mg}}{\text{L}}\right)(\text{Fin.Clar.Vol,MG})\left(8.34\frac{\text{lbs}}{\text{gal}}\right)}{\left(\frac{\text{WAS SS, mg}}{\text{L}}\right)(\text{WAS,MGD})\left(8.34\frac{\text{lbs}}{\text{gal}}\right) + \left(\frac{\text{S.E.SS, mg}}{\text{L}}\right)(\text{Plant Flow,MGD})\left(8.34\frac{\text{lbs}}{\text{gal}}\right)}$$

$$\text{MCRT} = \frac{(2460 \text{ mg/L})(1.5 \text{ MG})\left(8.34\frac{\text{lbs}}{\text{gal}}\right) + (1850 \text{ mg/L})(0.11 \text{ MG})\left(8.34\frac{\text{lbs}}{\text{gal}}\right)}{(8040 \text{ mg/L})(.06 \text{ MGD})\left(8.34\frac{\text{lbs}}{\text{gal}}\right) + (18 \text{ mg/L})(3.4 \text{ MGD})\left(8.34\frac{\text{lbs}}{\text{gal}}\right)}$$

$$\text{MCRT} = \frac{30,775 \text{ lbs MLSS} + 1697 \text{ lbs CCSS}}{4023 \text{ lbs/daySS} + 510 \text{ lbs/daySS}}$$

MCRT = 7.2 days

Activated Sludge Math

1. The flow to an aeration tank is 750,000 gpd. If the BOD content of the wastewater entering the aeration tank is 230 mg/L, how many pounds of BOD are applied to the aeration tank daily?
2. An aeration basin is 130 ft long, 50 ft wide, and holds wastewater to a depth of 15 ft. if the aeration basin has an MLSS concentration of 2300 mg/L, how many pounds of MLSS are under aeration?
3. The WAS flow at a 5 MGD capacity plant is 300 gpm, and the WAS TSS is 7500 mg/L. How many pounds of WAS are wasted each day?
4. An activated sludge aeration tank receives a primary effluent flow of 1.5 MGD with a BOD concentration of 175 mg/L. The mixed liquor volatile suspended solids is 2100 mg/L and the aeration tank volume is 400,000 gallons. What is the current F:M ratio?

5. Determine the MCRT given the following information:

Aeration tank = 1,500,000 gallons

Final clarifier = 100,000 gallons

Flow = 4,000,000 gallons per day

WAS pump rate = 71,000 gallons per day

MLSS = 2400 mg/L

S.E. SS = 19 mg/L


CCSS = 1850 mg/L

WAS = 6700 mg/L

Section 3

Introduction to Sampling and Wastewater Laboratory

Introduction to Sampling and Wastewater Laboratory




TN Department of Environment & Conservation

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Why Sample?

- Meet compliance requirements
- Process control
- Ensure public safety and protect the environment

Sampling and Analysis Plan



- Good sampling practices + Competent sample analysis = Quality data for process control



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Sampling Plan

- There are many questions to consider before actually collecting a sample
- The answer to these questions will help you put together a sampling plan


1. Why is the sample being collected?
2. What tests need to be run on the sample?
3. Where is the sample going to be collected from?
4. How is the sample going to be collected?
5. When does the sample need to be collected/analyzed?
6. Who is going to analyze the sample?

Reliable sampling data are obtained by collecting samples:

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




Automated Samplers



Manual Sampling Device

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Automatic Sampling Device




- Timesaver
- Composite: set to collect specific volumes over a period of time
- Refrigerated and thoroughly mixed
- Clean intake line regularly to prevent growth of bacteria or algae

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Preventative Sampler Maintenance

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




Samplers


- Sampling devices may include weighted buckets, beakers, or other containers attached to a rod or chain.

Simple Sampling Devices

Telescoping rod sampler with detachable plastic container.



Solid one-piece plastic pole with container.



Can you clean it?!

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Samplers – Approved or Not?



Considerations

- Collection
- Volume
- Storage and preservation
- Sample points
- Sampling frequency
- Include Sampling Plan in SOP

40 CFR 136 Table II

NPDES permit

Sample Types

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

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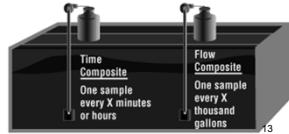
Grab Samples

- 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

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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



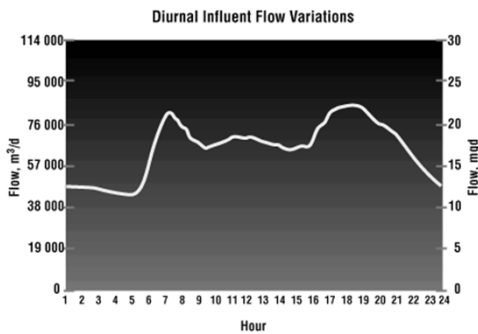
NPDES Permit - Section 1.2.1

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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 change:

- 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.
- Samples for *E. coli* can be collected at any point between disinfection and the actual discharge.
- The dissolved oxygen can drop in the outfall line; therefore, D.O. 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, dissolved oxygen must be measured after this step and as close to the end of the outfall line as possible.
- Total suspended solids and settleable solids can be collected at any point after the final clarifier.
- Biomonitoring tests (if required) shall be conducted on final effluent.

Flow Variations



Example of Flow-Proportioned Sample Collection

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

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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

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Composite Sample

- Refrigerated and thoroughly mixed
- Measure flow and sample volume
- BOD, total N, settleable solids
- NEVER use composite sample for bacterial analysis

Sampling Guidelines

- Representative
 - Proper container
 - Do not contaminate the lid
 - Preservative/ dechlorinating agent
 - 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

Sampling Guidelines

- Hold by base
 - Turn into current
 - Avoid air bubbles
- Label containers with:
 1. Sample Location
 2. Date and Time of collection
 3. Name of collector
 4. Any other pertinent information

Sample Labeling

Location: 196 E. Main Street, Springfield, TN

Date / Time: 9/22/2018 @ 8:15 AM

Sampled by: BS (Bob Smith)

Comments: grab sample
pH < 2 with H₂SO₄ and stored at 4°C

Chain of Custody

- Written record to trace possession and handling of samples from collection to reporting
 - In case of legal litigation
- Used when sending out samples to contract lab
- Should identify who handled sample from collection to transport to storage to analysis to destruction
 - Including dates, times, initials, addresses, etc.

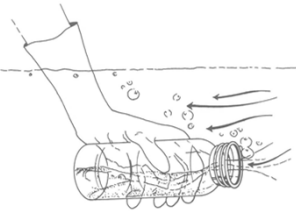
Sample Volume

- Depends on test procedure
- Headspace for mixing
- Preservative
- QA/QC comparisons

Sampling Point Selection

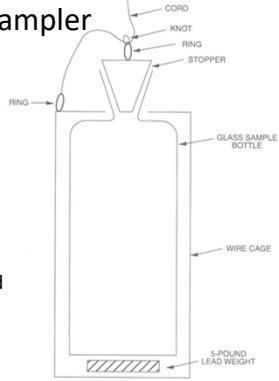
- Flow well mixed
- Exclude large particles (>1/4 inch)
- Exclude floating matter
- Readily accessible & in safe area

Subsurface Sampling

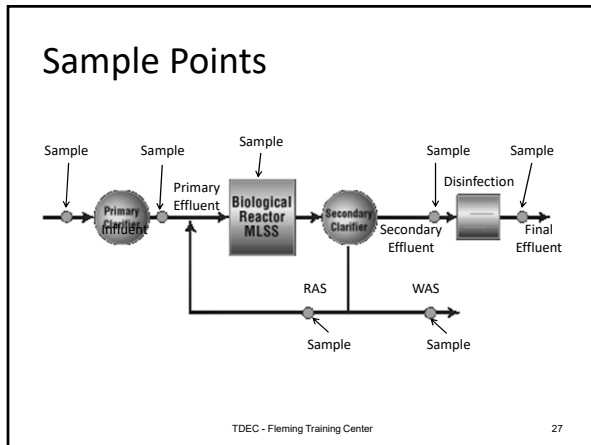


- Grasp container at base
- Plunge bottle mouth down into water
 - To avoid introducing any floating material
- Position mouth of bottle into current and away from hand
- Tip bottle slightly upward to allow air to exit so bottle can fill

Homemade Depth Sampler



- Collection from basins, tanks, lakes, reservoirs
- Pre-marked steel cable
- Pre-measured/marked rope
 - non-smearing ink/paint
- A jerk on the cord will remove the stopper and allow the bottle to fill



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

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Process Control

- “The permittee shall at all times properly operate and maintain all facilities and systems (and related appurtenances) for collection and treatment which are installed or used by the permittee to achieve compliance with the terms and conditions of this permit. Proper operation and maintenance also includes adequate laboratory and process controls and appropriate quality assurance procedures.”

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NPDES Permit

1.1 NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS

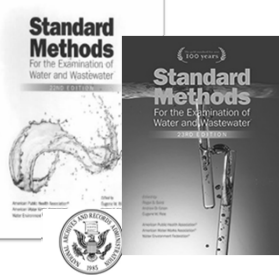
Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Basis
Total Suspended Solids (TSS)	<=	34	mg/L	Composite	Three Per Week	Daily Maximum
pH	<=	6	SU	Grab	Five Per Week	Minimum
pH	<=	9	SU	Grab	Five Per Week	Maximum

Description : External Outfall, Number : 001, Monitoring : Effluent Gross, Season : Summer						
Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Basis
CBOD ₅ , 5-day, 20 C	<=	11.2	mg/L	Composite	Three Per Week	Monthly Average
CBOD ₅ , 5-day, 20 C	<=	20	mg/L	Composite	Three Per Week	Daily Maximum
CBOD ₅ , 5-day, 20 C	<=	15	mg/L	Composite	Three Per Week	Weekly Average
CBOD ₅ , 5-day, 20 C	<=	375	mg/L	Composite	Three Per Week	Monthly Average
CBOD ₅ , 5-day, 20 C	<=	500	mg/L	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	52.5	mg/L	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	2	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	1	mg/L	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	1.6	mg/L	Composite	Three Per Week	Weekly Average
Nitrogen, Ammonia total (as N)	<=	50	mg/L	Composite	Three Per Week	Monthly Average
Nitrogen, total (as N)	Report	-	mg/L	Composite	Twice Per Month	Daily Maximum
Nitrogen, total (as N)	<=	4	mg/L	Composite	Twice Per Month	Monthly Average
Phosphorus, total (as P)	Report	-	mg/L	Composite	Twice Per Month	Daily Maximum
Phosphorus, total (as P)	<=	3	mg/L	Composite	Twice Per Month	Monthly Average

Description : External Outfall, Number : 001, Monitoring : Effluent Gross, Season : Winter						
Parameter	Qualifier	Value	Unit	Sample Type	Frequency	Statistical Basis
CBOD ₅ , 5-day, 20 C	<=	18.7	mg/L	Composite	Three Per Week	Monthly Average
CBOD ₅ , 5-day, 20 C	<=	750	mg/L	Composite	Three Per Week	Weekly Average
CBOD ₅ , 5-day, 20 C	<=	625	mg/L	Composite	Three Per Week	Monthly Average
CBOD ₅ , 5-day, 20 C	<=	22.5	mg/L	Composite	Three Per Week	Weekly Average
CBOD ₅ , 5-day, 20 C	<=	30	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	1.9	mg/L	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	65	mg/L	Composite	Three Per Week	Monthly Average
Nitrogen, Ammonia total (as N)	<=	4	mg/L	Composite	Three Per Week	Daily Maximum
Nitrogen, Ammonia total (as N)	<=	95	mg/L	Composite	Three Per Week	Weekly Average

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Tools for Success



- Refer to 40 CFR 136 for approved methods
- Latest revision went into effect on September 27, 2017
- Standard Methods for the Examination of Water and Wastewater.**
- The 23rd edition is the latest edition - But there is often a lag time

FEDERAL REGISTER

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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

Parameter number/name	Container ^{1,2}	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 ₂ S ₂ O ₅ ⁵	8 hours ^{22,23}
6. Fecal streptococci	PA, G	Cool, <10 °C, 0.008% Na ₂ S ₂ O ₅ ⁵	8 hours ²²
7. Enterococci	PA, G	Cool, <10 °C, 0.008% Na ₂ S ₂ O ₅ ⁵	8 hours ²²
8. Salmonella	PA, G	Cool, <10 °C, 0.008% Na ₂ S ₂ O ₅ ⁵	8 hours ²²
Table IA—Aquatic Toxicity Tests			
9-12. Toxicity, acute and chronic	P, FP, G	Cool, <6 °C ¹⁶	96 hours
Table IB—Inorganic Tests			
1. Acidity	P, FP, G	Cool, <6 °C ¹⁶	14 days
2. Alkalinity	P, FP, G	Cool, <6 °C ¹⁶	14 days
4. Ammonia	P, FP, G	Cool, <6 °C ¹⁶ + H ₂ SO ₄ to pH <2	28 days
6. Biochemical oxygen demand	P, FP, G	Cool, <6 °C ¹⁶	48 hours
15. Chemical oxygen demand	P, FP, G	Cool, <6 °C ¹⁶ + H ₂ SO ₄ to pH <2	28 days
16. Chloride	P, FP, G	None required	28 days

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.


Process Monitoring and Control Tests

- cBOD₅
- MLSS
- MLVSS
- Centrifuge (spin) Test
- Microscopic Examination
- SOUR
- Temp
- Depth of Blanket
- Thirty-minute settleometer
- SVI
- pH
- DO
- Nitrogen
 - Ammonia
 - Nitrate
 - Nitrite
 - Total Kjeldalh (TKN)

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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 ± 1° C for 5 days ± 6 hours in the dark

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History of BOD

- Thames River - London, England
 - Waste dumped in Thames River took 5 days to reach ocean



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History of BOD

- The Royal Commission on River Pollution, which was established in 1865, and the formation of the Royal Commission on Sewage Disposal in 1898, led to the selection in 1908 of BOD₅ as the definitive test for organic pollution of rivers.
- Five days was chosen because this was supposedly the longest time that river water took to travel from source to ocean in UK.

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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.

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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.

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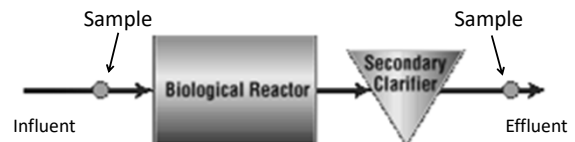
Biochemical Oxygen Demand (BOD)

- 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.

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BOD Sampling Locations



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

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BOD₅ 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 BOD₅ is the amount of D.O. used up over the 5-day period.



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BOD₅

- BOD₅ analysis must be done under these conditions:
 - Must be in the dark at 20°C ± 1°C
 - 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

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Biochemical Oxygen Demand (BOD)

REQUIREMENTS FOR VALID BOD₅ RESULTS

Blank depletion must be ≤ 0.2 mg/L DO

Initial DO must be ≤ 9.0 mg/L

Samples **must deplete** at least **2.0 mg/L DO**

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

BOD Equations

- See Formula Book

Unseeded

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

Seeded

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

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BOD Calculation

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

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

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

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

$$BOD = 185\ mg/L$$

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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

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

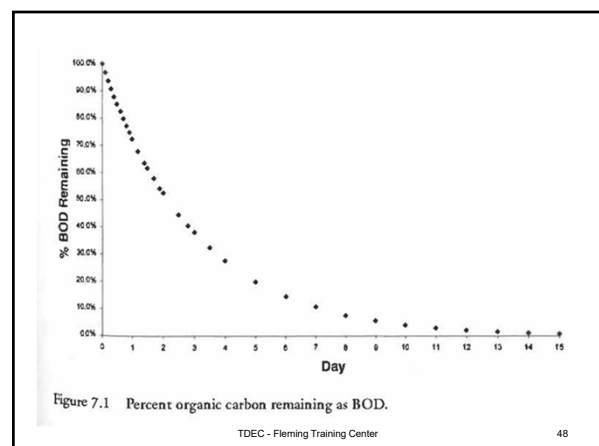
$$BOD = 102.5\ mg/L$$

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Ultimate 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.
- BOD consumed + BOD remaining = Ultimate BOD

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Chemical Oxygen Demand

- The COD test is used for more rapid assessment of organic strength.
- The COD test measures oxidizable organic matter
 - ...susceptible to oxidation by a strong chemical oxidant
- Can be useful for process control:
 - Test yields data in 2 to 4 hours
 - BOD typically lower than COD
 - Ratio must be established for a specific plant



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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 103-105°C

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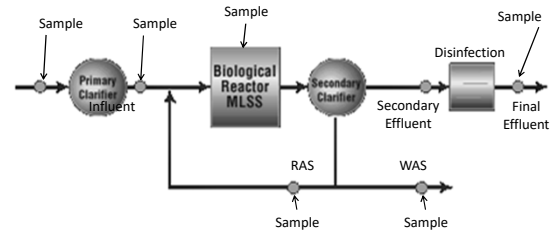
Suspended Solids



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Suspended Solids Sample Points



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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

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

- Where
 - A = final weight of pan, filter and residue, in grams
 - B = weight of prepared filter and pan, in grams

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MLSS Calculation

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

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

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

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

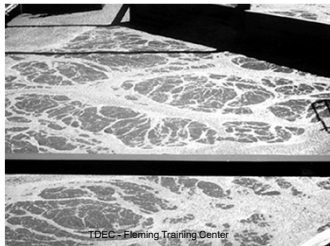
$$\text{MLSS} = 3868 \text{ mg/L}$$

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Suspended Solids

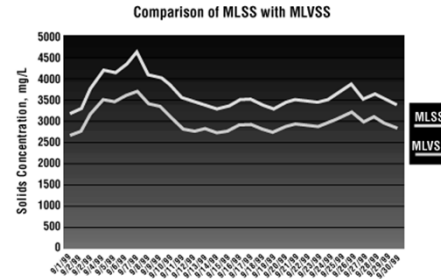
- Results of SS tests are used to determine secondary process removal efficiencies, SRT, F:M, and solids loading.



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MLSS vs. MLVSS

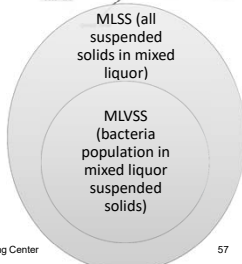
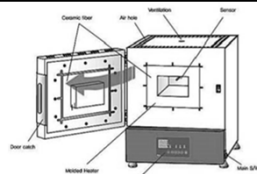
(Mixed Liquor Suspended Solids vs. Mixed Liquor Volatile Suspended Solids)



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MLVSS

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



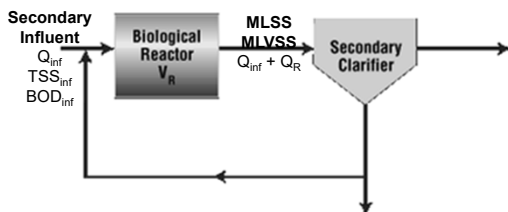
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Food to Microorganism Ratio

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

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



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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
 - Target F:M COD = $\frac{Target\ F:M_{BOD}}{BOD:COD}$

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F:M Example

BOD _{inf}	145 mg/L
Q _{inf}	15 MGD
MLVSS	2500 mg/L
Aerator Volume	2 MG

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

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 = $\frac{Current M - F (Food)}{F:M Target}$ (Microorganisms)

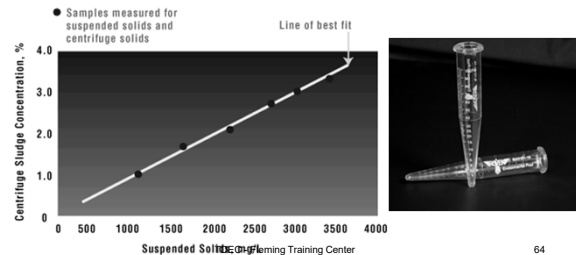
F:M Ratio

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

Centrifuge Spin Test

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

Example of a correlation of centrifuge and suspended solids concentration

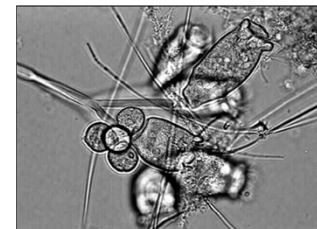


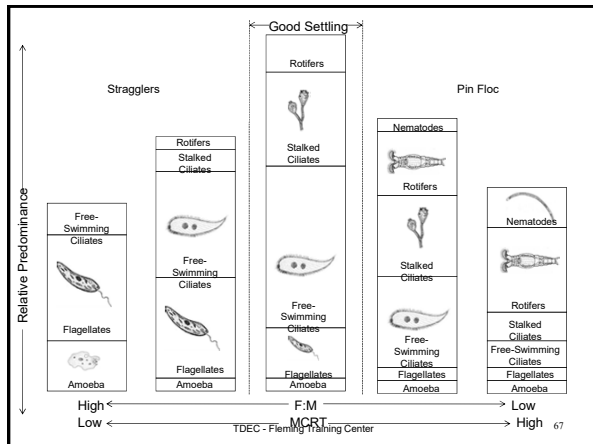
Microscopic Examination

- 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.

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

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

SOUR

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

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Temperature

- Microorganisms will respond to temperature changes

Seasonal Wastewater Temperature Variation – Northeastern U.S.

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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.

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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

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Thirty-Minute Settleometer

Index of Settleability Test Results

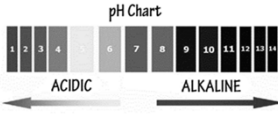
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Sludge Volume Index (SVI)

- 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.
- $SVI, mL/g = \frac{\text{Settled Sludge Vol, mL/L}(1,000)}{MLSS, mg/L}$
- 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

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pH

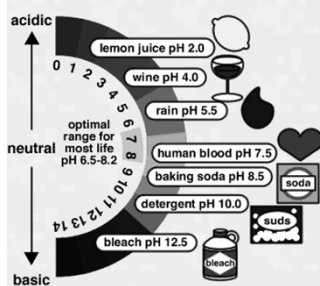


- Power of hydrogen
 - Measurement of the hydrogen ion concentration
 - $\text{pH} = -\log [\text{H}^+]$
 - Each decrease in pH unit equals a 10x increase in acid
- Scale runs from 0 to 14, with 7 being neutral
- Probe measures millivolts, then converts into pH units
 - Temperature affects millivolts 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.

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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



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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

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Nitrogen

- If your plant is required to nitrify (convert ammonia-nitrogen to nitrate-nitrogen), you must also include ammonia-nitrogen, nitrate-nitrogen and nitrite-nitrogen in your sampling
- By measuring these parameters, you can determine the efficiency of your plant and therefore make adjustments to your process

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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

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Chlorine Residual

- Approved Methods:
 - Amperometric titration
 - Iodometric titration – starch endpoint
 - Back titration
 - DPD - FAS
 - Spectrophotometric, DPD
 - Electrode
- NOTE: DPD color comparator is NOT an approved method

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Chlorine Residual

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



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Alkalinity

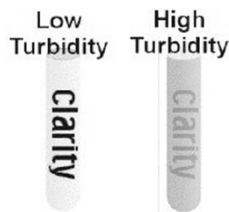
- Capacity of water to neutralize acids
- Due to presence of hydroxides, carbonates and bicarbonates
- Many chemicals (alum, chlorine, lime) alter water alkalinity
 - Alum and chlorine destroy
 - Lime adds
 - Nitrification and denitrification also affect alkalinity
- Titration using H_2SO_4 to pH endpoint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

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Turbidity

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

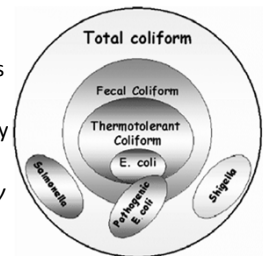


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Coliform Bacteria

- 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*



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Coliform Bacteria

- Comprises all the aerobic and facultative anaerobic gram negative, nonspore-forming, rod-shaped bacteria that ferment lactose within 48 hours $\sim 35^\circ C$
- 2 groups Coliform bacteria:
 - Fecal
 - Non-fecal
- The fecal group can grow at higher temperatures ($45^\circ C$) than the non-fecal coliforms



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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

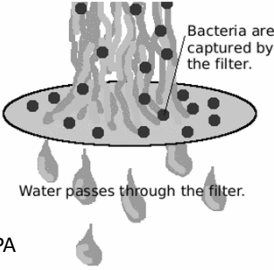


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Approved Methods

- 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)




Bacteria are captured by the filter.

Water passes through the filter.

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Membrane Filtration

Simultaneous Total Coliform and E.coli Screening Method 10029



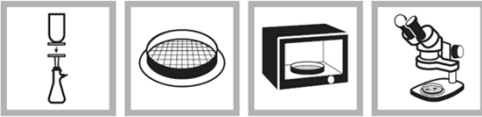
1. Use sterilized forceps to place a sterile, absorbent pad in a sterile petri dish. Replace the lid on the dish.
2. Invert ampules two or three times to mix broth. Break open an ampule of m-ColiBlue24 Broth using an ampule breaker. Pour the contents evenly over the absorbent pad. Replace the petri dish 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.

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.

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M-ColiBlue24® Membrane Filtration Method, Hach Company, www.Hach.com 92

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.

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M-ColiBlue24® Membrane Filtration Method, Hach Company, www.Hach.com 93

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



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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



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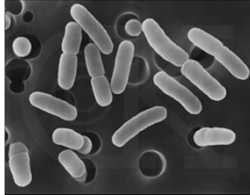
Membrane Filtration Supplies and Glassware

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



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Fecal Coliform



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Fecal Coliform

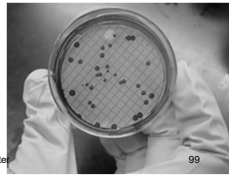
- A 100 mL volume of sample is filtered through a 47-mm membrane filter using standard techniques
- Filter is transferred to a 50-mm petri plate containing an absorbent pad saturated with mFC Broth
- Invert filter and incubate at **44.5±0.2°C** for 24 ± 2 hrs
- Fecal coliform density reported as number 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

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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

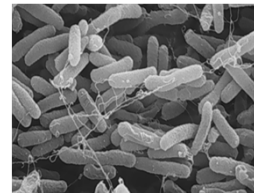


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Escherichia coli (*E. coli*) m-ColiBlue24[®]

m-ColiBlue24[®] with Membrane
Filtration

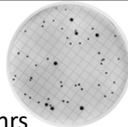


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E. coli m-ColiBlue24[®]

- Incubation is at **35 ± 0.5°C** for 24 ± 2 hrs
- *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.



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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



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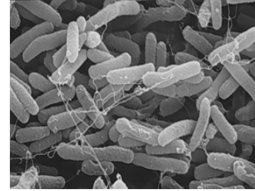
Expected Reactions of Various Microorganisms

- 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

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Escherichia coli (*E. coli*) Modified mTEC agar (EPA Method 1603) Modified mTEC Agar with Membrane Filtration



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EPA Method 1603

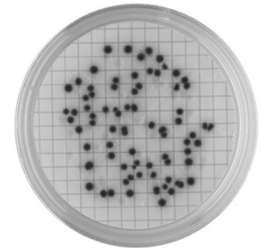
- Membrane Filter – modified mTEC agar
- Filter sample dilutions through a 47mm diameter sterile, white, grid marked filter (0.45µm pore size)
- Place sample in a petri dish with modified mTEC agar
- Invert dish and incubate for $35 \pm 0.5^\circ\text{C}$ for 2 hours
 - Resuscitates injured or stressed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

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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



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Method 1603

- QC Tests:

–Initial precision and recovery	–Filter sterility check
–Ongoing precision and recovery	–Method blank
–Matrix spike	–Filtration blank
–Negative control	–Media sterility check
–Positive control	

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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

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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 $35^\circ\text{C} \pm 0.5^\circ\text{C}$.
 - 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 $35^\circ\text{C} \pm 0.5^\circ\text{C}$
 - Absence of growth indicates sterility of the buffer and filtration assembly
 - Run daily

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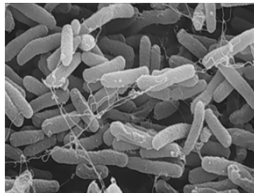
Method 1603

- 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

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



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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.

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Colilert® & Colilert-18®



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

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Colilert® & Colilert-18®

- Seal sample in Quanti-Tray
- Incubate at $35 \pm 0.5^\circ\text{C}$ for 18 hrs (Colilert-18) OR 24 hrs (Colilert)



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Colilert® & Colilert-18®

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



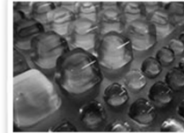
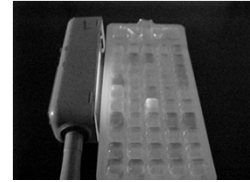
Left: The 97 well QuantiTray 2000 will count up to 2419 cfu without dilution.
Right: The 51 well QuantiTray will count up to 200 cfu without dilution.

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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



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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

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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

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Geometric Mean

- Reported on netDMR
- NPDES definition:
 - The geometric mean of any set of values is the nth root of the product of the individual values where “n” is equal to the number of individual values.
 - For the purposes of calculating the geometric mean, values of zero (0) shall be considered to be one (1)

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Geometric Mean

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

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

- 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

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Geometric Mean

- Geometric Mean – $(X_1)(X_2)(X_3)...(X_n)^{1/n}$
- Step 1: $1/n \rightarrow 1$ divided the number of test results. For our example above, there are four test results.
 - $1 \div 4 = 0.25$ (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.**
 - $60 \times 100 \times 1 \times 1 = 6000$ (Do Not clear out your calculator)
- Step 3: Punch the y^x button and then type in the number from Step 1, then punch =.
 - $6000 y^x 0.25 = 8.8011$



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Geometric Mean

- Geometric Mean – $(X_1)(X_2)(X_3)...(X_n)^{1/n}$
- Step 1: $1/n \rightarrow 1$ divided the number of test results. For our example above, there are four test results.
 - $1 \div 4 = 0.25$ (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.**
 - $60 \times 100 \times 1 \times 1 = 6000$ (Do Not clear out your calculator)
- Step 3: Punch the y^x button, then type in the number from Step 1, & then punch =.
 - $6000 y^x 0.25 = 8.8011$



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Geometric Mean

- Now, try one on your own:
- 20, 20, 210, 350
- $\frac{1}{4} = 0.25$
- $(20)(20)(210)(350) = 29,400,000$
- $(29,400,000)^{0.25} = 73.6$
- Geometric Mean = 73.6

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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 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) 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 (for 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 frequency; 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.

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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)

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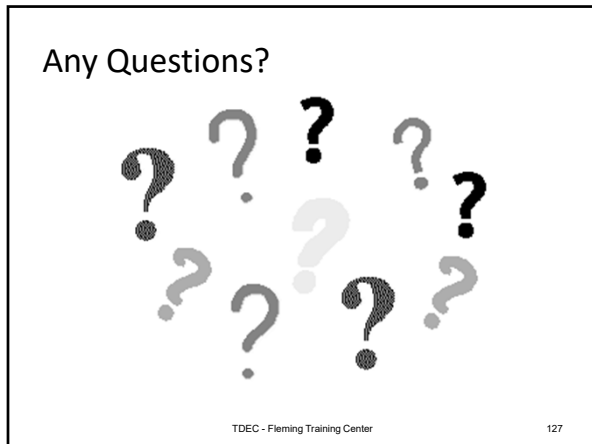
Tools for Success

- 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



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CHAPTER 3

Laboratory, Personnel, Maintenance Facilities and Safety Design

- 3.1 General
 - 3.2 Laboratory Facilities
 - 3.2.1 General
 - 3.2.2 Space Requirements
 - 3.2.3 Design
 - 3.2.3.1 Location
 - 3.2.3.2 Layout
 - 3.3 Personnel Facilities
 - 3.4 Maintenance Facilities
 - 3.4.1 Maintenance Shop
 - 3.4.2 Storage Requirements
 - 3.4.3 Yard Requirements
 - 3.5 Safety Design
- Appendix 3-A On-site Checklist

LABORATORY, PERSONNEL, MAINTENANCE FACILITIES & SAFETY DESIGN

3.1 General

Suggested considerations are presented in this chapter for laboratory, personnel, maintenance facilities, and safety. If testing is contracted out (particularly for lagoon systems) minimal maintenance facilities will only be required.

3.2 Laboratory Facilities

3.2.1 General

A guide to provision of laboratory facilities is the EPA publication Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, EPA-430/9-74-002.

Lab work involves a significant portion of a small facility's work tasks. Each facility should estimate work tasks by obtaining the following documents:

- a. "Minimum sampling schedule" should be obtained from the Permit Section of the Division of Water Pollution Control, containing compliance parameters from NPDES Permit as well as operation test.
- b. List of Approved Analytical Procedures. See Code of Federal Regulations (CFR), June 30, 1986, pp. 23693-23700 for lab methods and preservation procedures for NPDES data.
- c. Tennessee "Lab Manual" 1986. Contact the Julian Fleming Training Center in Murfreesboro.
- d. Tennessee "Laboratory Equipment and Supplies for Wastewater Treatment Plants." Contact the Julian Fleming Training Center in Murfreesboro.

3.2.2 Space Requirements

Specific laboratory facilities should be based on the needs of the treatment plant. Minimum suggested space for one MGD facilities is:

- Floor space of 200 sq. ft.
- Percent of floor space required for bench area is 40%
- Cabinet volume of 200 cubic foot.

These figures apply to a typical treatment plant monitoring program. If laboratory testing will be performed for other sources, such as industrial discharges, receiving waters, and sewer overflows, appropriate space increases should be provided. If some of the plant monitoring tests are performed at other facilities, the space required could be significantly less.

3.2.3. Design

The following factors should be key considerations in design of plant laboratories:

- Flexibility, which provides for changes in use requirements
- Adaptability, for changes in occupancy requirements
- Expandability, for changes in space requirements

3.2.3.1 Location

The laboratory should be located at ground level and easily accessible to all sampling points. To assure sufficient environmental control, the laboratory should be located away from vibrating machinery, corrosive atmospheres, or equipment which might have adverse effects on the performance of laboratory instruments or the analyst.

3.2.3.2 Layout

New lab layouts should be modeled after proven exemplary layouts. Efficient laboratory operation depends largely on the physical layout of the laboratory. The physical layout includes items such as working area arrangement, the number and location of sinks and electrical outlets, the arrangement of laboratory equipment, materials of construction, and lighting. The details of the layout can affect the accuracy of the laboratory tests. For example, tests that include identification of a colorimetric end point, as in heavy metals determinations, can be drastically affected by the type of lighting and the finishes on laboratory facilities.

The following factors should be considered when laying out a laboratory:

- a. A northern exposure is preferred for colorimetric analysis.
- b. Adequate lighting should be provided. Color-corrected fluorescent lighting is suggested.
- c. Wall and floor finishes should be nonglare-type and light in color. Flat-finish wall paint is suggested.

Floor finishes should be of a single color for ease of locating small items that have been dropped.

- d. Floor covering, in addition to being nonglare, should be easy to clean and comfortable.
- e. Doors shall have large glass windows for visibility into and out of the laboratory. There should be no obstructions near the doors.
- f. Aisle width between work benches should be at least 4 feet. Adequate spacing should be provided around free-standing equipment, workbenches, and file cabinets to facilitate cleaning.
- g. Storage space for reagent stock should be under workbenches. Reagent containers removed from storage areas under workbenches are less likely to be dropped than reagent containers removed from storage in the inconvenient and hard-to-reach areas above the workbenches. Only items that are infrequently used or chemicals of a nonhazardous nature should be stored above workbenches. Strong acids or bases should be stored within convenient reach of the laboratory personnel, preferably beneath or adjacent to the fume hood.
- h. Sufficient cabinet and drawer space should be provided for the storage of equipment and supplies. Wall cabinets should be no more than 30 inches above the workbench top so that the contents of the top shelving can be reached. The base cabinets under the workbenches should contain a combination of drawers and storage spaces for large items. All cabinets and drawers should be acid resistant.
- i. One sink with a large gooseneck faucet, large enough to wash laboratory equipment, should be provided for every 25 to 30 feet of bench length. One sink should be sufficient when total bench length is less than 25 feet. The sink should be made of chemical-resistant material.

Cup sinks, also of chemical-resistant material, should be provided at strategic locations on the bench surface to facilitate laboratory testing. The number of cup sinks depends largely on the type of tests that will be run; the general rule is one cup sink for every 25 to 30 feet of bench length. Cup sinks should be alternated with the wash sinks at 12- to 15-foot intervals.

Where workbench assemblies are provided in the center of the laboratory, a trough-type sink down the center of the workbench may be provided in lieu of cup sinks. A hot and cold water tap should be placed at approximately every 5 to 10 feet along the trough.

The use of an automatic dishwasher should be considered. Where dishwashers are provided, some of the sinks can be replaced by cup sinks.

- j. Electrical receptacles should be provided at strategic points for convenient and efficient operation of the laboratory. Duplex-type receptacles should be spaced at intervals along benches used for laboratory tests. Strip molding receptacles may be used. All receptacles must be elevated to prevent spills from entering the receptacles.
- k. Gas and vacuum fixtures should be provided at convenient locations.
- l. Bench tops should be suitable for heavy-duty work and resistant to chemical attack. Resin-impregnated natural stone and other manmade materials provide such a surface and should be used.
- m. Bench surfaces should be approximately 36 inches high for work done from a standing position and 30 inches high for work done while sitting.
- n. Bench surfaces should be approximately 30 inches wide.
- o. Equipment arrangement should be given special consideration in laying out the laboratory facility in conjunction with the facility's owner and operators. Plumbing, and/or electrical connections should be provided for units such as the distillation apparatus, drying ovens or other wall-mounted equipment. Pieces of equipment used for making common tests should be in proximity.

For example, the drying oven used in making total, suspended, and dissolved solids tests should be close to the muffle furnace for use in determining total volatile solids and volatile suspended solids from the samples dried in the drying oven. The drying oven and the muffle furnace should be near the

balance table because the balance is used in the weight determinations for the various solids tests.

- p. Safety is a prime consideration of a laboratory. The first aid kit, fire extinguisher, eye wash, and emergency shower should be near the main working area of the laboratory. If the safety shower is not provided in a separate shower stall, a floor drain should be nearby.
- q. Sources of loud or startling noises, such as alarms or composite sampling equipment, should be located at sites remote or otherwise isolated from the laboratory.
- r. The analytical balance should be on a separate table at least 30 inches long and 24 inches deep. The table should not transmit vibrations that would adversely affect the operation of the balance.
- s. A separate table is desirable for microscopes. This table should be about 30 inches long, 24 inches deep, and 27 inches high.
- t. Fume hoods, if provided, should be near the area where most laboratory tests are made.
- u. All labs which run BOD₅ require air-conditioning to achieve a sufficiently high, stable D.O. in the dilution water.

Laboratories should be separately air-conditioned, with external air supply for 100-percent makeup volume. Separate exhaust ventilation should be provided. Window air-conditioning should not blow directly on the analytical balance or furnaces.

- v. Panic hardware should be provided for doors opening to the outside to allow for rapid exiting in an emergency.

3.3 Personnel Facilities

Personnel facilities are generally located in the administration building. This building serves the needs of the supervisory staff, the operation and maintenance personnel, and often the laboratory staff.

Sewer maintenance personnel may also share the administration building.

However, facilities for the laboratory and operations and maintenance staff need not be provided in the administration building, even though this is customary.

A wastewater treatment plant staffed for 8 hours or more each day should contain support facilities for the staff. Toilets shall be provided in conformance with applicable building codes. The following should be provided:

- a. **Wash-up and changing facilities:** Showers, lockers, sinks, and toilets sufficient for the entire staff at design conditions. A heated and ventilated mudroom is desirable for changing and storage of boots, jackets, gloves, and other outdoor garments worn on the job. Each staff member should have separate lockers for street clothes and plant clothes. Separate wash-up and changing facilities should be available for men and women, with the exception of the mudroom.
- b. **Eating Facilities:** A clean, quiet area with facilities for storage and eating of light meals.
- c. **Meeting facilities:** A place to assemble the plant staff and visitors. In many cases, meeting facilities and the eating facilities will be the same.
- d. **Supervisors' facilities:** A place where discussion and writing can be carried out in private. A desk station should be provided for data entry.

Facilities should be provided for the storage of analytical methods and records, catalogs, as-built plans, operation and maintenance manual(s), etc.

Small mechanical treatment plants that are not manned 8 hours per day need not contain all of the personnel facilities required for larger plants, but shall contain a lavatory, and a storage area.

3.4 Maintenance Facilities

To assure adequate maintenance of equipment, convenient maintenance facilities should be available. Such facilities generally include a maintenance shop, a garage, storage space, and yard maintenance facilities.

Access to nearby municipal garages and other maintenance centers should be considered. Duplication of facilities should be avoided where possible.

3.4.1 Maintenance Shop

A separate maintenance shop should be designated where treatment plant equipment and vehicles can be repaired. The maintenance shop should be provided with the following facilities:

- a. Work space with adequate area and lighting, including a workbench with vise.
- b. Conveyances to move heavy items from the point of delivery to the appropriate work space.
- c. Storage for small tools and commonly used spare parts.
- d. Adequate power outlets and ratings for the equipment.

3.4.2 Storage Requirements

Storage space should be provided for paints, fuels, oils and lubricants, grounds maintenance equipment, spare parts, and collection system equipment.

In larger facilities, it may be desirable to have a separate storage building for things such as paints, fuel, oils and lubricants, spare parts, and yard supplies. For storage of flammable materials, the requirements of the uniform building code shall be met. In smaller facilities, it might be desirable to combine storage with the shop or garage so that the stored material can be protected against unauthorized use.

Where underground tanks are to be used to store controlled substances, the Division of Ground Water Protection shall be contacted regarding Underground Storage Tank (UST) requirements.

3.4.3 Yard Requirements

A landscaped yard helps to soften the visual impact of a treatment facility. Shrubs and trees judiciously located can screen unsightly areas from public view. Care must be taken that the plantings do not become a hindrance to operation. Deciduous leaves falling in clarifiers can hinder skimming and add unnecessarily to the digester loading. Roots from trees too close to pipes can cause clogging. Fencing should be adequate to prevent unauthorized or unattended entry.

3.5 Safety Design

The field of wastewater treatment has always been one of the most hazardous fields of employment.

This fact is accented by job-related deaths and accidents which happen each year. Safety designs are needed which should be supplemented by yearly inspections to gain awareness.

Adequate provisions shall be included in the design of all wastewater treatment facilities to minimize exposure of facility personnel and visitors to safety hazards.

Treatment facilities shall be designed in full compliance with the Occupational Safety and Health Standards of the State of Tennessee, Division of Occupational Safety and Health (TOSHA).

Pertinent safety design requirements as well as safety design practices are included in the attached on-site checklist for wastewater treatment plants (Appendix 3-A).

To gain awareness each operator should have other safety resources such as:

- 1.) Safety & Health in Wastewater Systems (MOP-1 by WPCF)
- 2.) Individual safety manual adopted by each plant's safety committee.
- 3.) Safety meetings with city.

Any unsafe practices or incidents should be reported to TOSHA and each facility's safety committee. As a last resort, complaints can be made anonymously by the operator or any other concerned citizen.

Appendix 3-A

On-Site Checklist

STANDARD SAFETY

1. Personnel Protective Clothing:
 - a. Safety helmets (for operators and visitors)
 - b. Ear protectors for high noise areas
 - c. Goggles
 - d. Gloves
 - e. Rubber boots with steel toes

2. Safety Devices Available for Use:
 - a. Non-sparking tools in areas where flammable or explosive gases may be present
 - b. Fire extinguishers readily available
 - c. Oxygen deficiency/explosive gas indicator
 - d. Self-contained breathing apparatus near entrance to chlorine room, away from fan discharge
 - e. Safety harness
 - f. First aid kits readily available
 - g. Ladders to enter manholes or wetwells (fiberglass or wooden for around electrical work)
 - h. Traffic control cones
 - i. Safety buoy at activated sludge plants
 - j. Live preservers for around lagoons
 - k. Portable crane/hoist

3. General Plant Safety:
 - a. Railing around all tanks, with openings chained off
 - b. No uncovered pits or wells
 - c. Explosion-proof fixtures, where needed
 - d. Equipment guards in place
 - e. Emergency telephone numbers posted
 - f. Proper flammable liquid storage
 - g. Covered trash cans
 - h. Ladders have safety cages or equipped with safety slide rail
 - i. Portable hoists for equipment removal; e.g., pumps, aeration equipment
4. Are plant personnel immunized for typhoid and tetanus?
5. No cross connections exist between a potable water supply and a non-potable source:
 - a. Pump and mixer seals
 - b. Digester heating system make-up water
 - c. Vacuum filter water sprays
 - d. Chemical mixing tank
 - e. Chlorinator water source
 - f. Yard hydrants
 - g. Properly installed backflow preventers
6. If anaerobic digesters are used, are the following present?:
 - a. Pressure/vacuum relief valves
 - b. "No smoking" signs
 - c. Explosimeter
 - d. Drip trap
 - e. Flame traps within 25' of the flame source

7. Electrical Safety:
 - a. All electrical circuitry enclosed and identified
 - b. Electrical test equipment available, such as a voltmeter and amperage meter
 - c. Rubber mats present for electrical work
 - d. The personnel are familiar with the electrical work to be performed
 - e. All personnel are trained in electrical safety, such as lockout procedures
 - f. Warning and/or caution signs present
 - g. Rubber gloves available
 - h. Ground fault interrupter used

8. Chlorine Safety:
 - a. NIOSH-approved self-contained 30 minute air pack
 - b. All standing chlorine cylinders are chained in place
 - c. All personnel are trained in the use of chlorine
 - d. Chlorine repair kit is available
 - e. Chlorine leak detector tied into the plant alarm system
 - f. Ammonia for checking chlorine leaks is present
 - g. Ventilator fan with an outside switch is present
 - h. Safety precautions posted
 - i. Doors open outward and are equipped with "panic" hardware

9. Process Chemical Safety:
 - a. Respirator to protect the operator against dust inhalation, when needed
 - b. All personnel are trained to handle the chemicals properly
 - c. Proper safety clothing for the chemical to be handled, such as rubber aprons, boots and gloves for handling ferric chloride
 - d. Has complied with the Tennessee Department of Labor, Hazardous Chemical Right To Know Law, T.C.A. 50-3-2001 thru 2019.
 - e. Emergency Action Plan on file with local Fire Department and appropriate Emergency Agency
 - f. Containment of chemical storage areas, including curbing and floor drains to appropriate areas

10. Laboratory Safety:
 - a. Eye wash and shower station is present
 - b. Fume hood is present
 - c. All chemicals properly labeled and stored
 - d. Laboratory safety devices such as pipette suction bulbs

INNOVATIVE SAFETY

1. Warning Signs:
 - a. Non-potable water
 - b. Chlorine hazard
 - c. No smoking
 - d. High Voltage
 - e. "Watch your step" signs in certain areas
 - f. Exit signs
 - g. Piping signs
2. Safety programs
3. Operators provided with a shower and a locker for their work clothes
4. Are the operators trained in first aid and CPR?

Sampling and Laboratory Vocabulary

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 103-105°C.
13. The term _____ refers to all the aerobic and facultative anaerobic gram negative, nonspore-forming, rod-shaped bacteria that ferment lactose within 48 hours ~ 35°C. 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

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

7. To perform the Suspended Solids test, the sample is filtered through a pre-weighed filter paper and dried in an oven at _____ degrees C.
8. Which of the following methods is **not approved** for analyzing chlorine residual?
- Amperometric titration
 - Spectrophotometric, DPD
 - Electrode
 - DPD color comparator
9. Interpret the following microscopic evaluation results:
- Predominance of ciliates and rotifers =
 - Predominance of rotifers and nematodes (worms) =
 - An abundance of amoebas =
10. Name two chemicals that will use up or destroy alkalinity in the water.
11. What is the typical (keep in mind that not all permits are the same) NPDES permit limit for Fecal Coliform?
- When testing for Fecal Coliforms, samples are incubated at _____ degrees C for _____ hours.
12. NPDES permits typically (keep in mind that not all permits are the same) have an *E. coli* limit as a monthly average of _____. When testing for *E. coli* using the mColiBlue24 method, samples are incubated at _____ degrees C for _____ hours.

13. When testing for *E.coli* using the Colilert or Colilert 18 methods, interpret the following results:

a. Yellow coloration = _____

b. Fluorescence = _____

14. Write out what the following QA/QC abbreviations stand for:

a. DOC = _____

b. MDL = _____

c. ICV = _____

d. CCV = _____

e. LRB = _____

f. LFM = _____

Section 4

Introduction to QA/QC, Standard Methods, and Standard Operating Procedures (SOPs)

Introduction to QA/QC Standard Methods Standard Operating Procedures (SOPs)

Introduction to Wastewater Class



Standard Methods

- 1880's movement for "securing the adoption of more uniform and efficient methods of water analysis"
- Drinking water only until 1925
- 1933 joint publication
 - Standard Methods of the Examination of Water and Sewage

Standard Methods

- Methods believed to be best available
- Recommendations of specialists, ratified by large number of analysts and other experts
- Truly consensus standards
- Offers valid and recognized basis for control and evaluation

Standard Methods



- Standard Methods for the Examination of Water and Wastewater
- Often a lag time between 40 CFR 136 approved methods and Standard Methods
- Look at Editorial Revision date on method, not latest Edition of SM

Code of Federal Regulations (CFR)

- The purpose of the CFR is to present the official and complete text of agency regulations in one organized publication and to provide a comprehensive and convenient reference for all those who may need to know the text of general and permanent Federal regulations

Code of Federal Regulations (CFR)

- The CFR is divided into 50 titles representing broad areas subject to Federal regulation
 - Each title divided into chapters
 - Each chapter divided into parts
 - Each part divided into sections
- **Wastewater: 40 CFR 136**
- CFR can supersede Standard Methods

Code of Federal Regulations (CFR)

- CFR will list approved methods for testing
- Includes:
 - Standard Methods
 - EPA methods
 - Hach methods
 - Etc.
- Always check to make sure you are using an approved method!

40 CFR 136 Method Update Rule

- This rule modifies the testing procedures approved for analysis and sampling under the Clean Water Act. The changes adopted in this final rule fall into the following categories: New and revised EPA methods (including new and/or revised methods published by ... the Standard Methods Committee... updated versions of currently approved methods; methods reviewed under the alternate test procedures (ATP) program; clarifications ...and amendments to the procedure for determination of the method detection limit to address laboratory contamination and to better account for intra-laboratory variability.
- QA/QC
- You Have Heard it All Before

2017 Update of 40 CFR 136

Clean Water Act Methods Update Rule for the Analysis of Effluent



Federal Register August 28, 2017,
effective September 27, 2017

- Standard Methods approved by date (editorial revision) not Edition
- Section 136.7 Quality Assurance and Quality Control

What is QA & QC?

- Quality Assurance (QA) = a plan for lab operations that specifies the measures required to produce defensible data with known precision and accuracy
- Quality Control (QC) = The routine application of procedures for controlling the accuracy and precision of the measurement process
 - Ex: proper calibration of instruments, or using analytical grade reagents



Section 136.7 Lab QA

- "...suitable QA/QC procedures..."
- "...QA/QC procedures are generally included in the method or may be found in the methods compendium..." (Ex. Standard Methods)
- "The permittee/lab shall follow these QA/QC procedures, as described in the method or methods compendium..." (Ex. Standard Methods)
- "If the method lacks QA/QC..."

Three QA Options

- A. ...follow equivalent EPA procedures
- B. Refer to QA/QC in consensus organization compendium. (Follow Standard Methods) Didn't we have that on the previous slide?
- C. Follow the 12 Steps where applicable.
- The 13th step requires an SOP (standard operating procedures)

12 Quality Control Elements

1. DOC – demonstration of capability
 2. MDL – method detection level
 3. LRB/MB – method blank
 4. LFB – laboratory fortified blank (standard)
 5. LFM/LFMD – laboratory fortified matrix/duplicate (spike)
 6. Internal standards, surrogate standards or tracer – only applies to organic analysis and radiochemistry
 7. Calibration- initial and continuing
 8. Control charts or other trend analysis
 9. Corrective action – root cause analysis
 10. QC acceptance criteria
 11. Definition of a batch (preparation and analytical)
 12. Minimum frequency for conducting all QC elements
 13. Unwritten 13th Step – SOP – Standard Operating Procedures need to be written and followed for all lab sampling and analyses
- Not all of these items apply to all tests, there are many exceptions!

Can you defend what you do?

- How do you interpret your Permit language or the Rule?
- Can you defend that interpretation, will a judge or jury support you?
- What do Regulators say and what is written?
 - Is it clear?
 - Don't be afraid to ask Why?
 - Don't be afraid to ask for directives in writing



What You Are Already Doing

- Most Labs are doing lots of QA/QC stuff – especially contract labs
- Write down what you do....SOP
- Summarize QC Data
 - Table Form
 - Average, Max, Min.
 - Control Charts



(Photo credit: Patient Care Technician)

Demonstration of Capability (DOC)

- DOC once for each analyst
- As a minimum, you must:
 1. Include a reagent blank
 2. Run at least 4 LFBs at a concentration between 10 times the MDL and the midpoint of a calibration curve.
- Signed Documentation!
 - Keep a signed form (documentation) that shows you have read and understand the SOPs and method
- What tests does this apply to?
 - Ammonia, BOD/cBOD, Chlorine, pH, DO, Nitrate, Nitrite, sTKN, Total Phosphorus, TSS
- How often?
 - Once for each analyst.
 - Recommended yearly for backup analyst who does not perform tests frequently
 - Each analyst should have a file kept on their training within and for the lab.

Method Detection Limit (MDL)

- Estimation of the detection limit for variety of physical and chemical methods
- EPA defines as: "the minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results"
- What tests does this apply to?
 - Ammonia, Chlorine, Nitrate, Nitrite, sTKN, Total Phosphorus, and TSS (MDL_b only)
- How often?
 - Annually – but at least every 13 months
 - Ongoing data collection and MDL validation is now required quarterly

What is an MDL study?

- It is a calculation that statistically gives the lowest concentration that a lab/facility can "see," or detect an analyte
- Not practical for many analyses
- As detector sensitivity improves, the background contamination of the lab, consumable supplies, and equipment can be more important in determining the detection limit than the sensitivity of the instrument

Method Detection Limit (MDL)

- Step (1): Estimate Initial MDL
 - a) The mean determined concentration plus 3 times the standard deviation of a set of method blanks
 - b) The concentration value that corresponds to an instrument signal-to-noise ratio in the range of 3 to 5
 - c) The concentration equivalent to three times the standard deviation of replicate instrumental measurements of spiked blanks
 - d) That region of the calibration where there is a significant change in sensitivity (i.e. a break in the slope of the calibration)
 - e) Instrumental limitations
 - f) Previously determined MDLs

Method Detection Limit (MDL)

- Step (2): Determine the Initial MDL
 - Select a spiking level, typically 2-10 times the estimated MDL See Guidance Documents on FTC website for more detailed guidance on specific methods.
 - Process at least 7 spiked samples and 7 method blank samples
 - Ideally, use pooled data from several analysts
 - Must be prepared in at least 3 batches on 3 separate dates and analyzed on 3 separate dates
 - Preparation and analysis can be on the same day



Method Detection Limit (MDL)

- Initial MDL continued...
 - Existing data may be used if compliant with the requirements for at least 3 batches, and generated within the last 24 months
 - The most recent available data for method blanks and spiked samples must be used



Method Detection Limit (MDL)

- Initial MDL continued...
 - If multiple instruments will be assigned the same MDL, sample analyses must be distributed across all the instruments
 - Minimum of 2 spiked and 2 blank samples prepared and analyzed on different dates is required for each instrument
 - The same prepared extract may be analyzed on multiple instruments so long as the minimum requirement of 7 preparations in at least 3 separate batches is maintained

Method Detection Limit (MDL)

- Evaluate the spiking level
 - If any spiked samples do not provide a numerical result greater than zero, repeat the spiked sample at a higher concentration
- Compute MDL_s – value based on spiked samples
- Compute MDL_b – value based on blank samples
 - Use the MDL calculator on the FTC website
- Whichever is greater is your MDL

Method Detection Limit (MDL)

- Step (3): Ongoing Data Collection
 - During any quarter in which samples are being analyzed, prepare and analyze a minimum of two spiked samples on each instrument, in separate batches, using the same spiking concentration used for the Initial MDL
 - MDL_s: Value calculated from the spiked samples
 - Minimum of 2 spiked samples on each instrument
 - Minimum of 8 per year (2 per quarter)
 - MDL_b: value calculated from the method blanks
 - No additional samples required – just use the routine method blanks

Method Detection Limit (MDL)

- At least once per year, re-evaluate the spiking level
 - If more than 5% of spikes are not positive numerical results, the spiking level must be increased and initial MDL re-determined
- If the method is altered in a way that can be expected to change its sensitivity, re-determine the initial MDL and restart the ongoing data collection

Method Detection Limit (MDL)

- Step (4): Annual Verification
 - At least once every 13 months you need to re-calculate your MDL_s and MDL_b
 - Include data generated in the last 24 months
 - But only data with same spiking level
 - Ideally, use all method blank results from the last 24 months for the MDL_b calculation
 - There is an option to use less data included in the rule

Method Detection Limit (MDL)

- The verified MDL is the higher of the two numbers (either the MDL_s or the MDL_b)
- Your existing MDL may be left unchanged if specific criteria are met
 - If verified MDL is within 0.5 – 2.0 times the existing MDL, and fewer than 3% of the method blank results have numerical results above the existing MDL
 - Otherwise, adjust the MDL to the new verification MDL

Method Detection Limit (MDL)

- Where do I find the MDL Calculator?
 1. Go to Fleming Training Center's website
 - <https://www.tn.gov/environment/program-areas/wr-water-resources/fleming-training-center.html>
 2. Middle row of boxes, left side, click on "Course Books and Reference Material"
 3. In the drop-down menu on left, click on "Waste Water Information"
 4. Click on "Method Update Rule – Method Detection Limit Math 2019"

Laboratory Reagent Blank (LRB)

- Also known as Method Blank
- Standard Methods 1020.B.5
 - A reagent blank (method blank) consists of reagent water and all reagents that normally are in contact with a sample during the entire analytical procedure (distillation, incubation, etc.)
- What tests does this apply to?
 - Ammonia, BOD/cBOD, Chlorine, sTKN, Total Phosphorus and TSS
- How often?
 - Depends on method QA/QC

Laboratory Fortified Blank (LFB)

- Standard Methods 1020.B.6:
 - A reagent water sample to which a known concentration of the analyte of interest has been added
 - Use an added concentration of at least 10 times the MDL, or less than or equal to the midpoint of the calibration curve
- Sample batch = 5% basis = 1 every 20 samples
 - At least once a month
 - What tests does this apply to?
 - Ammonia, BOD/cBOD, Chlorine, Nitrate, Nitrite, sTKN, Total Phosphorus, TSS

Laboratory Fortified Matrix and Duplicate (LFM/LFMD)

- Also known as a Spike and Spike dup
- Standard Methods 1020.B.7:
An additional portion of a sample to which a known amount of the analyte of interest is added before sample preparation
 - The LFM is used to evaluate analyte recovery in a sample
 - Add a concentration less than or equal to the midpoint of the calibration curve
 - Preferably the same concentration as the LFB (laboratory fortified blank)

Laboratory-Fortified Matrix and Duplicate (LFM/LFMD)

- Include at least one LFM with each sample set (batch) or on a 5% basis, or 1 for every 20 samples
 - At least once per month
- Calculate the RPD between the Spike and Spike Duplicate
 - $RPD = \frac{Range}{Average}$

Laboratory Fortified Matrix and Duplicate (LFM/LFMD)

- Also called a Matrix Spike/Matrix Spike Duplicate (MS/MSD)
- Shows if there are interferences in the effluent matrix
- What tests does this apply to?
 - Ammonia, Nitrate, Nitrite, sTKN, Total Phosphorus

Duplicate

- Duplicate samples are analyzed randomly to assess precision on an ongoing basis
 - Precision = A measure of the degree of agreement among replicate analyses of a sample
 - *How close is your duplicate to the sample?*
- Not a part of the 12 Steps of QA, it's an addition from the State of TN (or in the approved method)



Duplicate

- As a minimum, include one duplicate sample with each sample set or on a 5% basis
- Randomly select routine samples to be analyzed twice
- Process duplicate sample independently through the entire sample preparation and analysis
- Calculate the RPD (relative percent difference)
- Equal to or less than 20% RPD

Duplicate

- For samples that need to be analyzed on a 5% basis: once every 20 samples
 - Ex: Chlorine
- For samples that need to be analyzed on a 10% basis: once every 10 samples
 - Ex: TSS

Duplicate (Dup)

- What tests does this apply to?
 - BOD/CBOD, Chlorine, pH, DO, Nitrate, Nitrite, sTKN, TSS and Settleable Solids



Initial Calibration Verification & Continuing Calibration Verification

- | | |
|---|---|
| <ul style="list-style-type: none"> ▪ ICV <ul style="list-style-type: none"> • Standard Methods 1020.B.11.b • Perform initial calibration using at least three concentrations of standards for linear curves • Calibrate meter (DO, pH or ISE) or verify scale, colorimeter/spectrophotometer and thermometer | <ul style="list-style-type: none"> • CCV <ul style="list-style-type: none"> • Standard Methods 1020.B.11.c • Analysts periodically use a calibration standard to confirm that the instrument performance has not changed significantly since initial calibration. • Verify calibration by analyzing one standard at a concentration near or at the mid-point of the calibration range. • Verify the calibration (especially if preset by manufacturer) at beginning of day, after every 10 readings and at the end of the batch • Daily |
|---|---|

ICV – Balances/Scales

- SM 2020.B.2.a
 - Check instrument balances daily
- SM 9020.B.4.b
 - Service balances annually or more often as conditions change or problems occur
 - Check balances routinely, preferably daily before use, with at least two working weights that bracket the normal usage range (e.g. ANSI/ASTM Class 1 or NIST Class S accompanied by appropriate certificate) for accuracy, precision and linearity.
 - Record results along with date and technicians initials
 - Recertify reference weights as specified in the certificate of calibration or at least every 5 years.



ICV – Temperature

- SM 9020.B.4.a
 - Annually, or preferably, semiannually check accuracy of all working temperature sensing devices at the use temperature against a certified National Institute of Standards and Technology (NIST) thermometer or one traceable to NIST and conforming to NIST specifications.
 - Record calibration results, along with the date and the technician's signature, in a quality control logbook.
 - Verify accuracy of the reference certified thermometer as specified on the certificate of calibration or at least every 5 years.
 - State of TN recommends annual verification.

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ICV – Temperature

- Mark the necessary calibration correction factor on each temperature measuring device so that only calibrated-corrected temperature values are recorded.



ICV/CCV Other tests

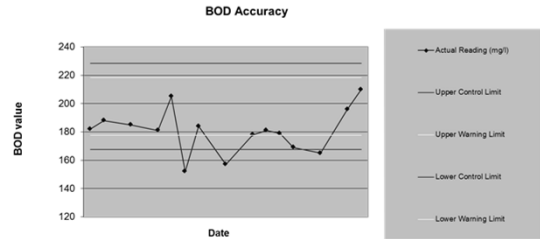
- | | |
|--|--|
| <ul style="list-style-type: none"> ICV <ul style="list-style-type: none"> ▪ What tests does this apply to? ▪ Ammonia, BOD/CBOD, Chlorine, pH, DO, Nitrate, Nitrite, sTKN, Phosphorus | <ul style="list-style-type: none"> CCV <ul style="list-style-type: none"> ▪ What tests does this apply to? ▪ Ammonia, BOD/CBOD, Chlorine, pH, DO, Nitrate, Nitrite, sTKN, Phosphorus |
|--|--|

Accuracy Control Charts

- Standard Methods 1020 B.13.a
 - The accuracy chart for QC samples (e.g., reagent blanks, LFBs, calibration check standards and LFM) is constructed from the average and standard deviation of a specified number of measurements of the analyte of interest.
 - The accuracy chart includes upper and lower warning levels (WL) and upper and lower control levels (CL).
 - Common practice is to use $\pm 2s$ and $\pm 3s$ limits for the WL and CL, respectively, where s represents standard deviation.

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BOD Accuracy Control Charts



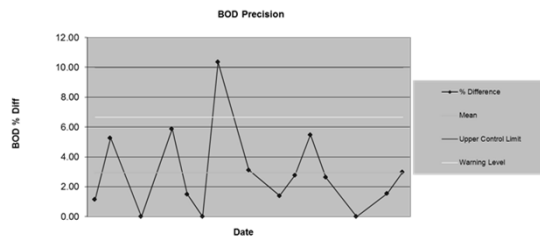
44

Precision Control Charts

- Standard Methods 1020 B.13.b
 - The precision chart also is constructed on the average and standard deviation of a specified number of measurements (e.g., %RSD [relative standard deviation] or RPD) for a replicate or duplicate analyses of the analyte of interest.

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BOD Precision Control Charts



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Control Charts

- **2014 Update** - Create and maintain control charts if you have *20-30 QC data points* within 90 days.
 - If you do not meet the above criteria, follow QC Acceptance Criteria below.
 - Blanks < MDL
 - LFB $\pm 15\%$
 - ICV/CCV $\pm 10\%$
 - LFM/LFMD $\pm 20\%$
 - RPD < 20%

47

Corrective Action

- Standard Methods 1020 B.15
 - QC data that are outside the acceptance limits or exhibit a trend are evidence of unacceptable error in the analytical process.
 - Take corrective action promptly to determine and eliminate the source of error.
 - Do not report data until the cause of the problem is identified and either corrected or qualified (see Table 1020.11)

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Corrective Action

- The corrective action plan needs to be in your SOP for each method on what to do if your QC tests fail or are out of range
- If something goes wrong, write down how you fixed it
- Any issues should be recorded and a sentence on how it can be prevented, if possible, in the future
- Common problems and their corrections should be covered in your Standard Operating Procedures (SOP)
 - If you see things frequently, you can give them qualifiers that are noted in your SOP;
 - R = rain event
 - D = bad dilution, etc.

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QC Acceptance

- Have in SOP for each method the acceptance ranges for standards, duplicates, spikes, etc. and make sure they match the method requirements.
- If not mentioned in method, these are the accepted criteria for QC:
 - Blank < reporting limit
 - LFB $\pm 15\%$
 - MS/MSD $\pm 20\%$
 - ICV/CCV $\pm 10\%$
 - RPD $\pm 20\%$

Batch Size & QC Frequency

- Each "Batch" could be daily, every 10 samples or every 20 samples
- Check method
- If you sample only once a month, need to run QC each time
- QC Frequency is usually lumped in with the definition of a "batch" and should be in the SOP of some kind

Ammonia SM4500-NH₃ D -2011

- Standard Methods
 - 4500-NH₃ A.1 – In general, direct manual determination of low concentrations of ammonia is confined to drinking waters, clean surface or groundwater and good-quality nitrified wastewater effluent.
 - 4500-NH₃ D.1.b. – Sample distillation is unnecessary
- Tennessee recommends that one sample is run yearly to compare the distilled and undistilled results and that the results are within 20% of each other.
 - Note – if distilled sample and undistilled sample are below detection limit, you cannot calculate the percent difference.

Ammonia SM4500-NH₃ D -2011

- DOC
- MDL
- LRB
- LFB
- LFM/LFMD
- ICAL/CCV
- Control Charts
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency



BOD₅/cBOD₅ SM5210 B – 2011 & Hach Method 10360

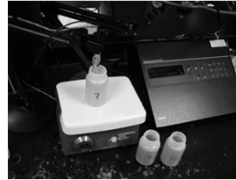
- DOC
- LRB
- LFB
- Dup
- ICAL/CCV
- Control Charts
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency



BOD₅/cBOD₅ SM5210 B – 2011 & Hach Method 10360

- Method Blanks
 - Real people language: analyze dilution water
 - Preferably one at the beginning and one at end
 - Run daily (every day of test set up)
 - Target value is less than 0.20 mg/L (preferably less than 0.10 mg/L)

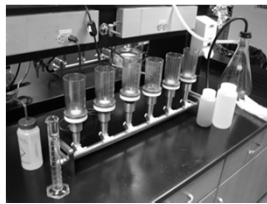
pH SM4500-H⁺ B – 2011 Electrometric Method



- DOC
- Dup
- ICAL/CCV
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency

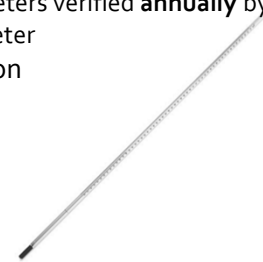
TSS SM2540 D – 2011 Dried at 103-105°C

- DOC
- LRB
- LFB
- Dup
- ICAL
- MDL (blanks only)
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency



Temperature SM2550 B – 2010 Thermometric Measurement

- ICAL
 - Have thermometers verified **annually** by an NIST thermometer
- Corrective Action
- QC Frequency



Standard Operating Procedure

- Here's that "13th Step", your SOP
- All procedures must be documented in some type of SOP
- It can be very simple but must provide the information necessary for someone who is not familiar with the test to perform it
 - Step by step instructions on how and where to collect the samples and then how to run the test
- It must include the QC Acceptance Criteria, the definition of a "Batch" and the minimum frequency of QC checks

Standard Operating Procedure (SOP)

- Describes the analytical method
- Sufficient detail that someone unfamiliar with the method could perform it and get satisfactory results
- Can include pictures (Ex: where samples are collected)
- It must include the QC Acceptance Criteria, the definition of a "Batch" and the minimum frequency of QC checks

Standard Operating Procedure (SOP)

- Should include :
 - Title of reference
 - Method #
 - Summary
 - Definitions
 - Interferences
 - Safety considerations
 - Equipment and supplies
 - Preservation and storage requirements
 - QC information
 - Etc...

Standard Operating Procedure (SOP)

- Annually:
 - Review/Update
 - Make any necessary adjustments
 - Changes to facility?
 - Changes to staff?
 - Document new Revision
 - Training
 - Have all analysts review/read
 - Have analysts sign off that they have done refresher
 - Documentation

Bench Sheets

- Where the analyst records the test results
- Even though data is transferred to the DMR, bench sheets are still an official record
- At a minimum, it should include:
 1. Date
 2. Time
 3. Analyst's initials
 4. Name of test/Method #
 5. Sample results
 6. Lot #s

Documentation

- 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

Just a few last notes...

- TN Guidance Document changes:
 - CBOD
 - Nitrification Inhibitor should be added to all samples, GGA, and Seed Controls. (Everything except blanks.)
 - pH
 - QC Acceptance Criteria (CCV and Duplicates) has been changed to "within +/- 0.1 s.u."

Any Questions?



Name of your WWTP
Your Street Address
Your town, TN XXXXX
(XXX) XXX-XXXX

Method: SM 4500-H⁺ B-2011 (22nd Ed.)
Date Created:
Revision Date:
Revision#: 1

Document Type: Standard Operating Procedure

Title: pH using SM 4500-H⁺ B-2011

Instrumentation: Name of your probe

Prepared By: (Lab Analyst name), Lab Analyst _____

Revised By: (Insert name), Lab Analyst _____

Approved By: (Insert name), Lab Manager _____

Approved By: (Insert name), Plant Manager _____

Table of Contents

- 1. Scope of Application.....page 2
- 2. Summary of Method.....page 2
- 3. Sample Handling and Preservation.....page 2
- 4. Interferences.....page 2
- 5. Apparatus.....page 2
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- 7. Procedure.....page 3
- 8. Quality Control.....page 4
- 9. Calculation.....page 5
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Name of your WWTP
Your Street Address
Your town, TN XXXXX
(XXX) XXX-XXXX

Method: SM 4500-H⁺ B-2011 (22nd Ed.)
Date Created:
Revision Date:
Revision#: 1

1. Scope and Application

- 1.1. This method is applicable for the analysis of pH (hydrogen ion concentration) surface water, domestic and industrial wastewaters.

2. Summary of Method

- 2.1. Manufacturer's instrument setup procedure is followed.
- 2.2. The meter is calibrated daily or at time of use with certified standards.
- 2.3. The calibration is verified with a mid-point or independent check standard (initial calibration verification or ICV).
- 2.4. The pH of the sample/samples is determined.
- 2.5. Continuing calibration verification is carried out using a mid-point or independent check standard. (CCV)

3. Sample Handling and Preservation

- 3.1. Samples are collected as 100 mL grab sample.
 - 3.1.1. Influent samples at influent sampler.
 - 3.1.2. Effluent samples at effluent sampler in Receiving Room.
- 3.2. Samples are collected in the morning when collecting composite samples.
- 3.3. Collect samples in a 100 mL plastic container.
 - 3.3.1. Fill container completely and cover until sample is analyzed.
- 3.4. Samples must be analyzed within 15 minutes of collection.

4. Interferences

- 4.1. Coatings of oily material or particulate matter can impair electrode response. Follow the manufacturer's recommendation for troubleshooting and cleaning if necessary.
- 4.2. Variation in temperature causes pH values to differ. This interference can be controlled with instruments having temperature compensation or by calibrating the electrode-instrument system at the temperature of the samples.
- 4.3. If compensation or calibration at the same temperature is not possible, it should be noted by reporting both the pH and the temperature at the time of analysis.

5. Apparatus

- 5.1. Orion Dual Star pH/ISE Meter
- 5.2. Orion Sure Flow Combination pH (Orion 9172BNWP)
- 5.3. Orion Automatic Temperature Compensation Probe (Orion 927007MD)

6. Reagents/Standards

- 6.1. Buffer Solution, pH 7 ± 0.2 (NIST), color coded yellow, 20L (Hach Cat. 22835-61)
- 6.2. Buffer Solution, pH 4.01 ± 0.2 (NIST), color coded red, 20L (Hach Cat. 22834-61)
- 6.3. Buffer Solution, pH 10.01 ± 0.2 (NIST), color coded blue, 20L (Hach Cat. 22836-61)
- 6.4. pH Storage Solution, 500 mL (Hach Cat. 27565-49)
- 6.5. Orion Filling Solution, Ross Reference Electrode Filling Solution, 60 mL (Orion 810007)
- 6.6. Deionized water for rinsing probe

Name of your WWTP
Your Street Address
Your town, TN XXXXX
(XXX) XXX-XXXX

Method: SM 4500-H⁺ B-2011 (22nd Ed.)
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Revision Date:
Revision#: 1

7. Procedure

7.1. General Information

7.1.1. All buffers and samples should either be at the same temperature, or, automatic (ATC), or manual temperature compensation performed.

7.1.1.1. To use automatic temperature compensation, plug the ATC probe into the jack labelled ATC on the rear panel and place into buffer/sample along with the pH electrode.

7.1.2. Stir all buffers and samples with a magnetic stirrer while a measurement is being made.

7.2. Instrument Setup

7.2.1. Prepare pH electrode as directed in the electrode instruction manual.

7.2.2. Securely connect electrodes to input 1.

7.2.2.1. For combination electrodes the BNC connector slides straight on; then is rotated to lock into place.

7.3. Instrument Calibration (Step 1)

7.3.1. In the measurement mode, press **cal** key.

7.3.2. Dual channel display only: Press the **▲/▼** keys to select channel 1 to be calibrated and press the **f2 (accept)** key.

7.3.3. Remove the fill hole cover during calibration and measurements to ensure a uniform flow of fill solution.

7.3.4. Rinse the pH electrode and ATC probe with deionized water, blot dry with a lint-free tissue and place the electrodes into the 7.0 buffer (Yellow).

7.3.4.1. Make sure that both the electrode tips are at least 1 inch below the surface of the solution.

7.3.5. When the electrode and buffer are ready, press the **f3 (start)** key.

7.3.6. Wait for the pH value on the meter to stop flashing and press the **f2 (accept)** key to accept the pH value.

7.3.7. Press the **f2 (next)** key to proceed to the next buffer and repeat steps 7.3.3-7.3.5 for 4.0 (Red) and 10.0 (Blue) Buffers.

7.3.8. Press **f3 (cal done)** key to end calibration.

7.3.9. Once the **f3 (cal done)** key is pressed, the meter will display a calibration summary including the average slope.

7.3.9.1. The slope should be 92-102%.

7.3.9.2. Log time of calibration, buffers used and slope in calibration log book.

7.3.10. Press the **f2 (log/print)** key to save and end the calibration.

7.3.11. The meter will automatically proceed to the measurement mode.

7.4. Initial Calibration Verification (Step 2)

7.4.1. As described in section 8.4 below, perform an ICV before starting a series of samples.

7.4.2. Record the results on the daily bench sheet.

7.5. Sample Measurements (Step 3)

7.5.1. Thoroughly rinse the pH electrode and temperature electrode with deionized water and blot dry with a clean towel.

7.5.2. Insert rinsed and dried electrodes into the sample making sure that the electrode tips are at least 1 inch below the surface of the sample.

7.5.3. Gently stir the sample while waiting for the instrument to stabilize.

7.5.4. Record the pH and the temperature on the daily bench sheet.

Name of your WWTP
Your Street Address
Your town, TN XXXXX
(XXX) XXX-XXXX

Method: SM 4500-H⁺ B-2011 (22nd Ed.)
Date Created:
Revision Date:
Revision#: 1

7.5.5.Repeat 7.5.1-7.5.4 for additional samples.

7.6. Continuing Calibration Verification ([Step 4](#))

7.6.1.As described in section 8.5 below, analyze a CCV after every 20 samples or at the end of each analytical run daily.

7.6.2.Record results on the daily bench sheet.

8. Quality Control

8.1. Initial Demonstration of Capability

8.1.1.Each analyst must successfully analyze 4 separate aliquots of pH buffer 7.0.

8.1.2.Each analyst must sign documentation that states the he/she has read and understands both this Standard Operating Procedure and SM 4500-H⁺ B-2000.

8.2. Duplicate

8.2.1.As a minimum, duplicates taken from the same sample will be performed on 1 out of every 20 samples or once a month, whichever is more frequent. The duplicate should agree within ± 0.2 s.u. of the original.

8.2.1.1. Duplicates will be analyzed every other Friday.

8.3. Calibration

8.3.1.Daily or at time of use (See 7.3 above).

8.4. Initial Calibration Verification

8.4.1.Following calibration and prior to starting a batch/series of samples, take the reading of a second standard pH 7.0 buffer as initial calibration verification (ICV).

8.4.2.If pH is within 0.2 pH units of the expected value, calibration is verified.

8.4.3.If pH is outside this range, repeat the ICV with a fresh aliquot of buffer.

8.4.4.If pH is still outside the acceptable range, recalibrate and note in log book.

8.5. Continuing Calibration

8.5.1.Analyze a calibration check standard (continuing calibration verification or CCV) after every 20 samples and/or at the end of each analytical run to recheck the validity of the calibration curve.

8.5.1.1. If the CCV is within 0.2 s.u. of the expected value, continue with sample analysis.

8.5.1.2. If the CCV differs by more than 0.2 s.u., repeat with a fresh aliquot of standard.

8.5.1.3. If this repeat CCV does not meet the criteria, a new calibration must be performed and all samples analyzed since the last valid calibration verification must be reanalyzed.

8.5.1.4. Any failure of Initial Calibration Verification (ICV), Continuing Calibration Verification (CCV) or Duplicate will be documented on daily bench sheet and calibration log book.

8.5.2.Established Batch Size

8.5.2.1. A batch is a maximum of 20 samples or all the samples analyzed during any calendar month, whichever is fewer.

Name of your WWTP
Your Street Address
Your town, TN XXXXX
(XXX) XXX-XXXX

Method: SM 4500-H⁺ B-2011 (22nd Ed.)
Date Created:
Revision Date:
Revision#: 1

9. Calculation

9.1. The pH meter reads directly in pH units. Report pH to the nearest 0.1 units.

10. References

- 10.1. Manufacturer's Instrument Manual
- 10.2. Method reference i.e., Standard Methods for the Examination of Water and Wastewater 4500-H⁺ B-2000.

Section 5

Microscopic Exam



Microscopic Exams
Wastewater Microbiology



1

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



Leeuwenhoek Microscope (circa late 1600s)

2

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

3

MICROSCOPES



4

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



5

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

6

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

7

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

8

COMPOUND MICROSCOPES

Light source

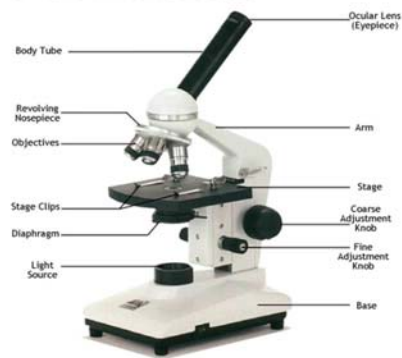
- “Illuminator” or lamp built into base
- Adjustable light intensity
- Mirror beneath stage, separate lamp required for illumination
- Brightfield: light rays passed through a condenser that directs rays through specimen

Diaphragm

- Rotating disc diaphragm: different holes through which light passes
- Iris diaphragm: aperture size is regulated by an adjustable arm on the side of the diaphragm's case

9

Parts of the Microscope



10

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

11

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

12

PROCEDURE (CONTINUED...)

When you are finished with your exam, clean oil off objective!

To store scope:

- move to low power objective
- raise stage, wrap cord around base
- lower stage gently to secure cord
- add protective cover

13

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

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SAMPLE COLLECTION

- Always collect a representative sample
 - Routine Samples - grab samples from same location and time
 - Non-routine Samples – collect what you are wanting to observe
- Once collected analyze within 15 minutes
 - Lack of DO can cause some bugs to appear dead
- Use a 100-300 mL plastic bottle for sample
- Samples
 - Conventional & Extended Aeration – Mixed Liquor from effluent end of aeration tank
 - Step-Feed & Contact Stabilization – at end of reaeration and effluent of aeration tank
 - Secondary Clarifier – clarifier effluent and settled sludge from the bottom
 - Foam – if suspect of filamentous bacteria

15

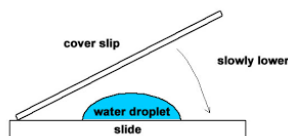
HOW TO PREPARE A WET MOUNT SLIDE

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 45° above sample
5. Slide slip toward sample drop
6. Allow sample to spread to cover slip edge

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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



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STAINING TYPES

Gram stain – helps identify foaming filaments

- Gram positive (purple): *Nocardia* (true branching), *Microthrix Parvicella* (purple spaghetti)
- Gram Negative (pink): Type 1863, Type 0092

Neisser stain

India Ink reverse stain

Polyhydroxybutyrate stain

Crystal Violet Sheath stain

18

SLIDE PREP, STAINING

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

19

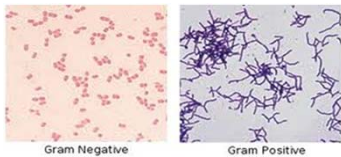
GRAM STAINS, HOW-TO

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

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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



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BACTERIA

- Convert dissolved organic material
 - Phosphates
 - Sugars
 - Proteins
 - Starches
- Comprise about 95% of activated sludge
 - Most are soil and aquatic bacteria
 - Major workhorses of the Activated Sludge System
- Sphere (coccus), rod (bacillus), and spiral (spirillum)
- Bacteria are more easily seen and identified by staining



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BACTERIA CLASSIFICATIONS

- Source of Energy
 - Autotrophs – self-feeders, use carbon dioxide as carbon source
 - Heterotrophs – use organic compounds as energy source
- Oxygen Requirements
 - Aerobic – require oxygen for growth
 - Anaerobic – grown in oxygen free environment
 - Facultative Aerobic – survive in both aerobic and anaerobic conditions
 - In absence of free oxygen, if available, use combined oxygen: Nitrates (NO₃), Sulfates (SO₄), etc.
 - Anoxic Zones
- Optimum Temperatures
 - Psychrophilic – 0 to 20° C
 - Mesophilic – 25 to 40° C
 - Thermophilic – 45 to 50° C

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FILAMENTS (FILAMENTOUS BACTERIA)

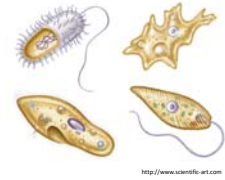
- Cells do not separate after cell division and grow in thread-like strands
- Some filaments OK for floc formation
 - Forms a backbone of sorts
 - Help aid in settling in clarifier
- Too many can end up competing with floc forming bacteria
 - Reduce settling
 - Reduce efficiency
- If you have excessive filaments:
 - Check DO levels > 1 PPM
 - Nutrients (N, P, FE)
 - pH
- No Filaments?
 - Check F/M ratio
 - Check DO, reduce if > 3.0 PPM



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PROTOZOA

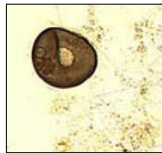
- Used as indicator organisms
 - Presence or absence
 - Number of bacteria in system
 - Effluent quality
 - Degree of treatment
- Predation on dispersed floc can help in secondary clarification
- No Protozoa?
 - F/M too high: Reduce wasting, increase return
 - Low to normal F/M: Increase DO, toxic shock
- Healthy protozoa, but dispersed floc?
 - Reduce mixing, reduce aeration



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AMOEBAE

- Earliest organism that show-up in activated sludge process
- Associated with "young sludge"
 - Startup
 - Recovering from "upset"
 - High F/M ratio
- Feed by pseudopodia (false feet)
 - Engulf small of organic matter
- Often encyst themselves in wastewater
 - Small numbers in activated sludge



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FLAGELLATES

- One or more hair-like appendages- Flagella
 - Propels itself in search of food
- Activated sludge activator
- Some feed on bacteria and small algae
 - Absorb soluble food through cell wall
- Others feed on soluble organic nutrients
 - Dominate early in treatment process when nutrients are high
 - Like a high F/M ratio
 - Could indicate DO is too low
 - Compete with bacteria



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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

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FREE SWIMMING CILIATES

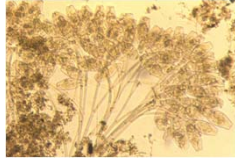
- Numerous hair-like extension called cilia
 - Beat rhythmically to propel in search of food
 - Direct solid food particles and bacteria through mouth
- Use lots of energy, require large amounts of food
 - Consume as many bacteria as possible
- Indicates process is approaching a stable operations



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STALKED CILIATES

- Only cilia is found around their mouths
 - Used to create a current to bring in food particles
- Feed mostly on suspended bacteria, algae, or smaller protozoa
- Rarely swing but attach to almost anything
- Grow separately or in colonies
 - Some are enclosed in a vase like sheath



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ROTIFERS

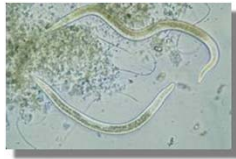
- Corona, wheel shaped organism with cilia
 - Moves constantly and brings food to rotifer
 - Can provide locomotion
- Has a mastax
 - A muscle that controls a set of jaws
 - Grinds the food brought in by cilia
- First to be affected by toxic load
 - Dead ones in sample – toxic load
- Clarify effluent by removing leftover bacteria, algae, and smaller protozoa
- Indication of a good settling sludge
 - Too many may need to waste



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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



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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



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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

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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*

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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

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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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ANY QUESTIONS?



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Section 6

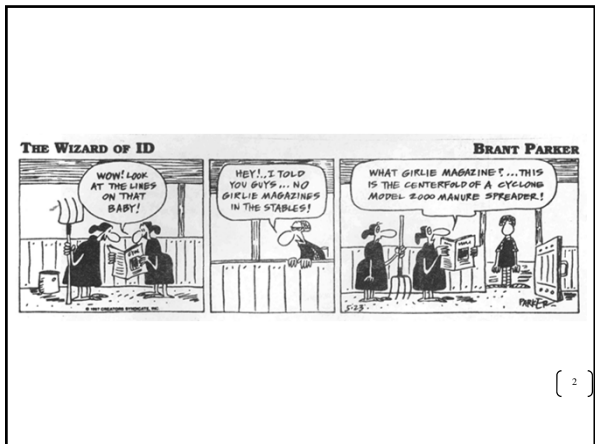
Sludge Thickening, Digestion and Dewatering

Sludge Thickening, Digestion, and Dewatering

- Or -
Now What Do We Do With It?

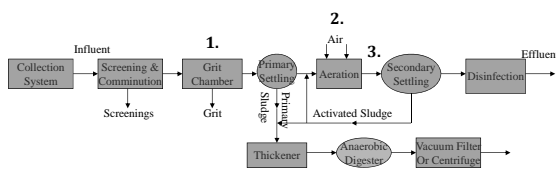
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Process Overview



{ 3 }

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

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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

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Sludge Thickening

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

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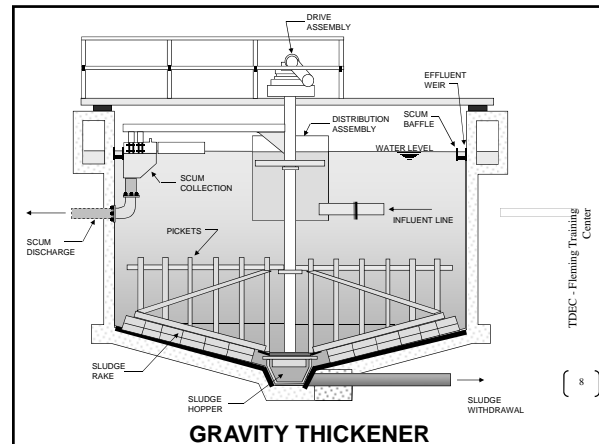
{ 6 }

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

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Gravity Thickening

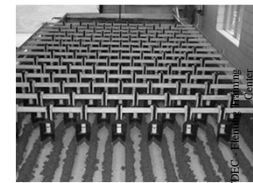
- Separates solids into three zones:
 1. Clear supernatant
 2. Sedimentation zone
 3. Thickening zone
- Dilute sludge is fed into center well
- Supernatant is returned to primary clarifier or plant headworks
- Thickened sludge is pumped to digester or dewatered

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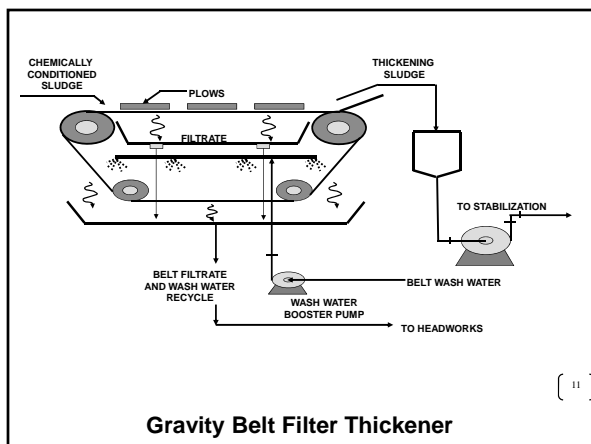
{ 9 }

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



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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 interstitial water from the float above the water level increases solids concentration (This is the *thickening* stage)

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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:
 - Anaerobically (in anaerobic digester, sludge heated and organics hydrolyzed into methane (CH₄), CO₂ and H₂O, and volatile solids reduced)
 - Aerobically (in unheated digester, producing CO₂ and H₂O, and reducing volatile solids)

General Overview

Before digestion of 100 pounds of sludge: 75% Volatile, 25% Fixed Solids	After a 65% reduction in Volatile Solids there is less sludge remaining to process

Biosolids Stabilization

Anaerobic Digestion

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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.

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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

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Anaerobic Digestion

- 2-phase process:
 - Acid formers - Facultative bacteria convert organic matter to volatile acids, CO₂, and H₂S
 - Methane producers - Anaerobic bacteria convert acids to CH₄ and CO₂
 - 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

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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

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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

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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.

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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.

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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.

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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).

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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)

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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.

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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.

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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)

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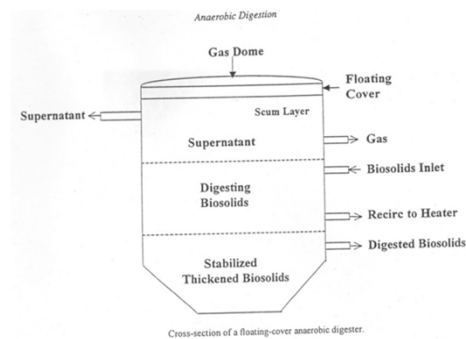
Feeding Anaerobic Digester

- 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

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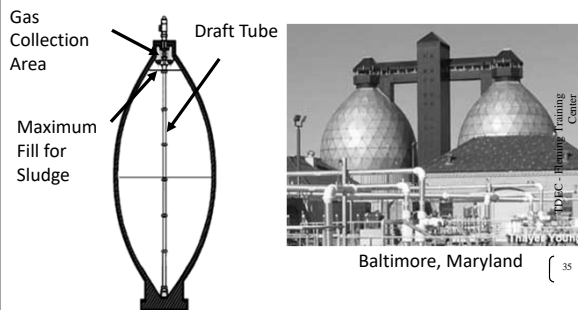
Anaerobic Digestion



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Cross-Section of an Egg-Shaped Digester



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Anaerobic Digesters

- | Fixed Cover Tanks | Floating Cover Tanks |
|--|--|
| <ul style="list-style-type: none"> • 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 | <ul style="list-style-type: none"> • 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 |

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Anaerobic Digesters - Covers

The diagrams show various cover types for anaerobic digesters. The top row includes Flat, Steel Truss, and Domed covers, collectively labeled as 'Fixed Covers'. The bottom row includes Floating, Gas Holder, and Membrane covers. A source note at the bottom reads: '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 °F (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 ft³ of gas is produced.

Anaerobic Digestion

- Volatile Acids to Alkalinity Ratio

$$\text{Ratio} = \frac{\text{volatile acids concentration, mg/L}}{\text{alkalinity concentration, mg/L}}$$
 - *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 CO₂ 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

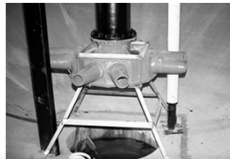
Mechanical mixing – most common method:

- 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

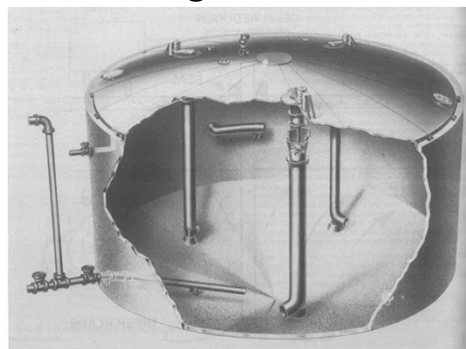



Fig. 12.22 Propeller mixer, draft tube, and digester. Courtesy of Dan Clark (copyright). Operation of Wastewater Treatment Plants, Vol II, seventh ed., p. 178

Anaerobic Digestion

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

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Gas Production

- The anaerobic digestion process (depending on the characteristics of the sludge) produces
 - 8-12 ft³ of gas for every pound of volatile matter **added**
 - 12-18 ft³ 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%.

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Gas Production

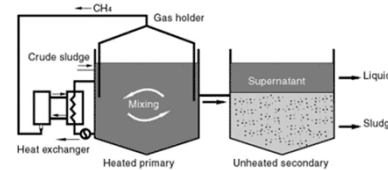
- Digester gas is used in plants in various ways:
 - For heating and mixing the digesters
 - Heating the plant buildings
 - Running engines
 - Air blowers for the activated sludge process
 - Electrical power for the plant
- Note: It is dangerous to start a digester when it is only partially full due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

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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



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Biosolids Stabilization

Aerobic Digestion

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Aerobic Digestion

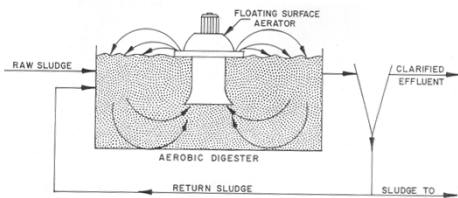
- Purpose: to extend decomposition of solids and regrowth of organisms to a point where available energy in active cells and storage of waste materials are low enough and material is stable enough for ultimate disposal
- Extended aeration of wastewater
 - Wastes stabilized by long-term aeration of about 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, CO₂, H₂O, SO₄⁻, NO₃⁻

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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

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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

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Sludge Dewatering

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Sludge Dewatering

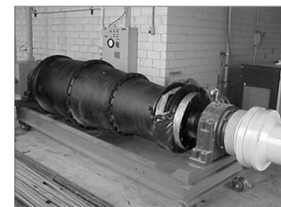
- Dewatering reduces sludge moisture and volume to allow for more economical disposal
1. Mechanical Dewatering:
 - Centrifuge*
 - Plate and Frame Press
 - Belt Press
 - Vacuum Filter*
 2. Drying Beds
 3. Blacktop Drying Beds
 4. Sludge Lagoon/Withdrawal to Land

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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



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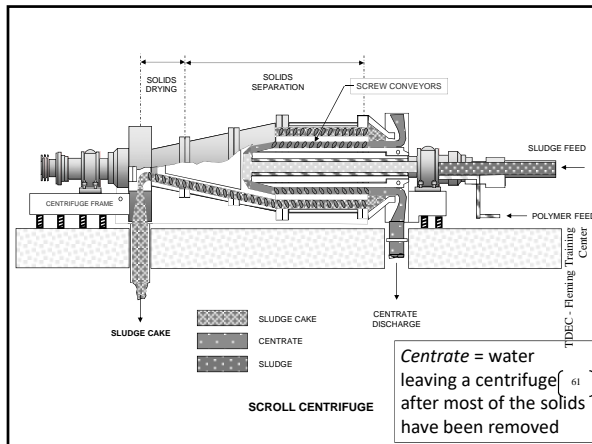


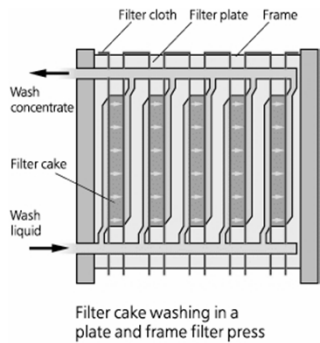
Plate-and-Frame

- 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

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Plate-and-Frame



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Plate-and-Frame

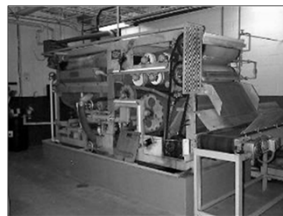


- JVAP (US Filter) – Chattanooga
- Modified plate and frame that is vacuum assisted
 - Steam heated at 163.4°F for 30 min
 - Entire process takes about 4 hours

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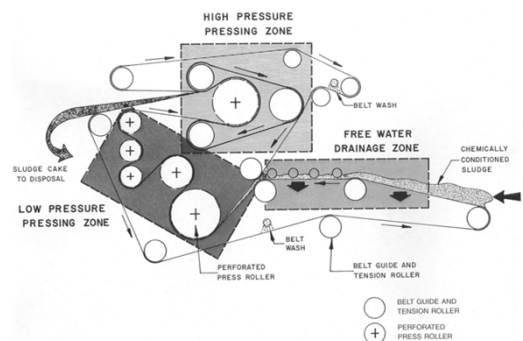
Belt Filter Press

- 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



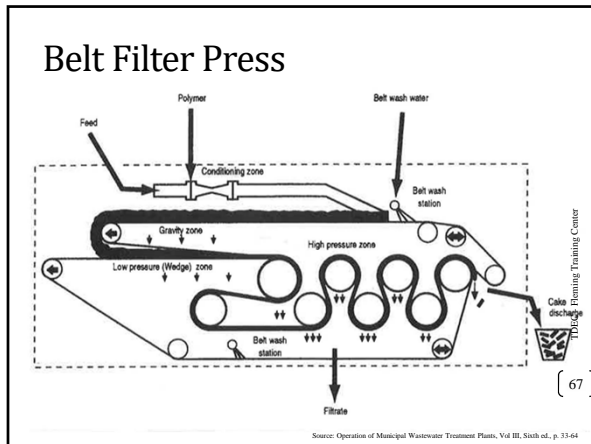
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Belt Filter Press



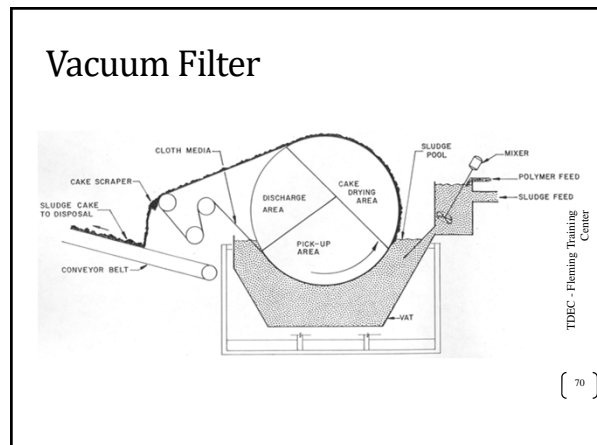
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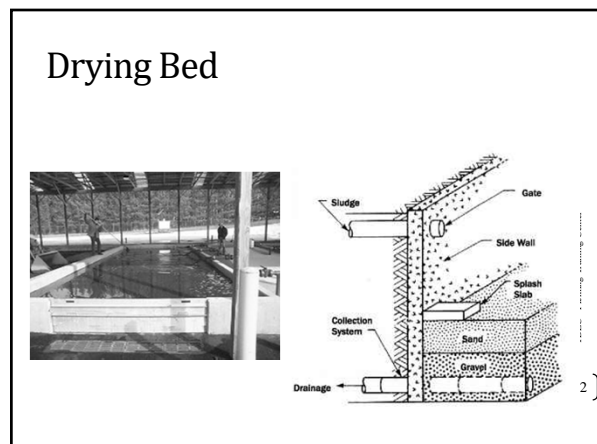


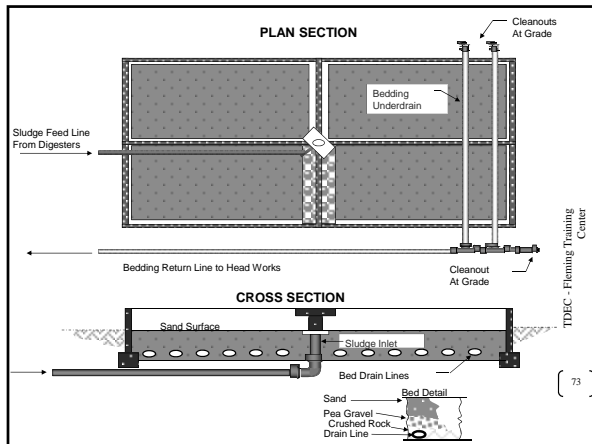
- ### Belt Filter Press
- Problem: Washout
 - “belt blinding” or “plugging”— result of inadequate belt washing or chemical blinding
 - Manually clean belts with high-pressure hose to restore at least some of the drainage
 - Polymer dose and belt speed too low
 - Hydraulic load too high
 - Problem: Cake solids too wet
 - Belt speed too high
 - Belt tension too low
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- ### 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
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- ### 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
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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 40°C (avg. temp 45°C) for 14 days or longer (during biosolids composting)
5. Add alkaline materials to raise the pH under specified conditions

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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

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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.

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Any Questions?



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CHAPTER 12

Sludge Processing and Disposal

12.1 General

- 12.1.1 Definition
- 12.1.2 Total Systems Approach To Design
- 12.1.3 Recycle Streams
- 12.1.4 Multiple Units
- 12.1.5 Sludge Pumps
- 12.1.6 Sludge Piping

12.2 Sludge Production

12.3 Thickening

- 12.3.1 General
- 12.3.2 Gravity Thickeners
- 12.3.3 Flotation Thickeners
- 12.3.4 Centrifugal Thickeners
- 12.3.5 Other Thickeners

12.4 Conditioning

- 12.4.1 General
- 12.4.2 Chemical

12.5 Digestion

- 12.5.1 Anaerobic Digestion
- 12.5.2 Aerobic Sludge Digestion

12.6 Composting

12.7 Sludge Dewatering

- 12.7.1 General
- 12.7.2 Sludge Drying Beds
- 12.7.3 Mechanical Dewatering

12.8 Sludge Storage Lagoons

12.9 Sludge Disposal

SLUDGE PROCESSING AND DISPOSAL

12.1 General

12.1.1 Definition

Sludge is a broad term used to describe the various aqueous suspensions of solids encountered during treatment of sewage. The nature and concentration of the solids control the processing characteristics of the sludge. Grit screenings and scum are not normally considered as sludge and therefore are not discussed in this section.

12.1.2 Total Systems Approach to Design

The most frequently encountered problem in wastewater treatment plant design is the tendency to optimize a given subsystem, such as sludge dewatering, without considering the side effects of this optimization on the overall plant operation and treatment costs.

Sludge handling processes can be classified as thickening, conditioning, stabilization, dewatering, and disposal. Numerous process alternatives exist within each of these categories. Each unit process should be evaluated as part of the total system, keeping in mind that the objective is to use that group of processes that provides the most cost-effective method of sludge disposal.

The analysis should include a materials balance to identify the amounts of material which enter, leave, accumulate, or are depleted in the given process and the system as a whole. Energy requirements should also be provided to aid in determining capital and operating costs of the total system.

12.1.3 Recycle Streams

Recycle streams from the process alternatives, including thickener overflow, centrate, filtrate, and supernatant, should be returned to the sewage treatment process at appropriate points to maintain effluent quality within the limits established. Volume and strength of each recycle stream should be considered in the plant design. Sidestream treatment should be provided if the load is not included in the plant design or if the side stream will upset the treatment process. Equalization of side streams should be considered to reduce instantaneous loading on the treatment process.

12.1.4 Multiple Units

Multiple units and/or storage facilities should be provided so that individual units may be taken out of service without unduly interrupting plant operation.

12.1.5 Sludge Pumps

12.1.5.1 Capacity

Pump capacities should be adequate to maintain pipeline velocities of 3 feet per second. Provisions for varying pump capacity are desirable.

12.1.5.2 Duplicate Units

Duplicate units shall be provided where failure of one unit would seriously hamper plant operation.

12.1.5.3 Type

Plunger pumps, progressing cavity pumps, or other types of pumps with demonstrated solids handling capability should be provided for handling raw sludge.

12.1.5.4 Minimum Head

A minimum positive head of 24 inches (or the manufacturer's recommendation) should be provided at the suction side of centrifugal-type pumps and is desirable for all types of sludge pumps. Maximum suction lifts should not exceed 10 feet (or the manufacturer's recommendation) for plunger pumps.

12.1.5.5 Sampling Facilities

Unless sludge sampling facilities are otherwise provided, quick-closing sampling valves should be installed at the sludge pumps. The size of valve and piping should be at least 1-1/2 inches.

12.1.6 Sludge Piping

12.1.6.1 Size and Head

Sludge withdrawal piping shall have a minimum diameter of 8 inches for gravity withdrawal and 6 inches for pump suction and discharge lines. Where withdrawal is by gravity, the available head on the discharge pipe should be at least 2 feet and preferably more, with provisions to backflush the line.

12.1.6.2 Slope

Gravity piping shall be laid on uniform grade and alignment. Slope on gravity discharge piping should not be less than 3 percent.

12.1.6.3 Cleaning

Provision should be made for draining and flushing suction and discharge lines. Where sludge pumps are available, piping should be such that suction lines can be backflushed with pump discharge or rodded. Glass-lined or equivalent pipe should be considered for raw sludge piping and scum lines.

12.1.6.4 Corrosion Resistance

Special consideration shall be given to the corrosion resistance and continuing stability of pipes and supports located inside digestion tanks.

12.2 Sludge Production

The sludge production rates listed in the literature have often been shown to be underestimated. The sludge production rates (SPR) listed below in Table 12-1 have been determined from various studies and provide a more realistic basis for designing solids handling facilities. These values shall be used for design unless other acceptable data is submitted.

Table 12-1
Sludge Production Rates

Type of Treatment	(lb sludge) SPR (lb BOD removed)
Conventional Activated Sludge	0.85
Extended Aeration	0.75
Contact Stabilization	1.00
Other Activated Sludge	0.85
Trickling Filter	0.75
Roughing Filters	1.00

12.3 Thickening

12.3.1 General

The cost-effectiveness of sludge thickening should be considered prior to treatment and/or disposal.

12.3.1.1 Capacity

Thickener design should provide adequate capacity to meet peak demands.

12.3.1.2 Septicity

Thickener design should provide means to prevent septicity during the thickening process. Odor consideration should be considered.

12.3.1.3 Continuous Return

Thickeners should be provided with a means of continuous return of supernatant for treatment. Provisions for side-stream treatment of supernatant may be required.

12.3.1.4 Chemical Addition

Consideration should be given to the use of chemicals or polymer to improve solids capture in the thickening process. This will not normally increase the solids level of the thickened sludge.

12.3.2 Gravity Thickeners

12.3.2.1 Stirring and skimming

Mechanical thickeners should employ pickets on rake arms for continuous gentle stirring of the sludge. Skimmers should be considered for use with biological sludges.

12.3.2.2 Depth and Freeboard

Tank depth shall be sufficient so that solids will be retained for a period of time needed to thicken the sludge to the required concentration and to provide storage for fluctuations in solids loading rates.

The thickener should be operated to avoid denitrification. At least two feet of freeboard shall be provided above the maximum water level.

12.3.2.3 Continuous Thickening

Variable-speed sludge draw-off pumps may be provided so that thickening can be continuous, or an adjustable on-off time clock control for pulse withdrawal may be used with constant-speed pumps to improve control over the thickening.

12.3.2.4 Solids and Surface Loading Rates

The engineer shall provide the design basis and calculations for the solids and surface loading rates and the support calculations upon request. Thickener solids loading rates vary with the type of sludge. Some typical solids loading rates are given below in Table 12-2. These values shall be used for design unless other acceptable data are submitted. For loading rates of other type sludges, refer to Table 5.2 of the EPA Process Design Manual-Sludge Treatment and Disposal.

**Table 12-2
Solids Loading Rate**

Type of Sludge	(lb/day/sq ft)
Primary	20-30
Activated sludge	5-6
Trickling filter	8-10
Primary and activated combined	6-10
Primary and trickling filter combined	10-12

Surface loading rates of 400 gallons per day per square foot (gpd/sq ft) or less will normally result in septic conditions. To prevent septic conditions, surface overflow rates should be maintained between 500 and 800 gpd/sq ft. For very thin mixtures or WAS only, hydraulic loading rates of 100-200 gpd/sq ft are appropriate. An oxygen-rich water source, such as secondary effluent, shall be available as a supplemental flow to the thickener to achieve the necessary overflow rates.

The diameter of a gravity thickener should not exceed 80 feet.

12.3.2.5 Bottom Slope

Bottom slopes shall be sufficient to keep the sludge moving toward the center well with the aid of a rake. Generally, the slope should be greater than conventional clarifiers. A floor slope of 2-3 inches per foot is recommended.

12.3.3 Flotation Thickeners

Flotation thickeners are normally used to concentrate waste activated sludge.

12.3.3.1 Air-Charged Water

The thickener underflow is generally used as a source of water for the air-charging units, although primary tank effluent or plant effluent may also be used.

12.3.3.2 Design Sizing

The engineer shall provide the design basis for sizing the units and for the support calculation. Design sizing should be based on rational calculations, including: total pounds of waste sludge anticipated, design solids and hydraulic loading of the unit, operating cycle in hours per day per week, removal efficiency, and quantity and type of chemical aids required. Flotation thickeners are normally sized by solids surface loadings.

Typical design loadings range from 1.0 to 2.5 pounds per hour per square foot. (See Table 12-3, for typical solids loading rates to produce a minimum 4% solids concentration.)

12.3.3.3 Hydraulic Loading Rates

If polymers are used, hydraulic loading rates of 2.5 gpm/sq ft or less should be used. The hydraulic loading rates shall be lower if polymers are not used. Hydraulic loading rates shall be based on the total flow (influent plus recycle). The design of any thickened sludge pump from DAF units should be conservative. Frequently, polymer conditioned sludge will result in a solids concentration greater than 4%. Pumps shall be capable of handling a sludge of at least 5% thickness.

TABLE 12-3

TYPICAL DAF THICKENER SOLIDS LOADING RATES NECESSARY TO PRODUCE A MINIMUM 4 PERCENT SOLIDS CONCENTRATION

<u>Solids loading rate, lb/sq ft/hr</u>		
<u>Type of sludge</u>	<u>No chemical addition</u>	<u>Optimum chemical addition</u>
Primary only	0.83 - 1.25	up to 2.5
Waste activated sludge (WAS)		
Air	0.42	up to 2.0
Oxygen	0.6 - 0.8	up to 2.2
Trickling filter	0.6 - 0.8	up to 2.0
Primary + WAS (air)	0.6 - 1.25	up to 2.0
Primary + trickling filter	0.83 - 1.25	up to 2.5

12.3.4 Centrifugal Thickeners

12.3.4.1 Pretreatment

Any pretreatment required is in addition of that required for the main wastewater stream. For example, separate and independent grit removal may be needed for the centrifuge feed stream.

Disc nozzle centrifuges require pretreatment of the feed stream. Both screening and grit removal are required to reduce operation and maintenance requirements. Approximately 11% of the feed stream will be rejected in pretreatment, consideration should be given to the treatment of this flow. It is usually routed to the primary clarifier.

Basket centrifuges do not require pretreatment and are recommended in small plants (1.0-2.0 MGD) without primary clarification and grit removal.

Solid bowl decanter centrifuges require grit removal in the feed stream and are a potentially high maintenance item.

12.3.4.2 Chemical Coagulants

Provisions for the addition of coagulants to the sludge should be considered for improving dewatering and solids capture.

12.3.4.3 Design Data

The engineer shall provide the design basis for loading rates and support calculations. Both hydraulic and solids loading rate limitations should be addressed.

12.3.5 Other Thickeners

Other thickener designs will be evaluated on a case-by-case basis. Pilot plant data shall be provided by the design engineer upon request.

12.4 Conditioning

12.4.1 General

Pretreatment of the sludge by chemical or thermal conditioning should be investigated to improve the thickening, dewatering, and/or stabilization characteristics of the sludge.

The effects of conditioning on downstream processes and subsequent side-stream treatment should be evaluated. Thermal conditioning will concentrate the BOD level of the side stream. Its treatment must be considered in calculating organic loadings of other units.

12.4.2 Chemical

Type of chemical, location of injection, and method of mixing should be carefully considered to ensure obtaining anticipated results. Pilot testing is often necessary to determine the best conditioning system for a given sludge.

12.5 Digestion

12.5.1 Anaerobic Digestion

12.5.1.1 General

a. Operability

Anaerobic digestion is a feasible stabilizing method for wastewater sludges that have low concentrations of toxins and a volatile solids content above 50%. It should not be used where wide variations in sludge quantity and quality are common. Anaerobic digestion is a complex process requiring close operator control. The process is very susceptible to upsets as the microorganisms involved are extremely sensitive to changes of their environment. Frequent monitoring of the following parameters is required:

- (i) pH (6.4 - 7.5 recommended)
- (ii) volatile acids/alkalinity ratio (always 0.5 or greater)
- (iii) toxics (volatile acids, heavy metals, light metal cations, oxygen, sulfides, and ammonia)
- (iv) temperature (within 1° F of design temperature)
- (v) recycle streams (BOD, SS, NH₃, phenols)

The importance of avoiding digester upsets cannot be overlooked. The methane-producer bacteria have a very slow growth rate and it will take two weeks or more to resume normal digester performance.

b. Multiple Units

Multiple units should be provided. Staged digestion design may be used, provided the units can be used in parallel as well as in series. Where multiple units are not provided, a lagoon or storage tanks should be provided for emergency use so that digestion tanks may be taken out of service without unduly interrupting plant operation. Means of returning sludge from the secondary digester unit to the primary digester should be provided. In large treatment plants where digesters are provided, separate digestion of primary sludges should be considered.

c. Depth

The proportion of depth to diameter should provide for the formation of a supernatant liquor with a minimum depth of 6 feet. Sidewall depth is generally about one-half the diameter of the digester for diameters up to 60 feet, and decreases to about one-third the diameter for diameters approaching 100 feet.

d. Maintenance Provisions

To facilitate emptying, cleaning, and maintenance, the following features are required:

(i) Slope

The tank bottom shall slope to drain toward the withdrawal pipe. A slope of between 1 inch per foot and 3 inches per foot is recommended.

(ii) Access Manholes

At least two access manholes should be provided in the top of the tank, in addition to the gas dome. One opening should be large enough to permit the insertion of mechanical equipment to remove scum, grit, and sand. A separate side wall manhole should be provided at ground level.

(iii) Safety

Nonsparking tools, rubber-soled shoes, safety harness, gas detectors for flammable and toxic gasses and the hose type or self-contained type breathing apparatus shall be provided.

e. Pre-thickening of sludge may be advantageous, but the solids content shall be less than 8% to ease mixing problems.

12.5.1.2 Sludge Inlets and Outlets

Multiple sludge inlets and draw-offs and multiple recirculation suction and discharge points should be provided to facilitate flexible operation and effective mixing of the digester contents, unless adequate mixing facilities are provided within the digester. One inlet should discharge above the liquid level and be located at approximately the center of the tank to assist in scum breakup. Raw sludge inlet points should be located to minimize short-circuiting to the supernatant drawoff.

12.5.1.3 Tank Capacity

a. General

Two cultures of bacteria are primarily involved in anaerobic digestion: acid formers and methane formers. Capacity of the digester tank shall be based on the growth rate of the methane-formers, as they have extremely slow growth rates.

b. Solids Basis

Where the composition of the sewage has been established, tank capacity should be computed from the volume and character of sludge to be digested. The total digestion tank capacity should be determined by rational calculations based upon factors such as volume of sludge added, its percent solids and character, volatile solids loading, temperature to be maintained in the digesters, and the degree or extent of mixing to be obtained. These detailed calculations shall be submitted to justify the basis of design.

Where composition of the sewage has not been established, the minimum combined digestion tank capacity outlined below shall be provided. Such requirements assume that the raw sludge is derived from ordinary domestic wastewater, a digestion temperature is maintained in the range of 85° to 100° F, there is 40 to 50 percent volatile matter in the digested sludge, and that the digested sludge will be removed frequently from the process.

(i) Completely Mixed Systems

For heated digestion systems providing for intimate and effective mixing of the digester designed for a constant feed loading rate of 150 to 400 pounds 1,000 cubic feet of volume per day in the active digesting unit. The design average detention time in completely mixed systems shall have sufficient mixing capacity to provide for complete digester turnover every 30 minutes.

(ii) Moderately Mixed Systems

For digestion systems where mixing is accomplished only by circulating external heat exchanger, the system may be loaded up to 40 pounds of volatile solids per 1,000 cubic feet of volume per day in the active digestion units. This loading may be modified upward or downward, depending upon the degree of mixing provided. Where mixing is accomplished by other methods, loading rates will be determined on the basis of information furnished by the design engineer.

c. Population Basis

Where solids data are not available, the following unit capacities shown in Table 12-4 for conventional, heated tanks shall be used for plants treating domestic sewage.

The capacities should be increased by allowing for the suspended solids population equivalent of any industrial wastes in the sewage. The capacities stated apply where digested sludge is dewatered on sand drying beds and may be reduced if the sludge is dewatered mechanically or otherwise frequently withdrawn.

Table 12-4
Cubic Feet Per Capita

<u>Type of Plant</u>	<u>Moderately Mixed Systems</u>	<u>Completely Mixed Systems</u>
Primary	2 to 3	1.3
Primary and Trickling Filter	4 to 5	2.7 to 3.3
Primary and Activated Sludge	4 to 6	2.7 to 4

For small installations (population 5,000 or less) the larger values should be used.

12.5.1.4 Gas Collection System

a. General

All portions of the gas system, including the space above the tank liquor, storage facilities, and piping shall be so designed that under all normal operating conditions, including sludge withdrawal, the gas will be maintained under positive pressure. All enclosed areas where any gas leakage might occur shall be adequately ventilated.

b. Safety Equipment

All necessary safety facilities shall be included where gas is produced. Pressure and vacuum relief valves and flame traps, together with automatic safety shutoff valves, are essential. Water-seal equipment shall not be installed on gas piping.

c. Gas Piping and Condensate

Gas piping shall be of adequate diameter and shall slope to condensation traps at low points.

The use of float-controlled condensate traps is not permitted. Condensation traps shall be placed in accessible locations for daily servicing and draining. Cast iron, ductile iron, and/or stainless steel piping should be used.

d. Electrical Fixtures and Equipment

Electrical fixtures and equipment in enclosed places where gas may accumulate shall comply with the National Board of Fire Underwriters' specifications for hazardous conditions. Explosion-proof electrical equipment shall be provided in sludge-digestion tank galleries containing digested sludge piping or gas piping and shall be provided in any other hazardous location where gas or digested sludge leakage is possible.

e. Waste Gas

Waste gas burners shall be readily accessible and should be located at least 50 feet away from any plant structure, if placed near ground level, or may be located on the roof of the control building if sufficiently removed from the tank. Waste gas burners shall not be located on top of the digester. The waste gas burner should be sized and designed to ensure complete combustion to eliminate odors.

f. Ventilation and Cover

Any underground enclosures connecting with digestion tanks or containing sludge or gas piping or equipment shall be provided with forced ventilation. Tightly fitting, self-closing doors shall be provided at connecting passageways and tunnels to minimize the spread of gas. A floating cover should be provided instead of a fixed cover for increased operational flexibility and safety.

g. Metering

Gas meters with bypasses should be provided to meter total gas production and utilization.

h. Pressure Indication

Gas piping lines for anaerobic digesters should be equipped with closed-type pressure indicating gauges. These gauges should read directly in inches of water. Normally, three gauges should be provided, one to measure the main line pressure, a second to measure the pressure upstream of gas-utilization equipment, and the third to measure pressure to wasteburners.

Gas-tight shutoff and vent cocks shall be provided. The vent piping shall be extended outside the building, and the opening shall be screened to prevent entrance by insects and turned downward to prevent entrance of rainwater. All piping shall be protected with safety equipment.

i. Gas Utilization Equipment

Gas-burning boilers, engines, and other gas utilization equipment should be located at or above ground level in well-ventilated rooms. Gas lines to these units shall be provided with suitable flame traps.

12.5.1.5 Heating

a. Insulation

Digestion tanks should be constructed above the water table and should be suitably insulated to minimize heat loss.

b. Heating Facilities

Sludge may be heated by circulating the sludge through external heaters or by units located inside the digestion tank.

(i) External Heating

Piping should be designed to provide for the preheating of feed sludge before introduction to the digesters. Provisions should be made in the layout of the piping and valving to facilitate cleaning of these lines.

Heat exchanger sludge piping should be sized for heat transfer requirements.

(ii) Internal Coils

Hot water coils for heating digestion tanks should be at least 2 inches in diameter and the coils, support brackets, and all fastenings should be of corrosion-resistant material. The use of dissimilar metals should be avoided to minimize galvanic action. The high point in the coils should be vented to avoid air lock.

(iii) Other Methods

Other types of heating facilities will be considered on their own merits.

c. Heating Capacity

Sufficient heating capacity shall be provided to consistently maintain the digesting sludge temperature to within 1°F (0.6°C) of the design temperature. An alternate source of fuel should be available and the boiler or other heat source should be capable of using the alternate fuel if digester gas is the primary fuel. Thermal shocks shall be avoided. Sludge storage may be required to accomplish this.

d. Hot Water Internal Heating Controls**(i) Mixing Valves**

A suitable automatic mixing valve should be provided to temper the boiler water with return water so that the inlet water to the heat jacket or coils can be held to below a temperature (130° to 150°F) at which sludge caking will be accentuated. Manual control should also be provided by suitable bypass valves.

(ii) Boiler Controls

The boiler should be provided with suitable automatic controls to maintain the boiler temperature at approximately 180°F to minimize corrosion and to shut off the main fuel supply in the event of pilot burner or electrical failure, low boiler water level, or excessive temperature.

(iii) Thermometers

Thermometers shall be provided to show temperatures of the sludge, hot water feed, hot water return, and boiler water.

12.5.1.6 Mixing

Facilities for mixing the digester contents shall be provided where required for proper digestion by reason of loading rates, or other features of the system.

12.5.1.7 Supernatant Withdrawal

a. Piping Size

Supernatant piping should not be less than 6 inches in diameter, although 4-inch lines will be considered in special cases.

b. Withdrawal Arrangements

(i) Withdrawal Levels

Piping should be arranged so that withdrawal can be made from three or more levels in the tank. A positive unvalved vented overflow shall be provided.

(ii) Withdrawal Selection

On fixed-cover tanks the supernatant withdrawal level should preferably be selected by means of interchangeable extensions at the discharge end of the piping.

(iii) Supernatant Selector

If a moveable supernatant selector is provided, provision should be made for at least one other draw-off level located in the supernatant zone of the tank in addition to the unvalved emergency supernatant draw-off pipe. High-pressure backwash facilities should be provided.

(iv) Sampling

Provisions shall be made for sampling at each supernatant draw-off level. Sampling pipes should be at least 1-1/2 inches in diameter.

(v) Supernatant Handling

Problems such as shock organic loads, pH, and high ammonia levels associated with digester supernatant shall be addressed in the plant design. Recycle streams should be bled continuously back to the treatment process.

12.5.2 Aerobic Sludge Digestion

12.5.2.1 Mixing and Aeration

Aerobic sludge digestion tanks shall be designed for effective mixing and aeration. Minimum mixing requirements of 20 cubic feet per minute per 1,000 cubic feet for air systems and 0.5 horsepower per 1,000 cubic feet for mechanical systems are recommended. Aeration requirements may be more or less than the mixing requirements, depending on system design and actual solids loading. Approximately 2.0 pounds of oxygen per pound volatile solids are needed for aeration.

If diffusers are used, types should be provided to minimize clogging and designed to permit removal for inspection, maintenance, and replacement without dewatering the tanks, if only one digester is proposed.

12.5.2.2 Size and Number of Tanks

The size and number of aerobic sludge digestion tank or tanks should be determined by rational calculations based upon such factors as volume of sludge added, its percent solids and character, the degree of volatile solids reduction required and the size of installation with appropriate allowance for sludge and supernatant storage.

Generally, 40 to 50 percent volatile solids destruction is obtained during aerobic digestion. To ensure a stabilized sludge which will not emit odors, the volatile solids content should be less than 60 percent in the digested sludge. Calculations shall be submitted upon request to justify the basis of design. The following design parameter ranges should be considered the minimum in designing aerobic digestion facilities.

a. Hydraulic Detention Time

Hydraulic detention time at 20°C should be in the range of 15 to 25 days, depending upon the type of sludge being digested. Activated sludge alone requires the lower detention time and a combination of primary plus activated or trickling filter sludges requires the high detention time. Detention times should be adjusted for operating temperatures other than 20°C.

b. Volatile Solids

The volatile solids loading shall be in the range of 0.1 to 0.2 pound of volatile solids per cubic foot per day.

c. Dissolved Oxygen

Design dissolved oxygen concentration should be in the range of 1 to 2 mg/l. A minimum of 1.0 mg/l shall be maintained at all times.

d. Mixing Energy

Energy input requirements for mixing should be in the range of 0.5 to 1.5 horsepower per 1,000 cubic feet where mechanical aerators are used; 20 to 35 standard cubic feet of air per minute per 1,000 cubic feet of aeration tank where diffused air mixing is used on activated sludge alone; and greater than 60 cubic feet per minute per 1,000 cubic feet for primary sludge alone and primary plus activated sludge.

e. Storage

Detention time should be increased for temperatures below 20°C. If sludge cannot be withdrawn during certain periods, additional storage capacity should be provided. Plants smaller than 75,000 gpd should have storage capacity of 2 cubic foot per population equivalent served.

12.5.2.3 Supernatant Separation

Facilities should be provided for separation or decantation of supernatant. Provisions for sidestream treatment of supernatant should be considered.

12.6 Composting

Composting operations will be considered on a case-by-case basis, provided that the basis for design and a cost-effective analysis are submitted by the engineer.

12.7 Sludge Dewatering

12.7.1 General

Drainage from drying beds and centrate or filtrate from dewatering units should be returned to the sewage treatment process at appropriate points preceding the secondary process. The return flows shall be returned downstream of the influent sample and/or flow measuring point and a means shall be provided to sample return flows. These organic loads must be considered in plant design.

12.7.2 Sludge Drying Beds

12.7.2.1 Area

It is recommended that wastewater systems have a hybrid sludge disposal method because of the seasonal downtime associated with drying beds. The amount of rainfall normal for our state makes the use of sludge drying beds insufficient at times.

Consideration shall be given to the location of drying beds to avoid areas where moisture in the air is higher than normal (i.e., adjacent to rivers where morning fog is common).

In determining the area for sludge drying beds, consideration shall be given to climatic conditions, the character and volume of the sludge to be dewatered, type of bed used, and methods of ultimate sludge disposal. Design calculations shall be submitted upon request to substantiate the area used.

Drying bed design should be based on square feet per capita or pounds of sludge solids per square foot per year.

Table 12-5 presents the range of values that should be used, these values are for drying anaerobically digested sludges. Additional area is required for wetter sludges such as those resulting from aerobic digestion; therefore, use the higher number of the required range.

Table 12-5 DRYING BED DESIGN CRITERIA*

<u>Type of Sludge</u>	<u>Open Beds</u>	<u>Covered Beds</u>	
	Per Capita (sq ft/capita)	Solids (lb/sq ft/yr)	Per Capita (sq ft/capita)
Primary	1.0 to 1.5	27.5	0.75 to 1.0
Attached Growth	1.25 to 1.75	22.0	1.0 to 1.25
Suspended Growth	2.50	15.0	2.00

*The design engineer should rely on his experience and the plant location.

These criteria are a minimum.

12.7.2.2. Percolation Type

a. Gravel

The lower course of gravel around the underdrains should be properly graded to range in size from 1/4-inch to 1-inch and should be 12 inches in depth, extending at least 6 inches above the top of the underdrains. It is desirable to place this in 2 or more layers. The top layer of at least 3 inches should consist of gravel 1/8 inch to 1/4 inch in size. The gravel shall be laid on an impervious surface so that the filtrate will not escape to the soil.

b. Sand

The top course shall consist of at least nine inches of sand with a uniformity coefficient of less than 3.5. For trickling filter sludge, the effective size of the sand shall be between 0.8 to 3.0 millimeter. For waste activated sludge, the effective size of the sand shall be between 0.5 to 0.8 millimeter. For combinations, use the lower size range.

c. Underdrains

Underdrains should be clay pipe, concrete drain tile, or other underdrain acceptable material and shall be at least 4 inches in diameter and sloped not less than 1 percent to drain. Underdrains shall be spaced between 8 and 20 feet apart. The bottom of the bed shall slope towards the underdrains. Consideration should be given to placing the underdrain in a trench.

12.7.2.3 Impervious Types

Paved surface beds may be used if supporting data to justify such usage are acceptable to the Department. The use of paved beds for aerobically digested sludge is generally not recommended.

12.7.2.4 Walls

Walls should be watertight and extend 15 to 18 inches above the ground surface. Outer walls should be curbed to prevent soil from washing onto the beds.

12.7.2.5 Sludge Removal

Not less than two beds should be provided and they should be arranged to facilitate sludge removal. Concrete truck tracks should be provided for all

percolation-type sludge beds with pairs of tracks for the beds on appropriate centers. If truck access is by way of an opening in the drying bed wall, the opening shall be designed so that no sludge will leak out during the filling process.

12.7.2.6 Sludge Influent

The sludge pipe to the beds should terminate at least 12 inches above the surface and be arranged so that it will drain. Concrete splash plates shall be provided at sludge discharge points.

12.7.3 Mechanical Dewatering

12.7.3.1 Methods and Applicability

The methods used to dewater sludge may include use of one or more of the following devices:

- a. Rotary vacuum filters
- b. Centrifuges, either solid bowl or basket type
- c. Filter presses
- d. Horizontal belt filters
- e. Rotating gravity concentrators
- f. Vacuum drying beds
- g. Other "media type" drying beds

The technology and design of sludge dewatering devices are constantly under development; therefore, each type should be given careful consideration.

The applicability of a given method should be determined on a case-by-case basis, with the specifics of any given situation being carefully evaluated, preferably in pilot tests. The engineer shall justify the method selected using pilot plant data or experience at a similar treatment plant.

12.7.3.2 Considerations

Considerations in selection should include:

- a. Type and amount of sludge
- b. Variations in flow rate and solids concentration
- c. Capacity of the equipment
- d. Chemicals required for conditioning
- e. Degree of dewatering required for disposal
- f. Experience and qualifications of plant staff
- g. Reliability
- h. Operation and maintenance cost
- i. Space requirements

12.7.3.3 Storage

Adequate storage shall be provided for all systems.

12.8 Sludge Storage Lagoons

Refer to Chapter 9, Ponds and Aerated Lagoons, for the requirements of sludge storage lagoons.

12.9 Sludge Disposal

The ultimate disposal of sludge through various methods (i.e., landfilling, land application) is subject to the regulations and/or guidelines of the Tennessee Division of Water Pollution Control (DWPC). Approval by DWPC is required prior to initiation of the selected disposal alternative.

Sludge Thickening, Digestion, and Dewatering Vocabulary

1. The primarily organic solid product produced by wastewater treatment processes that can be beneficially recycled is called _____. (This term replaces the word 'sludge' when referring to wastes that have been treated. In contrast, sludge is unprocessed and generally unsuitable for beneficial use.)
2. This group of bacteria is referred to as "acid formers" and they convert the organic or volatile matter into volatile acids during anaerobic digestion. _____
3. Aerobic digesters rely on _____, the situation that occurs when bacteria oxidize some of their own cellular mass instead of new organic matter that they would adsorb or absorb from their environment.
4. The process of _____ reduces sludge moisture and volume to allow for more economical disposal.
5. The washing of digested sludge with either fresh water, plant effluent, or other wastewater is called _____. The objective is to remove (wash out) fine particulates and/or the alkalinity in the sludge. This process reduces the demand for conditioning chemicals and improves settling or filtering characteristics of the solids.
6. The water leaving a centrifuge after most of the solids have been removed is called the _____.
7. _____ describes the treatment process in which wastewater solids and water (about 5% solids, 95% water) are placed in a large tank (known as a digester) and bacteria decompose the solids in the absence of oxygen.
8. During the anaerobic digestion process, two groups of bacteria work together in sequence: the saprophytic organisms, which produce volatile acids that will be consumed by the _____.
9. The measure of the capacity of a solution or liquid to neutralize acids or bases is called _____. This is the measure of the capacity of water or wastewater for offering a resistance to changes in pH. (*The volatile acid/alkalinity relationship is an indication of this with regards to digester contents.)
10. During _____, sludge to be treated is placed in a large aerated tank where aerobic microorganisms decompose the organic matter in the sludge. This digestion process may be used to treat only WAS, or trickling filter sludge and primary (raw) sludge, or waste sludge from activated sludge treatment plants designed without primary settling.
11. Cold temperature bacteria: _____
Medium temperature bacteria: _____

High temperature bacteria: _____

12. The most important factor to monitor with anaerobic digesters is the _____.

When this ratio starts to increase, corrective action must be taken immediately to prevent a sour digester.

13. This serves as the foundation of all regulatory policies regarding Biosolids: _____

Word Bank

Aerobic digestion

Biosolids

Saprophytic organisms

Anaerobic digestion

Thermophilic bacteria

Psychrophilic bacteria

Mesophilic bacteria

40 CFR 503

Methane fermenters

Centrate

Dewatering

Volatile acid/Alkalinity ratio

Endogenous respiration

Buffering capacity

Sludge Thickening, Digestion, and Dewatering Review Questions

1. Briefly explain what is happening during anaerobic digestion.
2. What happens if you add too much raw sludge to the digester?
3. Why is it hazardous to start a digester when it is only partially full?
4. A thick sludge as possible may be pumped to the digester by operating the sludge pump for several minutes per hour, at a rate not to exceed ____ _____, to clear the sludge hopper.
5. What causes foaming in an anaerobic digester and what steps would you take to prevent foaming from occurring?

6. List some common problems associated with a belt filter press and what can be done to attempt to fix those problems.

7. An operator is doing a routine inspection and notices that the floating cover on the anaerobic digester is tilting. What could be causing this condition?

8. 40 CFR 503 Regulations specify maximum levels of fecal coliform allowed in finished biosolids to meet Pathogen Reduction requirements for land application.

List the fecal coliform criteria for:

Class A biosolids= _____

Class B biosolids = _____

9. Laboratory tests show that the volatile acids/alkalinity ratio in your anaerobic digester is beginning to rise. You recognize that this is the first sign of a major problem, what do you do next?

What every operator should know about biosolids management for land application

Steve Wilson



Knowledge	Principles	Practical considerations
Regulatory requirements	Title 40, <i>Code of Federal Regulations</i> , Part 503 Various state and local rules	The 1993 40 <i>CFR</i> Part 503 Rule and technical support documents serve as the foundation of all regulatory policies. State or local jurisdictions can be more conservative in some cases, but never less stringent.
Terminology	<i>Biosolids</i> versus <i>sewage sludge</i>	<i>Biosolids</i> are the primarily organic solid product of wastewater treatment that can be beneficially used. <i>Sludge</i> or <i>sewage sludge</i> is unprocessed (<i>i.e.</i> , unstabilized) and generally unsuitable for beneficial use. The Part 503 rule does not use the term <i>biosolids</i> , but subsequent guidance and state-level policies have recognized the distinction between <i>sludge</i> and <i>biosolids</i> and use this terminology.
Product standards	Rules and guidance define acceptable (risk-based) chemical characteristics focusing on metals. Pathogen reduction and stabilization (vector attraction reduction) standards also are defined.	Metal (pollutant) limits are defined in the Part 503 rule. Metals rarely are limiting in beneficial use programs because pretreatment programs have been so effective. But operators always should check data for verification. Pathogen reduction will be to Class A or Class B standards depending on process technology. Class B product reuse has management practice limits to protect operator and public health. Stabilization standards, such as the minimum 38% volatile solids reduction through digestion, minimize odors during product handling and reuse and help minimize complaints.
Agronomic rates	Application rates are determined to match the amount of available nitrogen applied to the amount needed by crops.	Available nitrogen is calculated in units of pounds per dry ton. This value is converted to a wet (or as-applied) basis in either wet tons or gallons per acre in line with fertilizer recommendations for the crop being grown. Many guidance documents and even online spreadsheets are available to assist in making these calculations (see below). Spreader equipment then is calibrated to deliver this amount of material per unit of field.
Marketability	Class B biosolids generally are delivered at no cost or for a nominal fee; the land owner benefits from the fertilizer value. Class A products may be marketed more aggressively and sometimes are sold to offset production costs. Quality may be more important.	Product quality parameters include <ul style="list-style-type: none"> ■ meeting or exceeding all regulatory requirements, ■ lack of visible trash or foreign material, ■ low odor potential, ■ “soil-like” consistency (<i>i.e.</i>, manufactured topsoil or compost), and ■ dust-free product with uniform particle size (for dried products).



Steve Wilson



Steve Wilson

Knowledge	Principles	Practical considerations
Monitoring	Part 503 and state rules dictate sampling frequencies, parameters, and methodology.	<p>Testing generally includes Part 503 metals (arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc), nutrients (total Kjeldahl nitrogen, ammonium–nitrogen, nitrate–nitrogen, and phosphorus), and percent-total and percent-volatile solids.</p> <p>For Class A products, additional testing is required to demonstrate pathogen reduction to minimal (1000 MPN/g dry solids) levels.</p>
Reporting	Agencies must report process control details (to verify pathogen and vector attraction reduction), biosolids quantities, pollutant concentrations, nutrient values, and biosolids disposition information on an annual basis.	<p>At a minimum, a biosolids “preparer” must submit an annual report to the U.S. Environmental Protection Agency (EPA) for the previous year by February 19. Where authority has been delegated to states, the report goes to the state regulatory agency. Dual reporting to both state and EPA is not uncommon.</p> <p>The preparer must certify that all regulatory requirements have been met. In some cases, a contract “applier” must submit a separate report certifying land application practices. The preparer always should verify that a separate applier has met all requirements.</p>
Resources	Comprehensive guidance and training is available readily from several sources.	<p>A short list of sources includes the following:</p> <ul style="list-style-type: none"> ■ The Water Environment Federation provides access to state regulatory contacts, technical resources, and other documents at www.wef.org/biosolidsnews. ■ EPA lists a wealth of links and information at http://water.epa.gov/polwaste/wastewater/treatment/biosolids. ■ EPA also posts the <i>Plain English Guide to the Part 503 Rule</i> at http://water.epa.gov/scitech/wastetech/biosolids/503pe_index.cfm.
Networking	Become active in your regional or local biosolids community.	Regional biosolids communities include the Northwest Biosolids Management Association (Seattle), the North East Biosolids Recycling Association (Tamworth, N.H.), the Mid-Atlantic Biosolids Association (Philadelphia), the California Association of Sanitation Agencies (Sacramento, Calif.), and WEF Member Association biosolids committees.
Promoting public support	Share information.	News releases about program successes benefit public understanding by sharing positive biosolids recycling news.
Potential for public opposition	Be aware.	An Internet search for “biosolids” reveals the extent of unsupported, unscientific, negative information that is out there for the uninformed to use as the basis for their first impression of biosolids recycling. It’s important to understand what kind of faulty information the public may be exposed to.
Research and emerging issues	Support research.	Questions about fundamental biosolids benefits and controls – not to mention emerging constituents, personal care products, and other microconstituents – abound. Consider funding research with local universities directly through your agency or as a regional association member.

Steve Wilson is a chief scientist in the Portland, Ore., office of Brown and Caldwell (Walnut Creek, Calif.).

Section 7

Safety

Safety

Wastewater Treatment

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Safety

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

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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.

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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



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Traffic Safety



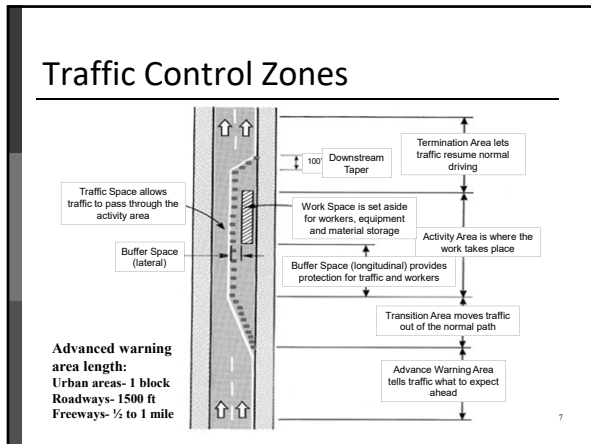
TDEC - Fleming Training Center 5

Traffic Control Zones

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



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Manhole Hazards

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

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Confined Space

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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

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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. Please refer to the manual for more information on 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 must be outside a permit required space
 - Entrant

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Atmospheric Hazards

- ❑ Need to have atmosphere monitored!!!
 - Explosive or flammable gas or vapor
 - ❑ These can develop in the collection system or sewer plant due 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%

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Hydrogen Sulfide – H₂S



- ❑ 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%)

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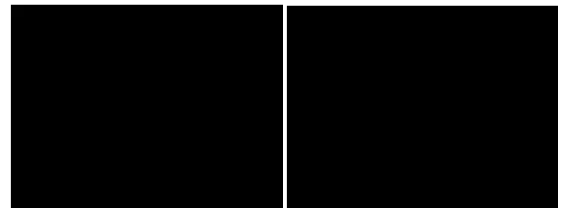
Hydrogen Sulfide – H₂S

%	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

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Hydrogen Sulfide – H₂S



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Methane Gas – CH₄

- ❑ 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

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Methane Gas – CH₄

%	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)

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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

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Carbon Monoxide - CO

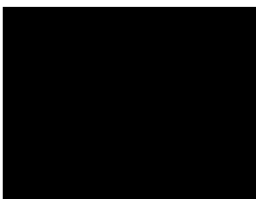
%	PPM	Hazard
74	740,000	Upper Explosive Limit (UEL)
12.5	125,000	Lower Explosive (LEL)
0.2	2,000	Unconscious in 30 minutes
0.15	1,500	IDLH
0.05	500	Sever headache
0.02	200	Headache after 2-3 hours
0.0035	35	8-hour exposure limit
0.0035	35	Alarm set point

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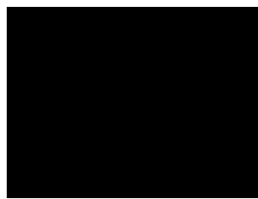
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Carbon Monoxide - CO

Carbon Monoxide poisoning



Canaries used to CO detection



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Oxygen – O₂

- ❑ 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

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Oxygen – O₂

%	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

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Oxygen – O₂

- When O₂ 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

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Oxygen – O₂

- 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

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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**



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Atmospheric Alarm Units

- Alarms set to read:
 - Flammable gasses exceeding 10% of the LEL
 - H₂S exceeds 10 ppm and/or
 - O₂ 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

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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

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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



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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



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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!

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Lockout / Tagout



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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

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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



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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

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Lockout/Tagout



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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

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Training Requirements

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

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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

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Required Record Keeping

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

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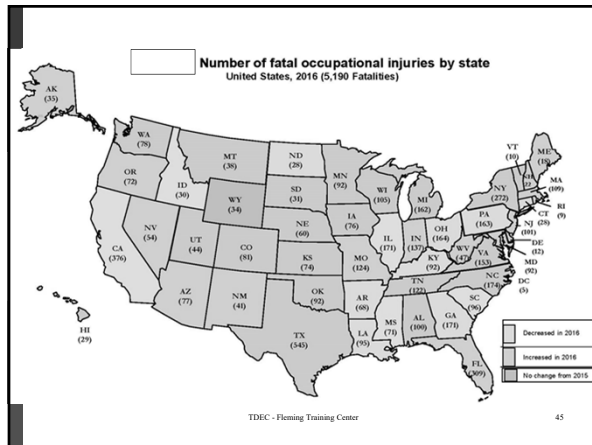
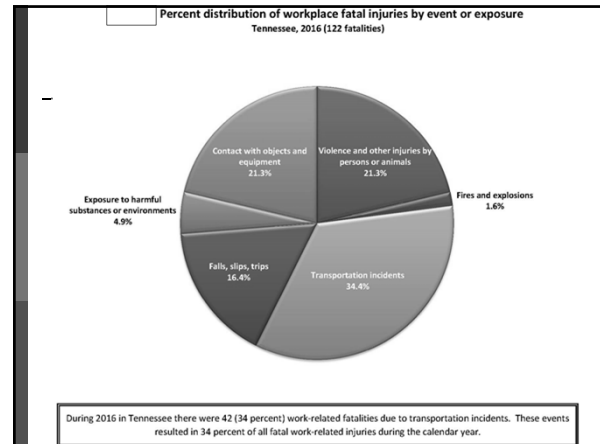
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Most Cited Industry Standards By TOSHA

- ❑ 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

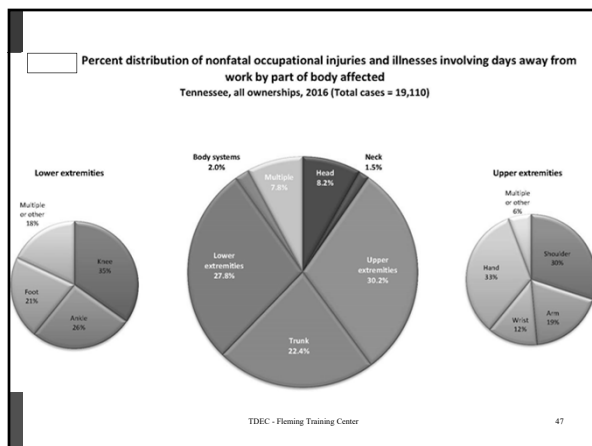
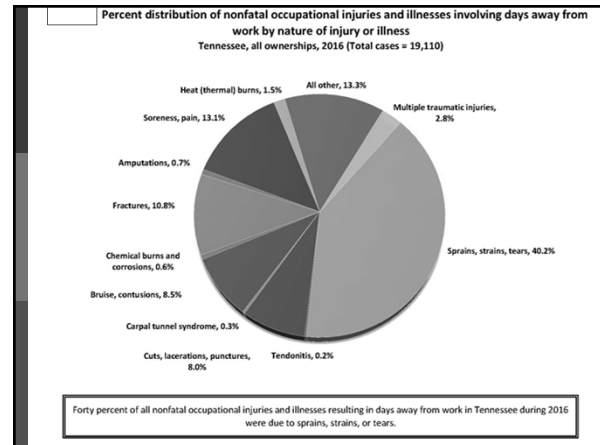
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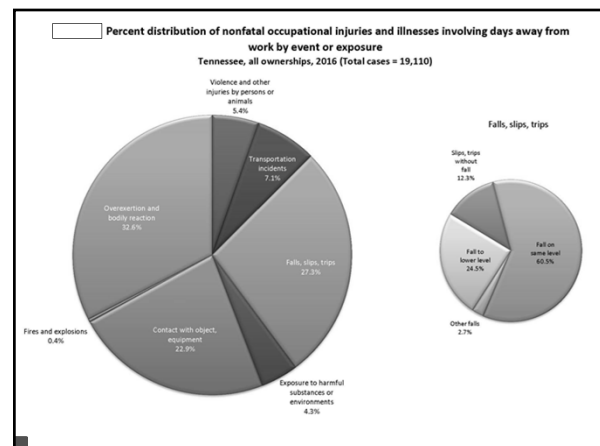
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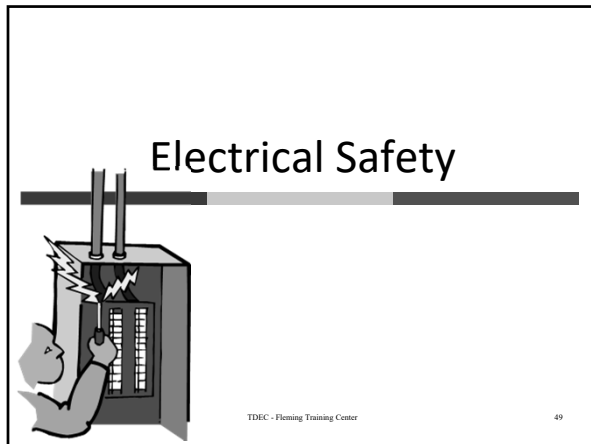
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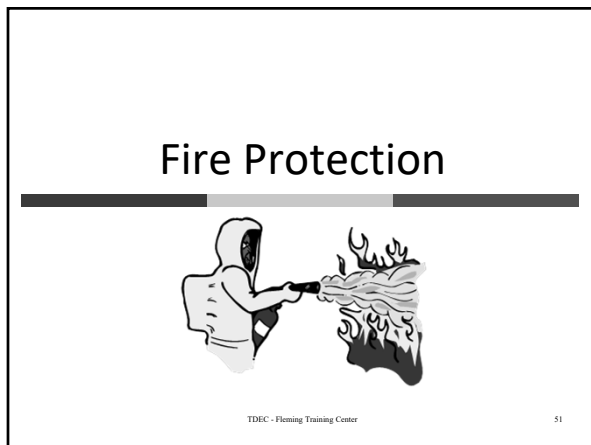


OSHA Says

- ❑ 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

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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.

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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.

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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.

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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

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Types of Fire Extinguishers

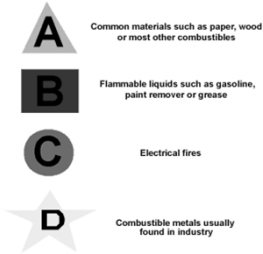
- Combination ABC are most common
- Have the types of extinguishers available depending upon analyses performed in each area

A
Common materials such as paper, wood or most other combustibles

B
Flammable liquids such as gasoline, paint remover or grease

C
Electrical fires

D
Combustible metals usually found in industry




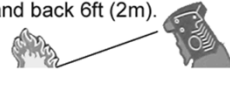
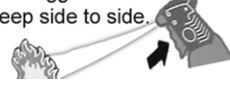
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Fire Extinguishers

- To operate a fire extinguisher, remember the word PASS
 - Pull the pin. Hold the extinguisher with the nozzle pointing away from you
 - Aim low. Point the extinguisher at the base of the fire.
 - Squeeze the lever slowly and evenly.
 - Sweep the nozzle from side-to-side.

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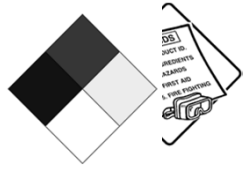
Fire Extinguishers

1. Pull pin. Hold unit upright. 
2. Aim at base of fire. Stand back 6ft (2m). 
3. Press trigger. Sweep side to side. 



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Chemical Safety



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Personal Protective Equipment

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



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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



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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

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Minimum Info for SDS

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

* Non mandatory

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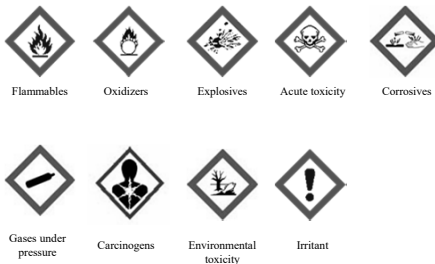
MSDS to SDS

- 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

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OSHA Pictograms



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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

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RTK Labels

HEALTH

FLAMMABILITY

REACTIVITY

PERSONAL PROTECTION

□ “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.

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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

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Chemical Label

HEALTH

4 Too dangerous to enter vapor or liquid

3 Extremely dangerous use full protective clothing

2 Hazardous – Use breathing apparatus

1 Slightly hazardous

0 Like ordinary material

FLAMMABLE

4 Extremely flammable

3 Ignites at normal temperatures

2 Ignites when moderately heated

1 Must be preheated to burn

0 Will not burn

REACTIVITY

4 May detonate – Vacate area if materials are exposed to fire

3 Strong shock or heat may detonate – Use monitors from behind explosive resistant barriers

2 Violent chemical change possible – Use hose streams from distance

1 Unstable if heated – Use normal precautions

0 Normally stable

4

3 3

W


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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

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Trenching



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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**

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Safety

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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.

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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.

Word Bank

Competent person	Carcinogen
Permit-required	Mercaptans
IDLH (Immediately Dangerous to Life or Health)	Oxygen deficiency
Chronic	Engulfment
Septic	
Spoil	
Nonsparking tool	
Oxygen enrichment	
Confined space	
Non-permit	
Sewer gas	
Lower explosive limit (LEL)	
Decibel	
Acute	
Olfactory fatigue	

Safety Review Questions

1. How can an explosive or flammable atmosphere develop in a collection system?
2. An atmospheric test unit should be used to determine if any hazards exist in a confined space prior to entry, list the order of what gases should be checked first, second, and third.
3. If an operator is scheduled to perform work in a manhole, when should the atmosphere in the manhole be tested?
4. When a blower is used to ventilate a manhole, where should the blower be located?
5. List the safety equipment recommended for use when operators are required to enter a confined space.
6. What are some early signs that an operator is not getting enough oxygen in a manhole or confined space?
7. How can collection system operators protect themselves from injury by the accidental discharge of stored energy?
8. How can collection system operators protect their hearing from loud noises they may encounter in a confined space?

9. How do you extinguish a fire?
10. What is the primary purpose of a safety data sheet (SDS)?
- To assist with the maintenance of proper inventories of materials
 - To provide a record of the proper storage of materials
 - To provide health and safety information regarding the use and handling of specific materials
 - To identify when materials have expired and need to be replaced
11. A sewer system shall not be entered without a self-contained breathing apparatus (SCBA) if the hydrogen sulfide level exceeds?
- 10 ppm
 - 100 ppm
 - 200 ppm
 - 500 ppm
12. Nobody may enter a confined space, as defined by OSHA or the employer, unless the proposed entrant has first undergone training in:
- The wearing, use, and maintenance of enhanced level B PPE
 - The details of the facility confined space entry procedures
 - Emergency first aid related to the contaminants expected to be present
 - Maintenance of the appropriate rescue equipment
13. Which class of extinguisher should be used for electrical fires?
- Class A
 - Class B
 - Class C
 - Class D

Trenching & Excavation Safety Checklist

Site Location _____ Date _____ Time _____ a.m.
p.m.

GENERAL INSPECTION

1. Has the "Competent Person" had specific training in—and is knowledgeable about—soil analysis, use of protective systems, and the requirements of 29CFR1926-Subpart P: Excavations and Trenches? YES NO N/A
2. Does the "Competent Person" have the authority to remove workers from the excavation immediately? YES NO N/A
3. Are excavations, adjacent areas, and protective systems inspected by a Competent Person:
A. Daily prior to the start of work, B. As needed throughout the shift, and C. After every rainstorm or other occurrence that could increase the hazard? YES NO N/A
4. Are ALL surface encumbrances removed or supported? YES NO N/A
5. Are ALL employees protected from loose rock or soil that could pose a hazard by falling or rolling into the excavation? YES NO N/A
6. Are hard hats worn by ALL employees? YES NO N/A
7. Are spoils, materials, and equipment set back at least 2 feet from the edge of the excavation? YES NO N/A
8. Are barriers provided at all remotely located excavations, wells, pits, shafts, etc.? YES NO N/A
9. Are walkways and bridges over excavations 6 feet or more in depth and 30 inches or more in width equipped with standard guard rails and toe boards? YES NO N/A
10. Are warning vests or other highly visible clothing provided and worn by all employees exposed to vehicular traffic? YES NO N/A
11. Are employees required to stand away from vehicles being loaded or unloaded? YES NO N/A
12. Are warning systems established and used when mobile equipment is operating near the edge of an excavation? YES NO N/A
13. Are employees prohibited from going under suspended loads? YES NO N/A
14. Are employees prohibited from working on the faces of sloped or benched excavations above other employees? YES NO N/A

UTILITIES

15. Are utilities companies contacted and/or utilities located as required by local, state, and federal law? YES NO N/A
16. Are the exact locations clearly marked? YES NO N/A
17. Are underground installations protected, supported, or removed when an excavation is open? YES NO N/A

ACCESS & EGRESS

18. Are ladders or other means of access and egress in place in all trenches 4 feet or more deep? YES NO N/A
19. Are all workers within 25 feet of a means of access and egress? YES NO N/A
20. Are the ladders that are used in excavations secured and extended 3 feet above edge of the excavation? YES NO N/A
21. Are ALL structural ramps used by employees designed by a "Competent Person?" YES NO N/A
22. Are ALL structural ramps used for equipment designed by a Registered Professional Engineer? YES NO N/A
23. Are ALL ramps constructed of materials of uniform thickness, cleated together, equipped with no-slip surfaces? YES NO N/A
24. Are employees protected from cave-ins when entering or exiting excavation? YES NO N/A

WET CONDITIONS

25. Are precautions taken to protect employees from water accumulation? YES NO N/A
26. Is water removal equipment monitored by "Competent Person?" YES NO N/A
27. Is surface water or runoff diverted after every rainstorm or other hazard-increasing occurrence? YES NO N/A

HAZARDOUS ATMOSPHERES

- 28. Is the atmosphere within ALL excavations tested when there is a reasonable possibility of an oxygen-deficient, oxygen-enriched, combustible, toxic, or other harmful contaminant? YES NO N/A
- 29. Are adequate precautions taken to protect employees from exposure to an atmosphere containing less than 19.5% oxygen and/or other hazardous atmosphere? YES NO N/A
- 30. Is verification provided to protect employees from an atmosphere containing flammable gas in excess of 10% of the lower explosive limit of the gas? YES NO N/A
- 31. Is emergency equipment available when hazardous atmospheres could or do exist? YES NO N/A
- 32. Are employees trained to use personal protective equipment and other rescue equipment? YES NO N/A

SOILS

- 33. Has the Competent Person classified the soil using one manual test and one visual test, as specified by the standard? YES NO N/A

Visual Test _____ (Type) Manual Test _____ (Type)

Soil Classified as: Solid Rock Type A Type B Type C

SUPPORT SYSTEMS

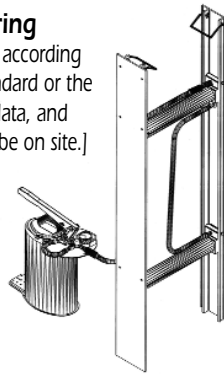
3 Primary Options are Available:

Note: If an excavation is deeper than 5 feet (4 feet in some states), a support system is required by federal law, except for excavations entirely in stable rock (very rare!). If an excavation is less than 5 feet deep (4 feet in some states), a support system is required if there is a potential for a cave-in, as determined by the "Competent Person."

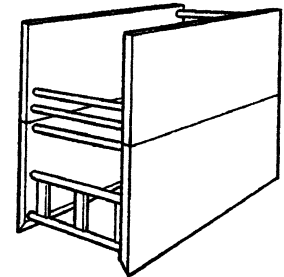
Option #1 – Sloping
[For excavations less than 20 feet deep.]

SOIL TYPE	MAXIMUM ALLOWABLE SLOPE (H:V)
Stable Rock	Vertical or 90°
Type A	¾:1 or 53°
Type B	1:1 or 45°
Type C	1½ : 1 or 34°

Option #2 – Shoring
[Shoring must be installed according to charts in the OSHA standard or the manufacturer's tabulated data, and these charts or data must be on site.]



Option #3 – Shielding
[Shielding must be installed according to the manufacturer's tabulated data, and this data must be on site.]



Note: A 4th option always available is a system designed by a Registered Professional Engineer [Designs must be in writing, they must meet OSHA's requirement, and must be on site.]

- 34. Are materials and/or equipment chosen based upon soils analysis, trench depth and expected loads? YES NO N/A
- 35. Are materials and equipment that are used for protective systems inspected and in good condition? YES NO N/A
- 36. Are damaged materials and equipment immediately removed from service? YES NO N/A
- 37. Are damaged materials and equipment inspected by a Registered Professional Engineer after repairs are made and before being placed back in service? YES NO N/A
- 38. Are protective systems installed without exposing employees to hazards of cave-ins, collapses, or threat of being struck by materials or equipment? YES NO N/A
- 39. Are ALL members of support systems securely fastened together to prevent failure? YES NO N/A
- 40. Are support systems provided to insure stability of adjacent structures, buildings, roadways, sidewalks, etc.? YES NO N/A
- 41. Are excavations below the level of the base or footing supported, and approved by a Registered Professional Engineer? YES NO N/A
- 42. Does back-filling progress with the removal of the support system? YES NO N/A
- 43. Is a shield system installed to prevent lateral movement? YES NO N/A
- 44. Are employees prohibited from remaining in a shield system during vertical movement? YES NO N/A

Job Notes: _____


Inspected by: _____

Construction techniques and equipment usage must be in accordance with all governmental regulations and manufacturers' instruction. All orders placed with TrenchSafety are subject to the terms, conditions, and warranty limitations contained in TrenchSafety's Rental and Sales Agreements.

Section 8

Cross Connection Control

Cross-Connection Control



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Outline

- Case studies of backflow incidents
- Basics of Cross-Connection Control
- Hydraulics
- Definitions
- Backflow Preventers
- Applications

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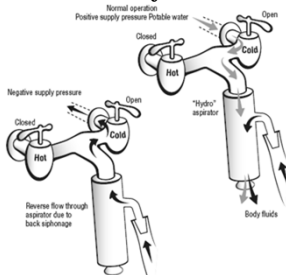
Backflow Case Study

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



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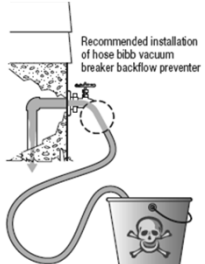
Backflow Case Study

Kool-Aid Laced with Chlordane

Exterminator submerged garden hoses in small buckets while mixing insecticide at the same time a water meter was being installed nearby

During a new water meter installation chlordane was backsiphoned into water lines and became mixed with Kool-Aid

A dozen children and three adults became sick



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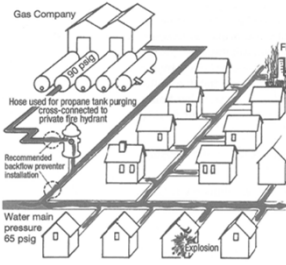
Backflow Case Study

Propane Gas in the Water Mains

Gas company initiated repairs on 30,000 gallon liquid propane tank by flushing with fire hydrant

Vapor pressure of propane residual in the tank exceeded water main pressure

Hundreds evacuated, two homes caught fire, water supply contaminated



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Backflow Case Study


EPA Study

EPA compiled backflow incident data from 1970 to 2001 and found:

459 incidents resulted in **12,093** illnesses

Backflow incidents can result in property damage, personal injury, and even death

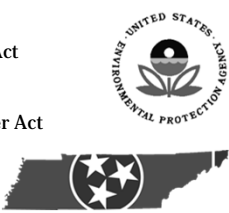




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Authority

- Federal
 - Federal Safe Drinking Water Act
- State
 - Tennessee Safe Drinking Water Act
 - Statute
 - Regulation
- Local
 - Ordinance (City) or Policy (Utility)
 - Plumbing Code
 - Cross Connection Control Plan



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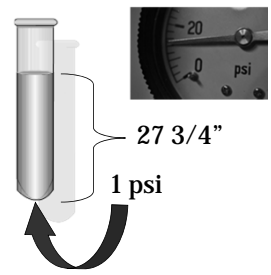
Hydraulics and Pressure



- 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

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Head Pressure

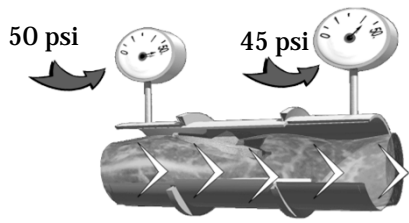


- 27 3/4" of water generates a pressure of one pound per square inch (psi)
- The pressure on the bottom of the container is generated by the weight of the water above it

$27 \frac{3}{4}'' = 2.31 \text{ Feet of Head}$

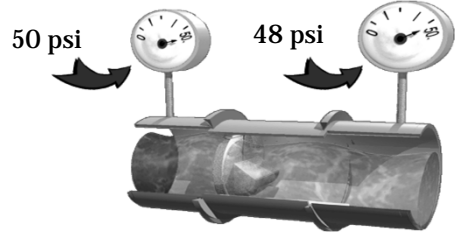
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Normal Flow



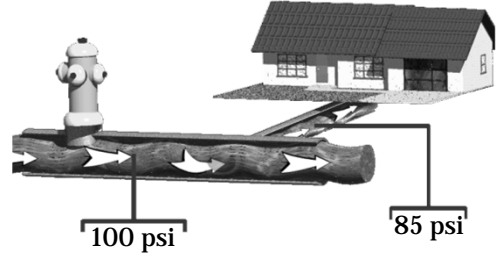
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No Flow



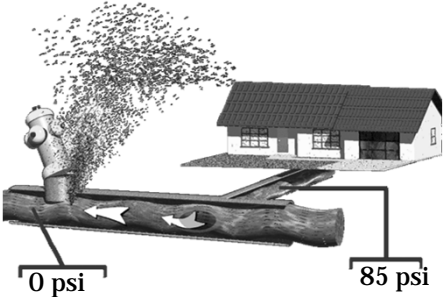
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Normal Flow



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Reverse Flow - Backflow




A diagram showing a pipe with a house on the right and a tank on the left. The house side is labeled '85 psi' and the tank side is labeled '0 psi'. Arrows indicate flow from the house towards the tank, with a large splash of water coming out of the tank, representing reverse flow.

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Backflow

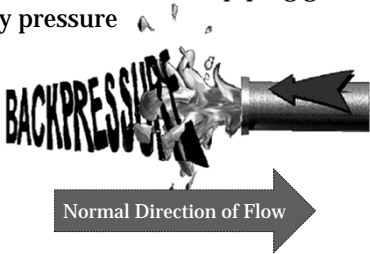
- The undesirable reversal of flow of water or other substances into the potable water distribution supply
- Occurs due to:
 - Backpressure
 - Backsiphonage



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Backpressure

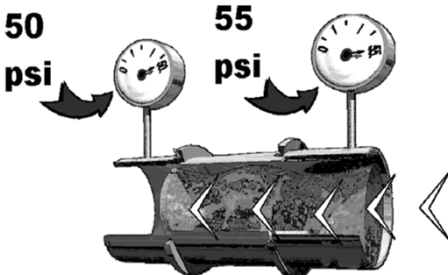
- Pressure in downstream piping greater than supply pressure



A diagram showing a pipe with a large arrow pointing right labeled 'Normal Direction of Flow'. A smaller arrow points left, and the word 'BACKPRESSURE' is written in large, bold, stylized letters across the pipe, indicating reverse flow.

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Backpressure

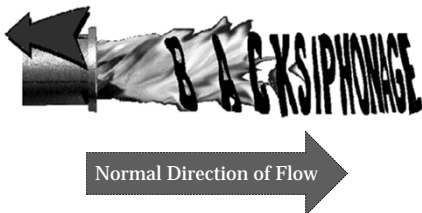


A diagram showing a pipe with two pressure gauges. The left gauge is labeled '50 psi' and the right gauge is labeled '55 psi'. Arrows point from the gauges to the pipe. A large arrow points right, and a smaller arrow points left, indicating reverse flow.

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Backsiphonage

- Sub-atmospheric pressure in the water system




A diagram showing a pipe with a large arrow pointing right labeled 'Normal Direction of Flow'. A smaller arrow points left, and the word 'BACKSIPHONAGE' is written in large, bold, stylized letters across the pipe, indicating reverse flow.

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Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?




- As backsiphonage occurs air will be drawn up into the water pipes


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Backsiphonage

What is drawn into the water pipes if backsiphonage occurs?

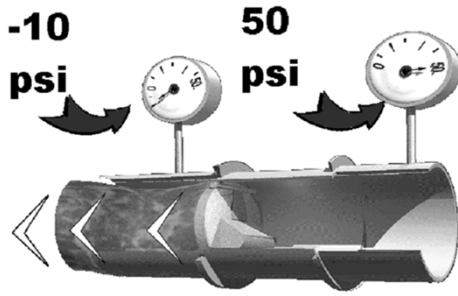


- Whatever is in the barrel...



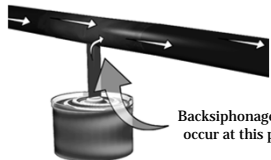

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Backsiphonage



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Aspirator Effect

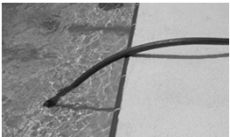



- As water flows through a pipe, the pressure against the walls of the pipe decreases as the speed of the water increases
- If a second pipe is attached there could be a low pressure area created at the point of connection which could siphon water from the attached pipe into the flowing pipe - Backsiphonage

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Cross-Connection


- An actual or potential connection between a potable water supply and any non-potable substance or source
- Cross-connection types:
 - Direct
 - Indirect



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Direct Cross-Connection

- A direct cross-connection is subject to backpressure or backsiphonage




Direct Connection

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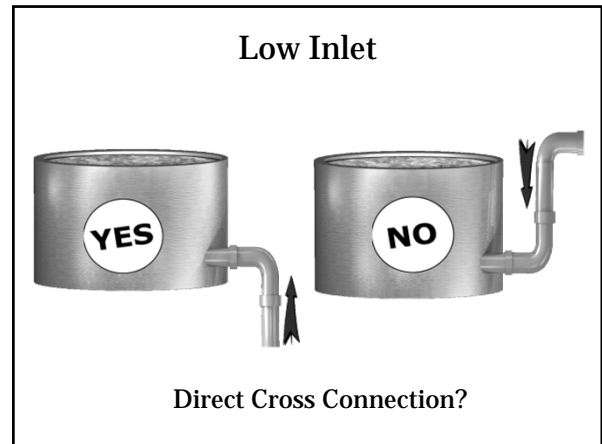
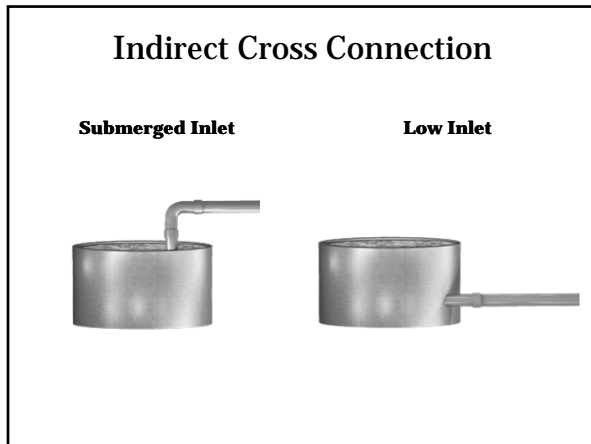
Indirect Cross-Connection

- An indirect cross-connection is subject to backsiphonage only



Submerged Inlet

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Degree of Hazard

<ul style="list-style-type: none"> • Non-Health Hazard • Low hazard • Will not cause illness or death • Pollutant 	<ul style="list-style-type: none"> • Health Hazard • High hazard • Causes illness or death • Contaminant
---	--




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The Backflow Incident

For backflow to occur three conditions must be met:

1. There must be a cross-connection. A passage must exist between the potable water system and another source.
2. A hazard must exist in this other source to which the potable water is connected.
3. The hydraulic condition of either backsiphonage or backpressure must occur.


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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)

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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

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Air Gap



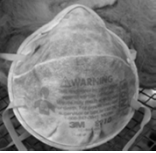
- An air gap is the *BEST* method of protection against backflow
- Approved air gap separation must have a vertical unobstructed distance of at least twice the internal diameter of the outlet pipe, but never less than 1 inch

2 X ID,
not <1 inch

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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




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Approved Air Gap Separation

Backflow Protection Against:

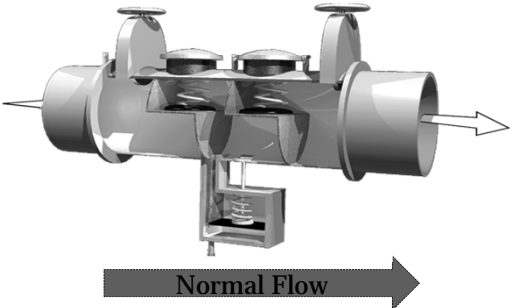
- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)

BEST METHOD OF PROTECTION



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Reduced Pressure Principle Assembly




Normal Flow

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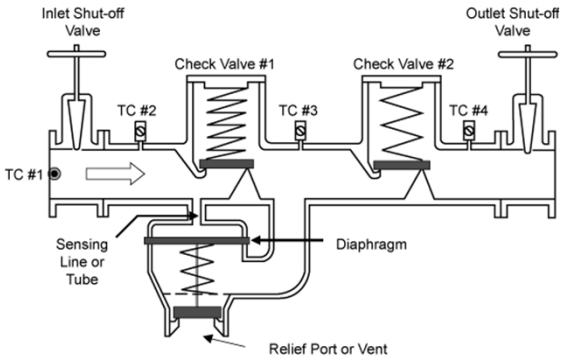
Reduced Pressure Principle Assembly

- 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



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RP



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RP

- The two check valves loaded in the closed position mechanically keep the water flowing in one direction through the assembly
- The relief valve assembly is designed to maintain a lower pressure in the zone between the two checks than in the supply side of the unit which hydraulically keeps the water flowing in one direction through the assembly
- Water always flows from high pressure to low pressure

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RP

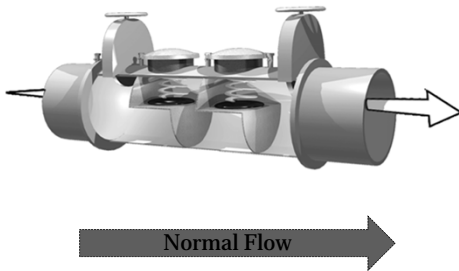
Backflow Protection Against:

- Backsiphonage
- Backpressure
- Contaminant (health hazard)
- Pollutant (non-health hazard)



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Double Check Valve Assembly (DC)



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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



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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

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Double Check Valve Assembly (DC)

Backflow Protection Against:

- Backsiphonage
- Backpressure
- Pollutant only



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Proper Installation for DC and RP

- Lowest part of the relief valve should be a minimum of 12 inches above either: the ground, the top of the opening of the enclosure wall, or the maximum flood level
- Whichever is highest, in order to prevent any part of the assembly from becoming submerged
- Maximum 60" above grade to the center line of assembly, if higher then safe permanent access must be provided for testing and servicing

* Tennessee Cross-Connection Control Manual and Design Criteria for Cross-Connection Control Plans, Ordinances, and Policies (2008) – Appendix B

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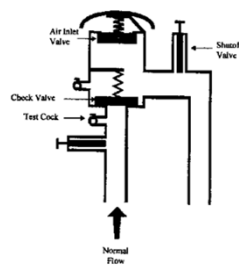
Proper Installation for DC and RP

- Assemblies should be installed in accordance with manufacturer's installations otherwise it voids the approval for the assembly
- Protected from vandalism and weather (if needed)
- RP requires adequate drainage – **cannot** be installed in a pit or meter box
- Must be accessible for testing and repair



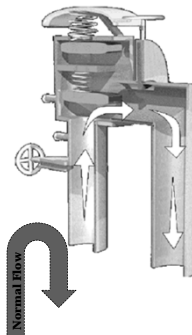
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Pressure Vacuum Breaker (PVB)



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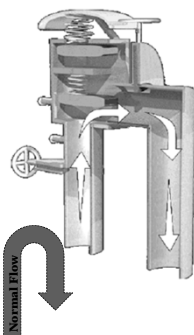
Pressure Vacuum Breaker (PVB)



- The pressure vacuum breaker or spill resistant vacuum breaker consists of an independently operating check valve loaded in the closed position and an independently operating air inlet valve loaded in the open position and located on the discharge side of the check valve, with tightly closing shutoff valves on each side of the check valves, and properly located test cocks for valve testing

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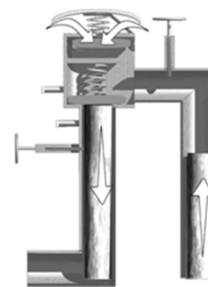
Pressure Vacuum Breaker (PVB)



- Incoming water pressure will compress the spring on the check and flow into the body
- As pressure builds up in the body it will compress the spring on the air valve and close it allowing water to travel downstream

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PVB Backsiphonage Condition

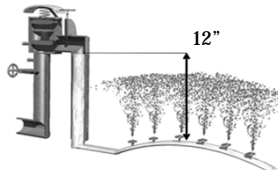


- In a backsiphonage condition there is a loss of supply pressure and the check valve is forced closed
- If the body loses pressure the air inlet valve is forced open allowing air into the body of the pressure vacuum breaker and breaking any siphon
- Only to be used to protect against backsiphonage

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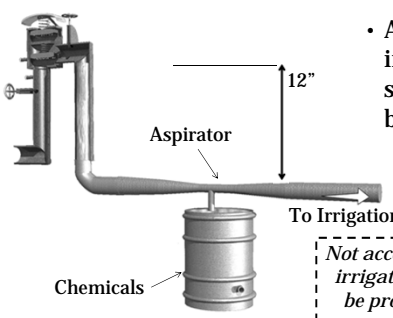
Installation of PVB

- PVB is not designed to protect against backpressure and cannot have any source of backpressure (including head pressure) downstream of the device
- Needs to be installed **12 inches** above the highest point downstream



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Pressure Vacuum Breaker



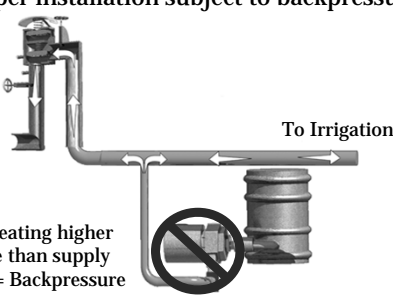
- Acceptable installation not subject to backpressure

Not acceptable in TN – all irrigation systems must be protected by an RP

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Pressure Vacuum Breaker

- Improper installation subject to backpressure




Pump creating higher pressure than supply pressure = Backpressure

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Pressure Vacuum Breaker


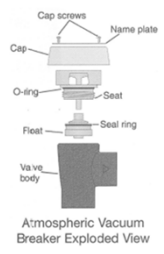
Backflow Protection Against:

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 12" above downstream piping



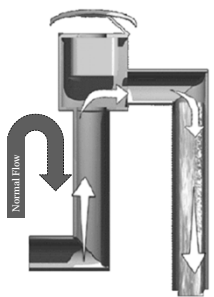
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Atmospheric Vacuum Breaker (AVB)

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Atmospheric Vacuum Breaker (AVB)



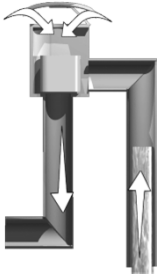
- The atmospheric vacuum breaker is a device designed to prevent backsiphonage. It consists of a body, a single moving float that acts as a check valve when there is no flow and as an air-inlet valve when flow is present, and an air-inlet opening covered by a cap

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Atmospheric Vacuum Breaker (AVB)

- During a backsiphonage condition the float drops by gravity due to the loss of incoming pressure which automatically opens the air inlet, introducing air into the system to break any siphon that has formed

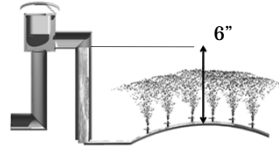
Loss of supply pressure



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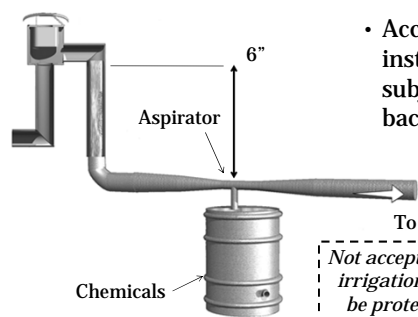
Installation of AVB

- AVB is not designed to protect against backpressure and cannot have any source of backpressure (including head pressure) downstream of the device
- Needs to be installed **6 inches** above the highest point downstream



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Atmospheric Vacuum Breaker




- Acceptable installation not subject to backpressure

Not acceptable in TN – all irrigation systems must be protected by an RP

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Atmospheric Vacuum Breaker

- Improper installation: downstream shutoff valves
- Shutoff valves downstream of an AVB can cause a continuous use situation
- The float of an AVB subjected to continuous use could begin to adhere to the air inlet and allow backflow




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Atmospheric Vacuum Breaker

Backflow Protection Against:

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 6"
- Non-Continuous Use



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	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	
Non – Health Hazard		AVB	
	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	PVB	
		AVB	

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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



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Cross Connection Control

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



Cross Connection Vocabulary Words

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

Air Gap – 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.

Air Inlet – 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) -

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

Aspirator Effect – 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.

Atmospheric Pressure – 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.

Atmospheric Vacuum Breaker (AVB) – 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.

Auxiliary Water Supply – 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.

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

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

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

Backsiphonage – 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.

Bypass – 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.

Check Valve – 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 one 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

<u>Connected System</u>	<u>Hazard Level</u>
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 fountains	Moderate
Access hole flush	High
Agricultural pesticide mixing tanks	High
Irrigation systems	Low to high
Watering troughs	Moderate
Autopsy tables	High

Cross Connection Vocabulary

1. In plumbing, the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or outlet supplying water to a tank, plumbing fixture or other container, and the overflow rim of that container is known as a(n) _____.
2. An _____ is a mechanical device consisting of a float check valve and an air-inlet port designed to prevent backsiphonage.
3. An _____ is any water source or system, other than potable water supply, that may be available in the building or premises.
4. The hydraulic condition of _____, caused by a difference in pressures, occurs when non-potable water or other fluids flow into a potable water system.
5. A backflow condition in which a pump, elevated tank, boiler or other means results in a pressure greater than the supply pressure is called _____.
6. _____ is a backflow condition in which the pressure in the distribution system is less than atmospheric pressure.
7. A _____ is a valve designed to open in the direction of normal flow and close with the reversal of flow.
8. A physical arrangement that connects the potable water supply with any other non-potable water supply is known as a _____.
9. _____ is 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.
10. A _____ is a substance that would constitute a non-health hazard and would be aesthetically objectionable if introduced into the potable water system.
11. The top edge of an open receptacle over which water will flow is called the _____.
12. A _____ is a device designed to prevent backsiphonage, consisting of one or two independently operating spring-loaded check valves and an independently operating spring-loaded air-inlet valve.
13. A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone with relief valve between the check valves is a _____.
14. A _____ is the term used to describe an organization that is engaged in producing and/or distributing potable water for domestic use.
15. The test kit gauge measures the _____ on the backflow prevention assemblies.

Word Bank

Differential pressure

Pollutant

Air Gap

Feed Water

Water Purveyor

Overflow Rim

Atmospheric Vacuum Breaker

Cross Connection

Reduced Pressure Principle Assembly

Pressure Vacuum Breaker

Auxiliary Supply

Check Valve

Backflow

Backsiphonage

Backpressure

5. What is the most reliable backflow-prevention method?
6. Is a single check valve position protection against backflow? Why or why not?
7. How often should a reduced-pressure-zone backflow preventer be tested?
8. In what position should an atmospheric vacuum breaker be installed relative to a shutoff valve? Why?
9. How does a vacuum breaker prevent backsiphonage?
10. List seven elements that are essential to implement and operate a cross-connection control program successfully?
 -
 -
 -
 -
 -
 -
 -



Section 9

Pumps and Equipment

Maintenance

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WASTEWATER PUMPS AND EQUIPMENT MAINTENANCE


TDEC - Fleming Training Center 2

Types of Pumps

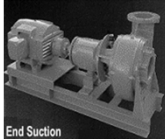
- Classified by character of material handled:
 - Raw wastewater
 - Grit
 - Sludge
 - Effluent




Chopper Pump



Recessed Impeller



End Suction



Submersible

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General Considerations

- Centrifugal pumps: wastewater
- Piston or diaphragm pumps: heavy solids
- Gear and piston pumps: high pressures
- Turbine or propeller pumps: mixing air or chemicals

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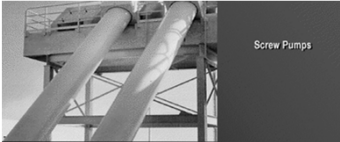
Types of Pumps

- Positive-Displacement Pumps
 - Metering pumps – sometimes used to feed chemicals
 - Piston pump
 - Screw pump
- Velocity Pumps
 - Vertical turbine
 - Centrifugal
 - Most common type in wastewater lift stations


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Positive-Displacement Pumps

- Sludge & chemical feed pumps
- Less efficient than centrifugal pumps
- **Cannot operate against a closed discharge valve**



Screw Pumps

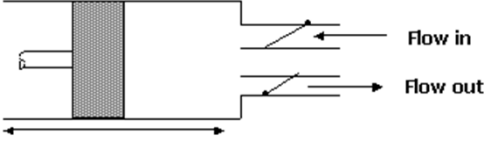


Progressive Cavity Pump

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Positive-Displacement Pumps

- Reciprocating (piston) pump - piston moves back and forth in cylinder, liquid enters and leaves through check valves



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Positive-Displacement Pumps

- Rotary pump - Use lobes or gears to move liquid through pump

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Screw Pumps

Incline screw pumps handle large solids without plugging

- 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

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Velocity 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

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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

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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

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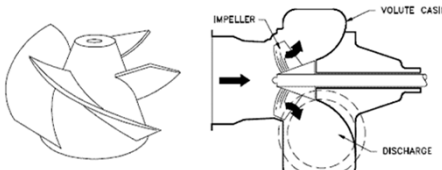
Velocity Pump Design Characteristics

- 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

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Velocity Pump Design Characteristics

- Mixed - flow designs
 - Has features of axial and radial flow
 - Centrifugal force and lifting action of impeller vanes combine to develop total dynamic head
 - Works well for water with solids



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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

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Most Common Centrifugal Pumps

- Horizontal non-clog type
- Vertical ball bearing type
- Propeller type

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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



Single Volute

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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

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Let's Build a Centrifugal Pump

- First we need a device to spin liquid at high speeds – an 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.
 - 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

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Impeller

- 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



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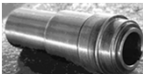
Let's Build a Centrifugal Pump

- Now we need a shaft to support and turn 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.

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Shaft and Sleeves

- 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.



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Let's Build a Centrifugal Pump

- 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

Keep the right amount of the right lubricant in bearings at all times.

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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

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Bearings

- 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.

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Let's Build a Centrifugal Pump

- To connect with the motor, we add a 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
 - 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

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Common Pump & Motor Connections

- Direct coupling
- Angle drive
- Belt or chain
- Flexible coupling
- Close-coupled



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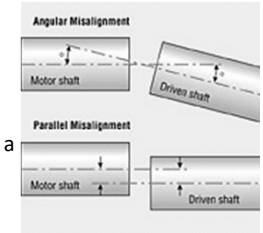
Couplings

- Connect pump and motor shafts
- Lubricated require greasing at 6 month intervals
- Dry has rubber or elastomeric membrane
- Calipers and thickness gauges can be used to check alignment on flexible couplings

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Misalignment of Pump & Motor

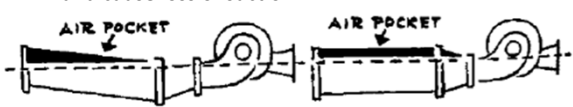
- Excessive bearing loading
- Shaft bending
- Premature bearing failure
- Shaft damage
- Checking alignment should be a regular procedure in pump maintenance.
 - Foundations can settle unevenly
 - Piping can change pump position
 - Bolts can loosen
 - Misalignment is a major cause of pump and coupling wear.



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Let's Build a Centrifugal Pump

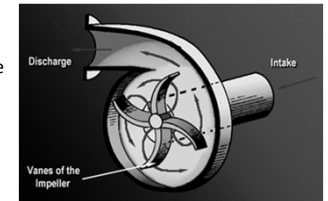
- Now we need a "straw" through which liquid can be sucked
 - Insure that the pipe does not put strain on the pump's casing
 - The horizontal pipe slopes upward toward the pump so that air pockets won't be drawn into the pump and cause loss of suction



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Let's Build a Centrifugal Pump

- 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.

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Let's Build a Centrifugal Pump

- Now our pump is almost complete, but 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

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Let's Build a Centrifugal Pump

- So we add wearing rings (aka wear rings) to plug internal liquid leakage
 - 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

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Let's Build a Centrifugal Pump

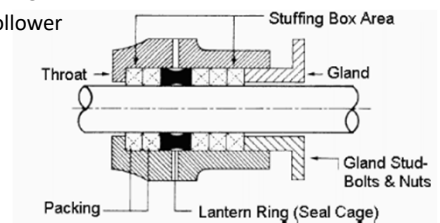
- To keep air from being drawn in, we use stuffing boxes
 - We have two good reasons for wanting to keep air out of our pump
 - We want to pump water, not air
 - Air leakage is apt to cause our pump to lose suction
 - Each stuffing box we use consists of a casing, rings of packing and a gland at the outside end
 - A mechanical seal may be used instead

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Stuffing Box

- Parts include:
 - Packing
 - Lantern ring
 - Gland follower

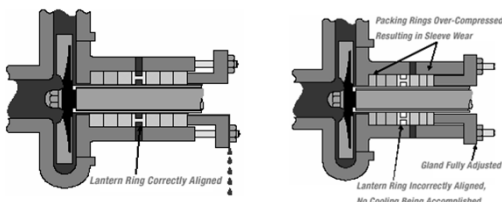


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Lantern Rings aka Seal Cages

- Perforated ring placed in stuffing box
- A spacer ring in the stuffing box that forms seal around shaft, helps keep air from entering the pump and lubricates packing



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Packing vs. Mechanical Seals

- If a pump has packing, water should drip slowly
- If it has a mechanical seal, no leakage should occur

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Packing Rings

- Provides a seal where the shaft passes through the pump casing in order to keep air from being drawn or sucked into the pump and/or the water being pumped from coming out



Graphite Seal Ring

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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 180° if only 2 rings are in stuffing box, space at 120° for 3 rings or **90° if 4 rings or more are in set**

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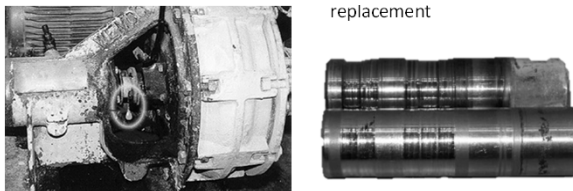
Packing Rings

- 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

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Packing Rings vs. Mechanical Seal

<ul style="list-style-type: none"> • Advantages <ul style="list-style-type: none"> • Less expensive, short term • Can accommodate some looseness 	<ul style="list-style-type: none"> • Disadvantages <ul style="list-style-type: none"> • Increased wear on shaft or shaft sleeve • Increased labor required for adjustment and replacement
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Mechanical Seals

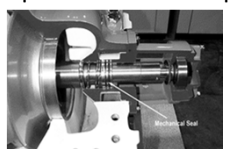


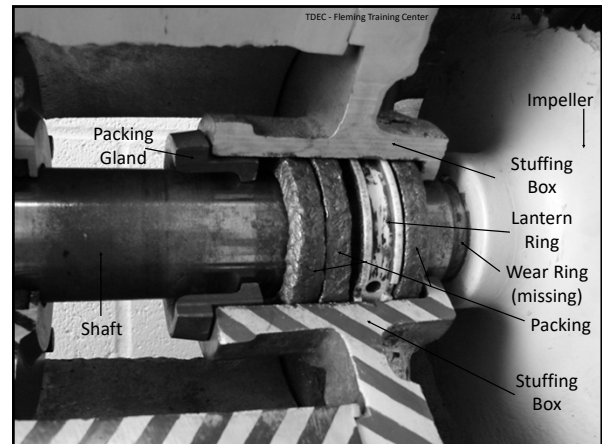
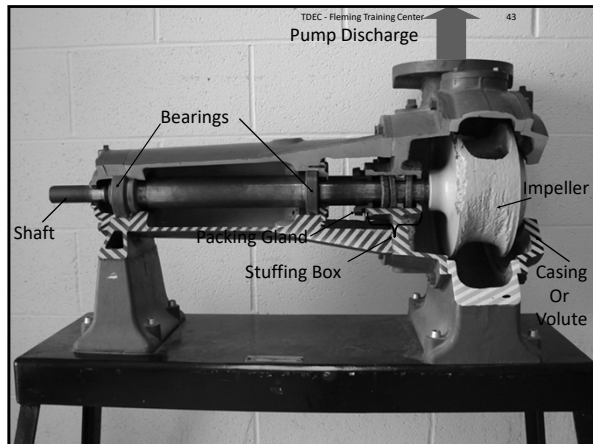
- Located in stuffing box
- Prevents water from leaking along shaft; keeps air out of pump
- **Should not leak**
- Consists of a rotating ring and stationary element
- **The operating temperature on a mechanical seal should never exceed 160°F (71°C)**
- Mechanical seals are always flushed in some manner 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.

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Mechanical Seal vs. Packing Rings

<ul style="list-style-type: none"> • Advantages <ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • Disadvantages <ul style="list-style-type: none"> • 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
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Centrifugal Pump Operation

- 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 Operation

- 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

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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

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Monitoring Operational Variables

- Vibration
 - Detectors can sense malfunctions causing excess vibration
 - Operators can learn to distinguish between normal and abnormal sounds



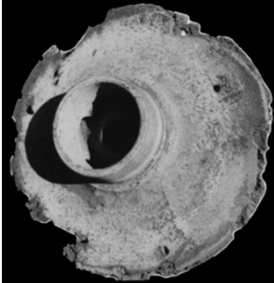
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Monitoring Operational Variables

- 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

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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

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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

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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

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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)

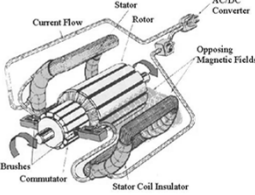


This impeller was damaged by cavitation

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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



TDEC - Fleming Training Center 57

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.



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Pump Safety: Wet Wells

- Confined spaces
- Corrosion of ladder rungs
- Explosive atmospheres
- Hydrogen sulfide accumulation
- Slippery surfaces



Manhole Cover, London

TDEC - Fleming Training Center 59

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

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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

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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



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Types of Pumps Found in Collection Systems

- Incline screw pump
- Centrifugal
- Pneumatic ejectors
- Piston
- Close-coupled
- Submersible
- Progress cavity
- Flexible stator and rotor

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EQUIPMENT MAINTENANCE

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Beware of Electricity


- Be careful around electrical panels, circuits, wiring, & equipment
 - Serious injury
 - Damage costly equipment
- Basic working knowledge is key




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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




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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.



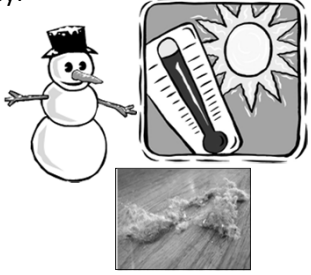
- Multimeter: checks for voltage
 - By holding one lead on ground and the other on a power lead, you can determine if power is available
 - You can also tell if it is AC or DC and the intensity or voltage (110, 220, 480 or whatever) by testing the different leads



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Need for Maintenance

- Performance and life of pumps and other equipment affected by:
 - Water
 - Dust
 - Humidity
 - Heat and cold
 - Vibration
 - Corrosive atmosphere




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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.

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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

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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

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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



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- 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

D.C. versus A.C.

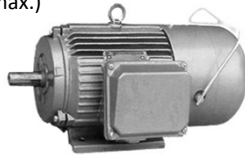
- Direct current (D.C.) is flowing in one direction only and is essentially free from pulsation
 - DC is seldom used in lift stations and wastewater treatment plants except in motor-generated sets, some control components of pump drives and standby lighting
 - DC is used exclusively in automotive equipment, 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

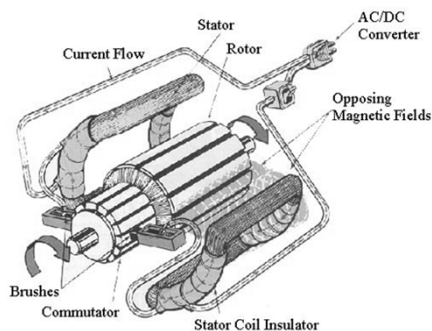
- Most common pump driver in wastewater pump stations
- **Motors pull the most current on start up.**
- Malfunction due to:
 - Thermal overload (40°C max.)
 - Contaminants
 - Single phasing
 - Old age
 - Rotor failure



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

Motor Components



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

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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

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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

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Compressors



- Increase the pressure of air or gas
- Common uses:
 - Wastewater ejectors
 - Pump control systems (bubblers)
 - Water pressure systems
 - Portable pneumatic tools

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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

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Valves

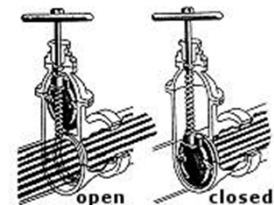
- Controlling device in piping systems to stop, regulate, check, or divert flow of liquids or gases
- Types of valves found in a pumping station
 - Butterfly – used on suction and discharge
 - Gate – used on suction and discharge
 - Plug – used on suction and discharge
 - Swing or ball check – used on discharge
 - Knife – used on suction and discharge
 - Wafer – used on discharge

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Valves


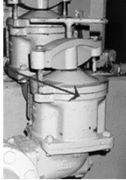
- Gate valve:
 - Open valve fully; reverse & close one-half turn
 - Operate all large valves at least yearly
 - Inspect valve stem packing for leaks; tighten if needed
 - Close valves slowly in pressure lines to prevent water hammer



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Valves

- Check valves: discharge of pump to provide positive shut off from force main pressure & prevent force main from draining back into wet well








Check Valve

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Valves

- Butterfly valves: often clog on sewer lines when installed to carry stormwater or wastewater
- Plug valves: less susceptible to plugging; sludge pumping

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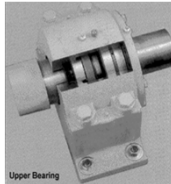
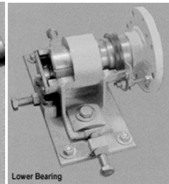
Lubrication

- 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

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Bearings

- Screw pumps are supported by 2 bearings, a ball or roller bearing above the flights & a sleeve bearing in the WW

Upper Bearing Lower Bearing

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Bearings

- Usually last for years if serviced properly
- Failures:
 - Fatigue – excessive load
 - Contamination
 - Brinelling – improper mounting
 - Electric arcing – leakage; short circuiting
 - Misalignment
 - Cam failure
 - Lubrication failure – dirty; too much; not enough; wrong kind

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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



Pump Vocabulary Words

1. Axial-Flow Pump – a pump in which a propeller-like impeller forces water out in the direction parallel to the shaft. Also called a propeller pump.
2. Bearing – anti-friction device used to support and guide a pump and motor shafts.
3. Casing – the enclosure surrounding a pump impeller, into which the suction and discharge ports are machined.
4. Cavitation – a condition that can occur when pumps are run too fast or water is forced to change direction quickly. A partial vacuum forms near the pipe wall or impeller blade causing potentially rapid pitting of the metal.
5. Centrifugal Pumps – a pump consisting of an impeller on a rotating shaft enclosed by a casing having suction and discharge connections. The spinning impeller throws water outward at high velocity, and the casing shape converts this velocity to pressure.
6. Closed-Coupled Pump – a pump assembly where the impeller is mounted on the shaft of the motor that drives the pump.
7. Diffuser Vanes – vanes installed within a pump casing on diffuser centrifugal pumps to change velocity head to pressure head.
8. Double-Suction Pump – a centrifugal pump in which the water enters from both sides of the impeller. Also called a split-case pump.
9. Foot Valve – 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. Keeps prime.
10. Frame-Mounted Pump – a centrifugal pump in which the pump shaft is connected to the motor shaft with a coupling.
11. Impeller – the rotating set of vanes that forces water through the pump.
12. Jet Pump – a device that pumps fluid by converting the energy of a high-pressure fluid into that of a high-velocity fluid.
13. Lantern Ring – 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.
14. Mechanical Seal – a seal placed on the pump shaft to prevent water from leaking from the pump along the shaft; the seal also prevents air from entering the pump.
15. Mixed-Flow Pump – a pump that imparts both radial and axial flow to the water.
16. Packing – rings of graphite-impregnated cotton, flax, or synthetic materials, used to control leakage along a valve stem or a pump shaft.
17. Packing Gland – a follower ring that compressed the packing in the stuffing box.
18. Positive Displacement Pump – a pump that delivers a precise volume of liquid for each stroke of the piston or rotation of the shaft.
19. Prime Mover – a source of power, such as an internal combustion engine or an electric motor, designed to supply force and motion to drive machinery, such as a pump.
20. Radial-Flow Pump – a pump that moves water by centrifugal force, spinning the water radially outward from the center of the impeller.
21. Reciprocating Pump – a type of positive-displacement pump consisting of a closed cylinder containing a piston or plunger to draw liquid into the cylinder through an inlet valve and forces it out through an outlet valve.
22. Rotary Pump – a type of positive-displacement pump consisting of elements resembling gears that rotate in a close-fitting pump case. The rotation of these elements alternately draws in and discharges the water being pumped.

23. Single-Suction Pump – a centrifugal pump in which the water enters from only one side of the impeller. Also called an end-suction pump.
24. Stuffing Box – a portion of the pump casing through which the shaft extends and in which packing or a mechanical seal is placed to prevent leakage.
25. Submersible Pump – a vertical-turbine pump with the motor placed below the impellers. The motor is designed to be submersed in water.
26. Suction Lift – the condition existing when the source of water supply is below the centerline of the pump.
27. Velocity Pump – the general class of pumps that use a rapidly turning impeller to impart kinetic energy or velocity to fluids. The pump casing then converts this velocity head, in part, to pressure head. Also known as kinetic pumps.
28. Vertical Turbine Pump – a centrifugal pump, commonly of the multistage, diffuser type, in which the pump shaft is mounted vertically.
29. Volute – the expanding section of pump casing (in a volute centrifugal pump), which converts velocity head to pressure head..
30. Water Hammer – the potentially damaging slam that occurs in a pipe when a sudden change in water velocity (usually as a result of too-rapidly starting a pump or operating a valve) creates a great increase in water pressure.
31. Wear Rings – rings made of brass or bronze 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.

Pumps, Motors, and Equipment Maintenance Vocabulary

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 the pump 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 delivers a precise volume of liquid with each stroke of the piston or rotation of the shaft.

19. 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 converts this velocity into pressure.
20. The expanding section of a pump casing which converts velocity head to pressure head is the _____.
21. The term _____ describes the potentially damaging slam that occurs in a 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.

Word Bank

Amperage	Voltage
Brinelling	Volute
Bearing	Water Hammer
Cavitation	Wear
Centrifugal	
Circuit	
Circuit Breaker	
Current	
Foot Valve	
Fuse	
Impeller	
Jogging	
Lantern Ring	
Mechanical	
Megger	
Packing	
Positive Displacement	
Resistance	

Pumps and Motors Review Questions

1. Leakage of water around the packing on a centrifugal pump is important because it acts as a (n):
 - a. Adhesive
 - b. Lubricant
 - c. Absorbent
 - d. Backflow preventer

2. What is the purpose of wear rings in a pump?
 - a. Hold the shaft in place
 - b. Hold the impeller in place
 - c. Control amount of water leaking from discharge to suction side
 - d. Prevent oil from getting into the casing of the pump

3. Which of the following does a lantern ring accomplish?
 - a. Lubricates the packing
 - b. Helps keep air from entering the pump
 - c. Both (a.) and (b.)

4. Closed, open, and semi-open are types of what pump part?
 - a. Impeller
 - b. Shaft sleeve
 - c. Casing
 - d. Coupling

5. When tightening the packing on a centrifugal pump, which of the following applies?
 - a. Tighten hand tight, never use a wrench
 - b. Tighten to 20 foot pounds of pressure
 - c. Tighten slowly, over a period of several hours
 - d. Tighten until no leakage can be seen from the shaft

6. Excessive vibrations in a pump can be caused by:
 - a. Bearing failure
 - b. Damage to the impeller
 - c. Misalignment of the pump shaft and motor
 - d. All of the above

7. What component can be installed on a pump to hold the prime?
 - a. Toe valve
 - b. Foot valve
 - c. Prime valve
 - d. Casing valve

8. The operating temperature of a mechanical seal should not exceed:
 - a. 60°C
 - b. 150°F
 - c. 160°F
 - d. 71°C
 - e. c and d

9. What is the term for the condition where small bubbles of vapor form and explode against the impeller, causing a pinging sound?
 - a. Corrosion
 - b. Cavitation
 - c. Aeration
 - d. Combustion

10. The first thing that should be done before any work is begun on a pump or electrical motor is:
 - a. Notify the state
 - b. Put on safety goggles
 - c. Lock out the power source and tag it
 - d. Have a competent person to supervise the work

11. Under what operating condition do electric motors pull the most current?
 - a. At start up
 - b. At full operating speed
 - c. At shut down
 - d. When locked out

12. As the impeller on a pump becomes worn, the pump efficiency will:
 - a. Decrease
 - b. Increase
 - c. Stay the same

13. How do the two basic parts of a velocity pump operate?

14. What are two designs used to change high velocity to high pressure in a pump?

22. How is the casing of a double-suction pump disassembled?

23. What is the function of wear rings in centrifugal pumps of the closed-impeller design?
What is the function of the lantern rings?

24. Describe the two common types of seals used to control leakage between the pump shaft and the casing.

25. What feature distinguishes a close-coupled pump and motor?

26. What is the value of listening to a pump or laying a hand on the unit as it operates?

27. When do most electric motors take the most current?

28. What are three major ways of reducing power costs where electric motors are used?

29. What effect could over lubrication of motor bearings have?

30. Why should emery cloth not be used around electrical machines?

31. What are the most likely causes of vibration in an existing pump installation?

32. What can happen when a fuse blows on a single leg of a three-phase circuit?

33. What is the first rule of safety when repairing electrical devices?

Equipment Maintenance Review Questions

1. What are some of the uses of a voltage tester?
2. How often should motors and wirings be megged?
3. An ohmmeter is used to check the ohms of resistance in what control circuit components?
4. What are the two types of protective/safety devices found in main electrical panels or control units?
5. What is the most common pump driver used in lift stations?
6. Why should inexperienced, unqualified, or unauthorized persons and even qualified and authorized persons be extremely careful around electrical panels, circuits, wiring, and equipment?
7. Under what conditions would you recommend the installation of a screw pump?
8. What is the purpose of packing?

9. What is the purpose of the lantern ring?

10. How often should impellers be inspected for wear?

11. What is the purpose of wear rings?

12. What causes cavitation?

13. How often should the suction filter of a compressor be cleaned?

14. How often should the condensate from the air receiver be drained?

15. What is the purpose of lubrication?

16. What precautions must be taken before oiling or greasing equipment?

17. If an ammeter reads higher than expected, the high current could produce
 - a. "Freezing" of motor windings
 - b. Irregular meter readings
 - c. Lower than expected output horsepower
 - d. Overheating and damage equipment

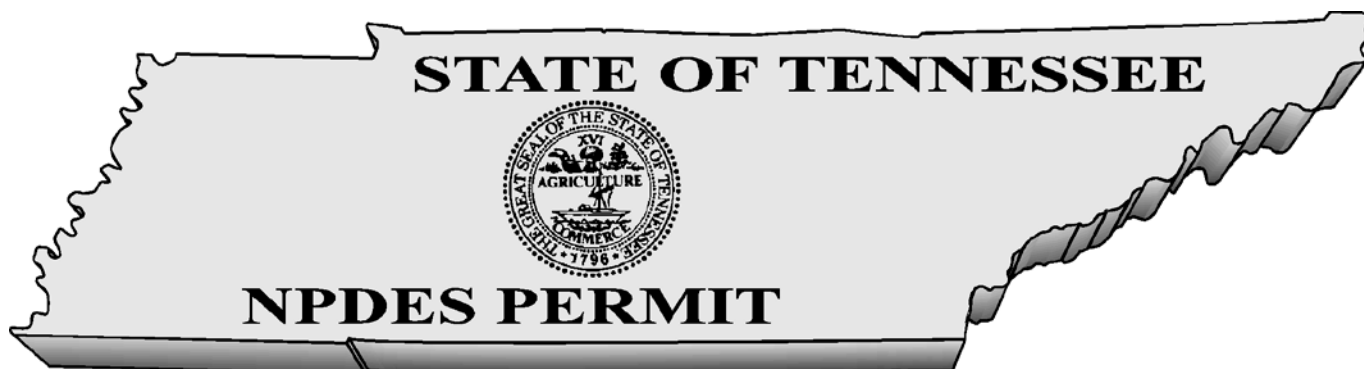
18. The greatest cause of electric motor failures is
 - a. Bearing failures
 - b. Contaminants
 - c. Overload (thermal)
 - d. Single phasing

19. Flexible shafting is used where the pump and driver are
 - a. Coupled with belts
 - b. Difficult to keep properly aligned
 - c. Located relatively far apart
 - d. Required to be coupled with universal joints

20. Never operate a compressor without the suction filter because dirt and foreign materials will cause
 - a. Deterioration of lubricants
 - b. Effluent contamination
 - c. Excessive water
 - d. Plugging of the rotors, pistons or blades

Section 10

NPDES Overview



No. «PERMIT_NUMBER»

Authorization to discharge under the
National Pollutant Discharge Elimination System (NPDES)

Issued By

**STATE OF TENNESSEE
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: **«Permittee_Name»
«Project_Name»**

is authorized to discharge: **«EFFLUENT_DESCRIPTION»**

from a facility located: **in «City», «County», Tennessee**

to receiving waters named: **«RECEIVING_STREAM»**

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

This permit shall become effective on:

This permit shall expire on:

Issuance date:

for Jennifer Dodd
Director

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1.0. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1.1. NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS

The City of City is authorized to discharge to the . Discharge 001 consists of municipal wastewater from a treatment facility with a design capacity of MGD. Discharge 001 shall be limited and monitored by the permittee as specified below:

Notes:  The permittee shall achieve removal of CBOD₅ and TSS on a monthly average basis. The permittee shall report all instances of releases, overflows and/or bypasses. See Part 2.3.3.a for the definition of overflow and Part 1.3.5.1 for reporting requirements.

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 next page for percent removal calculations.

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 than the MDL, the reporting of TRC at less than the MDL shall be interpreted to constitute compliance with the permit.

The wastewater discharge must be disinfected to the extent that viable coliform organisms are effectively eliminated. The concentration of the *E. coli* group after disinfection shall not exceed 126 cfu per 100 ml as the geometric mean calculated on the actual number of samples collected and tested for *E. coli* within the required reporting period. The permittee may collect more samples than specified as the monitoring frequency. 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 one (1) per 100 ml shall be considered as having a concentration of one (1) per 100 ml. In addition, the concentration of the *E. coli* group in any individual sample shall not exceed a specified maximum amount. A maximum daily limit of 487 colonies per 100 ml applies to lakes and exceptional Tennessee waters. A maximum daily limit of 941 colonies per 100 ml applies to all other recreational waters.

There shall be no distinctly visible floating scum, oil or other matter contained in the wastewater discharge. The wastewater discharge must not cause an objectionable color contrast in the receiving stream.

The wastewater discharge shall not 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, TCA 68-31-101 et seq. and the Tennessee Hazardous Waste Management Act, TCA 68-46-101 et seq.

Nothing in this permit authorizes take for the purposes of a facility's compliance with the Endangered Species Act. (40 C.F.R. 125.98(b)(1)).

For the purpose of evaluating compliance with the permit limits established herein, where certain limits are below the State of Tennessee published required detection levels (RDLs) for any given effluent characteristics, the results of analyses below the RDL shall be reported as Below Detection Level (BDL), unless in specific cases other detection limits are demonstrated to be the best achievable because of the particular nature of the wastewater being analyzed.

For CBOD_5 and TSS, the treatment facility shall demonstrate a minimum of % removal efficiency on a monthly average basis. This is calculated by determining an average of all daily influent concentrations and comparing this to an average of all daily effluent concentrations. The formula for this calculation is as follows:

$$\left[1 - \frac{\text{average of daily effluent concentration}}{\text{average of daily influent concentration}} \right] \times 100\% = \% \text{ removal}$$

The treatment facility will also demonstrate % minimum removal of the CBOD_5 and TSS based upon each daily composite sample. The formula for this calculation is as follows:

$$\left[1 - \frac{\text{daily effluent concentration}}{\text{daily influent concentration}} \right] \times 100\% = \% \text{ removal}$$

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 storm water runoff or the receiving stream. Appropriate flow measurement devices and methods consistent with accepted scientific practices shall be selected and used to insure the accuracy and reliability of measurements of the volume of monitored discharges. The devices shall be installed, calibrated and maintained to insure 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 less than plus or minus 10% from the true discharge rates throughout the range of expected discharge volumes.

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 change:

- 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.
- b. Samples for *E. coli* can be collected at any point between disinfection and the actual discharge.
- c. The dissolved oxygen can drop in the outfall line; therefore, D.O. 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, dissolved oxygen must be measured after this step and as close to the end of the outfall line as possible.
- d. Total suspended solids 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

Where the permit requires sampling and monitoring of a particular effluent characteristic(s) at a frequency of less than once per day or daily, the permittee is precluded from marking the "No Discharge" block on the Discharge Monitoring Report if there has been any discharge from that particular outfall during the period which coincides with the required monitoring frequency; i.e. if the required monitoring frequency is once per month or 1/month, the monitoring period is one month, and if the discharge occurs during only one day in that period then 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 according to methods prescribed in Title 40, CFR, Part 136, as amended, promulgated pursuant to Section 304 (h) of the Act.
- c. Composite samples must be proportioned by flow at time of sampling. Aliquots may be collected manually or automatically. The sample aliquots must be maintained at ≤ 6 degrees Celsius during the compositing period.
- d. In instances where permit limits established through implementation of applicable water criteria are below analytical capabilities, compliance with those limits will be determined using the detection limits described in the TN Rules, Chapter 0400-40-03-.05(8).
- e. All sampling for total mercury at the municipal wastewater plant (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:

- a. The exact place, date and time of sampling;
- b. The exact person(s) collecting samples;
- c. The dates and times the analyses were performed;
- d. The person(s) or laboratory who performed the analyses;
- e. The analytical techniques or methods used, and;
- f. The results of all required analyses.

1.2.5. Records Retention

All records and information resulting from the monitoring activities required by this permit including all records of analyses performed and calibration and maintenance of instrumentation shall be retained for a minimum of three (3) years, or longer, if requested by the Division of Water Resources.

1.3. REPORTING

1.3.1. Monitoring Results

Monitoring results shall be recorded monthly and submitted monthly using NetDMR. Submittals shall be no later than 15 days after the completion of the reporting period. If NetDMR is not functioning, a completed DMR with an original signature shall be submitted to the following address:


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

If NetDMR is not functioning, a copy of the completed and signed DMR shall be mailed to the City Environmental Field Office (EFO) at the following address:

**STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION
DIVISION OF WATER RESOURCES
City Environmental Field Office
1301 Riverfront Parkway, Suite 206
City, Tennessee 37402**

In addition, any communication regarding compliance with the conditions of this permit must be sent to the two offices listed above.

The first DMR is due on the 15th of the month following permit effectiveness.

DMRs and any other information or report must be signed and certified by a responsible corporate officer as defined in 40 CFR 122.22, a general partner or proprietor, or a principal municipal executive officer or ranking elected official, or his duly authorized representative. Such authorization must be submitted in writing and must explain the duties and responsibilities of the authorized representative. 

For purposes of determining compliance with this permit, data provided to the division electronically is legally equivalent to data submitted on signed and certified DMR forms.

1.3.2. Additional Monitoring by Permittee

If the permittee monitors any pollutant specifically limited by this permit more frequently than required at the location(s) designated, using approved analytical methods as specified herein, the results of such monitoring shall be included in the calculation and reporting of the values required in the DMR form. Such increased frequency shall also be indicated on the form.

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 Section 69-3-115 of the Tennessee Water Quality Control Act.

1.3.4. Monthly Report of Operation

Monthly operational reports shall be submitted on standard forms to the appropriate Division of Water Resources Environmental Field Office in Jackson, Nashville, City, Columbia, Cookeville, Memphis, Johnson City, or Knoxville. Reports shall be submitted by the 15th day of the month following data collection.

1.3.5. Bypass, Release and Overflow Reporting

1.3.5.1. Report Requirements

A summary report of known instances of sanitary sewer overflows, releases, and bypasses shall accompany the Discharge Monitoring Report (DMR). The report must contain the date(s), estimated duration in hours, estimated quantity of wastewater in gallons, and if applicable, the receiving stream for each instance of sanitary sewer overflow, release, or bypass. For each sanitary sewer overflow and release, the report shall identify (using the permittee's naming conventions) the next downstream pump station. For each sanitary sewer overflow, the report shall also identify whether it was a dry weather overflow.

The report must also detail activities undertaken during the reporting period to correct the reported sanitary sewer overflows and releases.

On the DMR, the permittee must separately report: the total number of sanitary sewer overflows for the reporting month and the cumulative total for the previous 12 months; the total number of dry-weather overflows for the reporting month and the cumulative total for the previous 12 months; the total number of releases for the reporting month; and the total number of bypasses for the reporting month. On the DMR, sanitary sewer overflows are coded "SSO, Dry Weather and SSO, Wet Weather" and releases are coded "Release [Sewer], Dry Weather and Release [Sewer], Wet Weather." Estimated total monthly volume for each type of event will be reported as gallons per month. Each release due to improper operation or maintenance shall be reported as such. Each discrete location of a sanitary sewer overflow or a release shall be reported as a separate value. A sanitary sewer

overflow or release occurring at one location over a period of up to 24 hours shall be reported as one occurrence. A sanitary sewer overflow or release occurring at one location over a period more than 24 hours shall be reported as the appropriate number of occurrences.¹

1.3.5.2. Anticipated Bypass Notification

If, because of unavoidable maintenance or construction, the permittee has need to create an in-plant bypass which would cause an effluent violation, the permittee must notify the division as soon as possible, but in any case, no later than 10 days prior to the date of the bypass.

1.3.6. Reporting Less Than Detection; Reporting Significant Figures

A permit limit may be less than the accepted detection level. If the samples are below the detection level, then report "BDL" or "NODI =B" on the DMRs. The permittee must use the correct detection levels in all analytical testing required in the permit. The required detection levels are listed in the Rules of the Department of Environment and Conservation, Division of Water Resources, Chapter 0400-40-03-.05(8).

For example, if the limit is 0.02 mg/l with a detection level of 0.05 mg/l and detection is shown; 0.05 mg/l must be reported. In contrast, if nothing is detected reporting "BDL" or "NODI =B" is acceptable.

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.

1.4. 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 For example, if a sanitary sewer overflow discharges continuously from 1 pm until 3 am the following morning, the event shall be reported as a single violation. Similarly, if the same sanitary sewer overflow discharges intermittently for the same time period, it should be reported as one violation. By contrast, if the same sanitary sewer overflow did not end until 3 pm two days later, it should be reported as three violations.

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.

2.0. GENERAL PERMIT REQUIREMENTS

2.1. GENERAL PROVISIONS

2.1.1. Duty to Reapply

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 Director of the Division of Water Resources (the "director") no later than 180 days prior to the expiration date. Such forms shall be properly signed and certified.

2.1.2. 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:

- a. To enter upon the permittee's premises where an effluent source is located or where records are required to be kept under the terms and conditions of this permit, and at reasonable times to copy these records;
- b. To inspect at reasonable times any monitoring equipment or method or any collection, treatment, pollution management, or discharge facilities required under this permit; and
- c. To sample at reasonable times any discharge of pollutants.

2.1.3. 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 offices of the Division of Water Resources. As required by the Federal Act, effluent data shall not be considered confidential.

2.1.4. Proper Operation and Maintenance

- a. The permittee shall at all times properly operate and maintain all facilities and systems (and related appurtenances) for collection and treatment which are installed or used by the permittee to achieve compliance with the terms and conditions of this permit. Proper operation and maintenance also includes adequate laboratory and process 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. Backup continuous pH and flow monitoring equipment are not required.
- b. Dilution water shall not be added to comply with effluent requirements to achieve BCT, BPT, BAT and or other technology based effluent limitations such as those in State of Tennessee Rule 0400-40-05-.09.

2.1.5. 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.

2.1.6. 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.

2.1.7. 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.

2.1.8. 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 in 40 CFR 122.29(b); or
- 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).

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.
- 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. The permittee shall also furnish to the director, upon request, copies of records required to be kept by 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 on 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

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 the 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 director, within 30 days, does not notify the current permittee and the new permittee of his intent to modify, revoke or reissue, or terminate the permit and to require that a new application be filed rather than agreeing to the transfer of the permit.

Pursuant to the requirements of 40 CFR 122.61, concerning transfer of ownership, the permittee must provide the following information to the division in their formal notice of intent to transfer ownership: 1) the NPDES permit number of the subject permit; 2) the effective date of the proposed transfer; 3) the name and address of the transferor; 4) the name and address of the transferee; 5) the names of the responsible parties for both the transferor and transferee; 6) a statement that the transferee assumes responsibility for the subject NPDES permit; 7) a statement that the transferor relinquishes responsibility for the subject NPDES permit; 8) the signatures of the responsible parties for both the transferor and transferee pursuant to the requirements of 40 CFR 122.22(a), "Signatories to permit applications"; and, 9) 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. Effect of Noncompliance

All discharges shall be consistent with the terms and conditions of this permit. Any permit noncompliance constitutes a violation of applicable state and federal laws and is grounds for enforcement action, permit termination, permit modification, or denial of permit reissuance.

2.3.2. Reporting of Noncompliance

- a. 24-Hour Reporting

In the case of any noncompliance which could cause a threat to public drinking supplies, or any other discharge which could constitute a threat to human health or the environment, the required notice of non-compliance shall be provided to

the Division of Water Resources in the appropriate Environmental Field Office within 24-hours from the time the permittee becomes aware of the circumstances. (The Environmental Field Office should be contacted for names and phone numbers of environmental response team).

A written submission must be provided within five days of the time the permittee becomes aware of the circumstances unless the director on a case-by-case basis waives this requirement. The permittee shall provide the director with the following information:

- i. A description of the discharge and cause of noncompliance;
 - ii. The period of noncompliance, including exact dates and times or, if not corrected, the anticipated time the noncompliance is expected to continue; and
 - iii. The steps being taken to reduce, eliminate, and prevent recurrence of the noncomplying discharge.
- b. Scheduled Reporting

For instances of noncompliance which are not reported under subparagraph 2.3.2.a above, the permittee shall report the noncompliance on the Discharge Monitoring Report. The report shall contain all information concerning the steps taken, or planned, to reduce, eliminate, and prevent recurrence of the violation and the anticipated time the violation is expected to continue.

2.3.3. Overflow

- a. Sanitary sewer overflows, including dry-weather overflows, are prohibited.
- b. The permittee shall operate the collection 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). Releases caused by improper operation or maintenance of the permittee’s collection and transmission system are prohibited.
- c. The permittee shall take all reasonable steps to minimize any adverse impact associated with releases.
- d. No new or additional flows shall be added upstream of any point in the collection or transmission system that experiences greater than 5 sanitary sewer overflows or releases (greater than 5 events per year)² or would otherwise overload any portion of the system. Unless there is specific enforcement action to the contrary,

² When determining if a location experiences chronic sanitary sewer overflows or releases the term “event(s)” includes dry weather overflows, wet weather overflows, dry weather releases and wet weather releases.

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 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 of 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 a Monthly Operating Report submitted to the local TDEC Environmental Field Office. The data measurement period shall be sufficient to account for seasonal rainfall patterns and seasonal groundwater table elevations.

- e. 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 the Division of Water Resources EFO staff to petition for a waiver based on mitigating evidence.

2.3.4. Upset

- a. **"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.
- b. An upset shall constitute an affirmative defense to an action brought for noncompliance with such 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."

2.3.5. 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.

2.3.6. Bypass

- a. **"Bypass" is the intentional diversion of waste streams from any portion of a treatment facility.** "Severe property damage" means substantial physical damage to property, damage to the treatment facilities which would cause 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.
- b. Bypasses are prohibited unless all of the following 3 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 construction and 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;
 - iii. The permittee submits notice of an unanticipated bypass to the Division of Water Resources in the appropriate Environmental Field Office within 24 hours of becoming aware of the bypass (if this information is provided orally, a written submission must be provided within five days). When the need for the bypass is foreseeable, prior notification shall be submitted to the director, if possible, at least 10 days before the date of the bypass.
- c. Bypasses not exceeding permit limitations are allowed **only** if the bypass is necessary for essential maintenance to assure efficient operation. All other bypasses are prohibited. Allowable bypasses not exceeding limitations are not subject to the reporting requirements of 2.3.6.b.iii, above.

2.3.7. 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 decrease due to solids wasting to the sludge disposal system. A washout can be caused by improper operation or from peak flows due to infiltration and inflow.

- b. A washout is prohibited. If a washout occurs the permittee must report the incident to the Division of Water Resources in the appropriate Environmental Field Office within 24 hours by telephone. A written submission must be provided within five days. The washout must be noted on the discharge monitoring report. 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 "**Bypassing**," "**Overflow**," and "**Upset**," 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.

3.0. 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.

Paragraph 1a-c applies if the STP does NOT have an approved pretreatment program:

Paragraph 2a-c applies if the pretreatment program is inactive:

Paragraph 3a-d applies if the STP has an approved or developing pretreatment program:

Paragraph 4a-c applies if the STP has a dormant pretreatment program:

3.2. POTW PRETREATMENT PROGRAM GENERAL PROVISIONS

As an update of information previously submitted to the division, the permittee will undertake the following activity.

(If developing, replace the above sentence with the one below, and delete the 120-day IWS submission requirement in 3.2.a.viii.)

Requirements of Section 3.2 shall apply after the division director or pretreatment coordinator has approved the pretreatment program by letter.

- 1a. The permittee shall submit the results of an Industrial Waste Survey (IWS) in accordance with 40 CFR 403.8(f)(2)(i), including any industrial users (IU) covered under Section 301(i)(2) of the Act. As much information as possible must be obtained relative to the character and volume of pollutants contributed to the POTW by the IUs. This information will be submitted to the Division of Water Resources, Pretreatment Section within one hundred twenty (120) days of the effective date of this permit, unless such a survey has been submitted within 3 years of the effective date. Development of a pretreatment program may be required after completion of the industrial user review. All requirements and conditions of the pretreatment program are enforceable through the NPDES permit.
- 2a. The current pretreatment program is in the inactive stage. The program will remain inactive as long as no significant industries discharge into the collection system. Should a significant industrial user request permission to discharge into the City system, then the City must request that the division reactivate the pretreatment program. This must be done prior to the industrial discharge taking place.

4.0. DEFINITIONS AND ACRONYMS

4.1. DEFINITIONS

“**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.

A “**bypass**” is defined as the intentional diversion of waste streams from any portion of a treatment facility.

A “**calendar day**” is defined as the 24-hour period from midnight to midnight or any other 24-hour period that reasonably approximates the midnight to midnight time period.

A “**composite sample**” is a combination of not less than 8 influent or effluent portions, of at least 100 ml, collected over a 24-hour period. Under certain circumstances a lesser time period may be allowed, but in no case, less than 8 hours.

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 concentration is the concentration of that 24-hour composite; when other sampling means are used, the daily concentration is the arithmetic mean of the concentrations of equal volume samples collected during any calendar day or sampling period.

“**Discharge**” or “discharge of a pollutant” refers to the addition of pollutants to waters from a source.

A “**dry weather overflow**” is a type of sanitary sewer overflow and is 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. Discharges from more than one point within a 24-hour period shall be counted as separate overflows.

“**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**” - 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 ONRWs the mitigation must occur within the ONRW.

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 is 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 (0) shall be considered to be one (1).

A “**grab sample**” is a single influent or effluent sample collected at a particular time.

The “**instantaneous maximum concentration**” is a limitation on the concentration, in milligrams per liter, of any pollutant contained in the wastewater discharge determined from a grab sample taken from the discharge at any point in time.

The “**instantaneous minimum concentration**” is the minimum allowable concentration, in milligrams per liter, of a pollutant parameter contained in the wastewater discharge determined from a grab sample taken from the discharge at any point in time.

The "**monthly average amount**", shall be determined by 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.

The "**monthly average concentration**", other than for *E. coli* bacteria, is the arithmetic mean of all the composite or grab samples collected in a one-calendar month period.

A "**one week period**" (or "**calendar-week**") is defined as 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.

"**Pollutant**" means sewage, industrial wastes, or other wastes.

A "**quarter**" is defined as 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.

A "**rainfall event**" is defined as 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.

A "**rationale**" (or "fact sheet") is 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 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.

A "**release**" is the flow of sewage from any portion of the collection or transmission system owned or operated by the permittee other than through permitted outfalls that does not add pollutants to 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 and transmission system owned or operated by the permittee. A "release" does not include backups into a building or private property caused by blockages or other malfunctions originating in a private lateral.

A "**sanitary sewer overflow (SSO)**" is defined as an unpermitted discharge of wastewater from the collection or treatment system other than through the permitted outfall.

"**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.

“**Severe property damage**” when used to consider the allowance of a bypass or SSO 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 or SSO. Severe property damage does not mean economic loss caused by delays in production.

“**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.

A “**subcoregion**” is a smaller, more homogenous area that has been delineated within an ecoregion.

“**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 activated sludge plants and is defined as 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.

The “**weekly average amount**”, shall be determined by the summation of all the measured daily discharges by weight divided by the number of days during the calendar week when the measurements were made.

The “**weekly average concentration**”, is the arithmetic mean of all the composite samples collected in a one-week period. The permittee must report the highest weekly average in the one-month period.

4.2. ACRONYMS AND ABBREVIATIONS

1Q10 – 1-day minimum, 10-year recurrence interval

30Q20 – 30-day minimum, 20-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 level

BOD₅ – five day biochemical oxygen demand

BPT – best practicable control technology currently available

CBOD₅ – 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*

EFO – environmental field office

LB(lb) - pound

IC₂₅ – inhibition concentration causing 25% reduction in survival, reproduction and growth of the test organisms

IU – industrial user

IWS – industrial waste survey

LC₅₀ – acute test causing 50% lethality

MDL – method detection level

MGD – million gallons per day

MG/L(mg/l) – milligrams per liter

ML – minimum level of quantification

ml – milliliter

MLSS – mixed liquor suspended solids

MOR – monthly operating report

NODI – no discharge

NPDES – national pollutant discharge elimination system

PL – permit limit

POTW – publicly owned treatment works

RDL – required detection limit

SAR – semi-annual [pretreatment program] report

SIU – significant industrial user

SSO – sanitary sewer overflow

STP – sewage treatment plant

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

State of Tennessee NPDES Permit Vocabulary

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 15th 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.

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

Section

Answers to Vocabulary and Review Questions

Section 1 Activated Sludge Part 2 Answers

Vocabulary:

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)

Review Questions:

1. C
2. A
3. C
4. C
5. A
6. B
7. B
8. B
9. B
10. A
11. D
12. C
13. B
14. A
15. A

Section 2 Intro to Wastewater Math Answers

Sedimentation Math Answers:

1. 2.41 hours
2. 1151.59 gpd/sq.ft.
3. 17,752.38 gpd/ft
4. 22.39 lbs/day/sq.ft.
5. 927.11 gpd/sq.ft.
6. 21.55 lbs/day/sq.ft.
7. 4806.34 lbs/day

8. 1.49 hrs

Chemical Dosage/Disinfection Math Answers

1. 5.00 lbs/day
2. 307.75 lbs/day
3. 33.36 lbs/day
4. 113.42 lbs/day
5. 3415.23 lbs
6. 0.8 mg/L
7. 6.47 mg/L
8. 20 min, above DT
9. 22.45 lbs
10. 6.42 lbs

Activated Sludge Math Answers:

1. 1438.65 lbs/day
2. 13989.43 lbs
3. 18.77 lbs/day
4. 0.31
5. 9.38 days
6. 6.86 days

Section 3 Introduction to Laboratory and Sampling Answers

Vocabulary:

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

Review Questions:

1. Autoclave, 121 degrees C for 15 min at 15 psi
2. 40 CFR 136, Table II
3. 8 hours, 36 hours, 28 days

4. If there is no existing bacterial population, for example: if samples were collected after disinfection, if nitrification inhibitor has been added, or if a toxic load was suspected in the plant.
5. 20, 0.2 mg/L, 2.0 mg/L, 9.0 mg/L
6. Grab sample is a volume of water, representative of the water quality at that exact time and place of sampling. A composite sample is a combination of not less than 8 influent or effluent portions, of at least 100 mL, collected over a 24-hour period. In certain circumstances, a lessre time period may be allowed, but in no case less than 8 hours. A composite sample is a series of grab samples mixed together, representative of the average water quality over a period of time.
7. 103 -105 degrees C
8. D.
9. (a) Process is operating well, good settling sludge (b) Old sludge, increase wasting (c) Young sludge, lots of food (BOD), insufficient biomass. Could indicate plant start-up or recovery after an upset.
10. Alum and chlorine
11. 200 cfu/100 ml, 44.5 +/- 0.2 degrees C, 24 +/- 2 hours
12. 126 cfu/100 ml, 35 +/- 0.5 degrees C, 24 +/- 2 hours
13. (a) positive for total coliforms (b) positive for E.coli
14.
 - a. Demonstration of capability
 - b. Method Detection Level
 - c. Initial Calibration Verification
 - d. Continuing Calibration Verification
 - e. Laboratory Reagent Blank (aka Standard)
 - f. Laboratory Fortified Matrix (aka Spike)

Section 6 Sludge Thickening, Digestion, and Dewatering Answers

Vocabulary:

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

Review Questions:

1. During anaerobic digestion, 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 2 different bacteria groups: saprophytic organisms (acid formers) and methane formers.
2. The acid fermenters will predominate, driving the pH down and creating an undesirable condition for the methane fermenters. The digester will go sour or acid. This could lead to foaming or frothing.
3. Explosive conditions created by a mixture of air and methane in partially full digesters
4. 50 GPM
5. Foaming is caused by an imbalance between the acid-forming bacteria and the methane-fermenting bacteria. This imbalance results in active gas production while solids separation has not progressed far enough (insufficient digestion).

To prevent it from occurring, ensure the contents are well mixed from bottom to top at all times. (short answer)

- Maintain a constant temp
 - Feed sludge at regular, short intervals
 - Exercise caution when breaking up scum blankets
 - Do not overdrain sludge from digester
 - Keep contents well mixed from bottom to top at all times
6. Problem: Washout caused by belt blinding, polymer dose, belt speed being too low, or hydraulic load too high. Belt blinding or plugging can be the result of inadequate belt washing or chemical blinding. Manually clean belts with high-pressure hose to restore at least some of the drainage.
Problem: Cake solids too wet. Belt speed could be too high – lower belt speed. Belt tension could be too low – raise belt tension.
 7. Water could be in the floating cover compartment (this could come from condensation or rain water), you would do a visual inspection of the flotation chamber to look for water or sludge, siphon or pump out any water or sludge and repair the leak.
The weight distribution could be off/uneven, in this case you would check the location of the weights and check the buoyancy chamber for leakage. If movable ballast or weights are provided, move them around until the cover is level.
If excess scum has accumulated around the edge, you would need to clean with chemicals or degreasing aids and hose down with water.
 8. Class A Less than (<) 1,000 MPN per gram of total dry solids

Class B Less than (<) 2 million MPN or cfu/gram of total dry solids
 9. Extend mixing time, Control heat more evenly, Decrease raw sludge feed rates, Decrease digested sludge withdrawal rates

10. To neutralize it if the digester is going sour. This will only raise the pH however, and not correct the initial cause of the problem.
11. Petroleum products and mineral oils
 - Rubber goods
 - Plastics (back sheets to diapers)
 - Filter tips from cigarettes
 - Hair
 - Grit (sand and other inorganics)
12. 1.0 mg/L
13. Raw or Secondary sludges.
Quality is regulated by: Sludge feed rate, Bowl speed, Chemical conditioners
14. (1) Pollutant Limits – Metals. The first parameter of the 3 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.

Section 7 Safety Answers

Vocabulary:

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

Review Questions:

1. Explosive or flammable atmospheres can develop at any time in the collection system. Flammable gases or vapors may enter a sewer or manhole from a variety of legal, illegal or accidental sources.
2. Oxygen, Combustible (Explosive), Toxic
3. If operators are scheduled to work in a manhole, the atmosphere in the manhole should be tested before anyone enters it, preferably before the cover is even removed, and atmospheric testing should continue for the entire time anyone is working in the manhole.
4. The blower used to ventilate a manhole should be located in an area upwind of the manhole and at least 10 feet from the manhole opening. If the blower has a gas-driven engine, the exhaust must be downwind from the manhole. The air intake to the blower should be 2-5 feet above the ground surface, depending on conditions (higher for dusty conditions).
5. SCBA (self-contained breathing apparatus); safety harness with lifeline, tripod and winch; portable atmospheric alarm unit; ventilation blower with hose; manhole enclosure (if entering a manhole); ladder or tripod with winch; ropes and buckets; hard hats; protective clothing; cones and barricades; first-aid kit; soap, water, paper towels and a trash bag
6. The early warning signs that an operator is not getting enough oxygen include: labored breathing (shortness of breath), chest heaving and change from usual responses
7. Operators can be protected from injury due to the accidental discharge of stored energy by following prescribed lockout/ tagout procedures.
8. Collection system operators can protect their hearing from loud noises by use of approved earplugs, earmuffs and/or person protective equipment.
9. To extinguish a fire, first identify the material burning (class or category) and then use the PASS method to put out the fire.
10. C
11. A
12. B
13. C

Section 8 Cross Connection Answers

Vocabulary:

1. Air gap
2. Atmospheric Vacuum Breaker
3. Auxiliary Supply
4. Backflow
5. Back pressure
6. Backsiphonage
7. Check Valve
8. Cross Connection
9. Feed Water
10. Pollutant
11. Overflow Rim
12. Pressure Vacuum Breaker
13. Reduced Pressure Principle Assembly
14. Water Purveyor
15. Differential Pressure

Review Questions:

1. A cross-connection is any connection or structural arrangement between a potable water system and a nonpotable system through which backflow can occur.
2. Backsiphonage is a condition in which the pressure in the distribution system is less than atmospheric pressure. In more common terms, there is a partial vacuum on the potable system. Backpressure is a condition in which a substance is forced into a water system because that substance is under a higher pressure than system pressure.
3. Fire demand, a broken water main or exceptionally heavy water use at a lower elevation than the cross connection, a booster pump used on a system, undersized piping
4. Typhoid fever, dysentery and gastroenteritis, salmonellosis, polio, hepatitis, brucellosis
5. The most reliable backflow prevention method is an air gap.
6. A single check valve is not considered positive protection against backflow. A check valve can easily be held partially open by debris, corrosion products or scale deposits.
7. Reduced-pressure-zone backflow preventers should be tested at least annually.
8. An atmospheric vacuum breaker must be installed downstream from the last shutoff valve. If it is placed where there will be continuing backpressure, the valve will be forced to remain open, even under backflow conditions.
9. When water stops flowing forward, a check valve drops, closing the water inlet and opening an atmospheric vent. This lets water in the breaker body drain out, breaking the partial vacuum in that part of the system.
10.
 - an adequate cross-connection control ordinance
 - an adequate organization with authority
 - a systematic surveillance program
 - follow-up procedures for compliance
 - provisions for backflow-prevention device approvals, inspection and maintenance
 - public awareness and information programs

Section 9 Pumps and Equipment Maintenance Answers

Vocabulary:

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

Pumps and Motors Review Questions:

1. B
2. C
3. C
4. A
5. C
6. D
7. B
8. C
9. B
10. C
11. A
12. A
13. A spinning impeller accelerates water to a high velocity within a casing, which changes the high-velocity, low-pressure water to a low-velocity, high-pressure discharge.
14. Volute casing and diffuser vanes
15. Mixed-flow pump (the design used for most vertical turbine pumps)
16. If a valve is closed in the discharge line, the pump impeller can continue to rotate for a time without pumping water or damaging the pump.
17. A multistage centrifugal pump is made up of a series of impellers and casings (housings) arranged in layers, or stages. This increases the pressure at the discharge outlet, but does not increase flow volume.
18. Shaft-type and submersible-type vertical turbines.
19. A close-coupled vertical turbine with an integral sump or pot.
20. Positive-displacement pumps are generally used in water plants to feed chemical into the water supply.
21. The foot valve prevents water from draining when the pump is stopped, so the pump will be primed when restarted.
22. The bolts holding the two halves of the casing together are removed and the top half is lifted off.
23. Wear rings prevent excessive circulation of water between the impeller discharge and suction area. Lantern rings allow sealing water to be fed into the stuffing box.
24. (1) Packing rings are made of graphite-impregnated cotton, flax, or synthetic materials. They are inserted in the stuffing box and held snugly against the shaft by an adjustable packing gland. (2) Mechanical seals consist of two machined and polished surfaces. One is attached to the shaft, the other to the casing. Spring pressure maintains contact between the two surfaces.

25. The pump impeller is mounted directly on the shaft of the motor.
26. An experienced operator can often detect unusual vibration by simply listening or touching. Vibration, especially changes in vibration level, are viewed as symptoms or indicators of other underlying problems in foundation, alignment and/or pump wear.
27. During start-up.
28. (1) Increase system efficiency; (2) spread the pumping load more evenly throughout the day; (3) reduce power-factor charges
29. The bearings may run hot, and excess grease or oil could run out and reach the motor windings, causing the insulation to deteriorate.
30. The abrasive material on emery cloth is electrically conductive and could contaminate electrical components.
31. Imbalance of the rotating elements, bad bearings and misalignment
32. A condition called single-phasing can occur, causing the motor windings to overheat and eventually fail.
33. Make sure the power to the device is disconnected. This is critical since rubber gloves, insulated tools and other protective gear are not guarantees against electrical shock.

Equipment Maintenance Review Questions:

1. A voltage tester can be used to test for voltage, open circuits, blown fuses, single phasing of motors and grounds.
2. At least once a year and twice a year if possible
3. Coils, fuses, relays, resistors and switches
4. Fuses and circuit breakers
5. A.C. induction motor
6. You can seriously injure yourself or damage costly equipment.
7. They can handle fluctuating flows with large solids and rags.
8. To keep air from leaking in and water leaking out where the shaft passes through the casing.
9. To allow outside water or grease to enter the packing for lubrication, flushing, and cooling and to prevent air from being sucked or drawn into the pump
10. Every 6 months or annually, depending on pumping conditions; if grit, sand or other abrasive material is being pumped, inspections should be more frequent
11. They protect the impeller and pump body from damage due to excessive wear.
12. Cavitation can be caused by a pump operating under different conditions than what it was designed for, such as off the design curve, poor suction conditions, high speed, air leaks into suction end and water hammer conditions.
13. The frequency of cleaning a suction filter on a compressor depends on the use of a compressor and the atmosphere around it. The filter should be inspected at least monthly and cleaned or replaced every three to six months. More frequent inspections, cleanings and replacements are required under dusty conditions such as operating a jackhammer on a street.
14. Daily
15. To reduce friction between two surfaces and to remove heat caused by friction.
16. Shut it off, lock it out and tag it so it can't be started unexpectedly and injure you.
17. D
18. C
19. C

20. C

Section 10 NPDES Overview

Vocabulary:

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