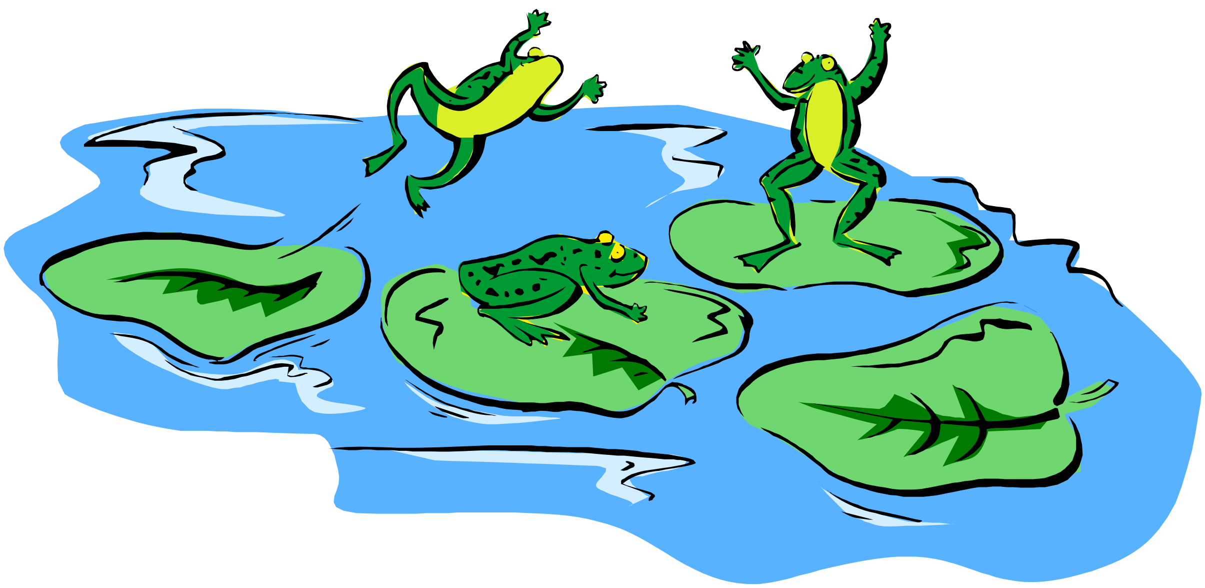
Biological/Natural Systems

#1204



Fleming Training Center
Your Partner in Clean Water

TDEC
TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

August 22-26, 2016
Fleming Training Center

STATE OF TENNESSEE
Fleming Training Center

Biological/Natural Systems

Course # 1204
August 22-26, 2016

Monday, August 22

8:30	Overview of Wastewater Treatment	Darryl Green
10:00	Rules and Regulations	Darryl Green
11:30	LUNCH	
1:30	Disinfection	Darryl Green
8:30	Wastewater Lagoons	Darryl Green
10:15	Effluent Discharge (Surface Waters, Irrigation, Overland Flow)	Darryl Green

Tuesday, August 23

8:30	Pumps	Darryl Green
11:00	LUNCH	
12:15	Septic Tanks	Fali Kapadia
	Constructed Wetlands; Aquatic Plants	Fali Kapadia

Wednesday, August 24

9:30	Packed Bed Filters & Sand Filters	Amanda Carter
12:45	Cross Connection Control	Amanda
11:00	LUNCH	
2:00	Safety	Amanda
12:15	Sampling and Laboratory Analyses	Amanda

Thursday, August 25

8:30	Math - Area and Volume - Velocity and Flow - Lagoon Math	Amanda Carter
11:30	LUNCH	
12:30	Math - continued - Disinfection - Lab - Pumps	Amanda

Friday, August 26

8:30	Wastewater Microbiology	Brandon Hulette
11:00	LUNCH	
12:15	Exam and Course Evaluation	Amanda Carter

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STATE OF TENNESSEE

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Biological/Natural System

Section 1

Introduction to Wastewater

Intro to Wastewater Treatment for BNS

Why do we treat waste?

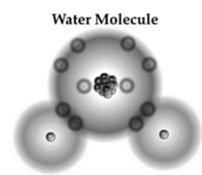
Prevention of Pollution

- Protection of public health and receiving streams is main job
- Today's technology is capable of treating wastewater so that receiving streams are reasonably unaffected

Purpose of Wastewater Treatment

- To protect public health by:
  - Removing solids
  - Stabilizing organic matter
  - Removing pathogenic organisms

What is Pure Water?



H_2O

- Water is made up of two hydrogen atoms and one oxygen atom
- "Pure" water is manufactured in labs
- Even rain and distilled water contain other substances called impurities

Types of Waste

- Organic waste
  - Contains carbon
- Inorganic waste
  - Salts
  - Metals
  - Gravel
  - Sand
- Both may come from domestic or industrial waste

Sludge and Scum

- If wastewater does not receive adequate treatment, solids may build up in the receiving stream as sludge in the bottom or scum floating to the surface
  - Sludge and scum are unsightly and may contain organic material that consumes oxygen or be an odor problem

Oxygen Depletion

- Most living creatures, including fish, need oxygen to survive
  - Most fish can survive with at least 5 mg/L DO
- When organic wastes are discharged to a receiving stream bacteria begin to feed on it, these bacteria need oxygen for this process
  - As more organic waste is added to the receiving stream, the bacteria reproduce
  - As the bacteria reproduce, they use up more oxygen
  - This can potentially cause a fish kill and odors

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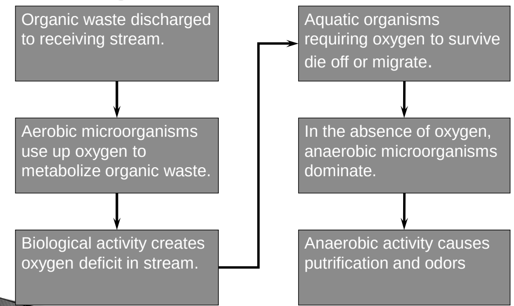
Oxygen Utilization by Aerobic Microorganisms



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Human Health

- Initial efforts came from preventing disease outbreaks
  - Most bacteria in wastewater are not harmful to humans
  - Humans who have a disease caused by bacteria or viruses can discharge some of these pathogens
  - Many serious outbreaks of communicable diseases have been traced back to contamination of drinking water or food from domestic wastewater
- Good personal hygiene is your best defense against infections and disease

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Diseases

- Bacteria
  - Cholera
  - Dysentery
  - Shigella
  - Salmonella
  - Typhoid
- Viruses
  - Polio
  - Hepatitis (Jaundice)
- Protozoa
  - Giardia lamblia
  - Cryptosporidium parvum

The LifeStraw is a portable water purification tool that purifies water from potential pathogens like typhoid, cholera, dysentery and diarrhea.

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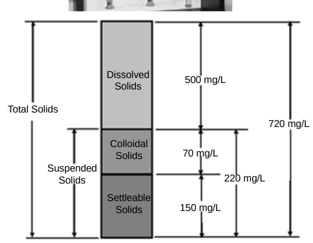
Solids

- Total solids
- Dissolved solids
- Suspended solids
  - Settleable
  - Nonsettleable
- Organic and inorganic solids
- Floatable solids



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NPDES Permit

- National Pollutant Discharge Elimination System
  - Required by the Federal Water Pollution Act Amendments of 1972 to help keep the nation's water suitable for swimming and for fish and other wildlife
  - Regulates discharges

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Water Pollution

- Any condition caused by human activity that adversely affects the quality of stream, lake, ocean, or groundwater.

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Water Pollution Impacts

- Unpolluted water has a wide diversity of aquatic organisms and contains enough dissolved oxygen.

- Polluted water inhibits the growth of aquatic organisms.

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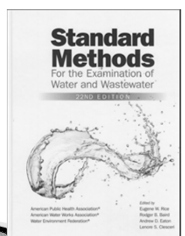
Reference Material

- *40 CFR 136*
- *Standard Methods for the Examination of Water and Wastewater.* AWWA, APHA, EPA.



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Organic Compounds

- An organic compound is a substance that contains carbon.
  - Cyanide
  - Cyanates
  - Carbon dioxide and its relatives are exceptions to that rule and are considered inorganic

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Importance of Organic Matter

- Organic material consumes oxygen in water.
  - Bacteria will "feed" on organic matter and most need oxygen to be able to do this.
  - We want these bacteria to "feed" on the organic matter and use it up in the plant and not in our receiving water.
- High concentrations of organic material can cause taste and odor problems in recreational and drinking water.
- Some material may be hazardous.

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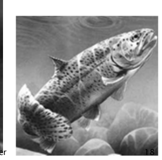
Dissolved Oxygen

- Dissolved oxygen is oxygen that has been incorporated into water.

- Many aquatic animals require it for their survival.



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Dissolved Oxygen

- There are two important factors that can influence the amount of dissolved oxygen present:
  - Water Temperature
  - Organic matter

Dissolved Oxygen

- Temperature:
  - Greater temperature → Less DO
  - Lower temperature → More DO

Dissolved Oxygen

- Organic material
  - Organic material requires oxygen to decompose.
  - More organic material requires more DO, and will tend to deplete water of DO.

Oxygen Demand

- The oxygen demand is the amount of oxygen required to oxidize a material.

Biochemical Oxygen Demand

- Biochemical oxygen demand, or BOD is the amount of oxygen used during the breakdown of organic material.
- BOD is considered an indirect measure of the organic content of a sample.
- Dissolved oxygen measured by Winkler method (titration) or using a meter and electrode.

BOD_5

- BOD_5 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)
  - Min. sample depletion 2 mg/L and final D.O. of 1 mg/L
  - Max depletion of blanks is 0.2 mg/L

BOD_5 Procedure

- Measure initial D.O.
- Incubate sample for 5 days
- Measure final D.O.
- The BOD_5 is the amount of D.O. used up over the 5-day period.

BOD

$$BOD_t = \frac{DO_i - DO_f}{\frac{V_s}{V_b}} = \frac{DO_i - DO_f}{P}$$

- BOD_t = BOD at t days ($^{mg}/_{L}$)
- DO_i = Initial DO ($^{mg}/_{L}$)
- DO_f = Final DO ($^{mg}/_{L}$)
- V_s = Volume of sample (mL)
- V_b = Volume of BOD bottle (mL) = 300 mL
- P = Percent sample, decimal

Ultimate BOD

- The ultimate BOD is the total amount of dissolved oxygen it would take to completely breakdown all the organic material in a sample over an infinite amount of time.
- BOD consumed + BOD remaining = ultimate BOD

Chemical Oxygen Demand (COD)

- COD is the equivalent amount of oxygen needed to break down organic matter using strong oxidizing agents.
- Sometimes measured to use as quick (2-4 hrs) process control test.
- Usually higher than BOD, but ratio varies.

Chemical Oxygen Demand

- Approximation of BOD
- Faster than BOD
- Generally somewhat higher than BOD

Oil and Grease

- Generally listed under one heading called FOG (fats, oils and greases) as it is often not important to know the exact make-up of this group of components.

Solids

- Cause many problems:
  - Fill storage areas, clog ditches and channels.
  - Interfere with mechanical systems.
  - Associated with taste/color/clarity problems in drinking water.

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Total Solid (TS)

- Total solids of a sample is the matter left behind after drying a sample of water at 103-105°C.

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Total Solids

- There are two ways that solid materials may be classified:
  - Suspended solids and dissolved solids
  - Volatile solids and fixed solids

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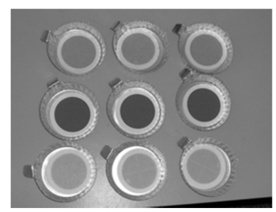
Solids

- Total suspended solids are the part of the sample that may be caught with a 1.5 µm filter.
- Total dissolved solids are the part of the sample that will pass through the filter.



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Solids

- Total volatile solids is the portion of the sample lost after the sample has been heated to 550°C. It is an approximation of the organic material present.

- Total fixed solids is the portion that still remains after heating. It is an approximation of the mineral matter present.

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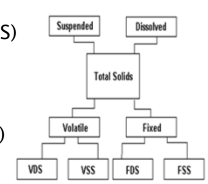
Solids

- These categories may be further groups:
  - Volatile dissolved solids (VDS)
  - Volatile suspended solids (VSS)
  - Fixed dissolved solids (FDS)
  - Fixed suspended solids (FSS)



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Solids

- The mass of solids per known volume of water is:

$$S = \frac{m_t - m_c}{vol}$$

- S = Solids concentration (mg/L)
- Mt = Mass of solids and container (mg)
- Mc = Mass of container (mg)
- Vol = volume of liquid sample (L)

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Nutrients

- Problems associated with excess nutrients:
  - Cause an increase in productivity of aquatic plants, leading to depleted DO levels
  - May cause odor problems
  - Extra vegetation near surface may inhibit light penetration of light into water
- Macronutrients:
  - Nitrogen (many WWTPs test for ammonia)
  - Phosphorus
  - Iron

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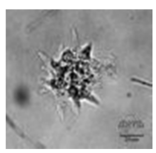
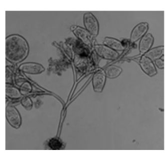
Microbial Organisms

- Serve many important purposes including degrading waste materials
- Some may be dangerous to human health and must be removed from water (pathogens)





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Testing for Microbial Organisms

- Fecal coliforms are used as an indicator organism.
- The sample material is placed in a nutrient bath (mFC broth) and incubated at 44.5±0.2°C for 24 hrs.

Dry air incubator and UV sterilizer for filter funnel.

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Testing for Microbial Organisms

- The number of colonies that form are proportional to how many microbial organisms are present in a sample.
- NPDES permits now require additional testing for *E. coli*.

Colilert media® and sample bottle (top) and results after incubation in QuantiTrays®.

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Salts

- Problems associated with excess salt:
  - Salty water not suitable to drink
  - Detrimental to plant growth
  - Can damage crops and the health of livestock.
  - Cation exchange capacity of soil measured in land application systems.

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Metals

- Problems associated with excess metals:
  - Can make water taste and smell bad.
  - Can stain
  - Metals in high enough concentrations are pollutants and can be serious health risks.

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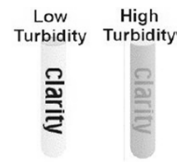
Turbidity

- Turbidity is a measure of the clarity of water or wastewater.
- Turbidity is influenced by the number of insoluble particles present.



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pH

- pH is the negative log of the hydrogen ion concentration.
- It can have a major impact on biological and chemical reactions.
- Electrometric method
- Discharge limit 6 to 9.

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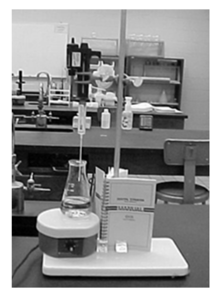
Alkalinity

- Alkalinity is the capacity of water to absorb hydrogen ions without significant pH change.
- Bicarbonates, carbonates, and hydroxides are the three chemical forms that contribute to alkalinity.



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Typical Influent Concentrations

Parameter	Influent Concentration	Effluent Goal**
BOD_5	200 mg/L	< 30 mg/L
TSS	200 mg/L	< 30 mg/L
TDS	800 mg/L	< 1000 mg/L
Settleable Solids	10 mL/L	< 0.1 ml/L
pH	6 – 9	6 – 9
Fecal Coliform	Too Numerous to Count	< 500 cfu/100 mL
TNK (Ammonia + Organic Nitrogen)	30 mg/L	< 10 mg/L Total Nitrogen
Nitrate-Nitrite	< 1.0 mg/L	
Phosphorous	2.0 mg/L	< 1.0 mg/L
Fats, Oils and Grease	Varies	None visible

** Depends on NPDES permit

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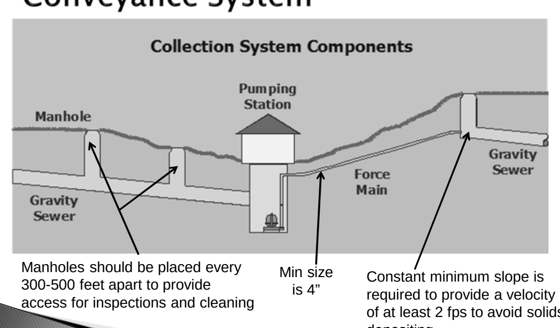
Wastewater Collection and Conveyance System



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Wastewater Collection and Conveyance System

- Manholes must be installed:
  - At the ends of any line 8” in diameter or larger line
  - Changes in grade, size of pipe or alignment
  - At intersections
  - And not greater than 400 ft. on a 15” diameter and smaller sewers or 500 ft. on 18-30” sewers
- Horizontal Separation – sewers should be laid with at least 10 feet of horizontal clearance from any existing or proposed water line
- Vertical Separation – when sewers must cross a water line, they should be laid 18” below the bottom of the water line

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Wastewater Collection and Conveyance System

- Hydrogen sulfide is made in the collection system and can:
  - Make waste more difficult to treat
  - Damage concrete structures
  - Cause odor problems
- Biological activity in long, flat sewer lines will likely cause:
  - Hydrogen sulfide production
  - Oxygen deficiency in sewers, manholes or wetwells
  - Metal and concrete corrosion
- Chlorine can be used in the collection system or at the plant headworks to oxidize hydrogen sulfide

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Wastewater Collection Safety

- When excavating sewers 5 feet or more, cave-in protection is required
  - Contouring
  - Drag shields
  - Shoring
  - Sloping

  (Drag shields, Shoring ← The most practical and best protection)
- If the ditch is 4 feet or deeper, ladders are required every 25 feet in the ditch

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Wastewater Collection Safety

- When entering a confined space, such as a manhole, you will need to have and use:
  - An approved man hoist
  - Forced air ventilator
  - Gas detector that checks for
    - Oxygen
    - Hydrogen sulfide
    - Explosive

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Sanitary, Storm and Combined

- Sanitary
  - Waste carried in from homes and commercial businesses in the city plus some industrial waste
- Storm
  - Storm runoff from streets, land and building roofs
  - Normally discharged to a watercourse without treatment
- Combined
  - Combination of sanitary and storm
  - Sanitary portions may become overloaded during storms

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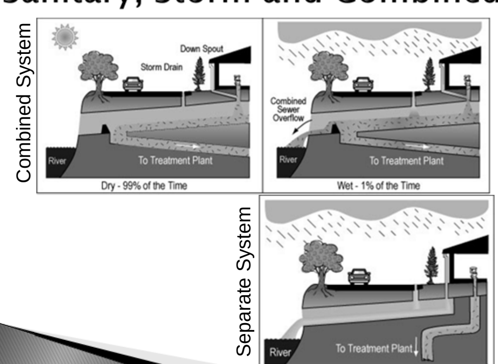
Sanitary, Storm and Combined



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Wastewater Treatment Processes

Preliminary Treatment → **Primary Treatment** → **Secondary Treatment** → **Tertiary Treat. (Advanced)** → **Disinfection**; **Solids Treatment**

- Preliminary Treatment:
  - Screening
  - Grit Removal
  - Preaeration
  - Flow Metering and Sampling
- Primary Treatment:
  - Sedimentation and Flotation
- Secondary Treatment:
  - Biological Treatment
  - Sedimentation
- Tertiary Treat. (Advanced):
  - Chemical Phosphorous Removal
  - Biological Nutrient Removal
  - Multimedia Filtration
- Disinfection:
  - Ultraviolet Irradiation
  - Chlorine Gas
  - Sodium Hypochlorite
  - Calcium Hypochlorite
- Solids Treatment:
  - Digestion
  - Dewatering
  - Disposal

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Wastewater Treatment Processes

Preliminary Treatment → **Primary Treatment** → **Secondary Treatment** → **Tertiary Treat. (Advanced)** → **Disinfection**; **Solids Treatment**

- Screening
- Grit Removal
- Preaeration
- Flow Metering and Sampling

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Aerated grit chamber
- 1 ft/sec flow through grit chamber
- Used to remove grit – heavy, mainly inorganic solids (sand, egg shells, gravel, seeds, etc.)
- Aeration also freshens wastewater and helps remove floatables

Mechanical bar screen with debris
- Failure to keep a bar screen clean can result in a shockload
- Removes roots, rags, cans, etc

Muffin Monster (grinder)

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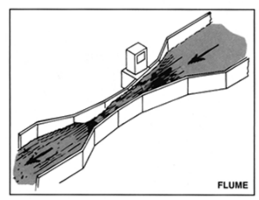
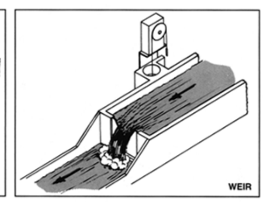
Flow Metering





- According to TN regulations concerning NPDES permits, flow measuring devices must be calibrated and maintained to ensure a ± 10% of true flow
- Flow is determined by the depth of the water

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Wastewater Treatment Processes

Preliminary Treatment → **Primary Treatment** → **Secondary Treatment** → **Tertiary Treat. (Advanced)** → **Disinfection**; **Solids Treatment**

- Sedimentation and Flotation

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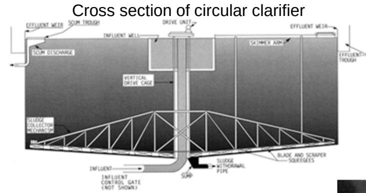
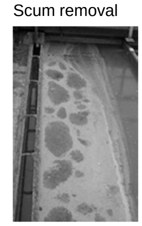
Primary Clarifier

Cross section of circular clarifier



Scum removal



- Velocity drops to < 1 fps
- Separates settleable and floatable solids
- Detention time ~ 1.5-2.0 hrs
- Raw water is gray

Rectangular clarifier

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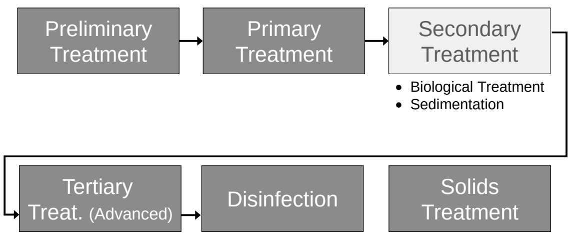
Wastewater Treatment Processes



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Biological Wastewater (WW) Treatment

- To remove the suspended solids & the dissolved organic load from the WW by using microbial populations.
- The microorganisms are responsible for:
  - Degradation of the organic matter
  - They can be classified into
    - Aerobic (require oxygen for their metabolism)
    - Anaerobic (grow in absence of oxygen)
    - Facultative (proliferate either with or without oxygen)

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Biological Wastewater (WW) Treatment

- If the microorganisms are **SUSPENDED** in the WW during biological operation
  - Example: lagoons or mechanical wastewater plants
    - Recycling of settled biomass is required for a mechanical type plant
- While the microorganisms that are **ATTACHED** to a surface over which they grow
  - Example: sand bed filter, some wetlands, trickling filter or RBC (rotating biological contactor)
  - Biomass attached to media (rock, plastic, etc.)
  - Recycling of settled biomass is not required.

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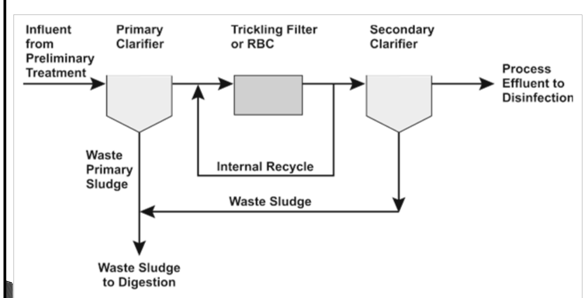
Attached Growth Biological Treatment Processes



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Trickling Filter

Secondary clarifier

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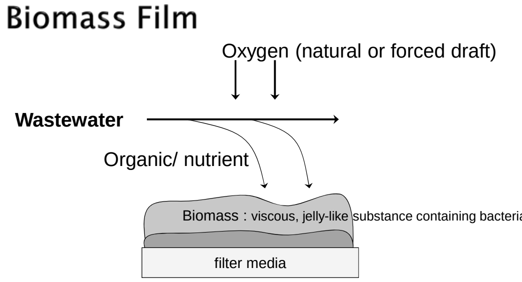
Cross-section of Attached Growth Biomass Film



Biomass = “zoogleal mass” or “Biofilm”
Filter media = rock, slag, coal, bricks, redwood blocks or molded plastic

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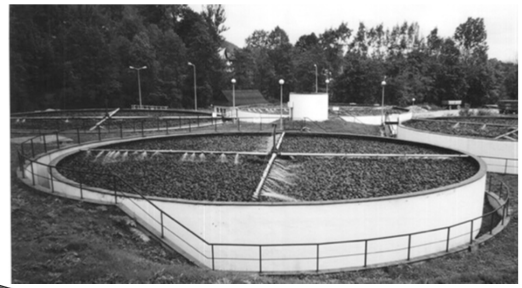
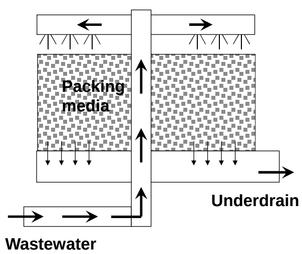
Attached Growth Systems: Advantages

- Simplicity
- Lower maintenance
- Lower power/electrical costs
- Less production excess biological solids
- Resistance to shock loads

Trickling Filter (TF)



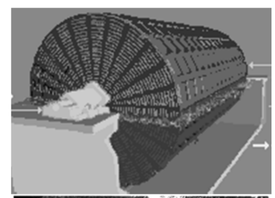
Trickling Filter (TF)– Side View



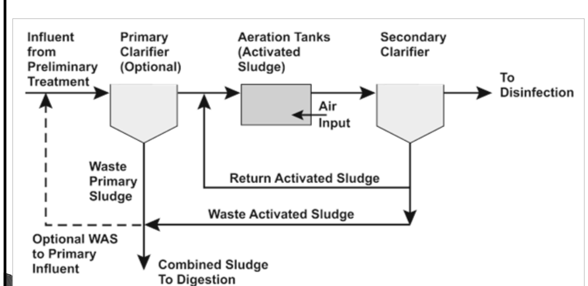
- TF consists of:
  - A rotating arm that sprays wastewater over a filter medium.
    - Filter medium: rocks, plastic, or other material.
  - The water is collected at the bottom of the filter for further treatment
  - Not really a filter, it does not work like sand or filter paper

RBC Features

- Treats domestic and biodegradable industrial wastes
- Rotating steel shaft with HDPE disc media (drum)
- Air or mechanically driven
- Drum rotates through WW for food then through air for oxygen



Suspended Growth Process Schematic



Fine Bubble Diffusers

Mechanical Aeration

Oxidation Ditch

SBR – Sequencing Batch Reactor

Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

Tertiary Treat. (Advanced):
- Chemical Phosphorous Removal
- Biological Nutrient Removal
- Multimedia Filtration

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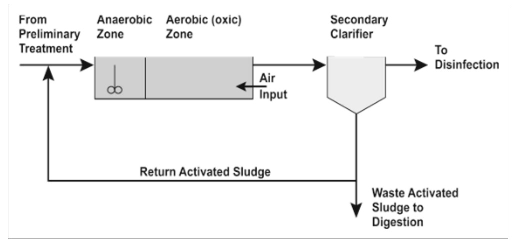
Biological Phosphorus Removal Process Schematic



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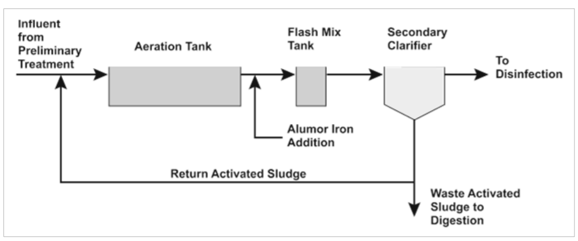
Chemical Precipitation Process Schematic



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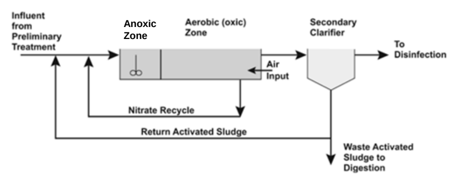
Denitrification Process Schematic



Anoxic or anaerobic zone added to aerobic activated sludge to denitrify to achieve low total N.

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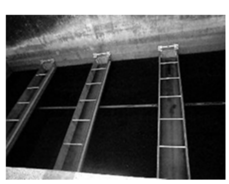
Sand Filtration



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Wastewater Treatment Processes

Preliminary Treatment → Primary Treatment → Secondary Treatment → Tertiary Treat. (Advanced) → Disinfection

Solids Treatment

Disinfection:
- Ultraviolet Irradiation
- Chlorine Gas
- Sodium Hypochlorite
- Calcium Hypochlorite

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Disinfection

- Purpose is to kill pathogenic organisms still in wastewater.
- Typically wastewater must contain 200 cfu/100mL for Fecal coliforms or 126 cfu/100mL for *E. coli* to be considered "disinfected"

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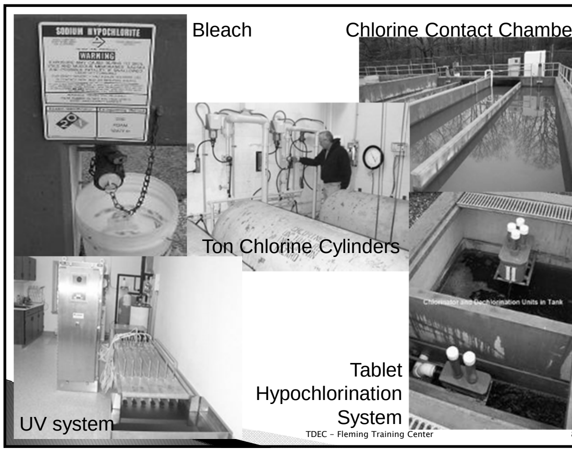

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Solids Treatment

Primary Treatment → Solids Treatment ← Secondary Treatment

Solids Treatment

- Digestion
- Dewatering
- Disposal

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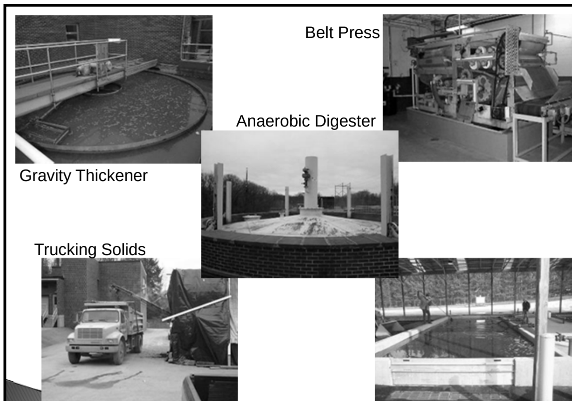

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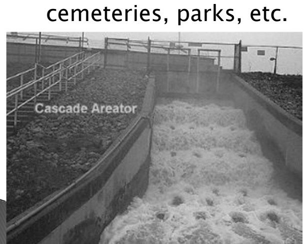
Effluent Discharge

- Most wastewater is discharged to a receiving stream, river, lake or ocean.
- Some is reclaimed or reused on golf courses, cemeteries, parks, etc.



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Wastewater Treatment Overview Vocabulary

______1. Aerobic Bacteria
______2. Anaerobic Bacteria
______3. Biochemical Oxygen Demand (BOD)
______4. Biochemical Oxygen Demand (BOD) Test
______5. Combined Sewer
______6. Detention Time
______7. Disinfection
______8. Effluent
______9. Grit
______10. Headworks
______11. Infiltration
______12. Inflow
______13. Inorganic Waste
______14. Organic Waste
______15. Pathogenic Organisms
______16. pH
______17. Primary Treatment
______18. Receiving Water
______19. Sanitary Sewer
______20. Secondary Treatment
______21. Septic
______22. Sludge
______23. Stabilize
______24. Storm Sewer
______25. Supernatant
______26. Weir
______27. Wet Well

A. A stream, river, lake, ocean or other surface or groundwaters into which treated or untreated wastewater is discharged.
B. The process designed to kill most microorganisms in wastewater, including essentially all pathogenic (disease-causing) bacteria.
C. The facilities where wastewater enters a wastewater treatment plant. This may consist of bar screen, comminutors, and a wet well and pumps.
D. An expression of the intensity of the basic or acidic condition of a liquid. The range is from 0 to 14 where 0 is most acidic, 14 most basic and 7 neutral. Natural waters usually range between 6.5 and 8.5.
E. To convert to a form that resist change. Bacteria that convert the material to gases and other relatively inert substances stabilize organic material. Stabilized organic material generally will not give off obnoxious odors.
F. The seepage of groundwater into a sewer system, including service connections. Seepage frequently occurs through defective or cracked pipes, pipe joints, connections or manhole walls.
G. Bacteria that will live and reproduce only in an environment containing oxygen that is available for their respiration, namely atmospheric oxygen or oxygen dissolved in water.
H. Water discharged into a sewer system and service connections from sources other than regular connections.
I. A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow the solids to settle out from the water being treated.

J. A pipe or conduit (sewer) intended to carry wastewater or waterborne wastes from homes, businesses and industries to the POTW (Publicly Owned Treatment Works).

K. The heavy material present in wastewater, such as sand, coffee grounds, gravel, cinders and eggshells.

L. The rate at which organisms use the oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. These measurements are used as a measurement of the organic strength of wastes in water.

M. A sewer designed to carry both sanitary wastewaters and storm- or surface-water runoff.

N. The settleable solids separated from liquids during processing.

O. Chemical substances of mineral origin.

P. A separate pipe, conduit or open channel (sewer) that carries runoff from storms, surface drainage and street wash, but does not include domestic and industrial wastes.

Q. Bacteria that live and reproduce in an environment containing no "free" or dissolved oxygen. These bacteria obtain their oxygen supply by breaking down chemical compounds that contain oxygen, such as sulfate (SO_4^{2-}).

R. Liquid removed from settled sludge.

S. Bacteria, viruses or protozoa that can cause disease (typhoid, cholera, dysentery) in a host.

T. (1) A wall or plate placed in an open channel and used to measure the flow. The depth of the flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. (2) A wall or obstruction used to control flow (from settling tanks and clarifiers) to assure a uniform flow rate and avoid short-circuiting.

U. A condition produced by anaerobic bacteria. If sever, the wastewater produces hydrogen sulfide, turns black, gives off foul odors, contains little or no dissolved oxygen and creates a high oxygen demand.

V. The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

W. Waste material that comes mainly from animal or plant sources. Bacteria and other small organisms generally can consume these.

X. A compartment or tank in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be located in the wet well.

Y. A procedure that measures the rate of oxygen use under controlled conditions of time and temperature. Standard test conditions include dark incubation at 20° C for a specified time (usually five days).

Z. Wastewater or other liquid – raw (untreated), partially or completely treated – flowing from a reservoir, basin, treatment process or treatment plant.

AA. A wastewater treatment process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.

Answers to Vocabulary

1. G
2. Q
3. L
4. Y
5. M
6. V
7. B
8. Z
9. K
10. C
11. F
12. H
13. O
14. W
15. S
16. D
17. AA
18. A
19. J
20. I
21. U
22. N
23. E
24. P
25. R
26. T
27. X

Section 2
Microbiology

Introduction to Microbiology

Biological Natural Systems

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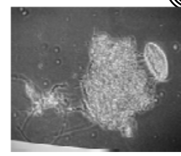
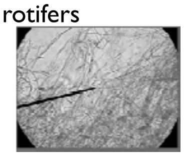
What are Microbes?

- Bacteria
- Protozoa
- Viruses
- Algae
- Metazoa- worms, rotifers
- Fungi



Crawling ciliate on activated sludge floc



Cyanobacteria

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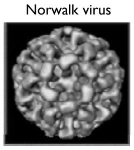
Why are they important?

Norwalk virus



Poliomyelitis

- Can cause disease
  - Most immediate importance
- Role in environment
  - Major decomposers in nature
  - Essential in a balanced ecosystem

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Why are they important?

- Role in treatment systems
  - Removed in water treatment
  - Key role in wastewater treatment
  - Major role in problems & solutions to solid waste

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What key role do they play?

- In lagoons:
  - Bacteria
    - Tiny one-celled organisms
    - Work horse for treatment
  - Algae
    - Use the carbon dioxide the bacteria produce to make oxygen with the help of sunlight
  - Vascular Plants
    - Duckweed

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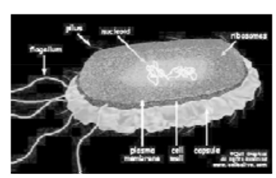
Viruses and Bacteria

- Viruses
  - Genetic material + protein coat
  - Reproduce only by infecting cells of other organisms
  - Pathogenic
- Bacteria
  - Most important



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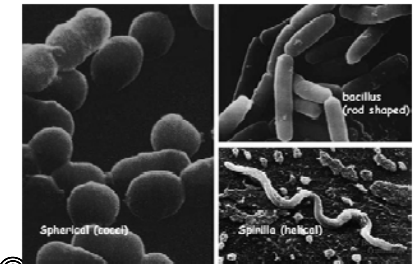
Bacteria Found in Wastewater



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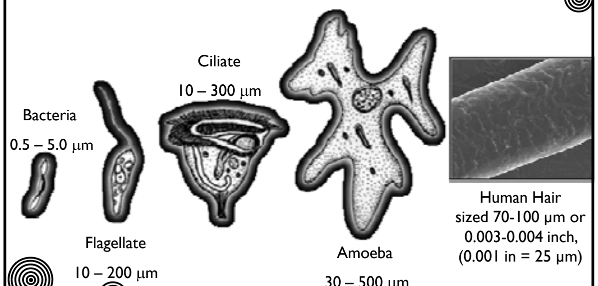
Size Range of Microorganisms



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Bacteria

- Binary fission is the process by which one mature cell divides into two new cells.
- Bacteria Reproducing

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Two Types of Bacteria

- Heterotrophic and autotrophic bacteria differ in the source of nutrition they require.
- Heterotrophic:
  - CBOD removers
  - Denitrifiers
- Autotrophic
  - Nitrifiers
  - Algae
  - Higher plants

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Heterotrophic

- Need organic carbon as their food source.
  - Humans
  - Protozoa
  - Most wastewater bacteria
- All animals are Heterotrophs, as are most microorganisms (the major exceptions being microscopic algae and blue-green bacteria).

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Heterotrophic

- Oxygen requirements:
  - Aerobes require free DO to function
  - Anoxic use nitrate (NO_3^-) and nitrite (NO_2^-), no free DO
  - Anaerobes thrive in the absence of free DO, use sulfate (SO_4^-) or carbon dioxide (CO_2)
  - Facultative bacteria prefer free DO but can function in its absence

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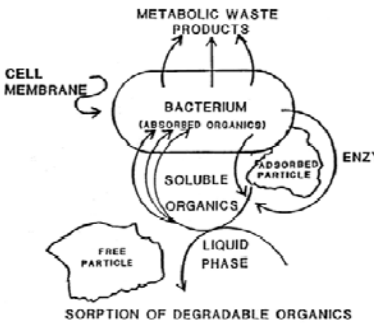
Bacteria "Eating"



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Food

- Two types of "food"
  - Dissolved
    - Example: sugar in oatmeal
  - "Chunky"
    - Example: oats in oatmeal
- Our body uses both "foods"
- We eat and our stomach and gut breaks the "chunky food" down into smaller dissolved food that our cells in our bodies can use.
- If you had to stay in the hospital and could not eat, they would "feed" you dissolved food in the form of sucrose, a sugar water.

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Aerobic Degradation

- Organics + O_2 + nutrients + bugs →

BOD or "food" | Oxygen | Nitrogen, Phosphorus & Iron

CO_2 + H_20 + new bugs + stable matter

Carbon Dioxide | Water | Will not have an oxygen demand on receiving stream

15 TDEC - Fleming Training Center 15

Autotrophic

- Use carbon dioxide (inorganic) as a carbon source
  - Autotrophic organisms take inorganic substances into their bodies and transform them into organic nourishment.
  - Autotrophic bacteria make their own food, either by photosynthesis (which uses sunlight, carbon dioxide and water to make food) or by chemosynthesis (which uses carbon dioxide, water and chemicals like ammonia to make food - these bacteria are called nitrogen fixers and include the bacteria found living in legume roots and in ocean vents).

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Algae

- Algae
  - Photosynthetic - Use energy from sun, carbon dioxide and nutrients to make more cells, water and oxygen
  - Eutrophication can cause algal blooms in receiving streams
    - Defined as overfertilization of lakes with nutrients and the changes that occur as a result
  - Key in operation of wastewater ponds: produce oxygen needed by bacteria
  - Types:
    - Green
    - Blue-green
    - Diatoms
    - Euglenoids

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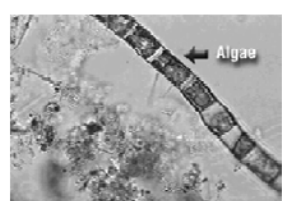
Green Algae

- These are the most desirable algae
- Bloom in Spring when predator numbers are low and water temperature is greater than 60°F



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Blue – Green Algae

- Also called Cyanobacteria
- Undesirable mats on lagoon surface
- Some produce odors and toxic byproducts
- Favored in poor growth conditions
  - Low light
  - High temperatures
  - Low nutrient conditions

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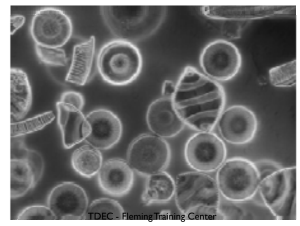
Diatoms

- Brown
- Predominate in winter when temperatures are less than 60°F



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Protozoa

- Single-celled animals that also reproduce by binary fission
- Have complex digestive systems that ingest organic matter which they use as an energy and carbon source
- Graze on bacteria that won't settle to the bottom of the lagoon
- Form cysts
- Beneficial in wastewater treatment

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Protozoa

- Examples:
  - Amoeba
  - Ciliates
  - Flagellate

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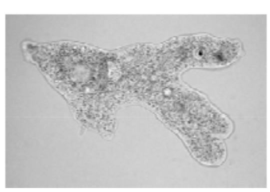
Amoeba

- Eats by bumping into food and engulfing particles
- Competes with bacteria



Amoeba eating

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Ciliate

- Free swimmers:
  - Usually move around using hair-like cilia to find food
  - Large numbers found in lagoons
  - Graze on amoebas, flagellates and smaller free swimmers

Paramecium eating

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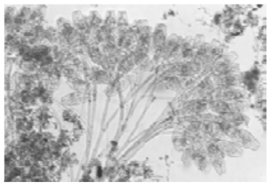
Ciliate

- Stalked ciliates:
  - Bring food to them by moving water with cilia on the "heads"



Stalked Ciliates

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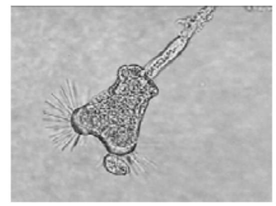
Ciliate

- Suctorian
  - Cilia have developed into hollow tentacles
  - Capture prey by sticking tentacle in it and then they suck out the cell content



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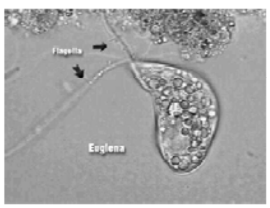
Flagellate

- They propel themselves around using a whip-like tail called a flagella
- Compete with amoeba and bacteria for food



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Metazoa

- Multi-cellular animals
- Slow growing
- Usually larger than protozoa and much larger than bacteria
- Examples:
  - Rotifer
  - Water Bear
  - Nematodes
  - Water Mite
  - Ostracods

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Rotifer

- Feed on bacteria and small protozoa
- Lagoons – consume large amount of algae
  - Continuous cropping
  - Keeps algae population in good condition
- Grinds up food and absorbs nutrients

Rotifer

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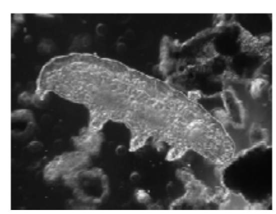
Water Bear

- Not common in lagoons
- Feeds on body fluids of protozoans, rotifers and nematodes
- Sensitive to ammonia



Water Bear

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Worms

- Multicellular organisms
- Diseases (tapeworms, roundworms)
- Beneficial in trickling filters (increase air penetration in biofilm and help in sloughing)
- Sensitive to ammonia

Ascaris and egg

Trickling filter

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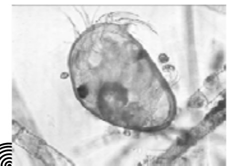
Other Metazoas

Ostracod

- Seedshrimp
  - Common in lagoons



Copepod

- Crustacean

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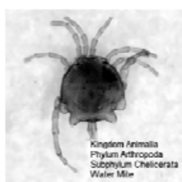
Other Metazoas

Cadoceran

- Water flea

Hydracarina

- Water mite



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Fungi

- Fungi
  - Soil organisms
  - Degrade dead organic matter (saprophytic)

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Section 3

Cross Connection Control

Cross Connection Control

Outline

2

- Basics of Cross Connection Control
- Hydraulics
- Definitions
- Backflow Preventers
- Applications

Basics of Cross Connection Control

3

United States Environmental Protection Agency Cross Connection Control Manual
www.epa.gov/ogwdw/pdfs/crossconnection/crossconnection.pdf

Tennessee Department of Environment & Conservation Cross Connection Control Manual & Design Criteria
www.tn.gov/environment/water/docs/fleming/crossconnection.pdf

Authority

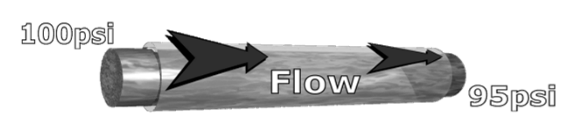
4

- Who has responsibility for the water served to the customer?
- Who has the responsibility to protect the water from Cross connections?
- What can happen if the water supplier does not act responsibly in the area of Cross connection control?
- Where does authority for the Cross connection control program come from?
- What can the water provider do to protect their system from contamination?

Hydraulics

5

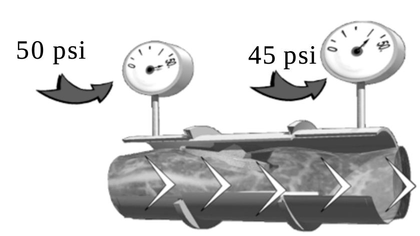
- Water pressure naturally tends to equalize



- Therefore, water flows from high pressure regions to low pressure regions

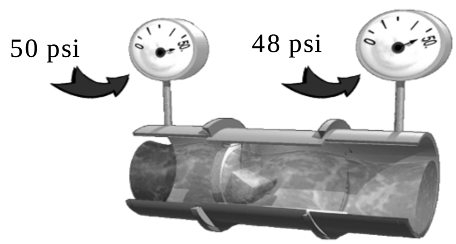
Normal Flow

6



No Flow

7



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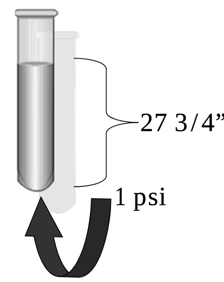
27 ¾” = 2.31 Feet of Head

8



- 27 3/4” of water generates a pressure of one pound per square inch (psi)

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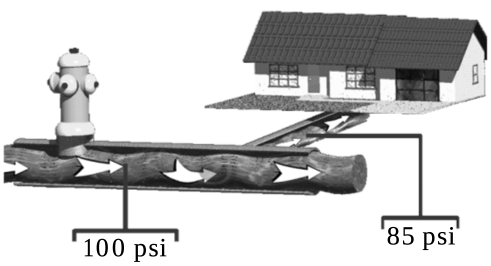
Normal Flow

9



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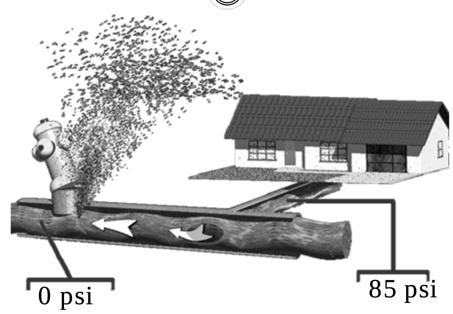
Reverse Flow

10



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Backflow

11

- 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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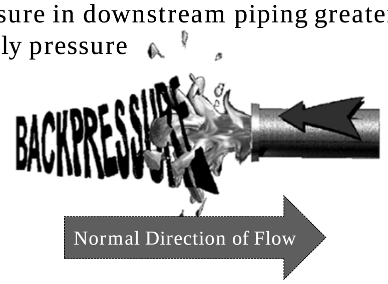
Backpressure

12

- Pressure in downstream piping greater than supply pressure



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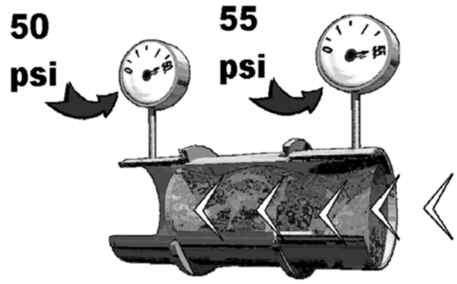
Backpressure

13



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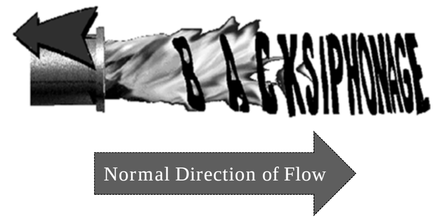
Backsiphonage

14

- Sub-atmospheric pressure in the water system



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Backsiphonage

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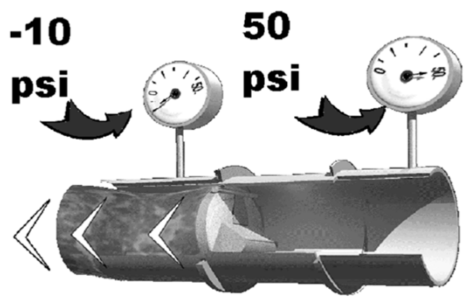

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Cross connection

16

- 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

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- A direct Cross connection is subject to backpressure or backsiphonage

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Indirect Cross connection

18

- An indirect Cross connection is subject to backsiphonage only

Submerged Inlet

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Aspirator Effect

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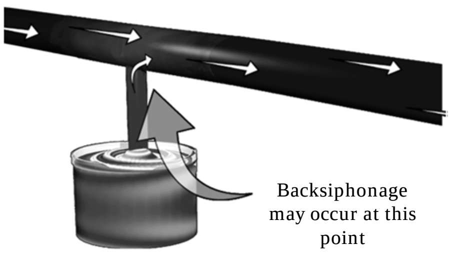


Degree of Hazard

20

- Non-Health Hazard
  - Low hazard
  - Will not cause illness or death
  - Pollutant
- Health Hazard
  - High hazard
  - Causes illness or death
  - Contaminant

The Backflow Incident

21

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.

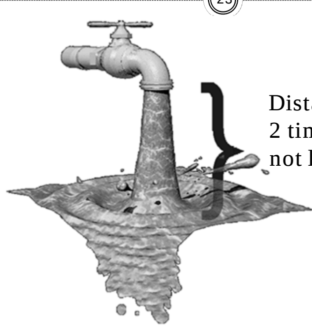
Five Means of Preventing Backflow

22

- Air Gap Separation
- Reduced Pressure Principle Assembly
- Double Check Valve Assembly
- Pressure Vacuum Breaker/ Spill-Resistant Vacuum Breaker
- Atmospheric Vacuum Breaker

Air Gap

23



Approved Air Gap Separation

24

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

25

	Indirect		Direct
	Backsiphonage Only		Backpressure and Backsiphonage
	Continuous Use	Non-Continuous Use	
Health Hazard	Air Gap	Air Gap	Air Gap
Non – Health Hazard	Air Gap	Air Gap	Air Gap

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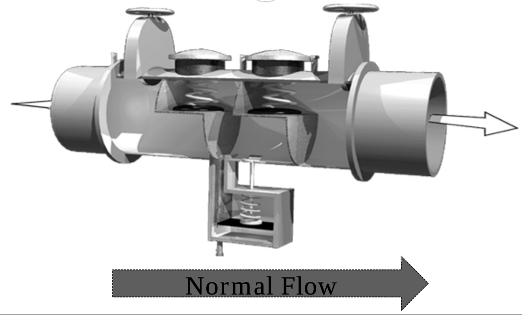
Reduced Pressure Principle Assembly

26



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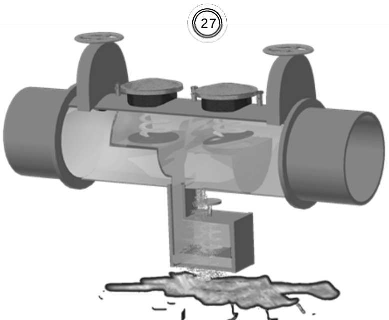
RP

27



Fouled Second Check with Backpressure

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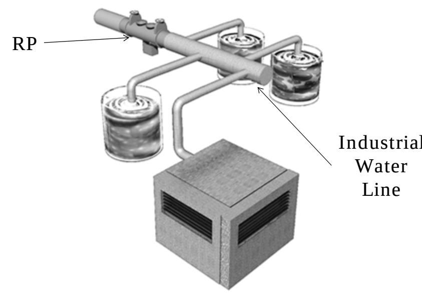
Where To Put an RP

28



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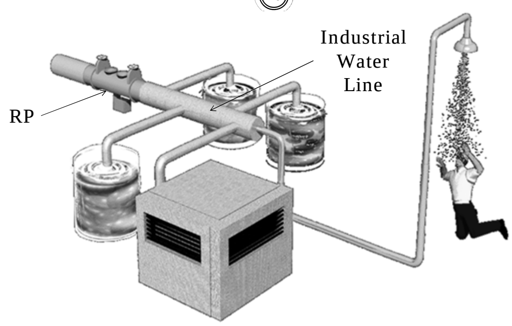
Where To Put an RP – Don't

29



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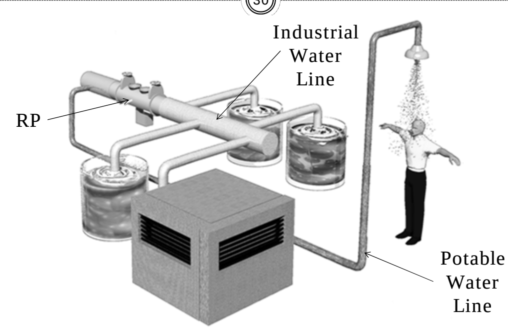
Where To Put an RP – Do

30



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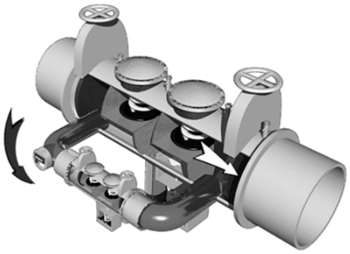
RP Detector Assembly

31

At least 3 GPM through bypass only



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RP

32

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

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33

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

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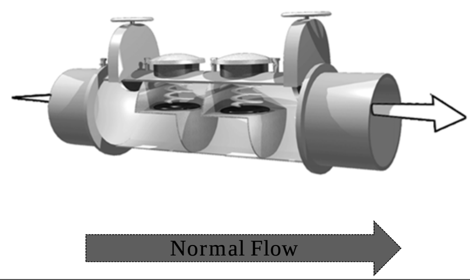
Double Check Valve Assembly (DC)

34



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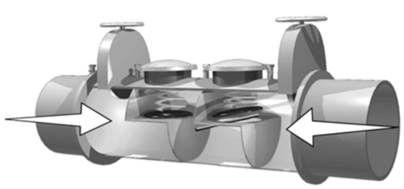
Double Check Valve Assembly (DC)

35

- Second check fouled during backpressure



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Double Check Valve Assembly (DC)

36

- Backsiphonage
- Backpressure
- Pollutant <u>only</u>

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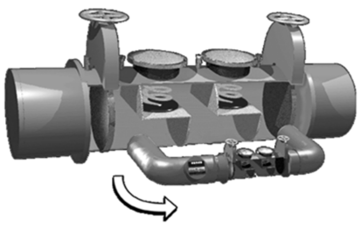
DC Detector Assembly

37



At least 3 GPM through bypass only

38

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

Proper Installation for DC and RP

39

- USC Recommendations:
  - Minimum 12” above grade
  - Maximum 36” above grade
  - Accessibility for testing and repair
  - Weather/vandalism protection (if needed) with adequate drainage

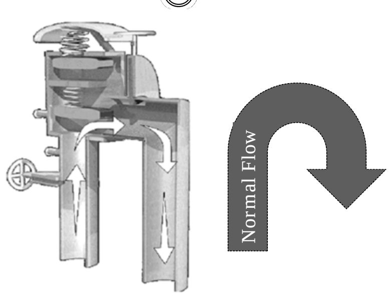
Proper Installation for DC and RP

40

- Backflow Preventers should only be installed vertically if they have been specifically approved for vertical orientation

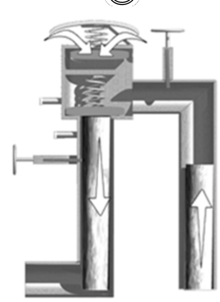
Pressure Vacuum Breaker (PVB)

41



PVB Backsiphonage Condition

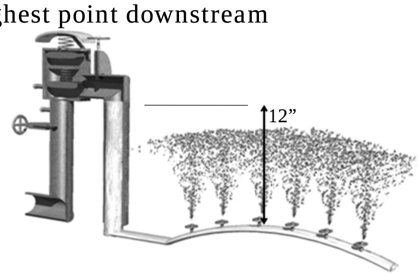
42



Installation of PVB

43

- Needs to be installed 12 inches above the highest point downstream



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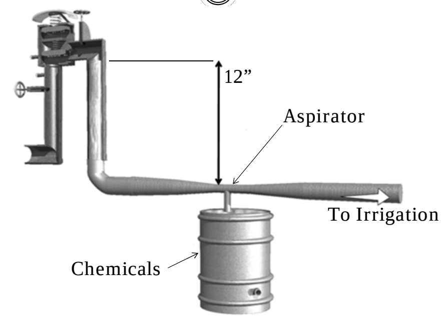
Pressure Vacuum Breaker

44



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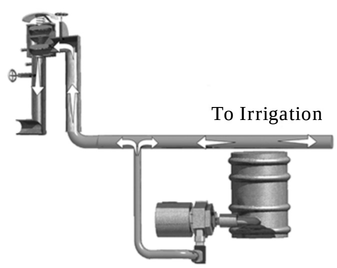
Pressure Vacuum Breaker

45

- Improper installation subject to backpressure



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Pressure Vacuum Breaker

46

- Backsiphonage Only
- Contaminant (health hazard)
- Pollutant (non-health hazard)
- Elevation - at least 12”

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47

	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	Air Gap	Air Gap	Air Gap
	RP	RP	RP
	DC	DC	DC
	PVB	**PVB**	

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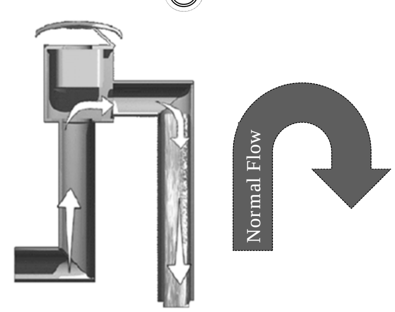
Atmospheric Vacuum Breaker (AVB)

48



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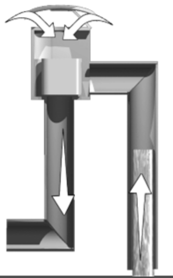
Atmospheric Vacuum Breaker (AVB)

49

- Backsiphonage condition



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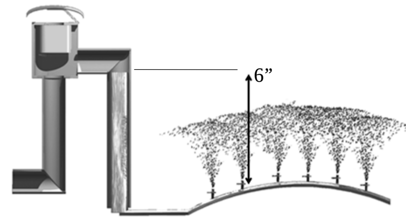
Installation of AVB

50

- Needs to be installed 6 inches above the highest point downstream



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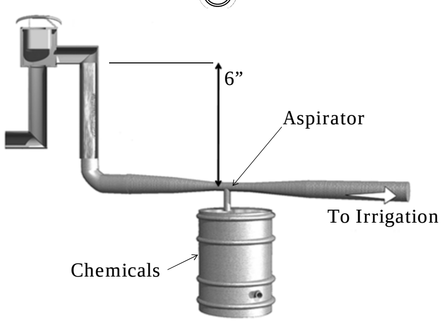
Atmospheric Vacuum Breaker

51



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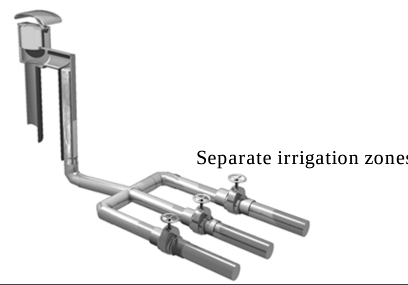
Atmospheric Vacuum Breaker

52

- Improper installation: downstream shutoff valves



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Atmospheric Vacuum Breaker

53

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

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54

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

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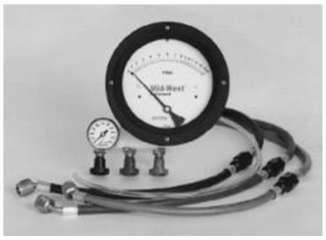
Testing of Assemblies

55

- Annual testing required
- Must be conducted by certified personnel



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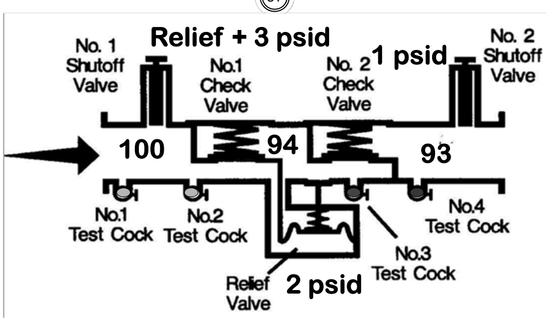
Method / Device Review

RP

57



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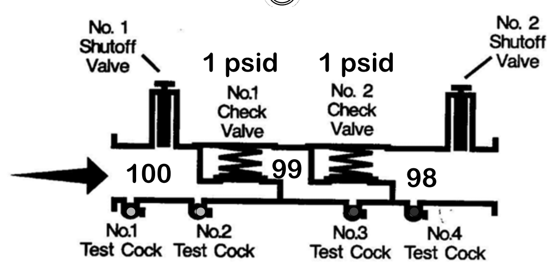
DC

58



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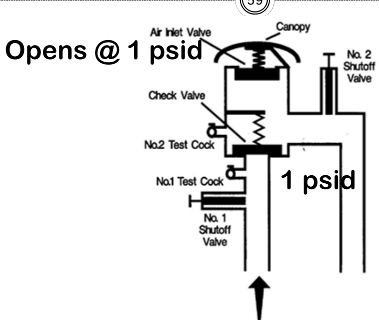
PVB

59



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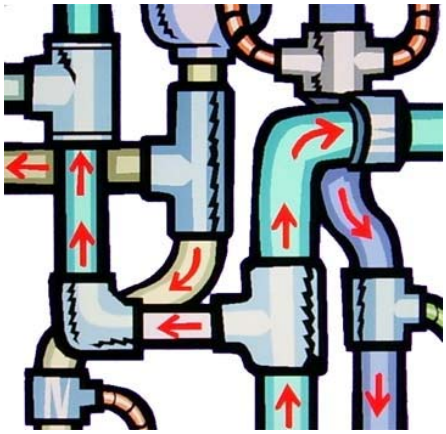

Vocabulary

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

Air Gap – 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 device, and the flood-level rim of the receptacle. This is the most effective method for preventing backflow.

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.

Backflow – The reversed 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 distribution system.

Back Pressure (Superior Pressure) – (1) A condition in which the pressure in a nonpotable system is greater than the pressure in the potable distribution system. Superior pressure will cause nonpotable liquids to flow into the distribution system through unprotected cross connections. (2) A condition in which a substance is forced into a water systems because that substance is under higher pressure than the system pressure.

Backsiphonage – (1) Reversed flow of liquid cause by a partial vacuum in the potable distribution system. (2) A condition in which backflow occurs because the pressure in the distribution system is less than atmospheric pressure.

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

<u>Chemical</u> – A substance obtained by a chemical process or used for producing a chemical reaction.

<u>Containment (Policy)</u> – To confine potential contamination within the facility where it arises by installing a backflow prevention device at the meter or curbstop.

<u>Contamination</u> – The introduction into water of any substance that degrades the quality of the water, making it unfit for its intended use.

<u>Continuous Pressure</u> – A condition in which upstream pressure is applied continuously (more than 12 hours) to a device or fixture. Continuous pressure can cause mechanical parts within a device to freeze.

<u>Cross Connection</u> – (1) Any arrangement of pipes, fittings or devices that connects a nonpotable system to a potable system. (2) Any physical arrangement whereby a public water system is connected, either directly or indirectly, with any other water supply system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture or other waste or liquid of unknown or unsafe quality.

<u>Cross Connection Control</u> – The use of devices, methods and procedures to prevent contamination of a potable water supply through cross connections.

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

<u>Direct Connection</u> – Any arrangement of pipes, fixtures or devices connecting a potable water supply directly to a nonpotable source; for example, a boiler feed line.

<u>Distribution System</u> – All pipes, fitting and fixtures used to convey liquid from one point to another.

<u>Double Check-Valve System Assembly</u> – A device consisting of two check valves, test cocks and shutoff valves designed to prevent backflow.

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

<u>Indirect Connection</u> – Any arrangement of pipes, fixtures or devices that indirectly connects a potable water supply to a nonpotable source; for example, submerged inlet to a tank.

Isolation (policy) – To confine a potential source of contamination to the nonpotable system being served; for example, to install a backflow prevention device on a laboratory faucet.

Liability – Obligated by law.

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.

Nontoxic – Not poisonous; a substance that will not cause illness or discomfort if consumed.

Physical Disconnection (Separation) – Removal of pipes, fittings or fixtures that connect a potable water supply to a nonpotable system or one of questionable quality.

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.

Pollution – Contamination, generally with man-made waste.

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 – A device consisting of one or two independently operating, spring-loaded check valves and an independently operating, spring-loaded air-inlet valve designed to prevent backsiphonage.

Reduced-Pressure-Principle or Reduced-Pressure-Zone Device (RP or RPZ) – A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the checks designed to protect against both backpressure and backsiphonage.

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 – An arrangement of pipes, fittings or devices that introduces water into a nonpotable system below the flood-level rim of a receptacle.

Superior Pressure – See backpressure.

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

Toxic – Poisonous; a substance capable of causing injury or death.

Vacuum (Partial Vacuum) – A condition induced by negative (sub atmospheric) pressure that causes backsiphonage to occur.

Venturi Principle – As the velocity of water increases, the pressure decreases. The Venturi principle can induce a vacuum in a distribution system.

Waterborne Disease – Any disease that is capable of being transmitted through water.

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

Some Cross-Connections and Potential Hazards

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

Cross Connection 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. Hose Bibb
______11. Overflow Rim
______12. Pressure Vacuum Breaker
______13. Reduced Pressure Zone Backflow Preventer
______14. RPBP

A. A valve designed to open in the direction of normal flow and close with the reversal of flow.
B. A hydraulic condition, caused by a difference in pressures, in which non-potable water or other fluids flow into a potable water system.
C. Reduced pressure backflow preventer.
D. 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.
E. A backflow condition in which the pressure in the distribution system is less than atmospheric pressure.
F. A faucet to which a hose may be attached.
G. A mechanical device consisting of two independently operating, spring-loaded check valves with a reduced pressure zone between the check valves.
H. Any water source or system, other than potable water supply, that may be available in the building or premises.
I. 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.
J. 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.
K. A backflow condition in which a pump, elevated tank, boiler or other means results in a pressure greater than the supply pressure.
L. Any arrangement of pipes, fittings, fixtures or devices that connects a nonpotable water system.
M. The top edge of an open receptacle over which water will flow.
N. A mechanical device consisting of a float check valve and an air-inlet port designed to prevent backsiphonage.

Cross-Connections Review Questions

1. Define a cross-connection.

2. Explain what is meant by backsiphonage and backpressure.

3. List four situations that can cause negative pressure in a potable water supply.
   -
   -
   -
   -

4. List six waterborne diseases that are known to have occurred as a result of cross-connections.
   -
   -
   -
   -
   -
   -

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?
    -
    -
    -
    -
    -
    -
    -

Vocabulary Answers:

1. D
2. N
3. H
4. B
5. K
6. E
7. A
8. L
9. I
10. F
11. M
12. J
13. G
14. C

Review Question Answers:

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 4

Septic Tanks

Septic Tanks

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What's Wrong with this Technology?

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Wastes and Water

- If water is not available
  - Then wastewater is not generated
  - The original low-flush toilet

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Wastewater Defined

- Wastewater is water that has been used to collect and transport waste
  - Water that has "stuff" in it
    - Suspended
    - Dissolved
    - Floating
    - Settleable

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What Color is it?

- Black Water
  - Toilets
  - Kitchen sink/dishwasher
- Grey Water
  - Shower/bath
  - Laundry
  - ***NOT septic tank effluent***
- Clear Water
  - Stormwater
  - Sump pump
  - Condensate
- Yellow Water
  - Well, you know

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Onsite Wastewater Treatment

- Usually consists of 2 major parts:
  - A septic tank
    - Provides primary treatment
  - A soil adsorption system
    - Usually a leach field
- Many communities, State parks and schools use individual septic tanks, but the clarified effluent is further treated by a sand filter, wetland or mound system

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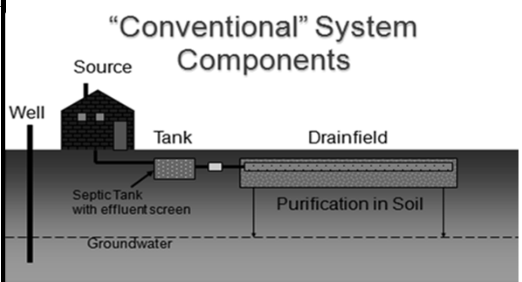
Subsurface Sewage Disposal Systems (SSDS) Components



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Crushed Rock Media

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Chambers

TDEC - Fleming Training Center 9

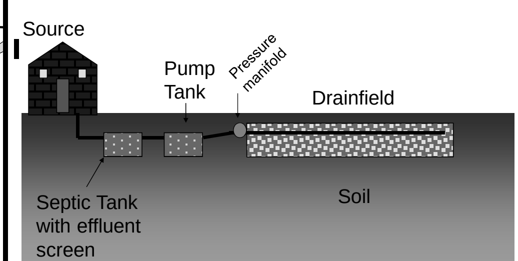
Large Diameter Gravelless Pipe

TDEC - Fleming Training Center 10

Expanded Polystyrene

TDEC - Fleming Training Center 11

Pump to Gravity



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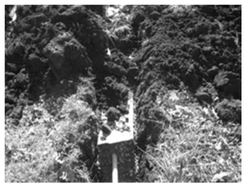
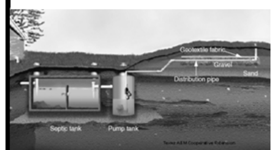
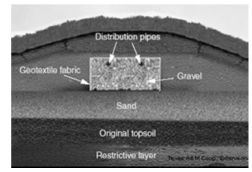
Low Pressure Pipe

Mound System

Provides soil-based treatment before water enters the subsurface – provides a solution for some sites with shallow soils





Finishing a Mound System


Lagoon

- Residential lagoons are permitted
  - Five acre homesite
  - Fencing
  - Not a common solution

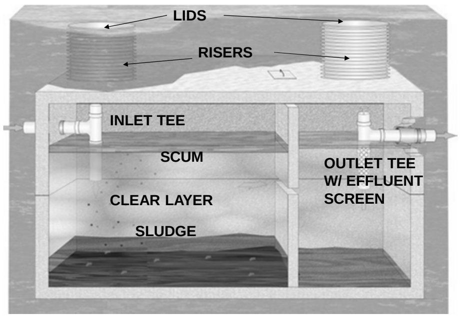
Septic Tanks

- Septic tank - essential for small scale wastewater management option
  - Single or multi-chambered watertight vault
  - Model of simplicity, energy-free gravitational settling device
  - Provides relatively quiescent conditions, allows suspended solids to settle and floatables to rise to surface
  - Provides space for very complex physical, chemical and biological processes
  - Accomplishes approximately 50% of ultimate treatment

Septic Tanks

- A typical septic tank may be a single-compartment tank or divided into two compartments
  - The first compartment commonly is as large as the second compartment and acts as the primary clarifier where the majority of grease, oils and retained and digested solids are removed
  - This first compartment also performs the function of the anaerobic digester where bacteria in the tank break down or reduce some of the heavy solids (sludge) that have accumulated on the bottom

Small System Primary Treatment



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Septic Tanks

- The first compartment is separated from the second by an interior baffle or wall
  - The baffle permits the wastewater from the clear water (supernatant) space between the sludge and scum layers to flow from the first compartment to the second compartment without carrying solids over from the first compartment
    - This second compartment acts like a secondary clarifier

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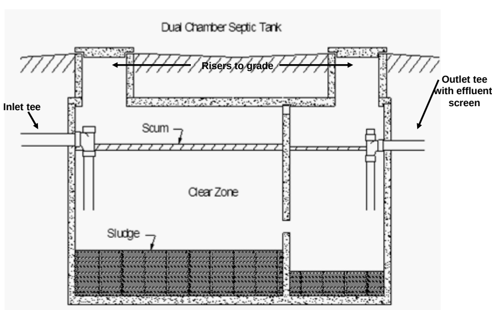
Typical Cross Section



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Liquid-Solid Separation

- Primary Treatment
  - Septic tanks
  - Hydraulic function
    - Should have two or three design-flow days of volume
    - Regulations provide specific volumes
    - Provides a damping effect on the inflow rate

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Materials Of Construction

- Reinforced concrete
  - Most common
- Fiber glass
- Polyethylene
- Steel (not used in TN)
  - Require a coating of other corrosion resistance treatment and cathodic protection in corrosive soils to prevent rusting and possible leakage.
- Must be structurally sound and watertight
  - Hydrostatic
  - Vacuum

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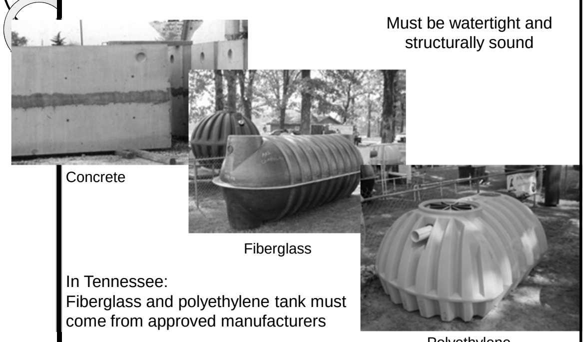
Tank Materials

Must be watertight and structurally sound



In Tennessee:
Fiberglass and polyethylene tank must come from approved manufacturers

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Concrete Tank Delivery


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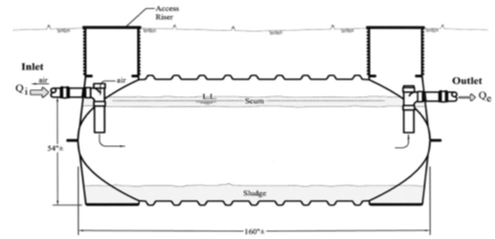
Typical Ribbed Fiberglass Septic Tanks



Section view of single compartment tank, 1,500 gallon.

- Equipped with at least one manhole at each end to provide access to the tank for maintenance.

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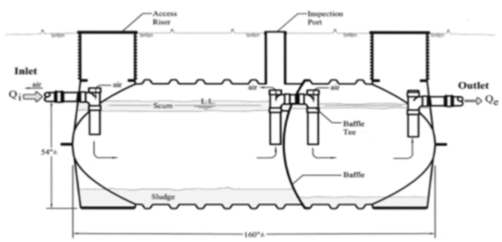
Typical Ribbed Fiberglass Septic Tanks (continued)



Two compartment tank with distinctly separate chambers.

- 1st compartment acts as a primary clarifier where the majority of grease, oils and retained solids are removed.

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Sizing

- Directly related to number of bedrooms in residence
- Common septic tank volumes
  - One or two bedrooms: 750 gal.
  - Three bedrooms: 900 gal.
  - Four bedrooms: 1,000 gal.
  - Add 250 gal. Of each additional bedroom
- Commercial size tanks
  - Based upon expected daily flow from commercial, institutional, and recreational facilities.
  - Min tanks size is 750 gal. for flows less than 500 gal.
  - Flows of 500-1500 gal. 1.5 x Q (daily flow in gal)
  - Flows over 1500gal V=1175 gal + .75Q

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Wastewater Sources

- Residential
  - single family homes
  - apartments
  - subdivisions
- Commercial
  - restaurants
  - fuel stations
  - bakeries
  - schools and day care
- These are the most common wastewater sources outside of sewage service areas
  - onsite (or near site) wastewater renovation is the most efficient and economical means of managing the source water

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Facility	Unit	Flow Range, gal/unit/day	Flow Typical gal/unit/day
Airport	Passenger	2-4	3
Apartment House	Person	40-80	50
Automobile Service Station	Vehicle Served	8-15	12
	Employee	9-15	13
Bar	Customer	1-5	3
	Employee	10-16	13
Boarding House	Person	25-60	40
Department Store	Toilet Room	400-600	500
	Employee	8-15	10
Hotel	Guest	40-60	50
	Employee	8-13	10
Industrial Building (sanitary waste only)	Employee	7-16	13

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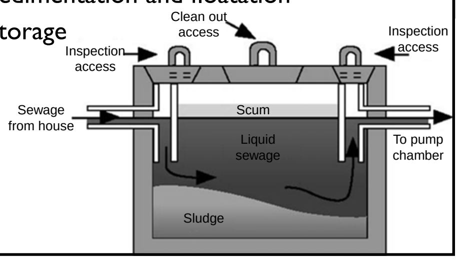
Processes Within Septic Tank

- Very complex physical, chemical and biological system
- Sedimentation and floatation
- Storage



Basic Assumptions

- 50% reduction in oxygen demand
  - Because organic solids remain in tank
  - Creates an accumulation in the tank
    - That is either very slow to degrade
    - Or will not degrade
- Tremendous reduction in suspended solids
- Minimal biotransformation
  - Anaerobic environment

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Sedimentation Theory

- Four types of sedimentation phenomena
  - Type 1: discrete particle
  - Type 2: flocculant
  - Type 3: hindered
  - Type 4: compression

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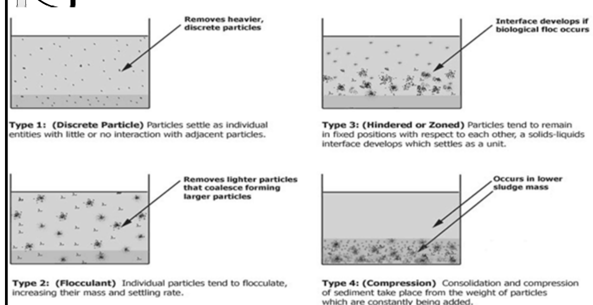
Types Of Settling Phenomena



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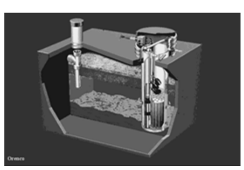
Compartmentation

- Conflicting findings whether it is beneficial (BOD and TSS)
- University of Washington found single chamber tank best
- University of Maine found two chamber tank best
- Need for further research



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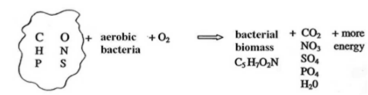
Biological Decomposition

- Two types of biological decomposition
  - Aerobic decomposition in presence of oxygen, rapid, releases great deal of energy.
    - Not likely in septic tank.



  - Anaerobic decomposition without the presence of oxygen

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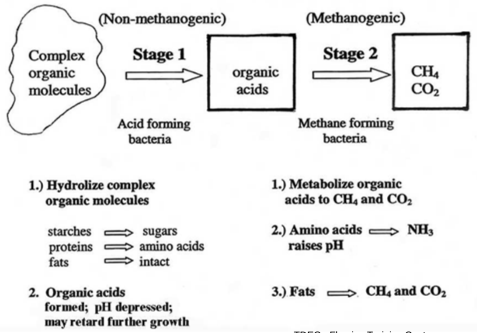
Two Stages In Anaerobic Decomposition



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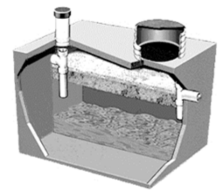
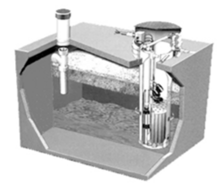
Single Compartments



Typical Gravity Septic Tank



Typical Dosing Septic Tank

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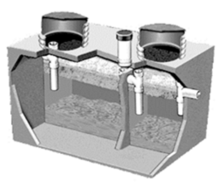
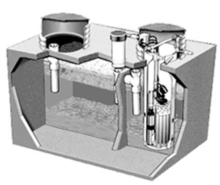
Two Compartments



Typical Gravity Septic Tank



Typical Dosing Septic Tank

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Reduction Of Organic Matter

- Generates H_2S gas, which is odorous
  - Gases vented through house vent, risers or soil absorption system
- Performance

Parameter	Average Raw Sewage Influent	Average Septic Tank Effluent	% Removal
BOD, mg/L	308	122	60
TSS, mg/L	316	72	77
Grease, mg/L	102	21	79

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Solids Accumulation

- Need to estimate the rate of septage (sludge + scum) accumulation
- Determines pump out intervals
- Empirical relationships show (sludge + scum) accumulation in gal/capita/year

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Checking Solids with Sludge Judge

- Here we have the sludge judge at right (used mainly in the municipal wastewater treatment plants) and the dip-stick at left.
- The dip-stick does not have a ball but a ball valve that takes a truer core of the septic tank and it is less prone to clogging.
  - It is important to get the measurement on the first try because the action of putting the instrument down disturbs the solids.

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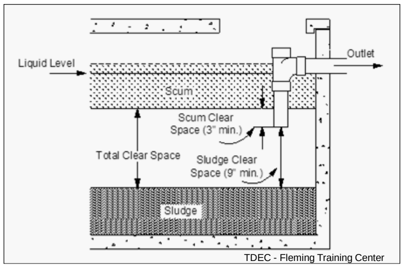
Need for Pumping

- **Pump when**
  - scum clear space is <3" or
  - sludge clear space is <9"



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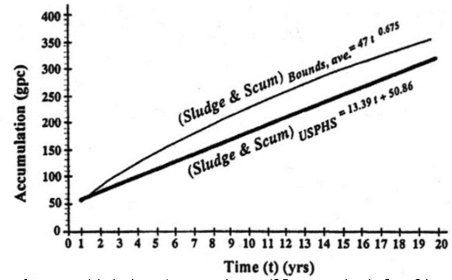
Rate of Septage Accumulation



Rates of septage (*sludge/scum*) accumulation *(95 percent level of confidence)* from bounds 1995

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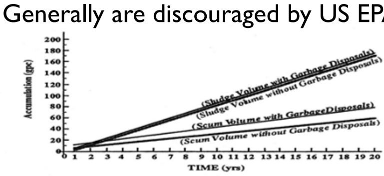
Garbage Disposals

- Makes little difference in sludge accumulation (2% increase)
- Increases scum 34%
- Generally are discouraged by US EPA



Accumulation rates for systems with garbage disposals and those without. From Bounds, 1995

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Circular Tanks

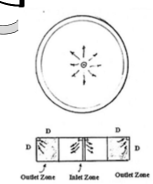

Figure a. Circular Tank Center Feed Elevation View

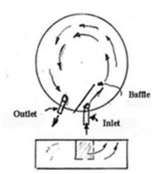

Figure b. Circular Tank Peripheral Feed Elevation view

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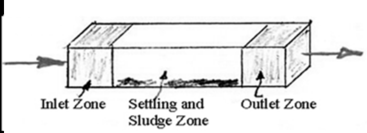
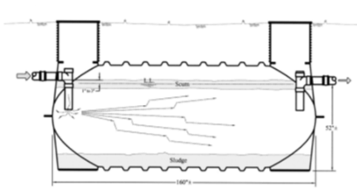
Four Zones Of Settling



Four zones of settling in large tanks



Zones of settling in a septic tank

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Inlets And Outlets

- Inlet – sanitary tee or baffle minimizes short circuiting and dissipates kinetic energy.
- Outlet – sanitary tee or baffle minimizes carryover of solids.
- Effluent filters and screens are final chance to trap solids.
- Gas deflection baffles deflect gases away from outlet

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Goal is Near Zero Velocity in Tank for Optimum Solids Removal

- The goal within a septic tank is to create conditions that will result in maximum solids removal.
  - This takes near zero flow velocity, long flow path through the tank, and a long residence time for the water within the tank.
- Desirable length:width ratios for tanks are in the 3:1 range, though many are less – 2:1 or 2.5:1
  - Maximize distance between inlet and outlet
- Shallow tanks (for a given volume) reduce the overflow rate so the residence time increases in the tank.
  - The shallow tank also reduces the settling distance so solids capture is soon so resuspension is less likely.
- The tank cross section shown here is desirable with an inspection and access port over inlet and outlet ends of the tank and a larger opening for tank cleaning in the center.
- Inlet to outlet drop ~ 2"

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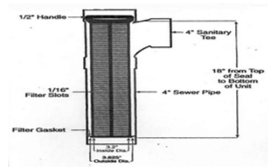
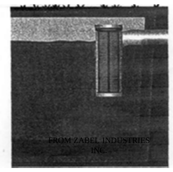
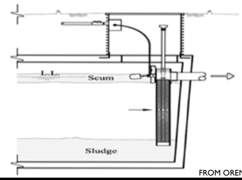
Outlet Filter Devices







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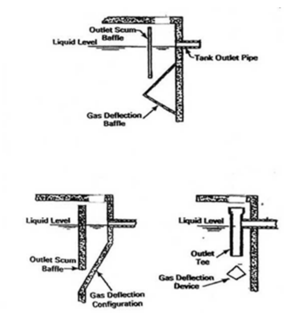
Outlet Filter Devices (Continued)



Gas deflection baffles

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Effluent Screens

Not required in Tennessee, but they are recommended.
Riser must be installed for maintenance.

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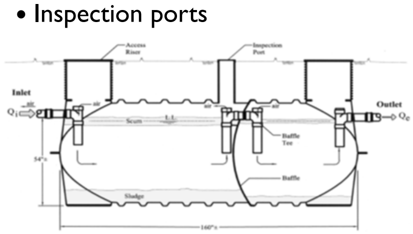
Access

- Risers, manholes for cleaning, maintenance and septage pumping
- Inspection ports



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Adding an After-Market Riser to a Septic tank

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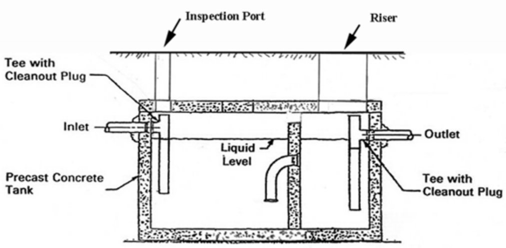
Floatation Collars

- Prevents tank from floating in high groundwater

Oil and Grease

- Organic compounds, oil, liquid and grease solids very troublesome in septic tanks
- Restaurants and other such facilities must have a grease interceptor

Double-Compartment Grease Trap



From US EPA Design Manual 1980

Trace Organics

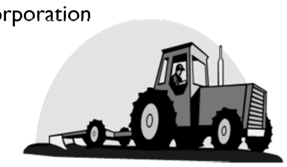
- May gain entrance from household activities
- Paint thinners, grease removers, rug shampoo liquids, etc.
- Chemicals in solution that are non-biodegradable
- Little or no removal in septic tank

Septage

- Highly variable odoriferous material in septic tank
- Solids content 3-10%

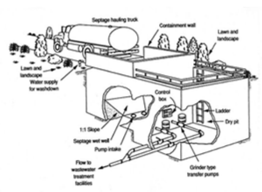
Septage Management

- Land application
  - Spread by hauler truck or farm equipment
  - Spray irrigation
  - Ridge and furrow
  - Subsurface incorporation



Septage Management

- Disposal at conventional wastewater treatment plant
  - Upstream manhole
  - Treatment headworks
  - Special sludge handling process
  - Septage handling and treatment plant



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Speaking of Additives

- Additives while sounding great are not recommended nor have they been shown to have any affect on the system.
- Just say No!
  - Some may be harmful
  - Research has shown little effect for sludge reduction
  - May not be cost effective

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Septic Tank Additives

- Advertised to remedy most known problems in septic tanks and drain fields
- Types of additives
  - Inorganic compounds
  - Organic solvents
  - Biological
- Over 1,000 additives on the market, yet no known authoritative testing has been done by manufacturers
- Not recommended

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Construction Considerations

- Location
- Bedding and backfill

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System Maintenance

- Know where all components of your system are located
  - Clean-out locations
  - Septic tank
  - Soil absorption area and reserve area
  - Cross overs

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Misconception

- Septic system maintenance is not required
  - Out of sight
  - Out of mind
  - Could be a very costly misconception
- Low Maintenance
  - But not "no maintenance"

Early plumbers

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Operation and Maintenance

- Inspected every 2-3 years
- Sludge and scum accumulations indicate need for pumping
- Non-decomposable (inorganic) material should be kept out of the tank

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When Should I Pump the Septic Tank?

- Varies according to use and size of tank
- Rough estimate: every 3 to 5 years
- How many teenagers are in the house?

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If You Have an Effluent Screen…

- It must be serviced
- Clogged effluent screen could back water up into house
- Must have access riser above screen for easy maintenance

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Effluent Screen Cleaning

- Wash off directly into the septic tank
- Should be done at the inlet end of the tank to prevent solids bypass
- Bypass protection on some models
- Rubber gloves should be used in this operation – and anytime one is handling sewage related objects.
- Use a backflow preventer and use YOUR hose instead of the homeowners.

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After Pumping…

- You must refill the tank with water to prevent the tank from floating
  - It is embarrassing
  - It is expensive to fix if it cracks

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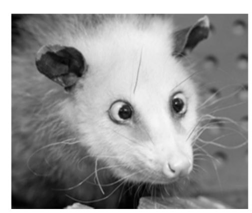
After Pumping….

- Do I need to add something to re-start the tank
  - No!!
  - Bacteria will naturally colonize the tank
  - No roadkill is needed to inoculate the tank



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Regulations

- State and local health departments promulgate and enforce laws
  - Early codes relied on soil percolation test
  - Regulations became standardized in spite of differing climate and soil conditions
  - Led to prescriptive designs
  - By late 1970s there was a gradual increase in sizes of septic tank and drain fields
  - Present emphasis, increased focus on system performance, pollutant transport fate and environmental impacts

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Regulations

- Regulations
  - Tennessee has a state-wide program
    - TDEC staff located in most counties
    - They approve the site before system is covered

    http://www.tn.gov/environment/water/septic-disposal.shtml
  - Several cities/counties have a local program
    - Local program must be equally or more stringent than State program

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Summary

- Septic tank complex physical, chemical and biological reactor
- Energy free, cost efficient
- Absolute necessity for small scale wastewater treatment system
- Generally can expect
  - 40-60% BOD removal
  - 40-80% SS removal
  - 96-98% settleable solids removal

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Always Pay the Backhoe Operator

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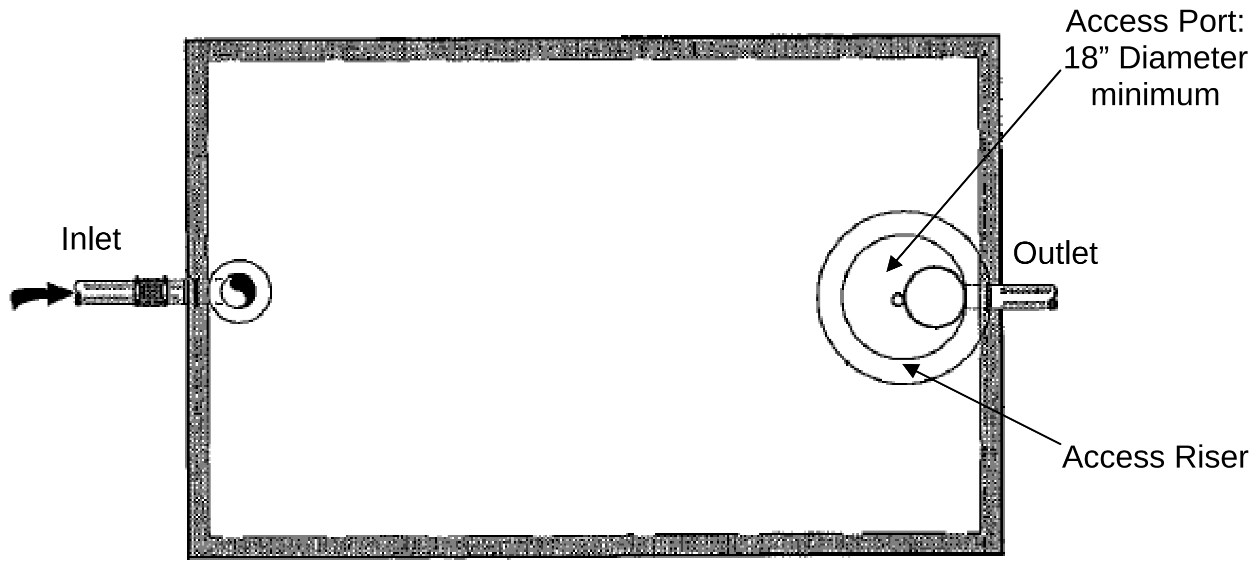
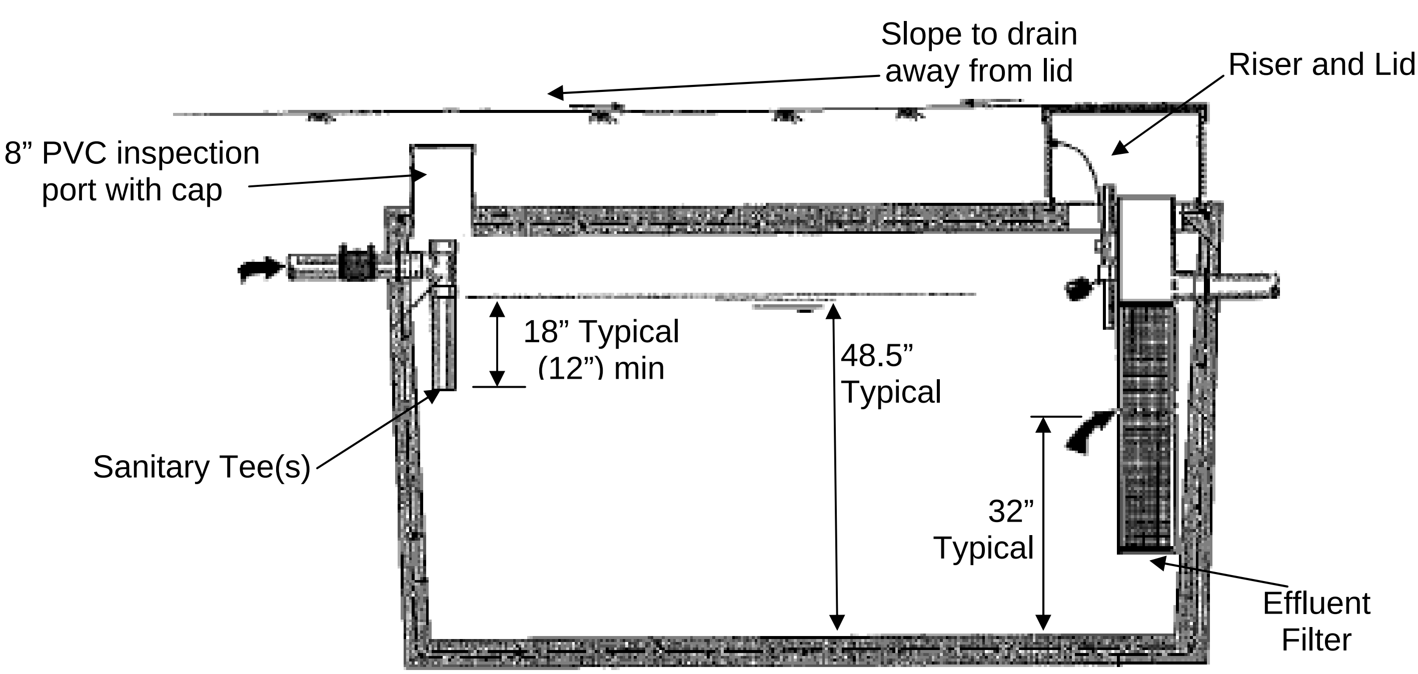
Single Compartment Septic Tank

Top View

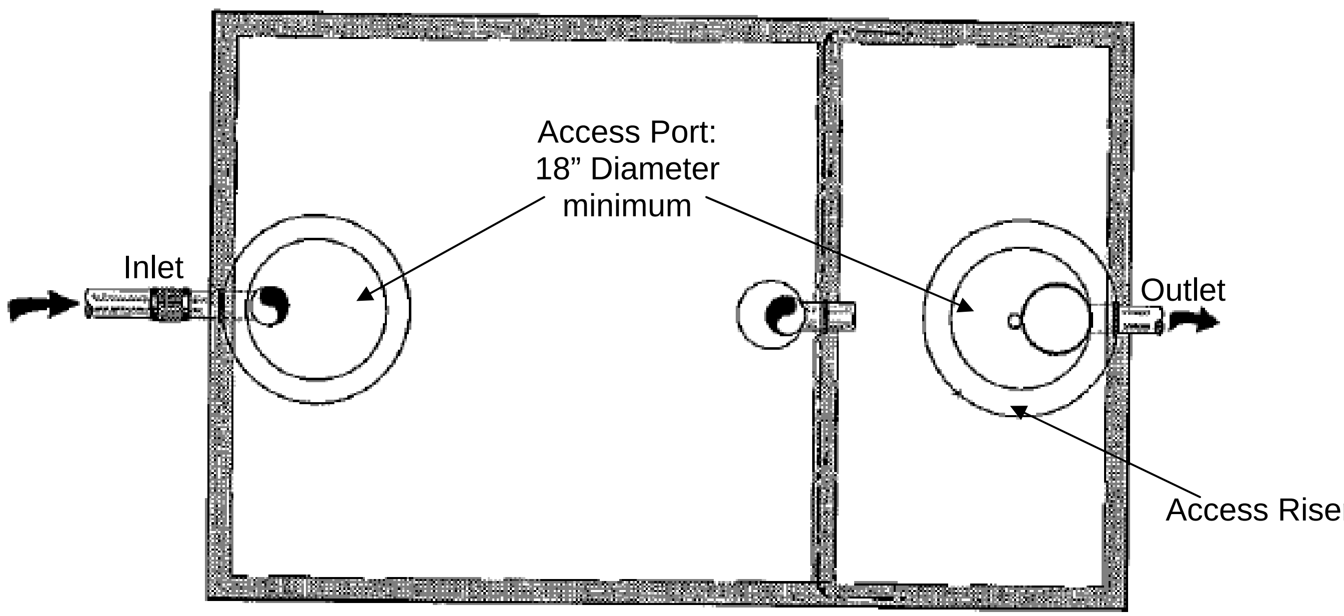


Side View

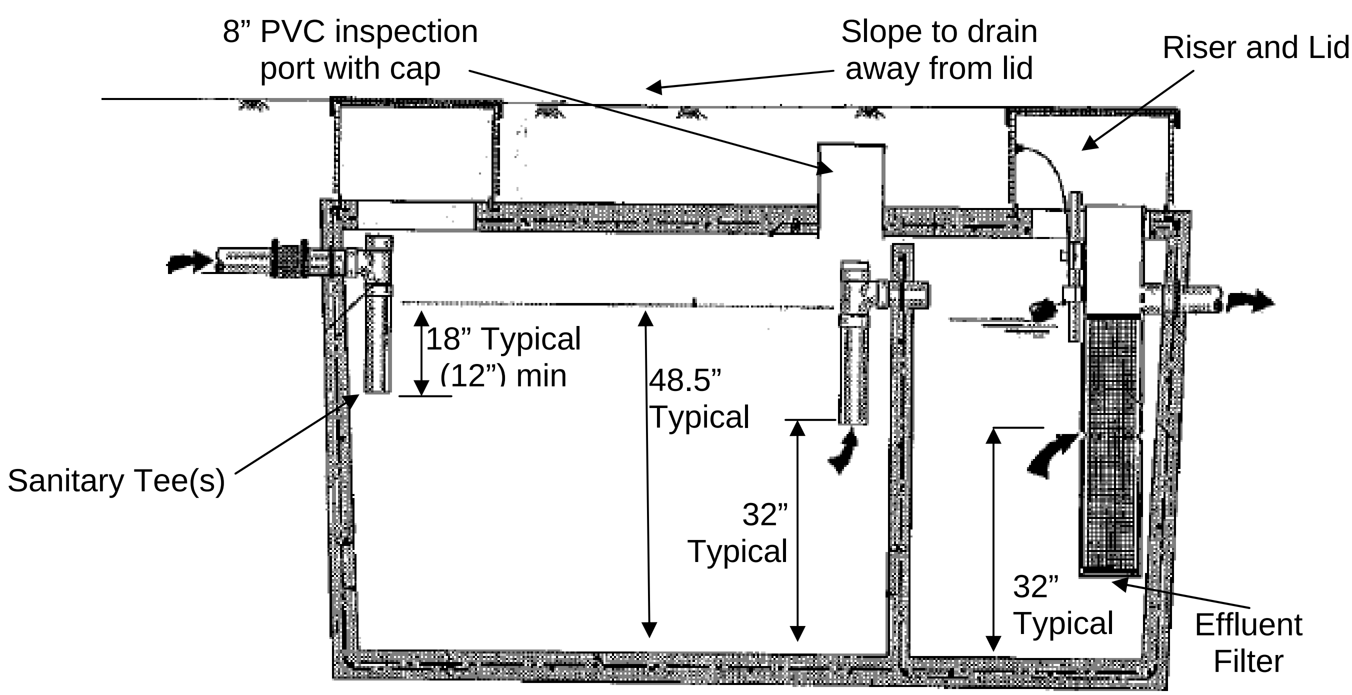


Two Compartment Septic Tank

Top View



Side View



Section 5

Wetlands

Wetlands

Treatment & Aquatic Plant Systems

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Constructed Treatment Wetlands & Aquatic Plant Systems

- Presentation Overview
- What are Constructed Wetlands?
- Mechanisms of treatment when using constructed wetlands
- Various applications for treating surface water using constructed wetlands
- Contaminants most commonly treated using constructed wetlands?

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Constructed Treatment Wetlands & Aquatic Plant Systems

- Important design consideration when considering using constructed wetlands
- Limitations
- Regulatory Issues?
- Aquatic plant systems

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What are Constructed Treatment Wetlands?

- Constructed treatment wetlands are manmade wetlands developed specifically to treat contaminants, typically in water that flows through them.
- They are constructed to imitate the structure and function of natural wetlands, which have been called "natural kidneys" because of their ability to remove contaminants from the water flowing through then.
- Wetlands are perhaps second only to tropical rain forests in biological productivity: plants grow densely, and their roots help support a rich microbial community in the sediment and soil.
- Download Guidance Document at: www.itrcweb.org click on "Guidance Documents"

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What are Constructed Treatment Wetlands?

- Man made
  - You may not use a natural wetland in TN
- Built specifically to remove contaminants in waters that flow through them
- Wide variety of removal processes
- Generally not designed to fully recreate the structure & function of natural wetlands

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Background

- Wetlands have been used to treat wastewater in US for several decades
  - Primarily municipal and stormwater
- Application of technology expanding to new areas
- Newer designs based on a more thorough understanding of science and underlying mechanisms

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Why Wetlands?

- Wetlands may offer a lower cost, lower maintenance alternative to standard chemical treatment
- Classic example of passive treatment
  - Passive treatment systems use natural processes to remove contaminants
  - Designed to be low maintenance
- A "perfect" passive system would operate indefinitely with no maintenance

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Key questions to ask

- Is a wetland appropriate for this situation?
- Is this the right design?
- Is the wetland big enough to handle changes over time?
- How long will it continue to provide treatment?
  - Will it be necessary to dispose of the substrate in the wetland?
- Will it produce consistent compliance?
- Are there any potential ecological impacts?

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Applications

- Stormwater Runoff
  - Organic matter, TSS, pathogens, N and P
- Municipal Waste Treatment
- Mine Drainage
  - Acid mine drainage for metals and acidity
- Industrial Waste Treatment
- Remedial Wastewater Treatment
- Effluent from Landfills
  - Landfill leachate for organic matter
- Agricultural
  - N and P removal of irrigation return waters
- On-site Wastewater

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What We Need to Know Before Constructing Treatment Wetlands

- Fundamental mechanisms of wetlands function
- Characteristics of the water being treated
  - Chemistry
  - Flow
- Site characteristics (Climate and Topography)
- Removal rates
- Regulatory Limits

- Constructed Treatment Wetlands are specifically engineered with water quality improvement as the primary goal.
- Wetland design hence necessitates an understanding of the fundamental mechanisms of pollutant removal.

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Mechanisms

- Chemical/Physical
  - Settling & sedimentation by gravity
  - Sorption of trace metals
  - Chemical Oxidation & Reduction-precipitation
  - Photo oxidation
  - Volatilization of liquids and solids that vaporize to atmosphere (ammonia, methane, hydrogen sulfide)
- Biological
  - Aerobic or anaerobic Biodegradation/ Biotransformation by bacteria
  - Phytoaccumulation
  - Phytostabilization
  - Rhizodegradation of hydrocarbons and pesticides
  - Phytodegradation
  - Phytovolatilization of mercury and selenium

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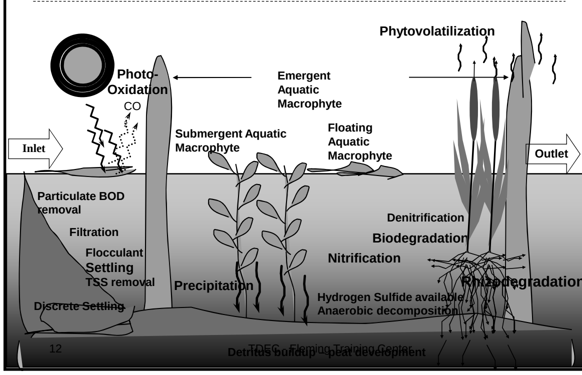
Discussed in the next 4 slides

Mechanisms



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Mechanisms

- Improvement in water quality is achieved through the interaction of the wastewater with the wetland's vegetation, microorganisms and soils. This slide is a schematic representation of processes that may occur in a constructed wetland.

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Mechanisms

- The primary Abiotic processes taking place in a wetland include:
  - Settling & sedimentation: This leads to removal of particulate and suspended matter by gravitational settling by acting upon the relative density differences between suspended particles and water.
  - Sorption: Wetland soils have a high trapping efficiency for a variety of chemical constituents by the combined processes of adsorption and absorption.
  - Precipitation: Involves the conversion of metals in the influent stream to its insoluble form and is a major and effective means for immobilizing these toxic metals
  - Photo oxidation is the break down/oxidation of compounds in the presence of sunlight.
  - Volatilization: is partitioning of the compounds into the gaseous state.

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Mechanisms

- In addition to these abiotic mechanisms, biotic mechanisms play an important role in treatment of impacted wastewater as it flows through the wetland system.
  - Plants are either responsible for direct uptake of contaminants or provide exudates that enhance microbial degradation – this is rhizodegradation.
  - The compounds of concern taken up by the plants are either enzymatically broken down by phytodegradation or are subsequently transpired through the leaves by phytovolatilization.
  - The uptake and accumulation of contaminants is phytoaccumulation and the sequestration of contaminants is phytostabilization.

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Mechanisms

- These abiotic and biotic processes for removal of inorganic and organic compounds will be discussed in the next few slides.

- Wetland systems can be designed to contain emergent, submergent and/or floating plants that create an environment that supports a wide range of physical, chemical, and microbial processes.

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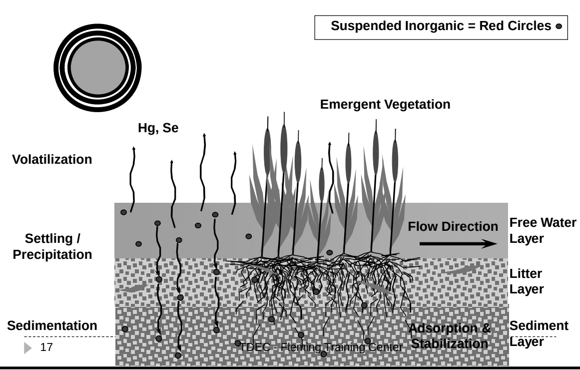
Chemical/Physical Mechanisms Treating Inorganic Compounds



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Chemical/Physical Mechanisms Treating Inorganic Compounds

- Wetland systems support a variety of of sequential and often complementary processes. The predominant abiotic processes for removal of inorganic contaminants is summarized in this slide.

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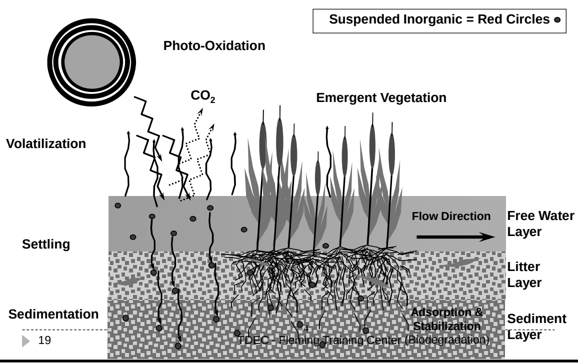
Chemical/Physical Mechanisms Treating Organic Compounds



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Chemical/Physical Mechanisms Treating Organic Compounds

- Similar to abiotic mechanisms involved in treating inorganic compounds, the organic contaminants are removed from the influent stream by settling/sedimentation, sorption, volatilization.
- In addition, photo-oxidation – oxidation in the presence of light may oxidize the organics to gaseous carbon dioxide (CO_2) which escapes from the wetland.

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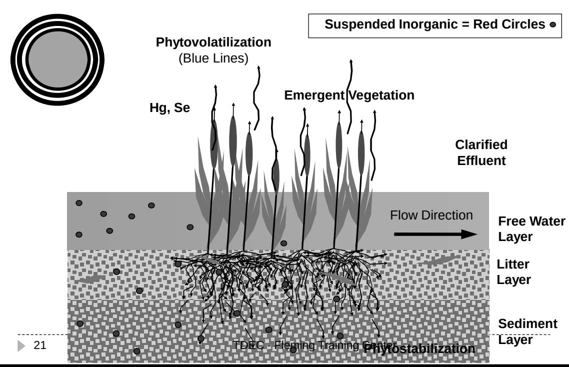
Biological Mechanisms Treating Inorganic Compounds



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Biological Mechanisms Treating Inorganic Compounds

- This slide describes some biotic mechanisms that can result in removal of these inorganic compounds.
- The fate of the inorganic contaminants may be governed by the mechanisms of phytostabilization in which the contaminants are immobilized through absorption and accumulation into the roots, adsorption onto the roots, or precipitation within the root zone.
- In case of dissolved inorganic contaminants, they may be taken up by the plants where they are either subject to accumulation in the plant itself, or be subsequently transpired through the leaves by the process of phytovolatilization.

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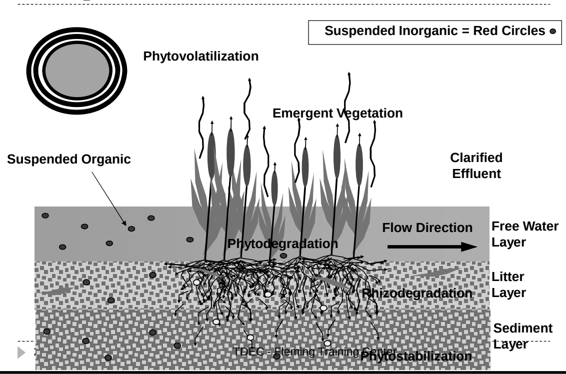
Biological Mechanisms Treating Organic Compounds



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Biological Mechanisms Treating Organic Compounds

- In addition to phytovolatilization, phytoaccumulation, phytostabilization, removal of organic contaminants also involves microbial degradation under aerobic/anaerobic conditions, rhizodegradation and phytodegradation.

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Primary Contaminant Removal Mechanisms

Contaminant Group or Water Quality Parameter	Physical	Chemical	Biological
Total Suspended Solids	Settling & filtration		Biodegradation
Organics • Biochemical Oxygen Demand	Settling	Oxidation	Biodegradation
Hydrocarbons • Fuels, oil and grease, alcohols, BTEX, TPH • PAHs, chlorinated and non-chlorinated solvents, pesticides, herbicides, insecticides	Diffusion/ Volatilization, Settling	Photochemical Oxidation	Biodegradation Phytodegradation Phytovolatilization Evapotranspiration
Nitrogenous Compounds • Organic N, NH_3, NH_4, NO_3^{-2}, NO_2^{-}	Settling		Biological denitrification Nitrification & Plant uptake
Phosphoric Compounds • Organic P, PO_4^{-3}	Settling	Precipitation Adsorption	Microbes Plant uptake
Metals • Al, As, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Se, Ag, Zn	Settling	Precipitation Adsorption Ion exchange	Phytoaccumulation Phyto-volatilization
Pathogens	UV radiation		Die-off Microbes

Removal Mechanisms for Metals

	Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Se	Ag	Zn
Oxidation and Hydrolysis	X					X		X				
Formation of insoluble sulfides		X	X		X		X				X	X
Binding to iron and manganese oxides		X			X	X	X	X	X			X
Filtration of solids and colloids			X				X				X	X
Reduction to non-mobile form by bacterial activity				X	X					X		
Sorption onto organic matter					X				X			
Formation of carbonates or sulfides						X						
Formation of carbonates								X	X			

Types of Systems

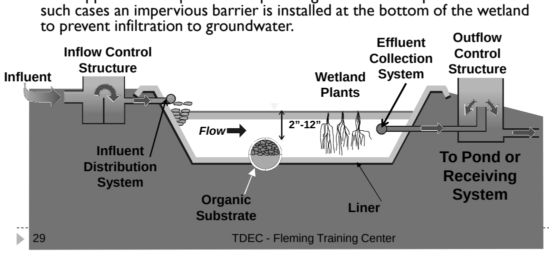
- Wetland systems are classified into SF, SSF, RB based on the flow pattern, matrix used as substrate.
  - Surface Flow (SF)
  - Subsurface Flow (SSF)

Surface Flow Wetlands (SF)

- Surface Flow systems simulate a type of natural wetlands in which contaminated water flows over the soil at shallow depths.
  - Water flow occurs above the substrate
- These are designed and constructed to exploit the biotic and abiotic processes naturally occurring in wetlands.
- The water surface is exposed to the atmosphere and hence aerobic processes predominate.
  - Preferred choice for treatment of contaminants that are predominantly removed by aerobic processes
- Also called free water surface (FWS) wetlands
- Advantages
  - Simple design
  - Less costly as compared to Subsurface systems

Surface Flow Wetland

- To minimize short circuiting in a surface flow wetland, control structures to effectively distribute inflow across the entire width of the wetland inlet and uniform collection of effluent across the total outlet width are very critical.
- Depending on the final treatment goal, different types of vegetation can be chosen.
- Most applications require that impact to groundwater be prevented – in such cases an impervious barrier is installed at the bottom of the wetland to prevent infiltration to groundwater.

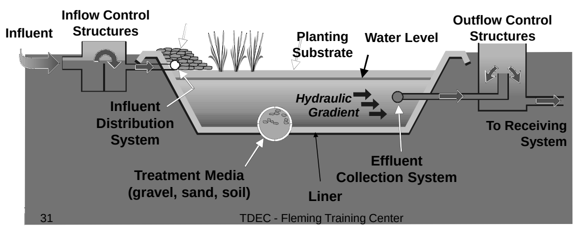


Subsurface Flow Wetland

- Water flows below ground surface through the substrate
- Two types of systems based on hydraulics:
  - Horizontal (most common)
    - Water flows under/through the substrate
  - Vertical
    - Configuration of the matrix forces the water to flow perpendicular to the length of the wetland
- Also known as
  - Rock Reed filters, Reed beds, Gravel beds, Vegetated submerged beds, or Root zone method

Subsurface Flow Wetland

- In a subsurface flow wetland system, water flow through the substrate.
- This substrate matrix could be gravel, sand, or soil.
- As in the surface flow systems, the inlet and outlet control structure and the influent/effluent distribution/collection system are used to prevent short circuiting and ensure uniform distribution along the width.



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Subsurface Flow Wetland Advantages

- Higher treatment efficiencies as compared to surface flow systems
  - More surface area for biofilm development
  - Efficient removal of BOD and SS from septic tank effluent
- Reduced risk of public exposure, odors and insect vectors
- Greater thermal protection due to subsurface flow of water
- Increased accessibility for maintenance

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Subsurface Flow Wetland Disadvantages

- You must monitor vegetation
- Low cost to construct (Advantage), but more expensive than Surface Flow system
- These should not be located after facultative lagoons

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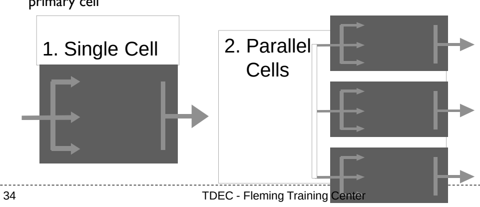
Typical Configurations of Constructed Wetlands

- The treatment goals and the available area decides the type of configuration chosen for a constructed wetland.
- Figure 1 is a single cell in which influent wastewater enters at one end, is treated as it moves to the other end.
- Figure 2 depicts a multiple cell configurations operated in parallel.
  - This configuration adds operational flexibility to the overall treatment process and can facilitate maintenance activities.
  - As with lagoons, parallel operation in winter prevents organic overload of 1st or primary cell



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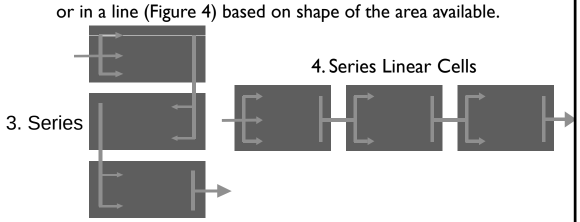
Typical Configurations of Constructed Wetlands

- Figures 3 and 4 show a series configuration in which constituent mass is gathered at the outlet end of one cell and redistributed to the inlet of the next cell.
  - The series configuration could be either serpentine (Figure 3) or in a line (Figure 4) based on shape of the area available.



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Choice of Wetland Type

- Treatment goals
- Mechanisms involved
- Maintenance Issues
- Air Emissions/Ecotoxicity Concerns
- Area availability
- Cost

- Each wetland type has its own advantages that we have seen in the previous slides and all the factors listed on this slide have to be weighed to make any decision of choice of wetland.

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Choice of Wetland Type

- Selection of the type of wetland will depend on treatment goals, which mechanisms can be optimized most efficiently in the different types, in some cases maintenance issues and cost.
  - For example, if volatilization is targeted as the primary removal mechanism for a specific contaminant, then Surface Flow would be the the best choice for optimizing the volatilization.
  - If the objective is to tackle run-off and prevent its impact to a waterbody, then then the 3rd type of wetland – riparian buffer needs to employed.
  - In case of water influent that is high in suspended solids, a Surface Flow wetland might offer less clogging problems and hence lesser maintenance issues and would be more suitable as compared to a Subsurface Flow.

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Municipal Wastewater Wetland Treatment

Tres Rios constructed wetlands, Arizona

- Used in 34 states to treat municipal wastewater
  - Typically as a polishing step also called tertiary treatment
- Now considered effective as a secondary treatment

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Municipal WW Characteristics & Removal Efficiencies, Tertiary Treat.

Constituent	Influent Concentration	Removal Efficiency
BOD	20 - 100 mg/L	67-80 %
Suspended Solids	30 mg/L	67-80 %
Ammonia Nitrogen	15 mg/L	62-84 %
Total Nitrogen	20 mg/L	69-76 %
Total Phosphorus	4 mg/L	48 %
Cd Cu Pb Zn	10 ug/L 50 ug/L 50 ug/L 300 ug/L	50-60 % 50-60 % 50-60 % 50-60 %

(Data is from Kadlec and Knight 1996)

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On-Site Waste Water

- Usually used when on site soils are not suitable for standard drain field or water table is too close to surface
  - Single Family Dwellings
  - Public Facilities
  - Parks
  - Apartment
  - Commercial Developments

- Septic tank feeds to wetland
  - Normally discharges to subsurface soils rather than surface water
- Can provide better than secondary levels of treatment for BOD, TSS and fecal coliform w/ variable performance for removal of ammonium nitrogen
- Can be surface or subsurface, in cold climates subsurface is preferred to minimize freezing problems
  - Subsurface also minimizes mosquito problems

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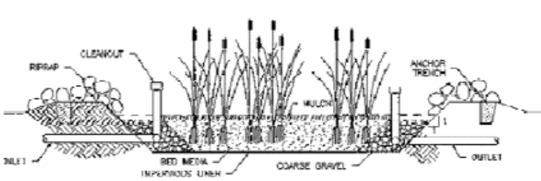
Liners & Berms

- Liners (synthetic or clay)
- Berms provide the basic containment structure for the constructed wetlands, and ensure that the basic hydrologic foundation of the wetlands is met.



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Inlet & Outlet

- Constructed wetlands require structures that can uniformly distribute wastewater into the wetlands, control the depth of water in the wetlands, and collect the treated effluent leaving the wetlands.
  - Flow distribution Structure
    - V-notch or horizontal weirs
    - Flow splitters for small flows (10,000 gpd or less).
  - Flow distribution piping
    - wastewater must be uniformly distributed in the front end of the wetlands
  - Flow Collection Piping
    - reverse of flow distribution
  - Level Adjust Structures
    - 100-foot long wetland with a 1% slope will have water standing 24 inches at one end and 12 inches at the other end.

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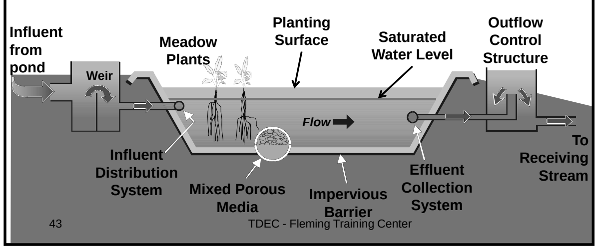
Wetland Inlet/Outlet Structures



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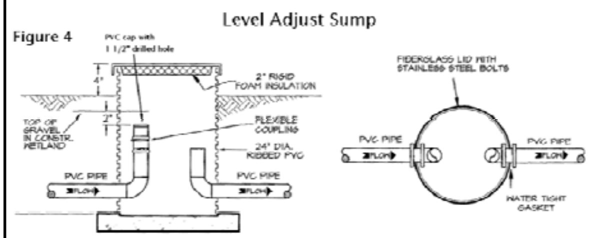
Level Adjust Sump



Images are courtesy of Southwest Wetlands Group (modified)

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Treatment Media

- More typical to subsurface flow wetlands
- Average treatment media depth is 12 to 30 inches
- Standard media
  - Sand
  - Gravel
  - Rock
- Surface flow media generally soil
- Organic material
  - Peat/hay bales
  - Compost

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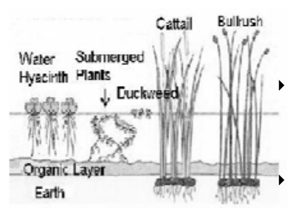
Plant Selection



- Native
- Noxious and invasive
  - Phragmites, purple loosestrife
  - Check your state's list of invasive plant species
- Vegetative form
  - Submerged
  - Floating
  - Emergent
- Select plants based on the type and objectives of your treatment wetland
- http://plants.usda.gov/wetland.html

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Design Implementation

- Soil erosion and sediment control
- Grading and sub-grading preparation/construction
- Plant installation
  - Grid spacing
  - Soil / stratum type
  - Fill wetland gradually, establishment period
- Post-construction activities
  - As-Built Reports
  - O&M
  - Monitoring

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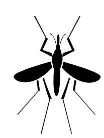
Operation & Maintenance

- O & M
  - Water level
  - Control of nuisance pests
    - Mosquitoes
    - Beavers
    - Muskrats
  - Longevity
  - Substrate Disposal
  - Invasive species



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Regulations

- Federal
- State
- Local

Your friendly regulator

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Federal Regulations

Federal law	Purpose	Responsible Agency
• Clean Water Act (CWA)	• Elimination or management of Point and Non Point Sources of Pollution.	• EPA Administers Section 402 (NPDES)
• National Environmental Policy Act (NEPA)	• Requires Federal agencies or anyone conducting an action on federal lands to consider the environmental impacts of that action	• Council of Environmental Quality (CEQ)
• Endangered Species Act (ESA)	• Protects all endangered or threatened species	• U.S. Fish and Wildlife Service

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Issues

- Treatment vs. Compliance
  - May not be able to meet extremely low limits
    - Background concentrations may exceed limits
  - Abandoned sites
    - Water quality improvement without meeting strict numeric standards
- Maintenance
  - During operation
  - Long term – plant removal/replanting in FWS
- Winter operation
  - Flow problems due to ice build up
  - Slower reaction rates

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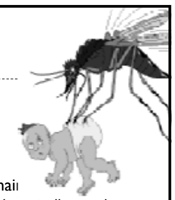
Issues (continued)



- Longevity
  - Function of parameter and removal process
- Substrate Disposal
- Ecological Impacts
  - Nuisance organisms will require monitoring and mai
    - Mosquitoes usually stay close to breeding area, (female typically travels < 1 mile) so if remote or in area with other wetlands, limits the impact subsurface systems minimize breeding area
    - In warmer climates, mosquito fish, successful in controlling population, some areas may consider Gambusia as a nuisance species
- Food chain impacts
  - Function of constituent and type of wetland, for trace metals, little metals into plant, most into sediment
  - Some metals more concern than others, e.g. lead
  - Can limit organisms exposure by using a subsurface flow

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Advantages

- Low maintenance
  - Passive
  - Solar-driven system
- Applicable in remote locations without utility access.
- Decreased emissions and sludge production compared to conventional treatment plants
- Able to remediate sites with multiple or mixed contaminants.

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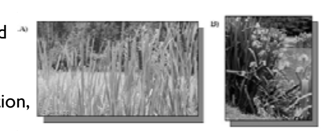
Advantages (continued)

- Habitat creation or restoration provides land reclamation upon completion.
- Favorable public perception, increased aesthetics, and lower noise than mechanical systems.
- Increasing regulatory acceptance and standardization.
- Carbon dioxide (greenhouse gas) sequestration.



A) Cattails B) Iris

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Aquatic Plants Systems: Water Hyacinths

- Spread laterally across surface to block algae growth, then spread vertically
- Nutrient removal through roots
  - Organic matter and TSS
- Wastewater treatment by bacteria on roots
- Summer use only in TN
- Optimum water temperature: 70-96°F
  - Die at temps 19-21°F

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Aquatic Plant Systems: Duckweed

- Cold tolerant: growth continues to 45°F (7°C)
- Sensitive to wind drifts: baffling system used
- Regular harvest for optimum performance
- Can compost, green manure, or feed to animals
  - Very high in protein
- Like water hyacinth, 95% water

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Aquatic Plant Systems: Duckweed

Floating Harvester

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Mosquito Control

- Below threshold for disease transmission or nuisance tolerance
- Mosquito fish (Gambusia)
- More frequent harvesting of plants on surface
- Spray water on surface (drown larvae) in evening
- Below threshold for disease transmission or nuisance tolerance
- Reduce organic load
- Maintain D.O.>1 mg/L

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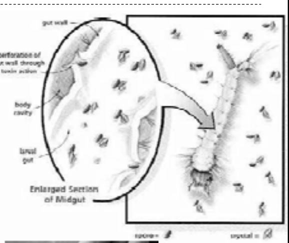
Mosquito Control with BTI

- BTI does not contain live bacteria – its active elements are crystalline spores which are suspended in water at treatment and destroy the gut lining after being filtered from water by feeding larvae.
- Methoprene is a mimic of the natural "hormone" which controls the moulting process when mosquito larvae become pupae.
- It produces high mortality in the pupal stage and is effective against some mosquito species at concentrations as low as 12 ppb.
- BTI is generally applied as a liquid formulation, while methoprene is usually presented coated onto sand granules or in a slow release charcoal matrix.



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Section 6

Lagoons

Wastewater Ponds & Lagoons

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Advantages of Ponds

- Economical to operate
- Capable of handling high flows
- Adaptable to changing loads
- Accumulate sludge at a rate of 0.2 lbs per lb of BOD (much lower than conventional facilities where the accumulation rate is 0.5 lbs to 1.0 lbs of solids per lb of BOD removed.)

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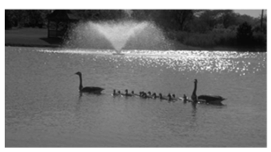
Advantages of Ponds

- Have an increased potential design life
- Serve as wildlife habitat
- Consume little energy
- Adaptable to land application
- Does not require highly trained personnel



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Disadvantages of Ponds

- May produce odors
- Require large land areas
- Are effected by climactic conditions
- May have high suspended solids levels in effluent (algae – green water)
- Might contaminate groundwater

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Types of Bacteria in Lagoons

- Aerobic bacteria
  - Need D.O. to live and grow
- Anaerobic bacteria
  - Live only where there is no D.O.
- Facultative bacteria
  - Can live with or without D.O.

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Aerobic Degradation

- Organics + O_2 + nutrients + bugs →

Organics: BOD or "food"; O_2: Oxygen; nutrients: Nitrogen, Phosphorus & Iron

CO_2 + H_2o + new bugs + stable matter

CO_2: Carbon Dioxide; H_2o: Water; stable matter: Will not have an oxygen demand on receiving stream

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Anaerobic Decomposition

- Organics + nutrients + bugs →

BOD or "Food" — Nitrogen and Phosphorus

$CH_4 + CO_2 + NH_4 + H_2S$ + other products

Methane, Carbon Dioxide, Ammonia, Hydrogen Sulfide

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Lagoon Treatment Process

- Physical
- Chemical
- Biological
- Indirect

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Lagoon Treatment Process

Physical

- Solids settling
- Volatilization of:
  - Carbon dioxide
  - Methane
  - Nitrogen gas
  - Reduced sulfur compounds

Chemical

- Precipitation in sludge layer

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Biological

- Bacterial oxidation of carbon compounds
- Bacterial release of ammonia from organic nitrogen compounds
  - Then the bacteria oxidize ammonia to nitrate
  - Finally bacteria can reduce nitrate to nitrogen gas
- Liberation of phosphorous and metals from their organic compounds and further removal

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Indirect

- Photosynthesis by algae removes carbon dioxide
  - Leads to an increase in pH values, which causes:
    - Precipitation of phosphorous and metals
    - Volatilization and loss of ammonia

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Photosynthesis vs. Respiration

Photosynthesis →

$$CO_2 + H_2o \leftrightarrow O_2 + CH_2O$$

← Respiration; carbohydrate

Algae produce oxygen during periods of sunlight and consume oxygen during the night

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What Happens to BOD?

- Aerobic respiration
  - 50% used by bugs as food, releasing carbon as CO_2
- Anaerobic respiration
  - Some released as methane
- New biomass reproduction
- Sludge accumulation
  - 0.2 lbs sludge produced per lb of BOD removed

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Why Remove Ammonia?

- Toxic to aquatic organisms
- Has an oxygen demand for receiving waters
- Converts to nitrate, which promotes algae growth in receiving stream

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What Happens to Ammonia?

- Stripped to atmosphere
  - Volatilization
  - Especially in complete mix aerated lagoons
  - Major removal pathway
- Microorganism uptake
  - 10-25% removed by algae and microorganisms, but given back as they die and decompose
- Converted to nitrogen gas

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Nitrification Reaction

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

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

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Denitrification Reaction

$$\underset{\text{Nitrate}}{NO_3} + \text{Food} \rightarrow \underset{\text{Carbon Dioxide}}{CO_2^-} + \underset{\text{Water}}{H_2O} + \underset{\text{Nitrogen Gas}}{N_2} + \underset{\text{Alkalinity}}{OH^-} + \text{New Bugs}$$

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What Happens to Phosphorous?

- Some uptake by algae and bacteria
- Some chemical precipitation, when calcium or magnesium is present
  - As pH increases to greater than 8.5, phosphorous removal rate increases

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Types of Lagoons

- Aerobic
- Anaerobic
- Facultative
- Aerated

Types of Bacteria in Stabilization Lagoons

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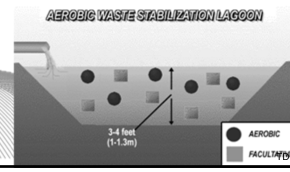
Aerobic Pond

- Shallow: 3-4 ft deep
- D.O. throughout water column
- Flat terrain with much sunshine
- D.O. due to photosynthesis



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Aerobic Pond

- Typically use higher depth in summer and lower depth in winter
- Use higher depth to accommodate I/I
- Detention time > 40 days is desirable
- Detention time can be adjusted by varying water depth

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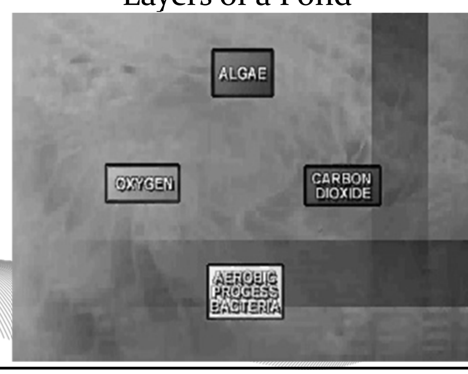
Decomposition in Aerobic Layers of a Pond



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Wind Action

- Wind creates surface mixing
- Mixing can remove oxygen from the water when the lagoon is supersaturated with oxygen
- Mixing can add oxygen when the lagoon is less than saturated
- Dikes and levees should be kept free of trees, bushes, etc., which could block wind

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Temperature

- Temperature is important to a lagoon's performance for 2 reasons:
  - Water will hold more oxygen at a cold temperature than at a warmer temperature
  - Biological activity decreases with a reduction in temperature
- A 10-degree drop in temperature can reduce bacterial activity by 50%
- The most desirable conditions for soluble BOD removal are warm temperatures with ample sunlight and a moderate breeze

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Sunlight

- Sunlight is vital to efficient lagoon operation
- Without it, algal photosynthesis would not occur and the oxygen content would drop
- The depth of sunlight penetration determines the extent to which the lagoon contents participate in oxygen production
- The density of algae affects sunlight penetration
- With good algae growth, sunlight penetration and oxygen production will be limited to the upper 2 to 3 feet

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Nutrients

- In addition to organic matter and oxygen, bacteria need a sufficient supply of nutrients to grow and multiply
- Nitrogen in the form of ammonia (NH_4^+) and phosphorus in the form of phosphate (PO_4^-) are the main nutrients needed
- Domestic wastewater normally has sufficient quantities of each

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pH

- The pH of a lagoon indicates whether its contents are acidic or alkaline
- An alkaline environment produces the best results.
- The pH normally varies throughout the day depending on algal activity
- The pH is usually higher during the day because algae are consuming more carbon dioxide (photosynthesis) than they are producing (respiration)
- The pH is typically lower at night because CO_2 is being produced (respiration) but not consumed by algae

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Dissolved Oxygen

- DO is vital for aerobic bacteria and preferred by facultative bacteria
- Some DO is produced by natural reaeration and much is produced by algal activity
- In warm months, DO levels during the day will often exceed saturation
- It is good practice to monitor DO levels in lagoons to determine normal ranges and to notice any drastic changes which may indicate potential problems

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Flow

- Regular flow monitoring is needed because:
  - It is required for NPDES permit compliance
  - Accurate flow data are needed to calculate BOD loadings
  - Records compiled from regular flow monitoring will serve as a basis for evaluating the amount of I/I which occurs
  - Effluent quality and performance can be related to flow if accurate flow records are kept

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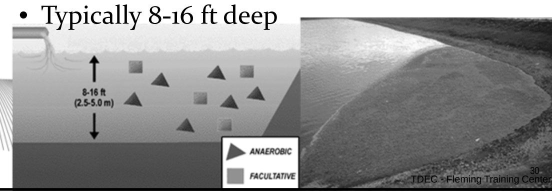
Anaerobic Pond

- No dissolved oxygen
- Treatment due to fermentation of sludge on bottom
- Highly efficient removal organic wastes
- Typically 8-16 ft deep



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Anaerobic Lagoons

- Typically used to pretreat high strength wastewater.
- Typically 15 - 20 feet deep to minimize heat losses and reduce land requirements
- Can produce odors and explosive gases (methane)
- Liners are recommended for top, bottom, and sides. A top cover is needed to retain/minimize heat losses.

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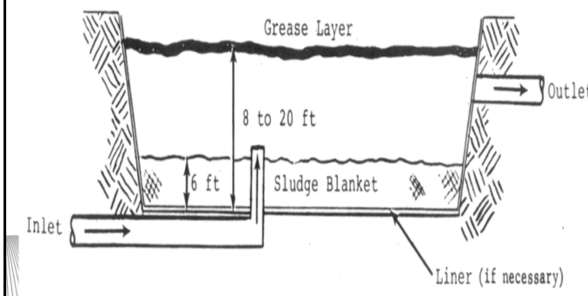
Anaerobic Lagoons



Ref: EPA, 1980, Innovative and Alternative Technology Assessment Manual

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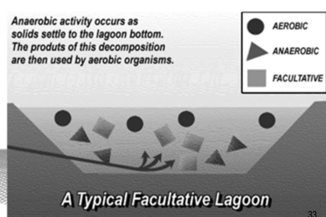
Facultative Lagoon

- Most common
- Upper portion aerobic due to algae
- Sludge layer anaerobic
- Depth: 4-8 ft
- DT: 5-30 day+



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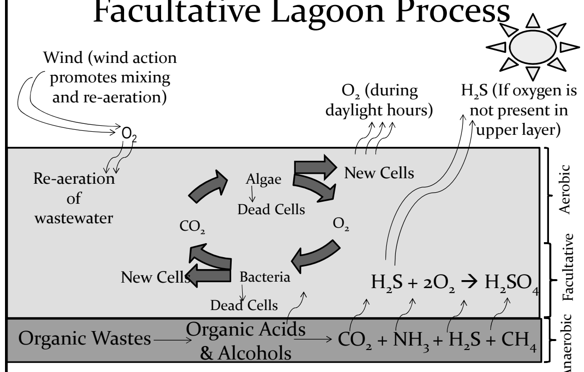
Facultative Lagoon Process



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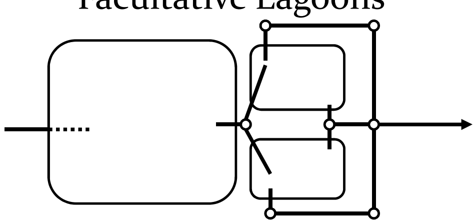
Facultative Lagoons



- Oxygen requirements satisfied by surface-to-air transfer and photosynthesis reactions.
- Residence times of 20 - 180 days. 30 days are common in the south.

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Facultative Lagoons

- BOD5 loading rates: ~ 30 lb. BOD5/acre/day overall
- BOD5 loading ~ 50 lb. BOD5/acre/day in the first cell.
- Typically use at least 2- cells and sometimes 3 cells.
- May require a liner to protect groundwater if seepage rate is greater than ¼ inch/day

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Aerated Lagoons

Aerated compared to Facultative

- Shorter detention times
- Heavier loadings

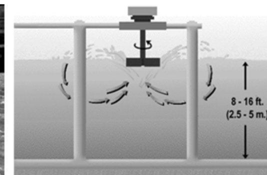
Detention Times

- Aerated Lagoons: 3-10 d
- Facultative Lagoons:
  - 5-30 days (typical)
  - 180 days (in cold climates)

Mechanically Aerated Ponds

Stationary or floating aerators

Allows for higher organic loading or shorter detention time in lagoon



Dissolved Oxygen

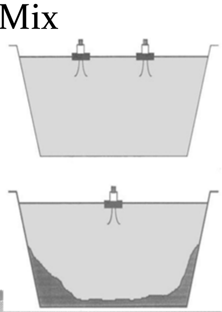
- DO is necessary for bacterial stabilization of organic matter
- The purpose of the aeration equipment is to supply the needed oxygen
- In most cases, operators should have the capability to control aerator "run-time" so that they can provide the amount of oxygen needed
- Many aerators are automatically controlled by timing devices

Methods of Controlling DO

- Minimum DO – Generally, at least 2 mg/L of DO should be maintained in the aerobic zone (Take DO readings at various locations and at various depths)
- BOD Removal – Generally, it is good practice to supply 1.5 times as much oxygen as the desired BOD5 removal (see next slide for typical aerator performance)

Aerated Lagoons: Partial vs. Complete Mix

- Less land; constructed deeper
- Uniform D.O or partial mix
- Not dependent for DO by sun/photosynthesis
- More maintenance required
- Greater energy costs to supply oxygen to bacteria
- Easily affected by temp.
- Require sedimentation unit after lagoon (complete mix)



Partial Mixed Aerated Lagoons (PMALs)

- Hydraulic residence time of 5-20 days
- Depth of 6-16 feet
- Will typically have an aerobic zone near the surface and a facultative zone in the bottom
- Sludge will accumulate in the facultative zone (bottom) and undergo anoxic/anaerobic treatment.
- Aerators provide both oxygen and mixing. Aerators do not completely mix the contents of the basin
- Organic loading: 10-150 lb BOD5/(ac-day)

Partial Mixed Aerated Lagoons

- The effluent may contain high concentrations of algae. A mg/L of suspended algae may contribute up to 0.5 mg/L of BOD5.
- Aeration requirements for mixing will typically be 4-10 hp/MG of volume.
  - Aeration/mixing requirements will vary from state to state.
- Several PMALs may be used in series and a polishing cell may be provided at the end of the partially mixed aerated cells.
- May require a liner to protect groundwater if seepage rate is greater than ¼ inch/day

Complete Mixed Aerated Lagoons (CMALs)

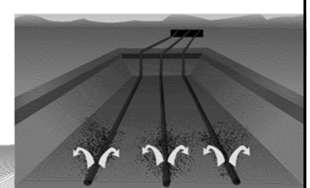
- Hydraulic residence time of 1-6 days
- Depth of 8-16 feet
- Will be completely aerobic (oxygen throughout)
- Aerators provide both oxygen and mixing. Aerators do not completely mix the contents of the basin but keep most solids in suspension.
- The mixing within the lagoon prevents algae from being exposed to sunlight for extended periods of time, which minimizes algae growth.
- Organic loading: 50-300 lb BOD5/(ac-day)

Complete Mixed Aerated Lagoons

- The effluent should not contain high concentrations of algae. Thus, algae biomass should contribute little to effluent BOD.
- Aeration requirements for mixing will typically be 20-30 hp/MG of volume.
  - Aeration/mixing requirements will vary from state to state.
- A PMAL or a polishing cell is usually provided after the completely mixed aerated cell to allow settling of biological solids.
- May require a liner to protect groundwater if seepage rate is greater than ¼ inch/day

Diffused Aeration Lagoons

Less mixing; more efficient oxygen transfer



Temperature

- Temperature is important to an aerated lagoon's performance for 2 reasons:
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  - Biological activity decreases with a reduction in temperature
- A 10-degree drop in temperature can reduce bacterial activity by 50%

Nutrients

- In addition to organic matter and oxygen, bacteria need a sufficient supply of nutrients to grow and multiply
- Nitrogen in the form of ammonia (NH4+) and phosphorus in the form of phosphate (PO4-) are the main nutrients needed
- Domestic wastewater normally has sufficient quantities of each

Flow

- Regular flow monitoring is needed because:
  - It is required for NPDES permit compliance
  - Accurate flow data are needed to calculate BOD loadings
  - Records compiled from regular flow monitoring will serve as a basis for evaluating the amount of I/I which occurs
  - Effluent quality and performance can be related to flow if accurate flow records are kept

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Typical Lagoon Design

Parameter	Aerobic	Facultative	Anaerobic	Aerated
Size, ac	<10, multiples	2-10 multiples	0.5-2.0	2-10, multiples
Operation	Series or Parallel	Series or Parallel	Series	Series or Parallel
Detention Time, days	10-40	5-30*	20-50	3-10
Depth, ft	3-4	4-8	8-16	6-20
pH	6.5-10.5	6.5-8.5	6.5-7.2	6.5-8.0
Temperature Range, °C	0-30	0-50	6-50	0-30
Optimum Temperature, °C	20	20	30	20
BOD5 Loading, lb/ac/d	54-110	45-160	180-450	——
BOD5 Removal, %	80-95	80-95	50-85	80-95

*180 days in cold climates

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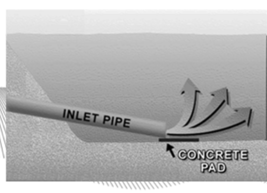
Pond Structures: Inlet

- Force main vs. gravity
- Single vs. multiple inlets
- Below surface best: prevents freezing



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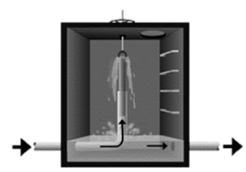
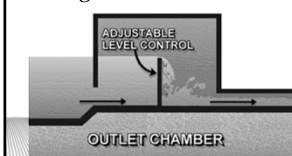
Pond Structures: Outlet

- Just below surface with scum baffle to minimize transfer of algae





Above: telescoping tube.

Left: flash boards

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•Synthetic liner
•Packed clay liner
•Berm or levee: grass and/or rip rap

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Factors Effecting Pond Operation

- Physical:
  - Surface area
  - Depth
  - Hydraulic load
  - Type of aeration
  - Temperature
  - Flow variations

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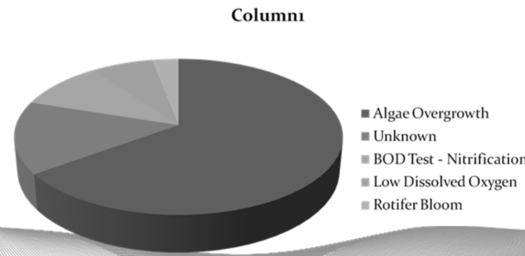
Factors Effecting Pond Operation

- Biochemical:
  - Organic loading rate
  - pH
  - Dissolved oxygen
  - Alkalinity
- Microbiological: bacteria, algae, etc.

Causes of High Effluent BOD and TSS

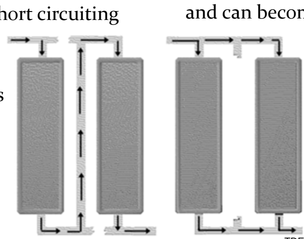


Lagoons in Series

Advantages
- Few algae and bacteria in final effluent
- Reduces short circuiting

Disadvantages
- First lagoon in series experiences heavy load and can become anaerobic

Series

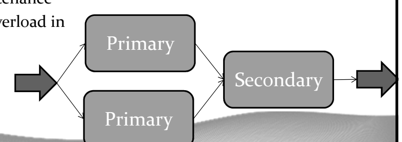


Parallel

Lagoons in Parallel

Advantages
- Can take heavier loads without becoming anaerobic
- One lagoon can be closed for cleaning and maintenance
- Prevents organic overload in winter

Disadvantages
- May not produce as good an effluent as series arrangement



Factors Operators Influent

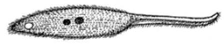
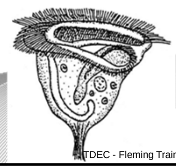
- Number of cells in series
- Continuous versus intermittent discharge
- Parallel versus series
- Recirculation
- Short-circuiting prevention
- Aerator operation
- Monitor organic loading
- Monitor sludge accumulation

Microorganisms in Wastewater Treatment Lagoons

- Single Celled:
  - Bacteria: treat wastewater
  - Algae
  - Protozoa:
    - Flagellates
    - Free Swimming Ciliates
    - Stalked Ciliates
- Multi Celled:
  - Metazoa:
    - Rotifers
    - Crustaceans

Protozoa

- Flagellates
  - Consume organic matter
  - Compete with bacteria
- Ciliates
  - Consume bacteria and algae in wastewater

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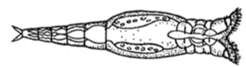
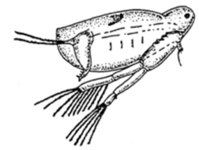
Metazoa

- Rotifers
  - Filter organic waste & bacteria
  - Indicate effective biological treatment
- Crustaceans feed on algae.

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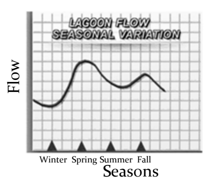
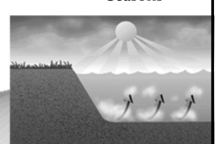
Monitoring Performance

- D.O. and pH: diurnal variation at several points in each cell and at several depths
  - Highest values in p.m.
- Seasonal flow variation
- Sludge production
- Actual detention time vs. design
- Spring overturn:
  - Bottom water becomes warmer & rises up
  - Surface is colder (more dense) than bottom and pond "flips"





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Daily Operation & Maintenance

Control of scum & mats of blue-green bacteria	Block sunlight; reduce green algae activity; odors; avian botulism	Agitation with water jets & rakes manually
Weeds	Mosquito breeding ground; scum accumulation; hinders circulation	Pull out young plants; maintain min. 3 ft depth; riprap; raise & lower water level
Insects	Nuisance; disease	Mosquito larvicide; surface aeration; addition *Gambusia* (mosquito fish)
Muskrats, groundhogs, turtles	Destroy berm walls by burrowing	Trap out; shoot; lower water level to expose den

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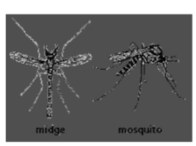
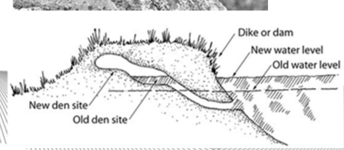
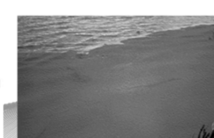
Daily O & M





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Causes of Poor Quality Effluent

- Aeration equipment failure
- Organic overload
- High total suspended solids (green algae)
- Toxic influent
- Loss of volume
- Short circuiting

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Low D.O. in Lagoon

- Low algae growth
- Excess scum
- Aeration problems
- Organic overload
- Short circuiting


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Odors in Lagoons

- Causes: overloading; poor housekeeping
- Treatment methods:
  - Add aeration
  - Feed sodium nitrate as oxygen source
  - Housekeeping- manual scum and algae removal
  - Masking agents

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Lagoon Safety

- Never work around a lagoon alone
- Never perform maintenance from a boat
- Never take a boat onto the lagoon alone

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Lagoon Safety



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Lagoon Effluent Polishing with Duckweed

- Duckweed covers surface of polishing pond
- Prevents sunlight penetration, killing green algae

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Polishing Pond

- Design Criteria:
- Organic Loading:
  - 20-25 lbs BOD/ac/day
- Hydraulic Loading:
  - 2350-2990 gpd/ac
- Water Depth
  - 5-6.5 ft

- Secondary Effluent Quality:
- BOD
  - < 30 ppm
- SS
  - < 30 ppm
- Total Nitrogen
  - < 15 ppm
- Total Phosphorous
  - < 6 ppm

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CHAPTER 9

Ponds and Aerated Lagoons

PONDS AND AERATED LAGOONS

9.1 General

This chapter describes the requirements for the following biological treatment processes:

a. Stabilization ponds

b. Aerated lagoons

Additionally, this chapter describes the requirements for use of hydraulic control release lagoons for effluent disposal.

A guide to provisions for lagoon design is the EPA publication Design Manual - Municipal Wastewater Stabilization Ponds, EPA-625/1-83-015.

9.1.1 Applicability

In general, ponds and aerated lagoons are most applicable to small and/or rural communities where land is available at low cost and minimum secondary treatment requirements are acceptable. Advantages include potentially lower capital costs, simple operation, and low O&M costs.

9.1.2 Supplement to Engineering Report

The engineering report shall contain pertinent information on location, geology, soil conditions, area for expansion, and any other factors that will affect the feasibility and acceptability of the proposed treatment system.

The following information should be submitted in addition to that required in the Chapter 1 section titled "Engineering Report and Preliminary Plans":

a. The location and direction of all residences, commercial development, and water supplies within 1/2 mile of the proposed pond

b. Results of the geotechnical investigation performed at the site

c. Data demonstrating anticipated seepage rates of the proposed pond bottom at the maximum water surface elevation

d. A description, including maps showing elevations and contours, of the site and adjacent area suitable for expansion

e. The ability to disinfect the discharge is required.

9.1.3 Effluent Requirements

See Chapter 1, Section 1.1.

9.2 Design Loadings

9.2.1 Stabilization Ponds

Stabilization ponds are facultative and are not artificially mixed or aerated. Mixing and aeration are provided by natural processes. Oxygen is supplied mainly by algae.

Design loading shall not exceed 30 pounds BOD per acre per day on a total pond area basis and 50 pounds BOD per acre per day to any single pond (from Middlebrooks).

9.2.2 Aerated Lagoons

An aerated lagoon may be a complete-mix lagoon or a partial-mix aerated lagoon. Complete-mix lagoons provide enough aeration or mixing to maintain solids in suspension. Power levels are normally between 20 and 40 horsepower per million gallons. The partial-mix aerated lagoon is designed to permit accumulation of settleable solids on the lagoon bottom, where they decompose anaerobically. The power level is normally 4 to 10 horsepower per million gallons of volume.

BOD removal efficiencies normally vary from 80 to 90 percent, depending on detention time and provisions for suspended solids removal.

The aerated lagoon system design for minimum detention time may be estimated by using the following formula; however, for the development of final parameters, it is recommended that actual experimental data be developed.

$$\frac{Se}{So} = \frac{1}{1 + 2.3K_1t}$$

where:

t = detention time, days
K_1= reaction coefficient, complete system per day, base 10. For complete treatment of normal domestic sewage, the K_1 value will be assumed to be:
K_1 = 1.087 @20^oC for complete mix
K_1 = 0.12 @20^oC for partial mix
Se = effluent BOD_5, mg/l
So = influent BOD_5, mg/l

The reaction rate coefficient for domestic sewage that includes significant quantities of industrial wastes, other wastes, and partially treated sewage should be determined experimentally for various conditions that might be encountered in the aerated ponds. Conversion of the reaction rate coefficient to temperatures other than 20 degrees C should be according to the following formula:

$K_1 = K_{20}\ 1.036^{(T-20)}$ (T = temperature in degrees C)

The minimum equilibrium temperature of the lagoon should be used for design of the aerated lagoon. The minimum equilibrium temperature should be estimated by using heat balance equations, which should include factors for influent wastewater temperature, ambient air temperature, lagoon surface area, and heat transfer effects of aeration, wind, and humidity. The minimum 30-day average ambient air temperature obtained from climatological data should be used for design.

Additional storage volume shall be considered for sludge storage and partial mix in aerated lagoons.

Sludge processing and disposal should be considered.

9.3 Special Details

9.3.1 General

9.3.1.1 Location

a. Distance from Habitation

A pond site should be located as far as practicable from habitation or any area that may be built up within a reasonable future period, taking into consideration site specifics such as topography, prevailing winds, and forests. Buffer zones between the lagoon and residences or similar land use should be at least 300 feet to residential property lines, and 1000 feet to existing residence structures.

b. Prevailing Winds

If practical, ponds should be located so that local prevailing winds will be in the direction of uninhabited areas. Preference should be given to sites that will permit an unobstructed wind sweep across the length of the ponds in the direction of the local prevailing winds.

c. Surface Runoff

Location of ponds in watersheds receiving significant amounts of runoff water is discouraged unless adequate provisions are made to divert storm water around the ponds and protect pond embankments from erosion.

d. Water Table

The effect of the ground water location on pond performance and construction must be considered.

e. Ground Water Protection

Ground Water Protection's main emphasis should be on site selection and liner construction, utilizing mainly compacted clay. Proximity of ponds to water supplies and other facilities subject to contamination and location in areas of porous soils and fissured rock formations should be critically evaluated to avoid creation of health hazards or other undesirable conditions. The possibility of chemical pollution may merit appropriate consideration. Test wells to monitor potential ground water pollution may be required and should be designed with proper consideration to water movement through the soil as appropriate.

An approved system of ground water monitoring wells or lysimeters may be required around the perimeter of the pond site to facilitate ground water monitoring. The use of wells and/or lysimeters will be determined on a case-by-case basis depending on proximity of water supply and maximum ground water levels. This determination will be at the site approval phase (see Section 1.1).

A routine ground water sampling program shall be initiated prior to and during the pond operation, if required.

f. Floodwaters

Pond sites shall not be constructed in areas subject to 25-year flooding, or the ponds and other facilities shall be protected by dikes from the 25-year flood.

9.3.1.2 Pond Shape

The shape of all cells should be such that there are no narrow or elongated portions. Round, square, or rectangular ponds should have a length to width ratio near 1:1 for complete mix ponds. Rectangular ponds with a length not exceeding three times the width are considered most desirable for complete mix aerated lagoons. However, stabilization ponds should be rectangular with a length exceeding three times the width, or be baffled to ensure full utilization of the basin. No islands, peninsulas, or coves are permitted. Dikes should be rounded at corners to minimize accumulations of floating materials. Common dike construction should be considered whenever possible to minimize the length of exterior dikes.

9.3.1.3 Recirculation

Recirculation of lagoon effluent may be considered. Recirculation systems should be designed for 0.5 to 2.0 times the average influent wastewater flow and include flow measurement and control.

9.3.1.4 Flow Measurement

The design shall include provisions to measure, total, and record the wastewater flows.

9.3.1.5 Level Gauges

Pond level gauges should be located on outfall structures or be attached to stationary structures for each pond.

9.3.1.6 Pond Dewatering

All ponds shall have emergency drawdown piping to allow complete draining for maintenance.

Sufficient pumps and appurtenances should be available to facilitate draining of individual ponds in cases where multiple pond systems are constructed at the same elevation or for use if recirculation is desired.

9.3.1.7 Control Building

A control building for laboratory and maintenance equipment should be provided.

9.3.1.8 General Site Requirements

The pond area shall be enclosed with an adequate fence to keep out livestock and discourage trespassing, and be located so that travel along the top of the dike by maintenance vehicles is not obstructed. A vehicle access gate of width sufficient to accommodate mowing equipment and maintenance vehicles should be provided. All access gates shall be provided with locks.

Cyclone-type fences, 5 to 6 feet high with 3 strands of barbed wire, are desirable, with appropriate warning signs required.

9.3.1.9 Provision for Sludge Accumulation

Influent solids, bacteria, and algae that settle out in the lagoons will not completely decompose and a sludge blanket will form. This can be a problem if the design does not include provisions for removal and disposal of accumulated sludge, particularly in the cases of anaerobic stabilization ponds and aerated lagoons. The design should include an estimate of the rate of sludge accumulation, frequency of sludge removal, methods of sludge removal, and ultimate sludge handling and disposal. Abandoning and capping of the lagoon is an acceptable solution (Re: The Division of Solid Waste Management guidelines for abandonment of a lagoon). However, the design life shall be stated in the report.

9.3.2 Stabilization Ponds

9.3.2.1 Depth

The primary (first in a series) pond depth should not exceed 6 feet. Greater depths will be considered for polishing ponds and the last ponds in a series of 4 or more.

9.3.2.2 Influent Structures and Pipelines

a. Manholes

A manhole should be installed at the terminus of the interceptor line or the force main and should be located as close to the dike as topography permits; its invert should be at least 6 inches above the maximum operating level of the pond to provide sufficient hydraulic head without surcharging the manhole.

b. Influent Pipelines

The influent pipeline can be placed at zero grade. The use of an exposed dike to carry the influent pipeline to the discharge points is prohibited, as such a structure will impede circulation.

c. Inlets

Influent and effluent piping should be located to minimize short-circuiting and stagnation within the pond and maximize use of the entire pond area.

Multiple inlet discharge points shall be used for primary cells larger than 10 acres.

All gravity lines should discharge horizontally onto discharge aprons. Force mains should discharge vertically up and shall be submerged at least 2 feet when operating at the 3-foot depth.

d. Discharge Apron

Provision should be made to prevent erosion at the point of discharge to the pond.

9.3.2.3 Interconnecting Piping and Outlet Structures

Interconnecting piping for pond installations shall be valved or provided with other arrangements to regulate flow between structures and permit variable depth control.

The outlet structure can be placed on the horizontal pond floor adjacent to the inner toe of the dike embankment. A permanent walkway from the top of the dike to the top of the outlet structure is required for access.

The outlet structure should consist of a well or box equipped with multiple-valved pond drawoff lines. An adjustable drawoff device is also acceptable. The outlet structure should be designed so that the liquid level of the pond can be varied from a 3.0- 5.0 foot depth in increments of 0.5 foot or less. Withdrawal points shall be spaced so that effluent can be withdrawn from depths of 0.75 foot to 2.0 feet below pond water surface, irrespective of the pond depth.

The lowest drawoff lines should be 12 inches off the bottom to control eroding velocities and avoid pickup of bottom deposits. The overflow from the pond shall be taken near but below the water surface. A two-foot deep baffle may be helpful to keep algae from the effluent. The structure should also have provisions for draining the pond. A locking device should be provided to prevent unauthorized access to level control facilities. An unvalved overflow placed 6 inches above the maximum water level shall be provided.

Outlets should be located nearest the prevailing winds to allow floating solids to be blown away from effluent weirs.

The pond overflow pipes shall be sized for the peak design flow to prevent overtopping of the dikes.

9.3.2.4 Minimum and Maximum Pond Size

No pond should be constructed with less than 1/2 acre or more than 40 acres of surface area.

9.3.2.5 Number of Ponds

A minimum of three ponds, and preferably four ponds, in series should be provided (or baffling provided for a single cell lagoon design configuration) to insure good hydraulic design. The objective in the design is to eliminate short circuiting.

9.3.2.6 Parallel/Series Operation

Designs, other than single ponds with baffling, should provide for operation of ponds in parallel or series. Hydraulic design should allow for equal distribution of flows to all ponds in either mode of operation.

9.3.3 Aerated Lagoons

9.3.3.1 Depth

Depth should be based on the type of aeration equipment used, heat loss considerations, and cost, but should be no less than 7 feet. In choosing a depth, aerator erosion protection and allowances for ice cover and solids accumulation should be considered.

9.3.3.2 Influent Structures and Pipelines

The same requirements apply as described for facultative systems, except that the discharge locations should be coordinated with the aeration equipment design.

9.3.3.3 Interconnecting Piping and Outlet Structures

a. Interconnecting Piping

The same requirements apply as described for facultative systems.

b. Outlet Structure

The same requirements apply as described for facultative systems, except for variable depth requirements and arrangement of the outlet to withdraw effluent from a point at or near the surface. The outlet shall be preceded by an underflow baffle.

9.3.3.4 Number of Ponds

Not less than three basins should be used to provide the detention time and volume required. The basins should be arranged for both parallel and series operation. A settling pond with a hydraulic detention time of 2 days at average design flow must follow the
aerated cells, or an equivalent of the final aerated cell must be free of turbulence to allow settling of suspended solids.

9.3.3.5 Aeration Equipment

A minimum of two mechanical aerators or blowers shall be used to provide the horsepower required. At least three anchor points should be provided for each aerator. Access to aerators should be provided for routine maintenance which does not affect mixing in the lagoon. Timers will be required.

9.4 Pond Construction Details

9.4.1 Liners

9.4.1.1 Requirement for Lining

The seepage rate through the lagoon bottom and dikes shall not be greater than a water surface drop of 1/4 inch per day. (Note: The seepage rate of 1/4 inch per day is 7.3 x 10^{-6} cm/sec coefficient of permeability seepage rate under pond conditions.) If the native soil cannot be compacted or modified to meet this requirement, a pond liner system will be required.

If a lagoon is proposed to be upgraded, it must be shown that it currently meets the 1/4-inch per day seepage rate before approval will be given.

9.4.1.2 General

Pond liner systems that should be evaluated and considered include (1) earth liners, including native soil or local soils mixed with commercially prepared bentonite or comparable chemical sealing compound, and (2) synthetic membrane liners. The liner should not be subject to deterioration in the presence of the wastewater. The geotechnical recommendations should be carefully considered during pond liner design. Consideration should also be given to construct test wells when required by the Department in any future regulations, or when industrial waste is involved.

9.4.1.3 Soil Liners

The thickness and the permeability of the soil liners shall be sufficient to limit the leakage to the maximum allowable rate of 1/4 inch per day. The evaluation of earth for use as a soil liner should include laboratory permeability tests of the material and laboratory compaction tests. The analysis should take into consideration the expected permeability of the soil when compacted in the field. All of the soil liner material shall have essentially the same properties.

The analysis of an earth liner should also include evaluation of the earth liner material with regard to filter design criteria. This is required so that the fine-grained liner material does not infiltrate into a coarser subgrade material and thus reduce the effective thickness of the liner.

If the ponds are going to remain empty for any period of time, consideration should be given to the possible effects on the soil liners from freezing and thawing during cold weather or cracking from hot, dry weather. Freezing and thawing will generally loosen the soil for some depth. This depth is dependent on the depth of frost penetration.

The compaction requirements for the liner should produce a density equal to or greater than the density at which the permeability tests were made. The minimum liner thickness should be 12 inches, to ensure proper mixing of bentonite with the native soil. The soil should be placed in lifts no more than 6 inches in compacted thickness. The moisture content at which the soil is placed should be at or slightly above the optimum moisture content.

Construction and placement of the soil liner should be inspected by a qualified inspector. The inspector should keep records on the uniformity of the earth liner material, moisture contents, and the densities obtained.

Bentonite and other similar liners should be considered as a form of earth liner. Their seepage characteristics should be analyzed as previously mentioned, and laboratory testing should be performed using the mixture of the native or local soil and bentonite or similar compound. In general, the requirements for bentonite or similar compounds should include the following: (1) The bentonite or similar compound should be high swelling and free flowing and have a particle size distribution favorable for uniform application and minimizing of wind drift; (2) the application rate should be least 125 percent of the minimum rate found to be adequate in laboratory tests; (3) application rates recommended by a supplier should be confirmed by an independent laboratory; and (4) the mixtures of soil and bentonite or similar compound should be compacted at a water content greater than the optimum moisture content.

9.4.1.4 Synthetic Membrane Liners

Requirements for the thickness of synthetic liners may vary due to the liner material, but it is generally recommended that the liner thickness be no less than 20 mils; that is, 0.020 inch. There may be special conditions when reinforced membranes should be considered. These are usually considered where extra tensile strength is required. The membrane liner material should be compatible with the wastewater in the ponds such that no damage results to the liner. PVC liners should not be used where they will be exposed directly to sunlight. The preparation of the subgrade for a membrane liner is important. The subgrade should be graded and compacted so that there are no holes or exposed angular rocks or pieces of wood or debris. If the subgrade is very gravelly and contains angular rocks that could possibly damage the liner, a minimum bedding of 3 inches of sand should be provided directly beneath the liner. The liner should be covered with 12 inches of soil. This includes the side slope as well. No equipment should be allowed to operate directly on the liner. Consideration should be given to specifying that the manufacturer's representative be on the job supervising the installation during all aspects of the liner placement. An inspector should be on the job to monitor and inspect the installation.

Leakage must not exceed 1/4-inch per day.

9.4.1.5 Other Liners

Other liners that have been successfully used are soil cement, gunite, and asphalt concrete. The performance of these liners is highly dependent on the experience and skill of the designer. Close review of the design of these types of liners is recommended.

9.4.2 Pond Construction

9.4.2.1 General

Ponds are often constructed of either a built-up dike or embankment section constructed on the existing grade, or they are constructed using a cut and fill technique. Dikes and embankments shall be designed using the generally accepted procedures for the design of small earth dams. The design should attempt to make use of locally available materials for the construction of dikes. Consideration should also be given to slope stability and seepage through and beneath the embankment and along pipes.

9.4.2.2 Top Width

The minimum recommended dike top width should be 12 feet on tangents and 15 feet on curves to permit access of maintenance vehicles. The minimum inside radius of curves of the corners of the pond should be 35 feet.

9.4.2.3 Side Slopes

Normally, inside slopes of either dikes or cut sections should not be steeper than 3 horizontal to 1 vertical. Outer slopes should not be steeper than 2 horizontal to 1 vertical. However, in many instances, the types of material used, maintenance considerations, and seepage conditions can indicate that other slopes should be used.

9.4.2.4 Freeboard

There should be sufficient freeboard to prevent overtopping of the dike from wave action and strong winds. A minimum of one foot is required.

9.4.2.5 Erosion Control

Erosion control should be considered for the inside slopes of the dike to prevent the formation of wavecut beaches in the dike slope. In the event that earth liners or membrane liners with earth cover are used, consideration should be given to erosion protection directly beneath aeration units. If the currents are strong enough, considering the type of material used for the earth cover, erosion pads may be necessary beneath the aeration units. Erosion control should also be considered wherever influent pipes empty into the pond. If a grass cover for the outer slopes is desired, they should be fertilized and seeded to establish a good growth of vegetative cover. This vegetative cover will help control erosion from runoff. Consideration should also be given to protection of the outer slopes in the event that flooding occurs. The erosion protection should be able to withstand the currents from a flood.

9.4.3 Prefilling

The need to prefill ponds in order to determine the leakage rate shall be determined by the Department and incorporated into the plans and specifications. The strongest consideration for prefilling ponds will be given to ponds with earth liners. Ponds in areas where the surrounding homes are on wells will also be given strong consideration for prefilling.

9.4.4 Utilities and Structures Within Dike Sections

Pipes that extend through an embankment should be bedded up to the springline with concrete. Backfill should be with relatively impermeable material. No granular bedding material should be used. Cutoff collars should be used as required. No gravel or granular base should be used under or around any structures placed in the embankment within the pond. Embankments should be constructed at least 2 feet above the top of the pipe before excavating the pipe trench.

9.5 Hydrograph Controlled Release (HCR) Lagoons

All lagoons requirements apply to HCR lagoons with the following additional concerns:

HCR lagoons control the discharge of treated wastewater in accordance with the stream's assimilative capacity. Detention times vary widely and must be determined on a case-by-case basis.

HCR sites require much receiving stream flow pattern characterization. For this purpose, EPA Region IV has developed a computer design program. The Division of Water Pollution Control can assist in sizing the HCR basin using this program. HCR sites may be more economical if the design is combined with summertime land application. Their design is more economical if summer/winter or monthly standards are available.

The design and construction of the in-stream flow measurement equipment are critical components of an HCR system. The United States Geological Survey (USGS) should be contacted during the design phase. The USGS also has considerable construction experience concerning in-stream monitoring stations, although construction need not necessarily be done or supervised by the USGS.

9.6 Polishing Lagoons

Polishing lagoons following activated sludge are not permissible in Tennessee due to the one-cell algae interference.

9.7 Operability

Once a pond is designed, little operation should be required. However, to avoid NPDES permit violations, pond flexibility is needed. Operation flexibility is best facilitated by the addition of piping and valves to each pond which allows isolation of its volume during an algal bloom.

9.8 Upgrading Existing Systems

There are approximately sixty existing lagoons in Tennessee which were built utilizing standards and criteria from the 1960 period. Most are single- or double-cell units which need upgrading. Many are required to meet tertiary standards. The upgrade case should, in general, utilize the guidance in this chapter or proven configurations. It is noted, however, that there are many lagoon combinations available, such as complete-mix pond, partial-mix pond, stabilization pond, HCR pond and marsh-pond (wetlands)concepts. The combination of these alternatives
should be based upon the effluent permit design standards as well as site economics.

Wastewater Lagoons Vocabulary

______1. Acidity
______2. Acre-foot
______3. Aerated Pond
______4. Aerobic
______5. Aerobic Stabilization
______6. Algae
______7. Algaecide
______8. Anaerobic Decomposition
______9. Aquatic Vegetation
______10. Bacteria
______11. Bioflocculation
______12. Chemical Oxygen Demand
______13. Coliform Group
______14. Composite (Proportional) Sample
______15. DO
______16. Diurnal
______17. Facultative Bacteria
______18. Facultative Pond
______19. Fixed Sample
______20. Fungi
______21. Grab Sample
______22. Hydraulic Loading
______23. Influent
______24. Inorganic Matter
______25. Milli
______26. Milligrams per Liter
______27. Molecular Oxygen
______28. Organic Loading
______29. Oxygen Available
______30. Oxygen Depletion
______31. Parallel Operation
______32. Percolation
______33. Photosynthesis
______34. Population Equivalent
______35. Riprap
______36. Series Operation
______37. Settleable Solids
______38. Short-circuiting
______39. Sludge Banks
______40. Splash Pad
______41. Stabilization
______42. Stabilized Waste
______43. Standard Methods
______44. Stop Log
______45. Super Saturation
______46. Suspended Solids
______47. Tertiary Treatment
______48. Total Solids
______49. Toxic
______50. Toxicity
______51. Volatile Solids

A. The quantity of solids in water that represent a loss in weight upon ignition at 550°C
B. A volume term referring to that amount of liquid, 1 acre in area, 1 foot deep
C. A collection of individual samples obtained at regular intervals, usually everyone or two hours during a 24-hour time span. Each individual sample is combined with the others in proportion to the flow when the sample is combined with the others in proportion to the flow when the sample was collected. The resulting mixture forms a representative sample and is analyzed to determine the average conditions during the sampling period.
D. A measure of the oxygen-consuming capacity of inorganic matter present in wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in mg/L during a specific test. Results are not necessarily related to the biochemical oxygen demand because the chemical oxidant may react with substances that bacteria do not stabilize.
E. Having a daily cycle.

F. A group of microscopic organisms lacking chlorophyll and use organic nutrients as a food source.
G. When wastewater being treated flows through one treatment unit and then flows through another similar treatment unit.
H. The movement or flow of water through soil or rocks.
I. Those bacteria that can adapt to aerobic or anaerobic conditions. Can utilize dissolved or combined oxygen (oxygen bound in a compound by a chemical action.)
J. The number of pounds of BOD added to treatment unit per day.
K. Those solids that will settle out when a sample of sewage is allowed to stand quietly for a one-hour period in an Imhoff cone.
L. That liquid entering a process unit or operation.
M. When wastewater being treated is split and a portion flows to one treatment unit while the remainder flows to another similar treatment unit.
N. The breakdown of complex organic matter by bacteria in the absence of dissolved oxygen.
O. Broken stones, boulders or other materials placed compactly or irregularly on levees or dikes for the protection of earth surfaces against the erosive action of water.
P. A group of bacteria that inhabit the intestinal tract of man, warm blooded animals and may be found in plants, soil, air and the aquatic environment.
Q. A log or board in an outlet box or device used to control the water levels in ponds.
R. A single sample not necessarily taken at a set time or flow. An instantaneous sample.
S. A process in which chlorophyll-containing plants produce complex organic (living) materials from carbon dioxide, water and inorganic salts, with sunlight as the source of energy. Oxygen is produced in this process as a waste product.
T. The volume of flow per day per unit area.
U. A condition that may exist in wastes and will inhibit or destroy the growth or function of certain organisms.
V. An expression used to indicate 1/1000 of a standard unit of weight, length or capacity (metric system).

milliliter (mL)	1/1000 liter (L)
milligram (mg)	1/1000 gram (g)
millimeter (mm)	1/1000 meter (m)

W. The most common type of pond in current use. The upper portion (supernatant) is aerobic, while the bottom layer is anaerobic. Algae supply most of the oxygen to the supernatant.
X. The situation in which water holds more oxygen at a specified temperature than normally required for saturation.
Y. Methods of analysis prescribed by joint action of the American Public Health Association (APHA), American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF).
Z. The oxygen molecule, O_2, which is not combined with another element to form a compound. Also called free oxygen.

AA. The process of reducing a material using a biological and chemical means to a form that does not readily decompose.
BB. Microscopic plants that contain chlorophyll and float or are suspended and live in water. They also may be attached to structures, rocks or other similar substances.
CC. That vegetation that will grow in or near water.
DD. Poisonous.
EE. A waste that has been treated or decomposed to the extent that, if discharged or released, its rate and state of decomposition would be such that the waste would not cause a nuisance or odors.
FF. Dissolved molecular oxygen usually expressed in mg/L, ppm or percent saturation.
GG. A unit of concentration on weight/volume basis. Equivalent to ppm when speaking of water or wastewater.
HH. The hydraulic conditions in a tank, chamber or basin where time of passage is less than that of the normal flow through period.
II. A wastewater treatment pond in which mechanical or diffused-air aeration is used to supplement the oxygen supply.
JJ. The loss of oxygen from water or wastewater due to biological, chemical or physical action.
KK. Any substance or chemical applied to kill or control algal growths.
LL. Simple or complex organisms without chlorophyll. The simpler forms are one-celled; higher forms have branched filaments and complicated life cycles. Examples are molds, yeast and mushrooms.
MM. A condition characterized by the presence of free dissolved oxygen in the aquatic environment.
NN. A means of expressing the strength of organic material in wastewater. In a domestic wastewater system, microorganisms use up about 0.2 pounds of oxygen per day for each person using the system (as measured by the standard BOD test).
OO. Refers to the solids contained in dissolved and suspended form in water. Determined on weighing after drying at 103°C.
PP. The concentration of insoluble materials suspended or dispersed in waste or used water. Generally expressed in mg/L on a dry weight basis. Usually determined by filtration methods.
QQ. A structure made of concrete or other durable material to protect bare soil fro, erosion by splashing or falling water.
RR. Chemical substances of mineral origin.
SS. The clumping together of fine dispersed organic particles by the action of bacteria and algae. This results in faster and more complete settling of the organic solids in wastewater.
TT. The accumulation of solids including silt, mineral, organic and cell mass material that is produced in an aquatic system.
UU. Any process of water renovation that upgrades treated wastewater to meet specific reused requirements. May include general cleanup of water or removal of the specific parts of wastes insufficiently removed by conventional treatment processes.

Typical processes include chemical treatment and pressure filtration. Also called Advanced Waste Treatment.

VV. That part of the oxygen available for aerobic stabilization of organic matter. Includes dissolved oxygen and that available in nitrites or nitrates, peroxides, ozone and certain other forms of oxygen.

WW. The stabilization of organic matter through metabolism into more complex matter by bacteria in the presence of dissolved oxygen.

XX. A sample that has chemicals added that prevent the water quality indicators of interest in the sample from changing before final measurements are performed later in the lab.

YY. The capacity of water or wastewater to neutralize bases. It is a measure of how much base can be added to a liquid without causing a great change in pH.

Wastewater Lagoons
Review Questions

1. A pond that has dissolved oxygen distributed throughout the pond.
    a. Aerobic
    b. Anaerobic
    c. Facultative

2. A pond that contains no dissolved oxygen near the bottom and does contain dissolved oxygen near the surface.
    a. Aerobic
    b. Anaerobic
    c. Facultative

3. A pond that contains no dissolved oxygen.
    a. Aerobic
    b. Anaerobic
    c. Facultative

4. Algae produce ____________________ from the water molecule through photosynthesis.
    a. Oxygen
    b. Carbon Dioxide
    c. Methane
    d. all of the above
    e. none of the above

5. Pond efficiency is affected by biological factors, which one is not a biological factor?
    a. The type of bacteria present
    b. The type and quantity of algae
    c. The activity of the organisms present
    d. Nutrient Deficiencies
    e. The temperature

6. A pond is not functioning properly when ______________________________.
    a. it creates a visual or odor nuisance
    b. it has a high BOD or suspended solids in its effluent
    c. it has a high coliform bacteria concentration in its effluent
    d. all of the above
    e. none of the above

7. A definite ____________ color in a pond indicates a flourishing algae population and is a good sign.
    a. green
    b. black
    c. gray
    d. all of the above
    e. none of the above

8. Most odors in ponds are caused by overloading and poor housekeeping.
    a. True
    b. False

9. The outlet of a pond should be submerged to prevent the discharge of floating materials.
    a. True
    b. False

10. The inlet of a pond should be submerged to distribute the heat of the influent as much as possible and to minimize the occurrence of floating materials.
    a. True
    b. False

11. When the pH and dissolved oxygen drop dangerously low, the loading should be:
    a. increased.
    b. left unchanged.
    c. decreased or stopped.
    d. all of the above
    e. none of the above

12. Ponds should be started in winter to take advantage of the increased efficiency associated with low temperatures.
    a. True
    b. False

13. Weeds are objectionable around a pond because ______________________.
    a. they provide a place for the breeding of insects
    b. they allow for scum accumulation
    c. they hinder pond circulation
    d. all of the above
    e. none of the above

14. An operator can use _________________ to break up accumulation of scum.
    a. rakes
    b. jets of water
    c. outboard motors
    d. all of the above
    e. none of the above

15. A drop in pH and dissolved oxygen may be caused by ________________.
    a. overloading
    b. lack of circulation
    c. wave action
    d. A & B
    e. A & C

16. Odors in ponds can be reduced by ___________________________.
    a. recirculation from aerobic units
    b. the use of floating aerators.
    c. chlorination
    d. all of the above
    e. none of the above

17. Suspended vegetation in a pond can be controlled by all of the following methods except ____________________.
    a. mowing regularly during the growing season
    b. keeping a few ducks in the pond
    c. mechanical harvesting
    d. skimming with rakes or boards
    e. keeping the pond exposed to a clean sweep of the wind

18. Herbicides can be used to control emergent weeds, suspended vegetation, and dike vegetation, but only as a last resort.
    a. True
    b. False

19. Emergent weeds can be controlled by lowering the water level, cutting or burning the weeds, and raising the water level.
    a. True
    b. False

20. Emergent weeds can be controlled by keeping the water more than _______ feet deep.
    a. 1.5
    b. 2.0
    c. 3.0
    d. all of the above

21. Excessive BOD loadings can occur when
    a. influent loads exceed design capacity due to population increases
    b. due to industrial growth
    c. industrial dumps or spills
    d. all of the above
    e. none of the above

22. Large amounts of brown or black scum on the surface of a pond is an indication that the pond is overloaded.
    a. True
    b. False

Answers to Vocabulary

1. YY
2. B
3. II
4. MM
5. WW
6. BB
7. KK
8. N
9. CC
10. F
11. SS
12. D
13. P
14. C
15. FF
16. E
17. I
18. W
19. XX
20. LL
21. R
22. T
23. L
24. RR
25. V
26. GG
27. Z
28. J
29. VV
30. JJ
31. M
32. H
33. S
34. NN
35. O
36. G
37. K
38. HH
39. TT
40. QQ
41. AA
42. EE
43. Y
44. Q
45. X
46. PP
47. UU
48. OO
49. DD
50. U
51. A

Answers to Review Questions:

1. A
2. C
3. B
4. A
5. E
6. D
7. A
8. A
9. A
10. A
11. C
12. B
13. D
14. D
15. D
16. D
17. A
18. A
19. A
20. C
21. D
22. A

Section 7

Effluent Discharge

Effluent Disposal

Biological Natural Systems

1

TDEC - Fleming Training Center

Effluent Disposal

- Dilution
  - Lakes
  - Rivers
  - Streams
- Wastewater Reclamation
  - Land application
  - Underground disposal

TDEC - Fleming Training Center

2

Disposal by Dilution

- Treatment required prior to discharge:
  - Stabilize waste
  - Protect public health
  - Meet discharge requirements
- Site specific
- Most common method of effluent disposal

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Disposal by Dilution

- Diffusers
- Cascading outfalls
  - Increase D.O.
  - Remove chlorine
  - Remove sulfur dioxide
- Surface discharge

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Land Treatment of Wastewater Effluent

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Land Treatment Systems

- When high-quality effluent or even zero-discharge is required, land treatment offers a means of reclamation or ultimate disposal

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LAND TREATMENT SYSTEMS

- Simulate natural pathways of treatment
- Use soil, plants, and bacteria to treat and reclaim wastewater
- Treatment is provided by natural processes as effluent moves through soil and plants
- Some of wastewater is lost by evaporation and transpiration
- Remainder returns to hydrologic cycle through surface runoff or percolation to groundwater

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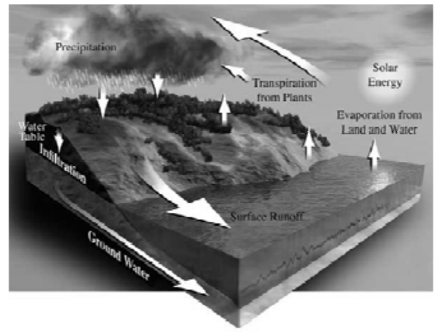
HYDROLOGIC CYCLE



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LAND APPLICATION SYSTEM

- Treatment prior to application
- Transmission to the land treatment site
- Storage
- Distribution over the site
- Runoff recovery system
- Crop systems

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SITE CONSIDERATIONS

- Control of ponding problems
  - Percolation
  - Crop selection
  - Drainage tiles
- Install PVC laterals below ground
- Potential odor release with spray systems
- Routine inspection of equipment
- Plan "B" in case system fails

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WASTEWATER RECLAMATION: LAND APPLICATION

- Irrigation most common:
  - Ridge and furrow
  - Sprinklers
  - Surface/drip systems
- Overland flow

Wastewater Treatment Plant & Poplar Tree Reuse System; Woodburn, Oregon

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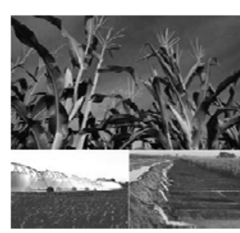
IRRIGATION

- Method depends on crop grown
  - Silage / hay
  - Parks / golf courses
  - Horticulture / timber / turf grass
- Water & nutrients enhance plant growth for beneficial use.
- Water removed by:
  - Surface evaporation & plant transpiration
  - Deep percolation to subsoil



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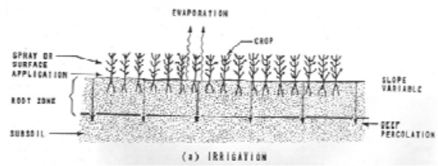
IRRIGATION



- Irrigation application of wastewater over relatively flat area, usually by spray (sprinklers) or surface spreading
- Water and nutrients are absorbed by plants and soil
- In soil, organic matter is oxidized by bacteria

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IRRIGATION

- Most common land treatment in US
- Spray: fixed or moving
- Surface spreading: controlled flooding or ridge & furrow
- Climate affects efficiency
  - If ground freezes, subsurface seepage is greatly reduced.
  - Therefore storage of treated wastewater may be necessary
- Ex: lawns, parks, golf courses, pastures, forests, fodder crops (corn, alfalfa), fiber crops, cemeteries

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IRRIGATION

- Irrigation also can serve as an alternative onsite disposal method for lots deemed unsuitable for conventional septic tank/soil absorption systems.
- Because irrigation systems are designed to deliver wastewater slowly at rates beneficial to vegetation, and because the wastewater is applied either to the ground surface or at shallow depths, irrigation may be permitted on certain sites with high bedrock, high groundwater, or slowly permeable soils.
- Irrigation systems also can be designed to accommodate sites with complex terrains.

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PRE-TREATMENT

- After wastewater receives primary and sometimes secondary treatment additional treatment maybe required prior to irrigation to reduce the amount of suspended solids and organisms in the wastewater.
  - Both can pose a threat to public health and clog systems.
  - Microorganisms, such as bacteria, can collect or multiply and create slime that clogs systems.
  - Pretreatment also minimizes odors in wastewater, so there is less potential for creating a public nuisance and attracting animals that can spread diseases.

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PRE-TREATMENT

- Different degrees of pretreatment are required for the wastewater depending on how it will be used and the intended method of irrigation.
  - Standards are more rigorous for surface irrigation methods, such as spray irrigation, and when irrigating food or feed crops or land intended for public use.
  - Biological pretreatment to remove organic matter from the wastewater is followed by filtration, to remove small particles from the wastewater, and disinfection.
  - Subsurface drip irrigation systems also employ filters mainly to protect against system clogging.
  - Additional treatment may be necessary to protect the receiving environment and may include secondary treatment plus disinfection.
  - This adds to the cost of building, operating, and maintaining systems, which should be considered when determining whether irrigation is a practical wastewater disposal option.

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IRRIGATION - SPRAY SYSTEMS

- Fixed
  - Buried or on surface
  - Cultivated crops or woodlands
- Moving - center pivot
- Minimum slope 2 – 3%
  - Promotes lateral drainage and reduces ponding
- Maximum slope in TN:
  - Row crops 8%
  - Forage crops 15%
  - Forests 30 %

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Irrigation - Spray Systems

Fixed

Moving

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Irrigation – Ridge & Furrow

- Wastewater flows through furrows between rows of crop
- Wastewater slowly percolates into soil
- Wastewater receives partial treatment before it is absorbed by plants

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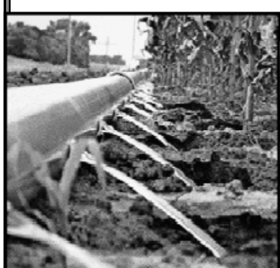
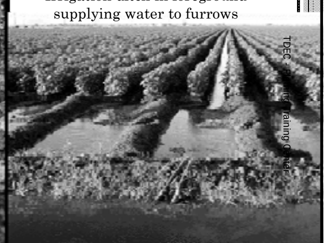
Irrigation – Ridge & Furrow



Gated pipe applying flow to furrows

Irrigation ditch in foreground supplying water to furrows



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Irrigation – Removal Efficiencies

Parameter	% Removal
BOD	98
COD	80
Suspended Solids	98
Nitrogen	85
Phosphorus	95
Metals	95
Microorganisms	98

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Irrigation – Removal Efficiencies

- Under normal circumstances:
  - Water and nitrogen are absorbed by crops
  - Phosphorus and metals are adsorbed by soil particles
  - Bacteria is removed by filtration
  - Viruses are removed by adsorption
- Nitrogen cycle
  - Secondary effluent contains ammonia, nitrate and organic nitrogen
  - Ammonia and organic nitrogen are retained in soil by adsorption and ion exchange, then oxidized to nitrate
  - Major removal mechanisms are ammonia volatilization, crop uptake and denitrification

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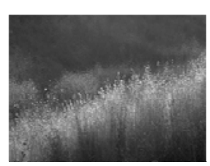
Overland Flow



- Spray or surface application
- 2-4% slope
- Slow surface flow treats wastewater
- Water removed by evaporation & percolation
- Runoff collection
- 6-12 hours/day, 5-7 days/week

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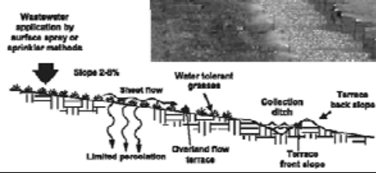
OVERLAND FLOW



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OVERLAND FLOW

- Wastewater is applied intermittently at top of terrace
- Runoff collected at bottom (for further treatment)
- Treatment occurs through direct contact with soil

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OVERLAND FLOW

- Low pressure sprays
  - <20 psi
  - Low energy costs
  - Good wastewater distribution
  - Nozzles subject to plugging
- Surface distribution
  - Generate minimal aerosols
  - Higher energy costs
  - Hard to maintain uniform distribution

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DISTRIBUTION METHODS

	Methods	Advantages	Limitations
Surface Methods	General	Low energy costs Minimize aerosols and wind drift Small Buffer zones	Difficult to achieve uniform distribution Moderate erosion potential
	Gated Pipe	Same as General, plus: Easy to clean Easiest to balance hydraulically	Same as General, plus: Potential for freezing and settling
	Slotted or Perforated Pipe	Same as General	Same as Gated Pipe, plus: Small openings clog Most difficult to balance hydraulically
	Bubbling Orifices	Same as General, plus: Not subject to freezing/settling Only the orifice must be leveled	Same as General, plus: Difficult to clean when clogged
Low-pressure Sprays		Better distribution than surface methods Less aerosols than sprinkler Low energy costs	Nozzles subject to clogging More aerosols and wind drift than surface methods
Sprinklers		Most uniform distribution	High energy costs Aerosol and wind drift potential Large buffer zones

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SUITABLE GRASSES

	Common Name	Perennial or Annual	Rooting Characteristics	Method of Establishment	Growing Height (cm)
Cool Season Grass	Reed canary	Perennial	sod	seed	120-210
	Tall fescue	Perennial	bunch	seed	90-120
	Rye grass	Annual	sod	seed	60-90
	Redtop	Perennial	sod	seed	60-90
	KY bluegrass	Perennial	sod	seed	30-75
	Orchard grass	Perennial	bunch	seed	15-60
Warm Season	Common Bermuda	Perennial	sod	seed	30-45
	Coastal Bermuda	Perennial	sod	sprig	30-60
	Dallis grass	Perennial	bunch	seed	60-120
	Bahia	Perennial	sod	seed	60-120

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SUITABLE GRASSES

- Well established plant cover is essential for efficient performance of overland flow
- Primary purpose of plants is to facilitate treatment of wastewater
- Planting a mixture of different grasses usually gives best results
- Ryegrass used as a nurse crop; grows quickly until other grasses are established

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Suitable Grasses

- Cool Season Grass – plant from Spring through early Summer or early Fall to late Fall
- Warm Season Grass – generally should be planted from late Spring through early Fall
- Planting time affected by expected rainfall, location, climate, grass variety, etc
- Amount of seed required to establish cover depends on:
  - Expected germination
  - Type of grass
  - Water availability
  - Time available for crop development

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Overland Flow – Removal Efficiencies

Parameter	% Removal
BOD	92
Suspended Solids	92
Nitrogen	70-90
Phosphorus	40-80
Metals	50

- Treatment by oxidation and filtration
  - SS removed by filtration through vegetative cover
  - BOD oxidized by microorganisms in soil and on vegetative debris
  - Nitrogen removal by denitrification and plant uptake

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Subsurface Drip Irrigation

- Also known as trickle systems
- With drip systems, treated wastewater is applied to soil slowly and uniformly from a network of narrow tubing (0.5- to 0.75- inch diameter), usually plastic or polyethylene, placed either on the ground surface or below ground at shallow depths of 6 to 12 inches in the plant root zone.
- The wastewater is pumped through the tubes under pressure, but drips out slowly from a series of evenly-spaced openings.
- The openings may be simple holes or, as is the case in most subsurface systems, they may be fitted with turbulent flow or pressure-compensating emitter devices.
- These emitter designs are proprietary and vary depending on the manufacturer of the system.

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Subsurface Drip Irrigation

- Since subsurface drip systems release wastewater below ground, directly to plant roots, they irrigate more efficiently and have advantages over surface irrigation
  - Soil surface tends to stay dry, which means less evaporation and there is little chance for the water to come in contact with plant foliage, animals or humans

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Subsurface Clogging

- Drip system emitter clogging was more of a problem in the past than it is today.
- Root intrusion into the drip tubing and internal clogging from the buildup of sediment, suspended solids, algae, and bacterial slime have been diminished greatly by better pretreatment, filtration, disinfection, and new tubing and emitter designs.
- Most systems allow weekly or biweekly forward flushing of the tubes to scouring velocity to remove slime and sediment buildup.

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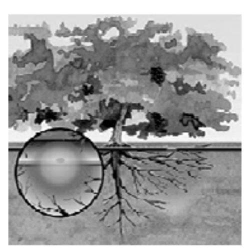
Subsurface Clogging



- US EPA approves the use of trifluralin to prevent root intrusion into the emitters
- One manufacturer has incorporated a chemical barrier into the tubing material

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Furrow vs. Subsurface

Less weed growth with subsurface drip irrigation

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Leach Fields

- Effluent from the septic tank flows by gravity or is pumped to a leach field for disposal.
- The wastewater effluent is absorbed by soil particles and moves both horizontally and vertically through the soil pores.
- The dissolved organic material in the effluent is removed by bacteria which live in the top ten feet of the soil.

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Leach Fields

- As the effluent moves through the soil, the temperature and chemical characteristics of the wastewater change and create an unfavorable habitat for most bacteria and viruses.
  - Therefore, as the septic tank effluent moves through the soil, organic material and microorganisms are removed.
- The wastewater generally percolates downward through soil and eventually enters a groundwater aquifer.
- A portion of the wastewater moves upwards by capillary action and is removed at the ground surface by evaporation and transpiration of plants.

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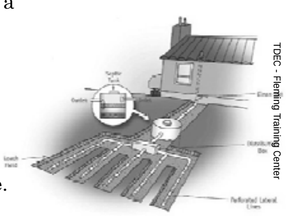
Leach Field Design

- A leach field consists of a series of four-inch diameter perforated distribution pipelines placed in two-to-three foot wide trenches.
- The perforated pipe is placed on top of gravel which is also used to backfill around the pipe.
- The gravel promotes drainage and reduces root growth near the pipeline.



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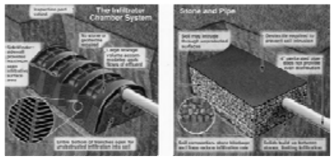
Leach Field Design

- Untreated building paper or straw is placed over the gravel to prevent fine soil particles from migrating into the gravel.
- The building paper or straw does not reduce the evapotranspiration of the wastewater.
- A minimum topsoil cover is placed over the gravel to protect the leach field, prevent contact with the wastewater and reduce infiltration from rain and snow.



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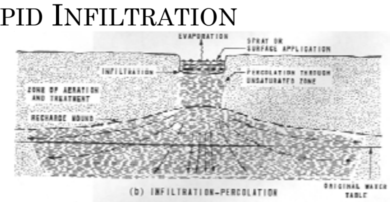
Rapid Infiltration



- Primary objective is to recharge the groundwater
- Wastewater is applied to spreading basins or seepage basins and allowed to percolate through the soil
- No plants are used or desired

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Rapid Infiltration

Picture of seepage basin in Nevada

Rapid Infiltration

- Effluent is discharged into a basin with a porous liner
- No plants needed or desired
- Primary objective is groundwater recharge
- Not approved in Tennessee
  - Due to Karst topography – cracks in limestone provide direct route of infiltration to groundwater and therefore no treatment achieved and groundwater may become contaminated

Land Treatment Limitations

- Sealing soil surface due to high SS in final effluent
  - More common in clay soils
  - Disk or plow field to break mats of solids
  - Apply water intermittently and allow surface mat to dry and crack
- Build up salts in soil
  - Salts are toxic to plants
  - Leach out the salts by applying fresh water
  - Rip up the soil 4 – 5 ft deep to encourage percolation

Land Treatment Limitations

- Excessive nitrate ions reach groundwater
  - Rain can soak soil so that no treatment is achieved
  - Do not apply nitrate in excess of crop's nitrogen uptake ability
  - Excessive nitrate in groundwater can lead to methylmoglobenemia (blue baby syndrome)
    - Too much nitrate consumed by child leads to nitrate in stomach and intestines where nitrogen is absorbed into bloodstream and it bonds to red blood cells preventing them from carrying oxygen.
    - Baby becomes oxygen deprived, turns blue and suffocates

Monitoring Requirements

Area	Test	Frequency
Effluent and groundwater or seepage	BOD	Two times per week
	Fecal coliform	Weekly
	Total coliform	Weekly
	Flow	Continuous
	Nitrogen	Weekly
	Phosphorus	Weekly
	Suspended solids	Two times per week
	pH	Daily
	Total dissolved solids (TDS)	Monthly
	Boron	Monthly
	Chloride	Monthly
Vegetation	- - - variable depending on crop - - -	
Soils	Conductivity	Two times per month
	pH	Two times per month
	Cation Exchange Capacity (CEC)	Two times per month

Water Quality Indicators

- Plant effluent analyzed prior to discharge:
  - In-stream: pH, D.O., temperature
  - In laboratory: BOD, COD, suspended solids, fecal coliforms, E. coli, N, P
- Disposal by dilution may require analysis of receiving stream upstream & downstream

Section 8

Safety

Safety

Safety

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

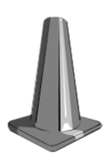
General Duty Clause

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

Before Leaving the Yard

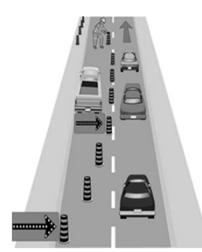
- Work assignments
- Equipment needs
- Equipment inspection
- Vehicle inspection
  - Mirrors and windows
  - Lights and horn
  - Brakes
  - Tires
  - Trailer hitch/safety chain

Traffic Safety

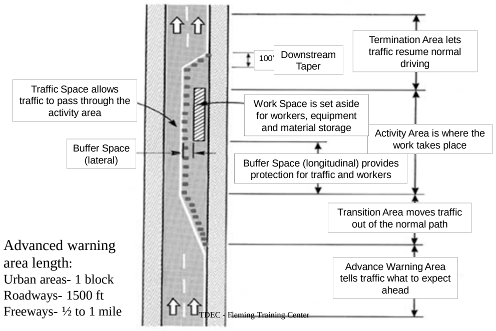


Traffic Control Zones

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



Traffic Control Zones



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

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Advanced Warning Area

- Must be long enough to give motorists adequate time to respond to particular work area conditions
- Typically ½ mile to one mile for highways
- 1500 feet for most other types of roads
- At least one block for urban streets

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Transition Area

- Not required if no lane or shoulder closure is involved
- Use of tapers
  - Channeling devices or pavement markings placed at an angle to direct traffic
- Traffic is channeled around the work area

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Buffer Space

- Provides margin of safety between transition zone and work area

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Work Area

- Ensure closed to traffic
- Shield by barriers
- Post **Road Construction Next ____ Miles** to inform drivers of the length of work area
- Do Not set up sign until work begins

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Termination Area

- Provides short distance for traffic to clear work area and return to normal traffic lanes
- Closing tapers are optional

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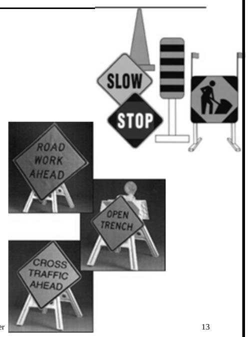
Traffic Signs

- Always use official signs
- Most permanent warning signs are diamond-shaped with black legends on yellow background
- Temporary signs have an orange background
- Best to use picture direction instead of wording
- Place end of construction signs about 500 feet beyond the end of the work site



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Channelizing Devices

- Warn and direct traffic away from workers
- Cones are 18-36 inches high and orange in color
- Drums are 2 orange and 2 white stripes

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Channelizing Devices

- Barricades are alternating orange and white strips marked with reflectors sloping downward in the direction traffic must turn
- Flaggers should wear lime green (or orange) and reflectors at night
- Should be positioned at least 100 feet from the work site always facing the oncoming traffic

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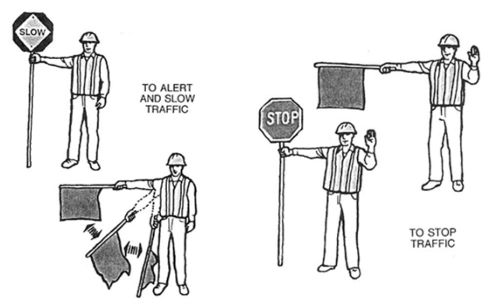
Flaggers



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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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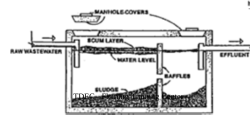
Confined Space Examples

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



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Equipment Needed for Confined Spaces

- Safety harness with lifeline, tripod and winch
- Electrochemical sensors
- Ventilation blower with hose

Equipment Needed for Confined Spaces

- PPE
- Ladder
- Rope
- Breathing Apparatus

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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

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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 duel to legal, illegal or accidental sources
  - Toxic or suffocating gases
    - Comes from natural breakdown of organic matter in wastewater or toxic discharges
  - Depletion or elimination of breathable oxygen
    - Oxygen deficient atmosphere

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Hydrogen Sulfide – H_2S

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

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Hydrogen Sulfide – H_2S

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

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Hydrogen Sulfide – H_2S

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Methane Gas – CH_4

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

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Methane Gas – CH_4

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

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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

Carbon Monoxide - CO

Oxygen – O_2

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

Oxygen – O_2

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

Oxygen – O_2

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

Oxygen – O_2

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

Atmospheric Alarm Units

- Continuously sample the atmosphere
- Test atmospheres from manhole areas prior to removing the cover if pick holes available
- Remove manhole covers with non sparking tools
- **Test for oxygen first**
- **Combustible gases second (methane at 5000 ppm)**

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Atmospheric Alarm Units

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

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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

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Lockout / Tagout

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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 When Lockout of Equipment

- 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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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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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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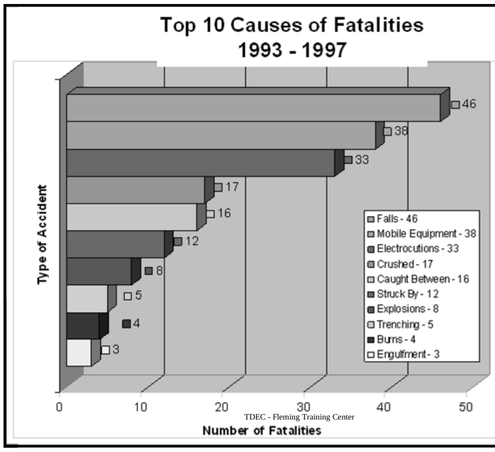
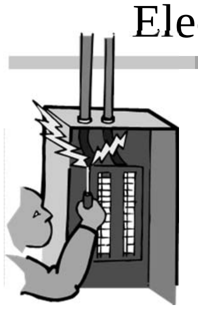


Electrical Safety



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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

Fire Protection Equipment

- Fire extinguishers shall be located where they are readily accessible.
- Shall be fully charged and operable at all times.
- All fire fighting equipment is to be inspected at least annually.

Fire Protection Equipment

- Portable fire extinguishers inspected at least monthly and records kept.
- Hydrostatic testing on each extinguisher every five years.
- Fire detection systems tested monthly if batter operated.

Types of Fire Extinguishers

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

Types of Fire Extinguishers

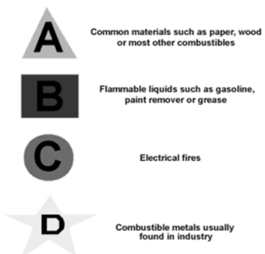
- Class C 
  - Use for areas electrical
  - Best is carbon dioxide extinguisher.
  - Using water to extinguish a class C fire risks electrical shock
- Class D
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire.

Types of Fire Extinguishers

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

Types of Fire Extinguishers

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

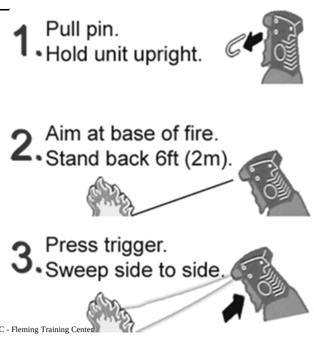


Fire Extinguishers

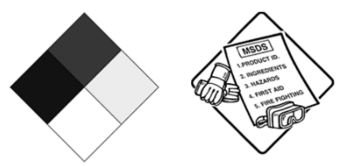
- To operate a fire extinguisher, remember the word PASS
  - **P**ull the pin. Hold the extinguisher with the nozzle pointing away from you
  - **A**im low. Point the extinguisher at the base of the fire.
  - **S**queeze the lever slowly and evenly.
  - **S**weep the nozzle from side-to-side.

Fire Extinguishers

Combo Extinguisher



Chemical Safety



Personal Protective Equipment

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

Material Safety Data Sheets

- Also 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

NFPA

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

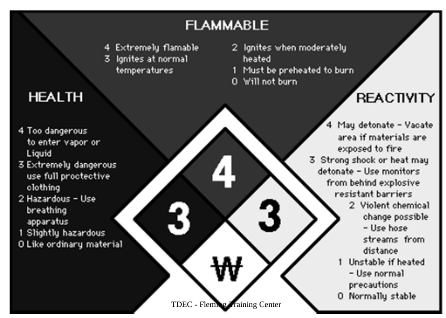
RTK Labels

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

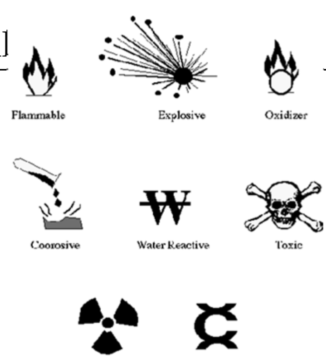
Degrees of Hazard

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

Chemical Label



Special



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

Name of Gas and Chemical Formula	Spec. Gravity	Explosive Range Lower Limit	Explosive Range Upper Limit	Common Properties	Physiological Effects	Most Common Source in Sewers	Method of Testing
Oxygen, O_2	1.11	Not flammable		Colorless, odorless, tasteless, non-poisonous gas. Supports combustion	Normal air contains 20.93% of O_2. If it becomes less than 19.5%, do not enter space without respiratory protection.	Oxygen depletion from poor ventilation and absorption or chemical consumption of available O_2.	Oxygen deficiency indicator.
Carbon Monoxide, CO	0.97	12.5	74.2	Colorless, odorless, nonirritating, tasteless, flammable, explosive	Hemoglobin of blood has strong affinity for gas causing oxygen starvation. 0.2-0.25% causes unconsciousness in 30 minutes.	Manufactured fuel gas.	CO ampoules.
Methane, CH_4	0.55	5.0	15.0	Colorless, tasteless, odorless, non-poisonous, flammable, explosive	Acts mechanically to deprive tissues of oxygen. Does not support life. A simple asphyxiant.	Natural gas, marsh gas, manufactured fuel gas, gas found in sewers.	1. Combustible gas indicator. 2. Oxygen deficiency indicator.
Hydrogen Sulfide, H_2S	1.19	4.3	46.0	Rotten egg odor in small concentrations, but sense of smell rapidly impaired. Odor not evident at high concentrations. Colorless, flammable, explosive, poisonous	Death in a few minutes at 0.2%. Paralyzes respiratory center.	Petroleum fumes, from blasting, gas found in sewers.	1. Hydrogen sulfide analyzer 2. Hydrogen sulfide ampoules.
Carbon Dioxide, CO_2	1.53	Not flammable		Colorless, odorless, nonflammable. Not generally present in dangerous amounts unless there is already a deficiency of oxygen	10% can't be tolerated for more than a few minutes. Acts on nerves of respiration.	Issues from carbonaceous strata. Gas found in sewers.	Oxygen deficiency indicator.
Chlorine, Cl_2	2.5	Not flammable Not explosive		Greenish yellow gas or amber color liquid under pressure. Highly irritating and penetrating odor. Highly corrosive in presence of moisture.	Respiratory irritant, irritating to eyes and mucous membranes. 30 ppm causes coughing. 40-60 ppm dangerous in 30 minutes. 1,000 ppm apt to be fatal in a few breaths.	Leaking pipe connections. Overdosage.	Chlorine detector. Odor. Strong ammonia on swab gives off white fumes.
Sulfur Dioxide, SO_2	2.3	Not flammable Not explosive		Colorless compressed liquefied gas with a highly pungent odor. Highly corrosive in presence of moisture.	Respiratory irritant, irritating to eyes, skin and mucous membranes. Only slightly less toxic than chlorine.	Leaking pipe and connections.	Sulfur dioxide detector. Odor. Strong ammonia on swab gives off white fumes.

Sewer Safety Vocabulary

______1. Aerobic
______2. Ambient
______3. Anaerobic
______4. Competent Person
______5. Confined Space
______6. Confined Space, Non-Permit
______7. Confined Space, Permit-Required (Permit Space)
______8. Decibel
______9. Engulfment
______10. Fit Test
______11. IDLH
______12. Mercaptans
______13. Olfactory Fatigue
______14. Oxygen Deficiency
______15. Oxygen Enrichment
______16. Septic
______17. Sewer Gas
______18. Spoil

A. A condition where atmospheric or dissolved molecular oxygen is not present in the aquatic (water) environment.
B. A unit for expressing the relative intensity of sounds on a scale from zero for the average least perceptible sound to about 130 for the average level where sound causes pain to humans. Abbreviated dB.
C. A space which is large enough and so configured that an employee can bodily enter and perform assigned work; has limited or restricted means for entry or exit and it not designed for continuous employee occupancy.
D. Compounds containing sulfur that have an extremely offensive skunk-like odor; also sometimes described as smelling like garlic or onions.
E. The use of a procedure to qualitatively or quantitatively evaluate the fit of a respirator on an individual.
F. An atmosphere containing oxygen at a concentration of less than 19.5% by volume.
G. A condition where atmospheric or dissolved molecular oxygen is present in the aquatic (water) environment.
H. A condition produced by anaerobic bacteria. If severe, the wastewater produces hydrogen sulfide, turns black, gives off foul odors, contains little or no dissolved oxygen and the wastewater has a high oxygen demand.
I. Immediately Dangerous to Life or Health. 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.
J. Gas in collection lines (sewers) that result from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases.
K. 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.
L. Excavated material such as soil from the trench of a sewer.

M. 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.
N. A condition where a person's nose, after exposure to certain odors, is no longer able to detect the odor.
O. A confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm.
P. An atmosphere containing oxygen at a concentration of more than 23.5% by volume.
Q. Surrounding. Ambient or surrounding atmosphere.
R. A confined space that has one or more of the following characteristics: contains or has the 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; or contains any other recognized serious safety of health hazard.

Safety Questions

1. How can traffic be warned of your presence in the street?

2. What is the <u>purpose</u> of the advance warning area?

3. List <u>six</u> types of traffic control devices.

4. How can explosive or flammable atmosphere develop in a collection system?

5. What types of hazardous atmospheres should an atmospheric test unit be able to detect in confined spaces?

6. If operators are scheduled to work in a manhole, when should the atmosphere in the manhole be tested?

7. When a blower is used to ventilate a manhole, where should the blower be located?

8. List the safety equipment recommended for use when operators are required to enter a confined space.

9. What are some early signs that an operator working in a manhole or other confined space is not getting enough oxygen?

10. How can collection system operators be protected from injury by the accidental discharge of stored energy?

11. How can collection system operators protect their hearing from loud noises?

12. How would you extinguish a fire?

Answers to Vocabulary and Questions

Vocabulary:

1. G	7. R	13. N
2. Q	8. B	14. F
3. A	9. M	15. P
4. K	10. E	16. H
5. O	11. I	17. J
6. D	12. D	18. L

Questions:

1. Traffic can be warned of your presence in a street by signs, flags or flashers and vehicles with rotating flashing lights. Vehicle-mounted traffic guides are also helpful. Flaggers can be used to alert drivers and to direct traffic around a work site.
2. The purpose of the advance warning area is to give drivers enough time to see what is happening ahead and adjust their driving patterns.
3. Types of traffic control devices include: signs, barricades, traffic cones, drums, vertical panels, lighting devices, advance warning arrow boards, flashing vehicle lights, high level warning devices and portable changeable message signs. Flaggers may also be used to control traffic.
4. 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.
5. An atmospheric test unit should be able to detect flammable and explosive gases, toxic gases and oxygen deficiency.
6. 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.
7. 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).
8. 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; firs-aid kit; soap, water, paper towels and a trash bag
9. 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
10. Operators can be protected from injury due to the accidental discharge of stored energy by following prescribed lockout/ tagout procedures.
11. Collection system operators can protect their hearing from loud noises by use of approved earplugs, earmuffs and/or person protective equipment.
12. To extinguish a fire, first identify the material burning (class or category) and then use the appropriate method to put out the fire.

Section 9

Pumps

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WASTEWATER PUMPS AND EQUIPMENT MAINTENANCE

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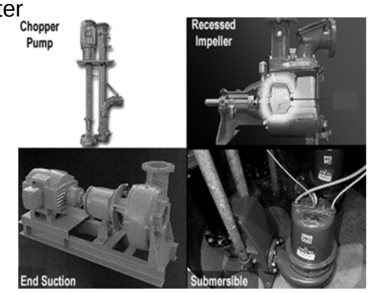
Types of Pumps

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



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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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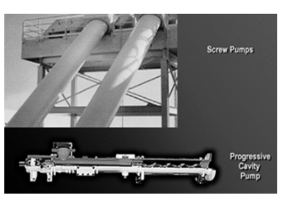
Positive-Displacement Pumps

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



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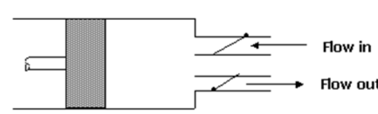
Positive-Displacement Pumps

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



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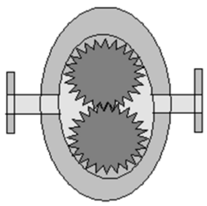
Positive-Displacement Pumps



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

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Screw Pumps

- 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

Incline screw pumps handle large solids without plugging

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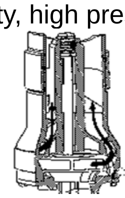
Velocity Pumps

- 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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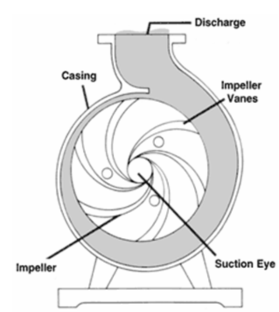
Velocity Pump Design Characteristics

- 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



Velocity Pump Design Characteristics

- Mixed - flow designs
  - Has features of axial and radial flow
  - Works well for water with solids

Centrifugal Pump

- Basically a very simple device: an impeller rotating in a casing
- The impeller is supported on a shaft, which in turn, is supported by bearings
- Liquid coming in at the center (eye) of the impeller is picked up by the vanes and by the rotation of the impeller and then is thrown out by centrifugal force into the discharge

Most Common Centrifugal Pumps

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

Advantages of Centrifugal Pumps

- Wide range of capacities
- Uniform flow at a constant speed and head
- Low cost
- Ability to be adapted to various types of drivers
- Moderate to high efficiency
- No need for internal lubrication

Disadvantages of Centrifugal Pumps

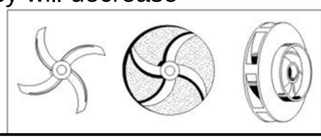
- Efficiency is limited to very narrow ranges of flow and head
- Flow capacity greatly depends on discharge pressure
- Generally no self-priming ability
- Can run backwards if check valve fails and sticks open
- Potential impeller damage if pumping abrasive water

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

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



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.

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.

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

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

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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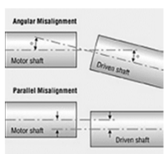
Misalignment of Pump & Motor

- 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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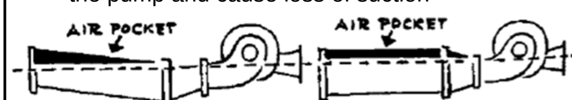
Let's Build a Centrifugal Pump

- 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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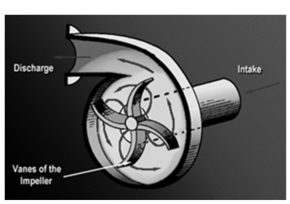
Let's Build a Centrifugal Pump

- We contain and direct the spinning liquid with a casing
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape



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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

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

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

Stuffing Box

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

Packing vs. Mechanical Seals

- If a pump has packing, water should drip slowly

- If it has a mechanical seal, no leakage should occur

Packing Rings

- Asbestos or metal ring lubricated with Teflon or graphite
- Provides a seal where the shaft passes through the pump casing in order to keep air form being drawn or sucked into the pump and/or the water being pumped from coming out

Packing Rings

- If new packing leaks, stop the motor and repack the pump
- Pumps need new packing when the gland or follower is pulled all the way down
- The packing around the shaft should be tightened slowly, over a period of **several hours** to just enough to allow an occasional drop of liquid (**20-60 drops per minute** is desired)
  - Leakage acts as a lubricant
- Stagger joints 180º if only 2 rings are in stuffing box, space at 120º for 3 rings or **90º if 4 rings or more are in set**

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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

- Advantages
  - Less expensive, short term
  - Can accommodate some looseness

- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and replacement

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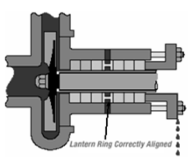
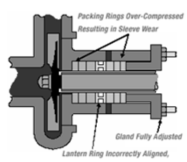
Lantern Rings

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





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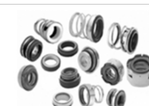
Mechanical Seals



- 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 160ºF (71ºC)
- 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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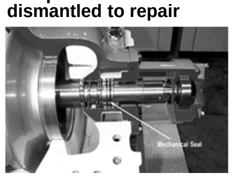
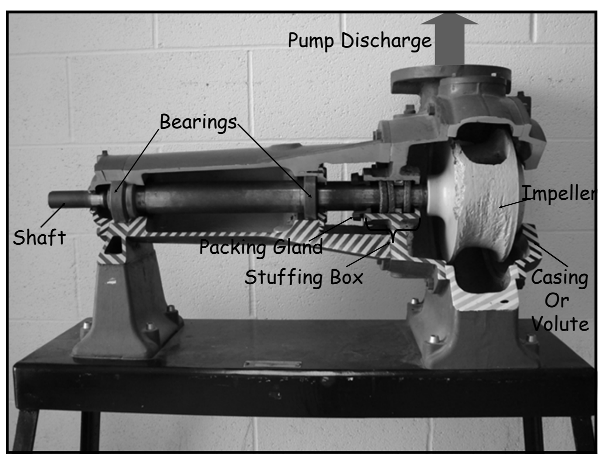
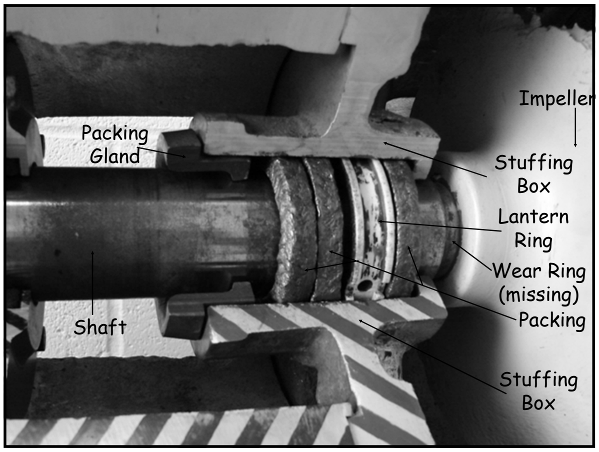
Mechanical Seal vs. Packing Rings

- Advantages
  - **Last 3-4 years**, which can be a savings in labor
  - Usually there is **no damage to shaft sleeve**
  - **Continual adjusting, cleaning or repacking is not required**
  - Possibility of flooding lift station because a pump has thrown its packing is eliminated; however mechanical seals can fail and lift stations can be flooded
- Disadvantages
  - **High initial cost**
  - **Great skill and care needed to replace**
  - When they fail, the pump must be shut down
  - **Pump must be dismantled to repair**







Self-Priming Pump Basics – Part 1

Self-Priming Pump Basics – Part 2

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

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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 motor by feel

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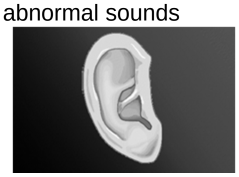
Monitoring Operational Variables

- 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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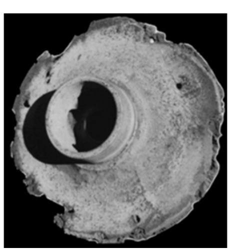
Monitoring Operational Variables



- 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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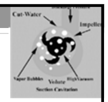
Monitoring Operational Variables

- 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

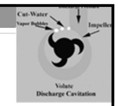
Suction Cavitation



- Suction Cavitation occurs when the pump suction is under a low pressure/high vacuum condition where the liquid turns into a vapor at the eye of the pump impeller.
- This vapor is carried over to the discharge side of the pump where it no longer sees vacuum and is compressed back into a liquid by the discharge pressure.
- This imploding action occurs violently and attacks the face of the impeller.
- An impeller that has been operating under a suction cavitation condition has large chunks of material removed from its face causing premature failure of the pump.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

Discharge Cavitation



- Discharge Cavitation occurs when the pump discharge is extremely high.
- It normally occurs in a pump that is running at less than 10% of its best efficiency point.
- The high discharge pressure causes the majority of the fluid to circulate inside the pump instead of being allowed to flow out the discharge.
- As the liquid flows around the impeller it must pass through the small clearance between the impeller and the pump cutwater at extremely high velocity.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

Discharge Cavitation

- This velocity causes a vacuum to develop at the cutwater similar to what occurs in a venturi and turns the liquid into a vapor.
- A pump that has been operating under these conditions shows premature wear of the impeller vane tips and the pump cutwater.
- In addition due to the high pressure condition premature failure of the pump mechanical seal and bearings can be expected and under extreme conditions will break the impeller shaft.

Information from http://www.pumpworld.com/Cavitation_discharge.htm

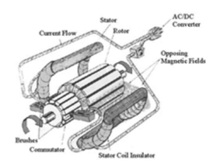
Inspection and Maintenance

- Inspection and maintenance prolongs life of pumps
  - Checking operating temperature of bearings
  - Checking packing glands
  - Operating two or more pumps of the same size alternatively to equalize wear
  - Check parallel and angular alignment of the coupling on the pump and motor
    - A feeler gauge, dial indicator calipers are tools that can be used to check proper alignment
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

Inspection: Impellers

- Wear on impeller and volute
- Cavitation marks
- Chips, broken tips, corrosion, unusual wear
- Tightness on shaft
- Clearances
- Tears or bubbles (if rubber coated)

Pump Won't Start?



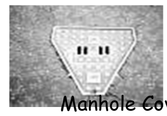
- Incorrect power supply
- No power supply
- Incorrectly connected
- Fuse out, loose or open connection
- Rotating parts of motor jammed mechanically
- Internal circuitry open

Pump Safety

- Machinery should always be turned off and locked out/tagged out before any work is performed on it
- Make sure all moving parts are free to move and all guards in place before restarting
- Machinery creating excessive noise shall be equipped with mufflers.

Pump Safety: Wet Wells

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




Manhole Cover, London

Pump Facts

- Sewer pumps used in a lift station shall be capable of passing at least a 3 inch diameter sphere
- Pump suction and discharge opening shall be no less 4 inches in diameter
- Each pump must have its own intake line
- Wet wells should be designed to avoid turbulence near the intakes
- The velocity in the suction line of a pump should not exceed 6 fps
- The velocity in the discharge line of a pump should not exceed 8 fps

Pump Facts

- Ventilation in wet wells shall provide for at least 12 complete air changes per hour if continuous and 30 changes per hour if intermittent
- Ventilation in dry wells shall provide for at least 6 complete air changes per hour if continuous and 30 changes per hour if intermittent

Pump Facts

- The maximum recommended suction lift for a pump in a pumping station is 15 feet
- Minimum force main size is 4 inches
- A gasoline powered centrifugal pump in good condition can lift water (suction lift) up to 18 inches of mercury
  - 20 feet of possible suction lift
- Head is the amount of energy possessed by water at any point in a hydraulic system
  - Feet divided by 2.31 equals psi (pounds per square inch) in head

Types of Pumps Found in Collection Systems

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

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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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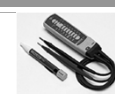
Tools, Meters & Testers



- 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

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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

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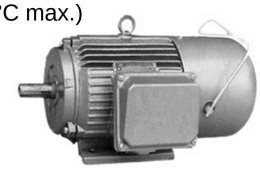
Batteries

- 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

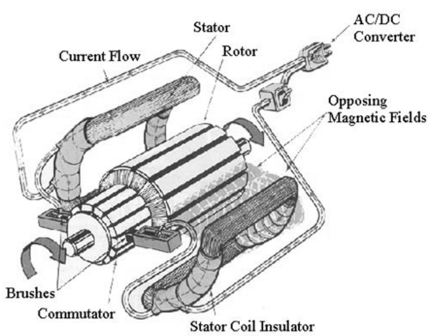
- Most common pump driver in wastewater pump stations
- Motors pull the most current on start up.
- Malfunction due to:
  - Thermal overload (40°C max.)
  - Contaminants
  - Single phasing
  - Old age
  - Rotor failure



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

Motors

- Routine cleaning of pump motors includes:
  - Checking alignment and balance
  - Checking brushes
  - Removing dirt and moisture
  - Removal of obstructions that prevent air circulation
- Cool air extends the useful life of motors
- A motor (electrical or internal combustion) used to drive a pump is called a prime mover
- The speed at which the magnetic field rotates is called the motor synchronous speed and is expressed in rpm

Motors

- If a variable speed belt drive is not used for 30 days or more, shift the unit to minimum speed setting
- Emory cloth should not be used on electric motor components because it is electronically conductive and may contaminate parts
- Ohmmeters used to test a fuse in a motor starter circuit
- The most likely cause of a three-phase motor not coming to speed after starting – the motor has lost power to one or more phases

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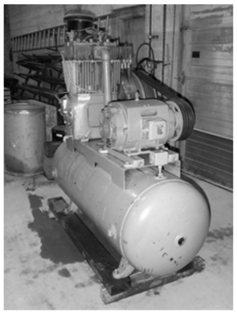
Compressors



- 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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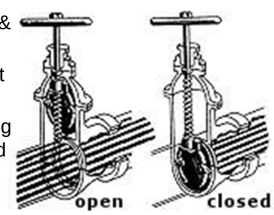
Valves

- 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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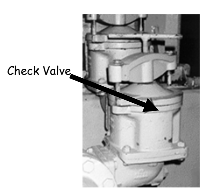
Valves

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



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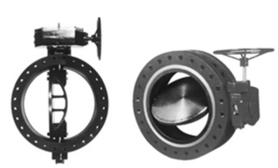
Valves

- 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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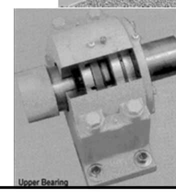
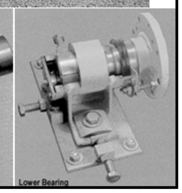
Bearings

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





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Bearings

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

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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

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.

Pump and Motor 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?

15. In what type of pump are centrifugal force and the lifting action of the impeller vanes combined to develop the total dynamic head?

16. Identify one unique safety advantage that velocity pumps have over positive-displacement pumps.

17. What is the multistage centrifugal pump? What effects does the design have on discharge pressure and flow volume?

18. What are two types of vertical turbine pump, as distinguished by pump and motor arrangement, which are commonly used to pump ground water from wells?

19. What type of vertical turbine pump is commonly used as an inline booster pump?

20. Describe the two main parts of a jet pump.

21. What is the most common used of positive-displacement pumps in water plants today?

22. What is the purpose of the foot valve on a centrifugal pump?

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

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

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

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

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

28. Define the term “racking” as applied to pump and motor control.

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

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

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

32. Why should emery cloth not be used around electrical machines?

33. What are the most likely causes of vibration in an existing pump installation?

34. What can happen when a fuse blows on a single leg of a three-phase circuit?

35. Name at least three common fuels for internal-combustion engines.

36. List the type of information that should be recorded on a basic data card for pumping equipment.

37. What is the first rule of safety when repairing electrical devices?

Answers:

1. B	4. A	7. B	10. C
2. C	5. C	8. E	11. A
3. C	6. D	9. B	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. The jet pump consists of a centrifugal pump at the ground surface and an ejector nozzle below the water level.
21. Positive-displacement pumps are generally used in water plants to feed chemical into the water supply.
22. The foot valve prevents water from draining when the pump is stopped, so the pump will be primed when restarted.
23. The bolts holding the two halves of the casing together are removed and the top half is lifted off.
24. 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.
25. (1) Packing rings are made of graphite-impregnated cotton, flax, or synthetic materials. They are inserted in the stuffing box and held snuggly 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.
26. The pump impeller is mounted directly on the shaft of the motor.
27. 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.
28. Racking refers to erratic operation that may result from pressure surges when the pump starts; it is often a problem when the pressure sensor for the pump control is located too close to the pump station.
29. During start-up.
30. (1) Increase system efficiency; (2) spread the pumping load more evenly throughout the day; (3) reduce power-factor charges
31. The bearings may run hot, and excess grease or oil could run out and reach the motor windings, causing the insulation to deteriorate.
32. The abrasive material on emery cloth is electrically conductive and could contaminate electrical components.
33. Imbalance of the rotating elements, bad bearings and misalignment
34. A condition called single-phasing can occur, causing the motor windings to overheat and eventually fail.
35. gasoline, propane, methane, natural gas and diesel oil (diesel fuel)
36. make, model, capacity, type, date and location installed, and other information for both the driver (motor) and the driven unit (pump)
37. 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 Vocabulary

______1. Amperage
______2. Brinelling
______3. Cavitation
______4. Circuit
______5. Circuit Breaker
______6. Current
______7. Fuse
______8. Jogging
______9. Mandrel
______10. Megger
______11. Resistance
______12. Voltage

A. A safety device in an electric circuit that automatically shuts off the circuit when it becomes overloaded. The device can be manually reset.
B. Tiny indentations (dents) high on the shoulder of the bearing race or bearing. A type of bearing failure.
C. A special tool used to push bearing in or to pull sleeves out. Also can be a gage used to measure for excessive deflection in a flexible conduit.
D. 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.
E. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. 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.
F. The electrical pressure available to cause a flow of current (amperage) when an electric circuit is closed.
G. The frequent starting and stopping of an electric motor.
H. A movement or flow of electricity.
I. An instrument used for checking the insulation resistance on motors, feeders, bus bar systems, grounds and branch circuit wiring.
J. 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.
K. That property of a conductor or wire that opposes the passage of a current, thus causing electrical energy to be transformed into heat.
L. The complete path of en electric current, including the generating apparatus or other source; or, a specific segment or section of the complete path.

Equipment Maintenance 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 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 are the advantages of a pneumatic ejector?

9. What is the purpose of packing?

10. What is the purpose of the lantern ring?

11. How often should impellers be inspected for wear?

12. What is the purpose of wear rings?

13. What causes cavitation?

14. How often should the suction filter of a compressor be cleaned?

15. How often should the condensate from the air receiver be drained?

16. What is the <u>purpose</u> of lubrication?

17. What precautions must be taken before oiling or greasing equipment?

18. 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

19. The <u>greatest cause</u> of electric motor failures is
    a. Bearing failures
    b. Contaminants
    c. Overload (thermal)
    d. Single phasing

20. 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

21. 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

22. Leakage of water around a packing on a centrifugal pump is important because it acts as a(n):
    a. Adhesive
    b. Lubricant
    c. Absorbent
    d. Backflow preventer
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    a. 60°C
    b. 150°F
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    c. Aeration
    d. Combustion

31. 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

32. 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

33. Positive displacement pumps are rarely used for water distribution because:
    a. They require too much maintenance
    b. They are no longer manufactured
    c. They require constant observation
    d. Centrifugal pumps are much more efficient

34. Another name for double-suction pump is
    a. Double-jet pump
    b. Reciprocating pump
    c. Horizontal split-case pump
    d. Double-displacement pump

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

Answers to Vocabulary and Questions

Vocabulary:

1. J
2. B
3. E
4. L
5. A
6. H
7. D
8. G
9. C
10. I
11. K
12. F

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. To pump fluctuating flows with large solids and rags.
8. They can handle limited flows with relatively large solids. Maintenance is not as complicated as the maintenance on most pumps; however, maintenance must be performed when scheduled.
9. To keep air from leaking in and water leaking out where the shaft passes through the casing
10. 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
11. Every 6 months or annually, depending on pumping conditions; if grit, sand or other abrasive material is being pumped, inspections should be more frequent
12. They protect the impeller and pump body from damage due to excessive wear.
13. 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.
14. 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.
15. Daily
16. To reduce friction between two surfaces and to remove heat caused by friction
17. Shut it off, lock it out and tag it so it can’t be started unexpectedly and injure you
18. D
19. C
20. C
21. C
22. B
23. C
24. C
25. A
26. C
27. D
28. B
29. E
30. B
31. C
32. A
33. D
34. C
35. A

Section 10

Math

1

Area, Volume and Conversions

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2

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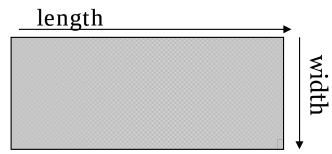
Area

- Surface of an object
- Two dimensional
- Measured in:
  - Square inches
  - Square feet
  - Square meters, etc.

Area Formulas

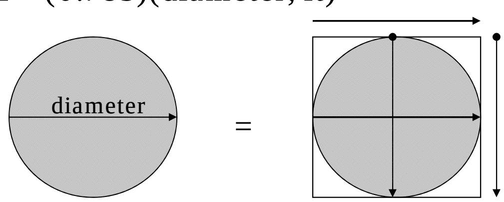
- Rectangle

A = (length, ft)(width, ft)



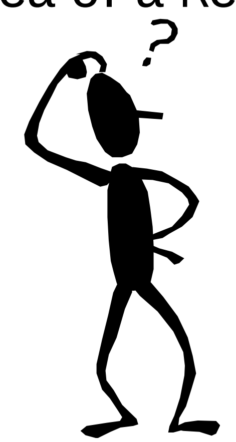
- Circle

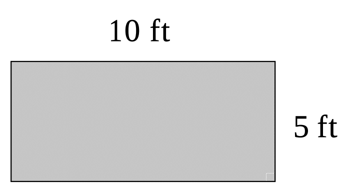
$A = (0.785)(\text{diameter, ft})^2$



Diameter is equal to length and width of a square and a circle takes up 78.5% of square

Area of a Rectangle



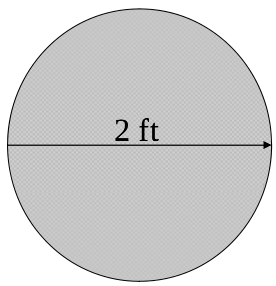


A = (l, ft)(w, ft)

A = (10 ft)(5 ft)

$A = 50\ ft^2$

Area of a Circle



Diameter = 2 ft

$A = (0.785)(D, ft)^2$

$A = (0.785)(2ft)(2ft)$

$A = 3.14\ ft^2$

Volume

- The amount of space an object occupies
- Volume = (area)(third dimension) or

$$V = (l)(w)(d)$$

- Measured in:
  - Cubic inches
  - Cubic feet
  - Gallons
  - Acre-feet, etc.

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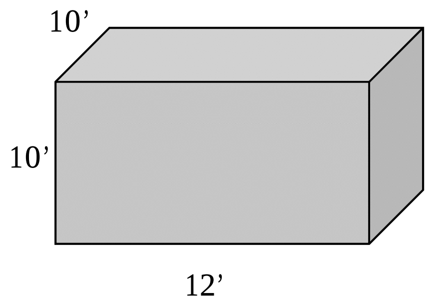
Volume of a Rectangular Tank, ft^3

V = (length, ft)(width, ft)(depth, ft)

V = (12 ft)(10ft)(10ft)

V = 1200 ft^3



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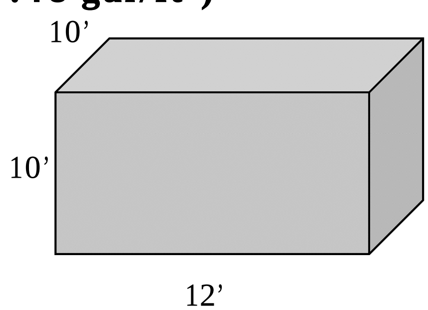
Volume of a Rectangular Tank, gal

V, ft^3 = 1200 ft^3

V, gal = (Volume, ft^3)(7.48 gal/ft^3)

V, gal = (1200 ft^3)(7.48)

V, gal = 8976 gal

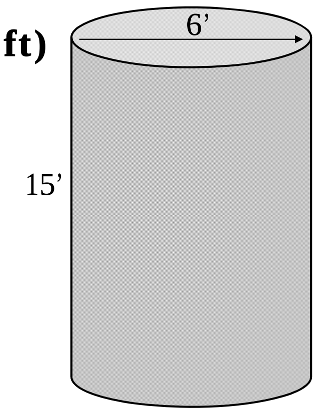


Volume of a Cylinder, ft^3

$V = (0.785)(D, ft)^2(height, ft)$

$V = (0.785)(6\ ft)(6\ ft)(15\ ft)$

$V = 424\ ft^3$



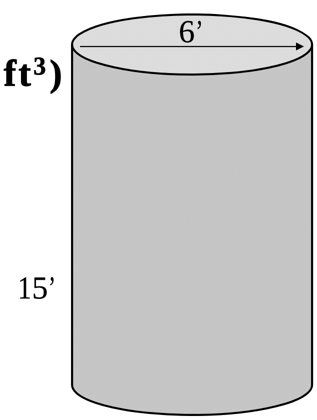
Volume of a Cylinder, gallons

$V, ft^3 = 424\ ft^3$

$V, gal = (Volume, ft^3)(7.48\ gal/ft^3)$

$V, gal = (424\ ft^3)(7.48)$

$V, gal = 3171.52\ gal$



11

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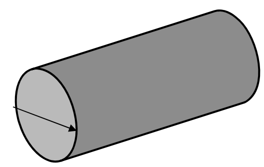
Note

- When calculating area and volume, if you are given a pipe diameter in inches, convert it to feet.

$$8 \not{in}. \times \frac{1 \text{ ft}}{12 \not{in}} = 0.6667 \text{ ft}$$



Diameter = 8 in

12

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Conversions

- Need to know:
- The number that relates the two units
  - Ex: 12 inches in a foot, 454 grams in a pound, 3785 mL in a gallon
- Whether to multiply or divide
  - Ex: smaller to larger or larger to smaller

13

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Conversions

Conversion Factors

1 acre	=	43,560 ft^2
1 foot of head	=	0.433 psi
1 psi	=	2.31 feet of head
1 yd^3	=	27 ft^3
1 gal	=	3.785 Liters
1 gallon of water	=	8.34 lbs
1 cubic foot of water	=	7.48 gallons
1 lb	=	453.6 grams
1 mile	=	5280 feet
1%	=	10,000 $^{mg}/_{L}$

→ Multiply

- Just looking at the units, if you are given miles and you need feet, we are going from left to right on the page, therefore multiply

14

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Conversions

- You have just laid ¼ mile of sewer line. How many feet is this?

¼ = 0.25 miles

(0.25 miles)(5280 feet/mile) = 1320 feet

15

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Percent to Decimal

Percent = per one hundred

20%	=	20/100	=	0.20
5%	=	5/100	=	0.05
12.25%	=	12.25/100	=	0.1225
0.5%	=	0.5/100	=	0.005

Move decimal 2 places to the left.

16

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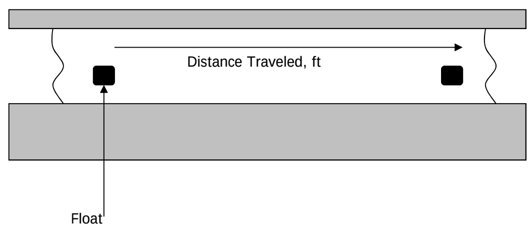
Velocity

- Distance per time
- Measured in:
  - Miles per hour
  - Feet per second
  - Feet per minute

Velocity Formulas

- Velocity, ft/sec = $\frac{\text{distance traveled, ft}}{\text{time, sec}}$
- Velocity, ft/min = $\frac{\text{distance traveled, ft}}{\text{time, min}}$



Velocity

- A cork is placed in a channel and travels 400 feet in 2 minutes and 25 seconds. What is the velocity of the wastewater in the channel, ft/min?

- 25 seconds/60 = 0.4167
- Vel = $\frac{400 \text{ ft}}{2.4167 \text{ min}}$ = 165.5 ft/min

19

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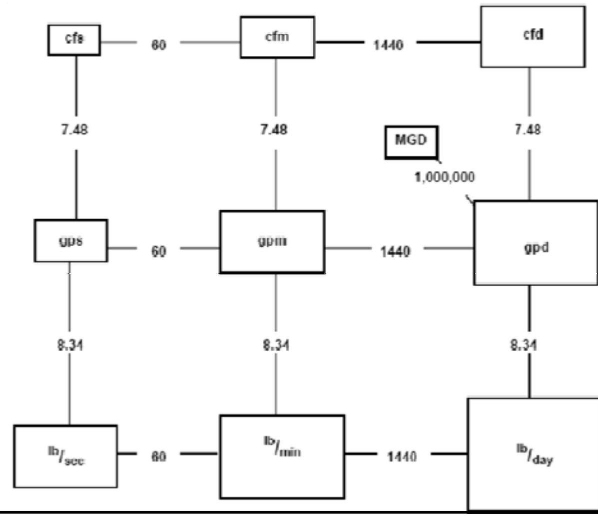
Flow Conversions – Box Method

Small to Big → multiply

Big to Small → divide



20

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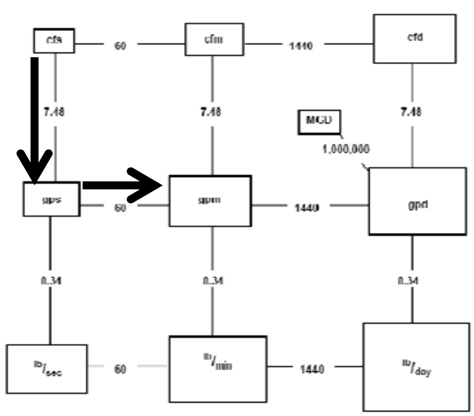
Flow Conversions – Box Method

- Convert a flow of 2.7 cfs to gpm.



$(2.7)(7.48)(60) = 1211$ gpm

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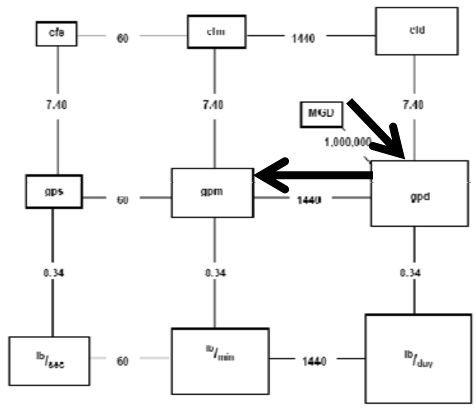
Flow Conversions – Box Method

- Convert a flow of 1.0 MGD to gpm.



$$\frac{(1.0)(1{,}000{,}000)}{1440} = 694 \text{ gpm}$$

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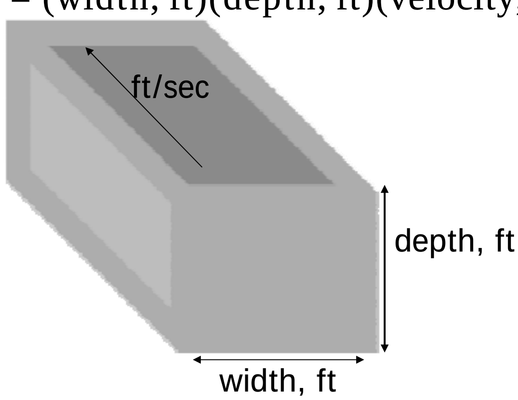
TDEC - Fleming Training Center

Flow in a Channel

- Q, ft^3/sec = (Area, ft^2)(Velocity, ft/sec)
- Q, ft^3/sec = (width, ft)(depth, ft)(velocity, ft/sec)



23

TDEC - Fleming Training Center

Flow in a Channel

- A channel 36 inches wide has water flowing to a depth of 2 feet. If the velocity of the water is 1.2 ft/sec, what is the flow in the channel in ft^3/sec?

- Q = (3ft)(2 ft)(1.2 ft/sec)

  = 7.2 ft^3/sec

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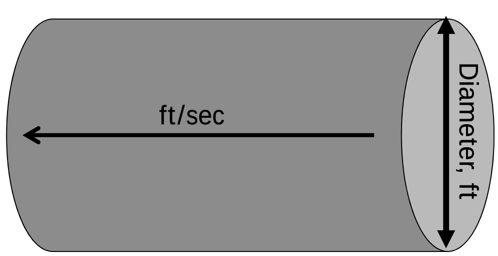
TDEC - Fleming Training Center

Flow in a Pipe Flowing Full

- Q, ft^3/sec = (Area, ft^2)(Velocity, ft/sec)
- Q, ft^3/sec = (0.785)(Diameter, ft)^2(velocity, ft/sec)



25

TDEC - Fleming Training Center

Flow in a Pipe Flowing Full

- The flow through a 10-inch diameter sewer is flowing full at 2.5 ft/sec. What is the flow rate in ft^3/sec and gal/day?

- Q = (0.785)(0.8333)(0.8333)(2.5) = 1.36 ft^3/sec

- (1.36 ft^3/sec)(7.48 gal/ft^3)(60 sec/min)(1440 min/day) = 880,699.5 gal/day

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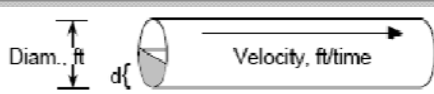


TDEC - Fleming Training Center

Flow in a Partially Full Pipe

- Q = (factor from d/D table)(Diameter, ft)^2(vel, fps)

depth/Diameter Table							
0.01	0.0013	0.26	0.1623	0.51	0.4027	0.76	0.6404
0.02	0.0037	0.27	0.1711	0.52	0.4127	0.77	0.6489
0.03	0.0069	0.28	0.1800	0.53	0.4227	0.78	0.6573
0.04	0.0105	0.29	0.1890	0.54	0.4327	0.79	0.6655
0.05	0.0147	0.30	0.1982	0.55	0.4426	0.80	0.6736
0.06	0.0192	0.31	0.2074	0.56	0.4526	0.81	0.6815
0.07	0.0242	0.32	0.2167	0.57	0.4625	0.82	0.6893
0.08	0.0294	0.33	0.2260	0.58	0.4724	0.83	0.6969
0.09	0.0350	0.34	0.2355	0.59	0.4822	0.84	0.7043
0.10	0.0409	0.35	0.2450	0.60	0.4920	0.85	0.7115
0.11	0.0470	0.36	0.2546	0.61	0.5018	0.86	0.7186
0.12	0.0534	0.37	0.2642	0.62	0.5115	0.87	0.7254
0.13	0.0600	0.38	0.2739	0.63	0.5212	0.88	0.7320
0.14	0.0668	0.39	0.2836	0.64	0.5308	0.89	0.7384
0.15	0.0739	0.40	0.2934	0.65	0.5404	0.90	0.7445
0.16	0.0811	0.41	0.3032	0.66	0.5499	0.91	0.7504
0.17	0.0885	0.42	0.3130	0.67	0.5594	0.92	0.7560
0.18	0.0961	0.43	0.3229	0.68	0.5687	0.93	0.7612
0.19	0.1039	0.44	0.3328	0.69	0.5780	0.94	0.7662
0.20	0.1118	0.45	0.3428	0.70	0.5872	0.95	0.7707
0.21	0.1199	0.46	0.3527	0.71	0.5964	0.96	0.7749
0.22	0.1281	0.47	0.3627	0.72	0.6054	0.97	0.7785
0.23	0.1365	0.48	0.3727	0.73	0.6143	0.98	0.7816
0.24	0.1449	0.49	0.3827	0.74	0.6231	0.99	0.7841
0.25	0.1535	0.50	0.3927	0.75	0.6318	1.00	0.7854

Flow in a Partially Full Pipe

- A 10-inch diameter pipeline has water flowing at a depth of 4 inches. What is the gal/min flow if the velocity of the wastewater is 3.1 fps?

- d/D = 4 inches of water ÷ 10-inch diameter = 4/10 = 0.4 ↝ 0.2934
- Q = (0.2934)(0.8333)(0.8333)(3.1) = 0.6316 ft^3/sec
- (0.6316 ft^3/sec)(7.48 gal/ft^3)(60 sec/min) = 408,169 gpm

AREA, VOLUME, AND CONVERSIONS

Area

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

2. Calculate the surface area of a basin which is 90 feet long, 25 feet wide, and 10 feet deep.

3. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

4. Calculate the area (in ft^2) for an 18" main that has just been laid.

Volume

5. Calculate the volume (in ft^3) for a tank that measures 10 feet by 10 feet by 10 feet.

6. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

7. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

8. A new water main needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

9. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to calculate 5% of the tank volume. How many gallons will this be?

Conversions

10. How many seconds in one minute?

11. How many minutes in one hour?

12. How many minutes in one day?

13. Convert 3.6 ft^3/sec to gps.

14. Convert 2.4 ft^3/sec to gpm.

15. A treatment plant produces 6.31 MGD. How many gpm is that?

16. A pump delivers 695 gpm. How many MGD will that be?

17. How many pounds of water are in a tank containing 800 gallons of water?

ANSWERS:

1.	540 ft^2	10.	60
2.	2,250 ft^2	11.	60
3.	3.14 ft^2	12.	1440
4.	1.77 ft^2	13.	26.9 gps
5.	1,000 ft^3	14.	1,077 gpm
6.	9,050.8 gal	15.	4,382 gpm
7.	359 gal	16.	1.0 MGD
8.	48,442.35 gal	17.	6672 lbs
9.	150,000 gal		

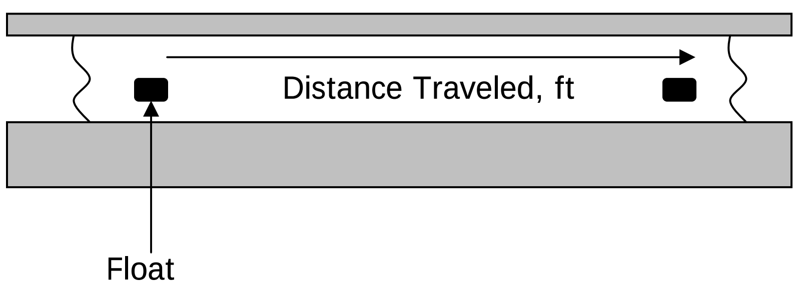
Applied Math for Wastewater
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

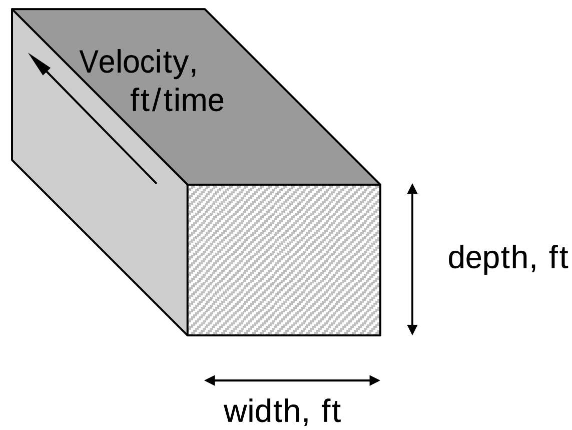
2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec?

3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min?



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$



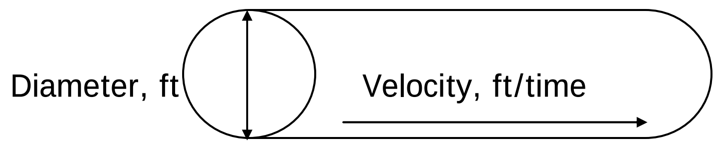
$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \quad \underset{(ft/time)}{(V)}$$

Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = (0.785)\underset{(ft)(ft)}{(D)^2} \underset{(ft/time)}{(vel)}$$

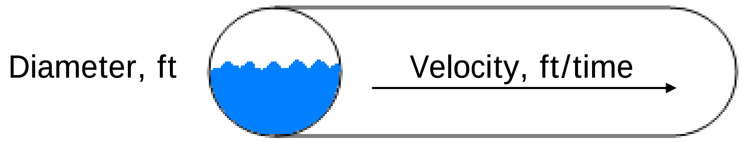
Flow through full pipe

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

9. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

10. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = \overbrace{(\text{Factor from d/D Table})\ \underset{(ft)(ft)}{(D)^2}} \quad \underset{(ft/time)}{(vel)}$$

<u>Flow through pipe flowing less than full</u>

11. A 12-inch diameter pipeline has water flowing at a depth of 6 inches. What is the gpm flow if the velocity of the wastewater is 300 fpm?

12. A 10-inch diameter pipeline has water flowing at a velocity of 3.2 fps. What is the gpd flow rate if the water is at a depth of 5 inches?

13. An 8-inch pipeline has water flowing to a depth of 5 inches. If the flow rate is 415.85 gpm, what is the velocity of the wastewater in fpm?

Answers:

1. 185 ft/min
2. 2.2 ft/sec
3. 210 ft/min
4. 16.8 ft^3/sec
5. 900 ft^3/min and 9.69 MGD
6. 1.8 ft
7. 10 ft^3/sec
8. 0.59 ft^3/sec
9. 532 gpm
10. 6 in
11. 881 gpm
12. 563,980 gpd
13. 240 ft/min

Lagoon Math

BOD Loading

1. Calculate the BOD loading (lbs/day) on a pond if the influent flow is 390,000 gal/day with a BOD of 245 mg/L.

2. The BOD concentration of the wastewater entering a pond is 158 mg/L. If the flow to the pond is 220,000 gal/day, how many lbs/day BOD enter the pond?

3. The flow to a waste treatment pond is 175 gal/min. If the BOD concentration of the water is 221 mg/L, how many pounds of BOD are applied to the pond daily?

4. The BOD concentration of the influent wastewater to a waste treatment pond is 190 mg/L. If the flow to the pond is 125 gpm, how many pounds of BOD are applied to the pond daily?

Organic Loading Rate

5. A 7.5-acre pond receives a flow of 200,000 gal/day. If the influent flow has a BOD content of 190 mg/L, what is the organic loading rate in lbs/day/ac on the pond?

6. A pond has an average width of 400 feet and an average length of 710 feet. The flow to the pond is 157,000 gal/day with a BOD content of 147 mg/L. What is the organic loading rate in lbs/day/ac on the pond?

7. The flow to a pond is 70,000 gpd with a BOD content of 124 mg/L. The pond has an average width of 220 feet and an average length of 382 feet. What is the organic loading rate in lbs/day/ac on the pond?

BOD Removal Efficiency

8. The BOD entering a waste treatment pond is 207 mg/L. If the BOD in the pond effluent is 39 mg/L, what is the BOD removal efficiency of the pond?

9. The influent of a waste treatment pond has a BOD content of 262 mg/L. If the BOD content of the pond effluent is 130 mg/L, what is the BOD removal efficiency of the pond?

10. The BOD entering a waste treatment pond is 280 mg/L. If the BOD in the pond effluent is 45 mg/L, what is the BOD removal efficiency of the pond?

11. The BOD entering a waste treatment pond is 140 mg/L. If the BOD in the pond effluent is 56 mg/L, what is the BOD removal efficiency of the pond?

Hydraulic Loading Rate

12. A 20-acre pond receives a flow of 3.3 acre-feet/day. What is the hydraulic loading rate on the pond in in./day?

13. A 15-acre pond receives a flow of 5 acre-feet/day. What is the hydraulic loading rate on the pond in in./day?

Population Loading

14. A 4-acre wastewater pond serves a population of 1320 people. What is the population loading on the pond?

15. A wastewater pond serves a population of 5460 people. If the pond covers 18.5 acres, what is the population loading on the pond?

Detention Time

16. A waste treatment pond has a total volume of 17 ac-ft. If the flow to the pond is 0.42 ac-ft/day, what is the detention time of the pond (days)?

17. A waste treatment pond is operated at a depth of 6 feet. The average width of the pond is 440 feet and the average length is 680 feet. If the flow to the pond is 0.3 MGD, what is the detention time in days?

18. The average width of the pond is 240 feet and the average length is 390 feet. A waste treatment pond is operated at a depth of 5 feet. If the flow to the pond is 70,000 gal/day, what is the detention time, in days?

19. A waste treatment pond has an average length of 680 ft., an average width of 420 ft., and a water depth of 4 ft. If the flow to the pond is 0.47 ac-ft/day, what is the detention time for the pond in days?

ANSWERS:

1.	796.9 lbs/day	11.	60%
2.	289.9 lbs/day	12.	2 in/day
3.	464.5 lbs/day	13.	4 in/day
4.	285.2 lbs/day	14.	330
5.	42.3 lbs/day/acre	15.	295
6.	29.5 lbs/day/acre	16.	40 days
7.	37.5 lbs/day/acre	17.	45 days
8.	81%	18.	50 days
9.	50%	19.	56 days
10.	84%		

Applied Math for BNS
Chemical Dosage

- To convert between mg/L concentrations and % concentrations, use the conversion of 1% = 10,000 mg/L
- mg/L is “parts per million” concentration or ppm

Chemical Feed Rate (Full Strength), lbs/day

1. Determine the chlorinator setting (lbs/day) needed to treat a flow of 4.4 MGD with a chlorine dose of 3.2 mg/L.

2. The desired dosage for chlorine is 1.1 mg/L. If the flow to be treated is 1,660,000 gpd, how many lbs/day of chlorine is required?

3. Determine the chlorinator setting (lbs/day) needed to treat a flow of 1.2 MGD with a chlorine dose of 1.7 mg/L.

4. To control hydrogen sulfide (H_2S) and odors in an 8-inch sewer, the chlorine dose must be 10 mg/L when the flow is 0.37 MGD. Determine the chlorine feed rate in lbs/day.

5. A wastewater flow of 3.8 cfs requires a chlorine dose of 15 mg/L. What is the desired chlorine feed rate in lbs/day?

6. A company contends a new product effectively controls roots in sewer pipes at a concentration of 150 mg/L if the contact time is 60 minutes. How many pounds of chemical are required, assuming perfect mixing, if 450 feet of 6-inch sewer were to be treated?

Chemical Feed Rate (Less than Full Strength), lbs/day

7. A total chlorine dose of 10.8 mg/L is required to treat a particular wastewater. If the flow is 2.77 MGD and the calcium hypochlorite has 65% available chlorine, calculate the lbs/day of hypochlorite required.

8. The desired dose of a polymer is 4 mg/L. The polymer literature provided indicates the compound is 60% active polymer. If a flow of 4.2 MGD is to be treated, how many lbs/day of polymer compound must be fed?

9. The effluent from a wastewater lagoon requires a chlorine dose of 18 mg/L. If the average daily flow is 1,095,000 gpd and sodium hypochlorite (15% available chlorine) is to be used to disinfect the wastewater, how many lbs/day of hypochlorite are required?

10. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite (65% available chlorine). The recommended dose is 15 mg/L chlorine. If your flow is 75 gpm, how much calcium hypochlorite is required, lbs/day?

11. If sodium hypochlorite (15% available chlorine) is used instead in #10, how many gallons must be fed daily? (Assume 1 gallon of solution weighs 8.34 lbs.)

12. To inactivate and control slime in the collection system, 40% sodium hydroxide (NaOH) can be fed at about 8,000 mg/L over one hour. If the NaOH solution is used to treat a section of 12-inch sewer 800 ft long, calculate the volume in gallons of NaOH solution required. (Assume 1 gallon solution weighs 8.34 lbs)

Chlorine Dose, Demand and Residual, mg/L

13. A secondary wastewater effluent is tested and found to have a chlorine demand of 4.8 mg/L. If the desired chlorine residual is 0.9 mg/L, what is the desired chlorine dose, mg/L?

14. The chlorine dose for a secondary effluent is 8.4 mg/L. If the chlorine residual after a 30 minute contact time is found to be 0.8 mg/L, what is the chlorine demand, mg/L?

15. What should the chlorinator setting be (lbs/day) to treat a flow of 3.9 MGD if the chlorine demand is 8 mg/L and a chlorine residual of 1.5 mg/L is desired?

16. A secondary effluent is tested and found to have a chlorine demand of 4.9 mg/L. If the desired residual is 0.8 mg/L, what is the desired chlorine dose (mg/L)?

17. The chlorine dosage for a secondary effluent is 8.8 mg/L. If the chlorine residual after 30 minutes of contact time is found to be 0.9 mg/L, what is the chlorine demand in mg/L?

18. The chlorine demand of a secondary effluent is 7.9 mg/L. If the chlorine residual of 0.6 mg/L is desired, what is the desired chlorine dosage in mg/L?

Chemical Dosage, mg/L

19. The chlorinator is set to feed 31.5 lbs of chlorine per 24 hours for a plant flow of 1.6 MGD. Calculate the chlorine residual for a chlorine demand of 1.85 mg/L.

20. A wastewater plant has a flow of 2,570 gpm. If the chlorinator is feeding 93 pounds per day, what is the dose in mg/L?

21. What should the chlorinator setting be in lbs/day to treat a flow of 4.0 MGD if the chlorinator demand is 9 mg/L and a chlorine residual of 1.7 mg/L is desired?

Hypochlorination

22. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

23. How many pounds of 65% HTH are used to make 1 gallon of 3% solution?

24. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

<u>Use the following information for problems 25 – 28:</u>
At 8:00 a.m. on Monday morning a chlorine cylinder weighs 83 pounds. At 8:00 a.m. on Tuesday morning the same cylinder weighs 69 pounds.

25. What is the chlorinator feed rate in pounds per day?

26. Estimate the chlorine dose in mg/L for the chlorinator. The flow totalizer reads 12,982,083 gallons at 8:00AM on Monday morning and 13,528,924 at 8:00AM on Tuesday morning. (Note: This totalizer does not zero out each morning.)

27. If the setting on the chlorinator does not change, how many pounds of chlorine will be left in the cylinder on Friday morning at 8:00 a.m.?

28. How many 150-lb chlorine cylinders will this water plant need in a month (with 30 days) if the chlorinator setting remains the same?

Use the following information for problems 29 – 31:
At 8:00 a.m. on Friday morning a chlorine cylinder weighs 298 pounds. That afternoon at 4:00 p.m. the same cylinder weighs 216 pounds.

29. What is the chlorinator feed rate in pounds per day?

30. How many pounds of chlorine will be in the cylinder at 8:00 a.m. on Saturday morning if the feed rate does not change?

31. What is the minimum number of ton cylinders the operator will need in a month with 31 days (at this feed rate)?

Answers:

1. 117 lbs/day
2. 15.2 lbs/day
3. 17.0 lbs/day
4. 30.9 lbs/day
5. 307 lbs/day
6. 0.83 lbs
7. 384 lbs/day
8. 234 lbs/day
9. 1096 lbs/day
10. 20.8 lbs/day
11. 10.8 gpd
12. 93.9 gpd
13. 5.7 mg/L
14. 7.6 mg/L
15. 309 lbs/day
16. 5.7 mg/L
17. 7.9 mg/L
18. 8.5 mg/L
19. 0.51 mg/L
20. 3.0 mg/L
21. 357 lbs/day
22. 3.8 lbs
23. 0.4 lbs
24. 11.5 lbs
25. 14 lbs/day
26. 3.1 mg/L
27. 27 lbs
28. 3 cylinders
29. 246 lbs/day
30. 52 lbs
31. 4 cylinders

Applied Math for Wastewater Treatment Laboratory

Bacteriological, fecal coliform and *E. coli*

1. Calculate the geometric mean for the following fecal coliform test results: 60, 100, 0, 0, 40, 20, 20, 45, 55, 60, 20, 20

2. Calculate the geometric mean for the following fecal coliform test results: 0, 0, 50, 50, 25, 100, 100, 50, 75, 50

Solutions

3. How many mL of 0.7 N NaOH is needed to get 750 mL of 0.05 N NaOH?

4. How many mL of 0.5 N NaOH react with 800 mL of 0.1 N HCl?

Biochemical Oxygen Demand, BOD

- Blanks must not deplete more than 0.2 mg/L DO
- The sample must deplete at least 2.0 mg/L DO, if it does not, the dilution is too weak and report as inadequate depletion
- After 5 days of incubation at 20ºC ± 1.0ºC, the sample must have at least 1.0 mg/L DO, if less than, the sample was too strong

5. Given the following information, determine the BOD of the wastewater:

   Sample Volume = 5 mL
   BOD Bottle Volume = 300 mL
   Initial DO of Diluted Sample = 6 mg/L
   Final DO of Diluted Sample = 3.5 mg/L

6. Given the following information, determine the BOD of the wastewater:

   Sample Volume = 10 mL
   BOD Bottle Volume = 300 mL
   Initial DO of Diluted Sample = 8.3mg/L
   Final DO of Diluted Sample = 4.2 mg/L

7. Given the following primary effluent BOD test results, calculate the 7-day average:

   April 10 – 190 mg/L
   April 11 – 198 mg/L
   April 12 – 205 mg/L
   April 13 – 202 mg/L
   April 14 – 210 mg/L
   April 15 – 201 mg/L
   April 16 – 197 mg/L

Alkalinity

8. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 24 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.2 to 4.5.

9. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 10.1 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.5 to 4.5.

Temperature

10. The influent to a treatment plant has a temperature of 72ºF. What is the temperature expressed in degrees Celsius?

11. Convert 56º F to degrees Celsius.

12. The effluent of a treatment plant is 22ºC. What is this temperature expressed in degrees F?

Answers:

1. 21
2. 26
3. 53.6 mL
4. 160 mL
5. 150 mg/L
6. 123 mg/L
7. 200 mg/L
8. 240 mg/L
9. 101 mg/L
10. 22.2ºC
11. 13.3ºC
12. 71.6ºF

Applied Math for Wastewater
Pump Horsepower & Efficiency

1. A pump must pump 2,500 gpm against a total head of 73 feet. What horsepower (water horsepower) will be required to do the work?

2. A pump is delivering a flow of 1,035 gpm against 46.7 feet of head. What horsepower will be required?

3. If a pump is to deliver 630 gpm of water against a total head of 102 feet, and the pump has an efficiency of 78%, what power must be supplied to the pump?

4. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

5. What is the overall efficiency if an electric power equivalent to 36 hp is supplied to the motor and 16.3 hp of work is accomplished?

6. A pump is discharging 1,250 gpm against a head of 71 feet. The wire-to-water efficiency is 82%. If the cost of power is $0.028/kW hr, what is the cost of the power consumed during a week in which the pump runs 126 hours?

7. A wet well is 12 feet long and 10 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 2.6 feet during a 5-minute pumping test, what is the gpm pumping rate?

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. $71.93
7. 467 gpm

Section 10

AREA, VOLUME, AND CONVERSIONS

Area

1. A basin has a length of 45 feet and a width of 12 feet. Calculate the area in ft^2.

   Area = (w, ft)(l, ft)
   = (45 ft)(12 ft) = 540 ft^2

2. Calculate the surface area of a basin which is 90 feet long, 25 feet wide, and 10 feet deep.

   Area = (90 ft)(25 ft)
   = 2250 ft^2

   (10 feet → fluff, you don't need)

3. Calculate the area (in ft^2) for a 2 ft diameter main that has just been laid.

   Area = $(0.785)(D, ft)^2$
   = (0.785)(2 ft)(2 ft) = 3.14 ft^2

4. Calculate the area (in ft^2) for an 18" main that has just been laid.

   18/12 = 1.5 ft
   Area = (0.785)(1.5 ft)(1.5 ft)
   = 1.77 ft^2

Volume

5. Calculate the volume (in ft^3) for a tank that measures 10 feet by 10 feet by 10 feet.

   Vol, ft^3 = (l, ft)(w, ft)(d, ft)
   = (10 ft)(10 ft)(10 ft) = 1000 ft^3

6. Calculate the volume (in gallons) for a basin that measures 22 feet by 11 feet by 5 feet.

   7.48 gal/ft^3
   Vol., gal = (22 ft)(11 ft)(5 ft)(7.48) = 9051 gal

Math

Section 10

7. Calculate the volume of water in a tank (in gallons), which measures 12 feet long, 6 feet wide, 5 feet deep, and contains 8 inches of water.

8/12 = 0.6667 ft Vol., gal = (12 ft)(6 ft)(0.6667 ft)(7.48)

= 359 gal

8. A new water main needs to be disinfected. The main is 30" in diameter and has a length of 0.25 miles. How many gallons of water will it hold?

30/12 = 2.5 ft Vol., gal = (0.785)(2.5 ft)(2.5 ft)(1320 ft)(7.48)

(0.25)(5280) = 1320 ft

= 48,442 gal

9. A 3 million gallon water tank needs to be disinfected. The method you will use requires you to calculate 5% of the tank volume. How many gallons will this be?

(3,000,000 gal)(0.05) = 150,000 gal

Conversions

10. How many seconds in one minute? 60 sec/min

11. How many minutes in one hour? 60 min/hr

12. How many minutes in one day? $\left(\frac{60\ min}{hr}\right)\left(\frac{24\ hr}{d}\right) = \frac{1440\ min}{day}$

13. Convert 3.6 ft^3/sec to gps. $\frac{3.6\ ft^3}{sec} \Big| \frac{7.48\ gal}{ft^3} = 26.9$ gps

14. Convert 2.4 ft^3/sec to gpm. $\frac{2.4\ ft^3}{sec} \Big| \frac{7.48\ gal}{ft^3} \Big| \frac{60\ sec}{min} = 1077$ gpm

15. A treatment plant produces 6.31 MGD. How many gpm is that?

$\frac{6.31\ MG}{D} \Big| \frac{1{,}000{,}000\ gal}{1\ MG} \Big| \frac{1\ D}{1440\ min} = 4382$ gpm

Section 10

16. A pump delivers 695 gpm. How many MGD will that be?

$$\frac{695 \text{ gal}}{\text{min}} \times \frac{1440 \text{ min}}{\text{D}} \times \frac{1 \text{ MG}}{1{,}000{,}000 \text{ gal}} = 1.0 \text{ MGD}$$

17. How many pounds of water are in a tank containing 800 gallons of water?

$$800 \text{ gal} \times \frac{8.34 \text{ lbs}}{1 \text{ gal}} = 6672 \text{ lbs}$$

ANSWERS:

1.	540 ft^2	10.	60
2.	2,250 ft^2	11.	60
3.	3.14 ft^2	12.	1440
4.	1.77 ft^2	13.	26.9 gps
5.	1,000 ft^3	14.	1,077 gpm
6.	9,050.8 gal	15.	4,382 gpm
7.	359 gal	16.	1.0 MGD
8.	48,442.35 gal	17.	6672 lbs
9.	150,000 gal		

Applied Math for Collections
Flow and Velocity

Velocity

1. A cork is placed in a channel and travels 370 feet in 2 minutes. What is the velocity of the wastewater in the channel, ft/min?

   $$\text{Vel.} = \frac{\text{distance, ft}}{\text{time}} = \frac{370\text{ ft}}{2\text{ min}} = \boxed{185\text{ ft/min}}$$

2. A float travels 300 feet in a channel in 2 minutes and 14 seconds. What is the velocity in the channel, ft/sec? 2 min + 14 sec = 134 seconds total

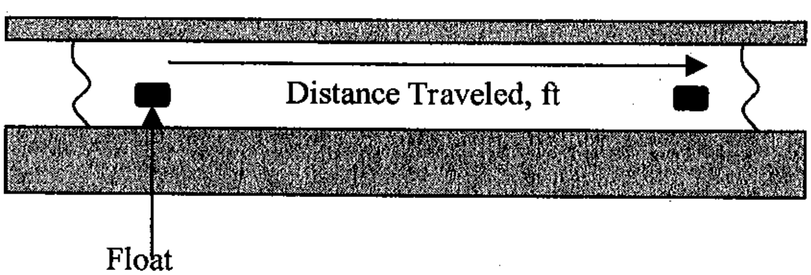
   means we need time in seconds!!

   $$\text{Vel} = \frac{300\text{ ft}}{134\text{ sec}} = \boxed{2.2\text{ ft/sec}}$$

3. The distance between manhole #1 and manhole #2 is 105 feet. A fishing bobber is dropped into manhole #1 and enters manhole #2 in 30 seconds. What is the velocity of the wastewater in the sewer in ft/min? 30 sec = 0.5 min

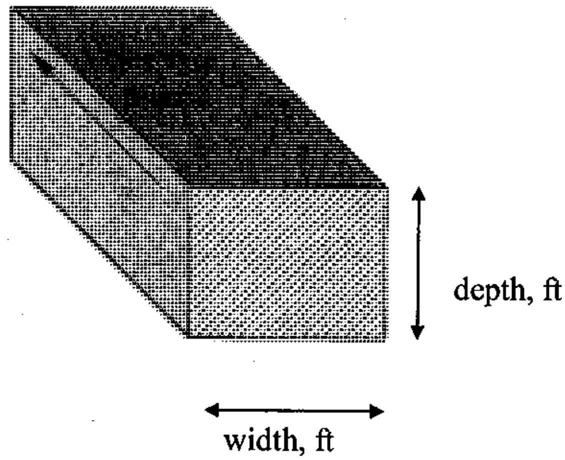
   need time in minutes

   $$\text{Vel} = \frac{105\text{ ft}}{0.5\text{ min}} = \boxed{210\text{ ft/min}}$$



$$\text{Velocity} = \frac{\text{Distance Traveled, ft}}{\text{Duration of Test, min}}$$

$$= \text{ft/min}$$



$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(A)} \quad \underset{(ft/time)}{(V)}$$

Flow in a channel

4. A channel 48 inches wide has water flowing to a depth of 1.5 feet. If the velocity of the water is 2.8 ft/sec, what is the flow in the channel in cu ft/sec?

w = 48 in = 4 ft
d = 1.5 ft
vel = 2.8 ft/sec

$Q = (w)(d)(vel)$
$= (4\text{ ft})(1.5\text{ ft})(2.8\text{ ft/sec})$
$= 16.8\ ft^3/sec$

5. A channel 3 feet wide has water flowing to a depth of 2.5 feet. If the velocity through the channel is 120 feet/min, what is the flow rate in cu ft/min? in MGD?

w = 3 ft
d = 2.5 ft
vel = 120 ft/min

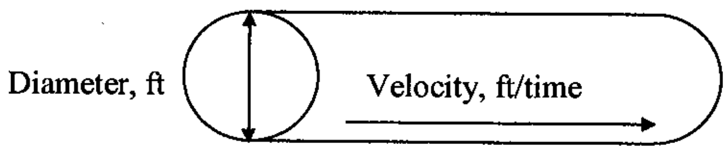
$Q = (3\text{ ft})(2.5\text{ ft})(120\text{ ft/min}) = 900\ ft^3/min$

$\frac{(900\ ft^3/min)(1440)(7.48)}{1,000,000} = 9.69\ MGD$

6. A channel is 3 feet wide and has water flowing at a velocity of 1.5 ft/sec. If the flow through the channel is 8.1 ft^3/sec, what is the depth of the water in the channel in feet?

w = 3 ft
vel = 1.5 ft/sec
$Q = 8.1\ ft^3/sec$

$Q = (w)(d)(vel)$
$\underset{ft^3/sec}{8.1} = \underset{ft}{(3)}\underset{ft}{(d)}\underset{ft/sec}{(1.5)}$
$8.1 = (4.5)(d)$
$\frac{8.1}{4.5} = d$
$1.8 = d$ ft



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = \underset{(ft)(ft)}{(0.785)(D)^2} \quad \underset{(ft/time)}{(vel)}$$

<u>Flow through full pipe</u>

7. The flow through a 2 ft diameter pipeline is moving at a velocity of 3.2 ft/sec. What is the flow rate in cu ft/sec?

D = 2 ft
vel = 3.2 ft/sec

Q = (0.785)(D, ft)(D, ft)(vel)
= (0.785)(2 ft)(2 ft)(3.2 ft/sec)
= **10 ft³/sec**

8. The flow through a 6 inch diameter pipeline is moving at a velocity of 3 ft/sec. What is the flow rate in ft^3/sec?

D = 6 in = 0.5 ft
vel = 3 ft/sec

Q = (0.785)(0.5 ft)(0.5 ft)(3 ft/sec)
= **0.59 ft³/sec**

9. An 8 inch diameter pipeline has water flowing at a velocity of 3.4 ft/sec. What is the flow rate in gpm?

D = 8 in = 0.6667 ft
vel = 3.4 ft/sec

Q = (0.785)(0.6667 ft)(0.6667 ft)(3.4 ft/sec)
= (1.1862 ft³/sec)(60)(7.48) = **532 gpm**

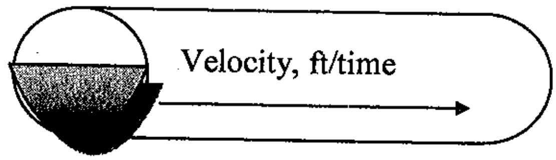
10. The flow through a pipe is 0.7 ft^3/sec. If the velocity of the flow is 3.6 ft/sec, and the pipe is flowing full, what is the diameter of the pipe in inches?

Q = 0.7 ft³/sec
vel = 3.6 ft/sec

Q = (0.785)(D, ft)(D, ft)(vel)
0.7 = (0.785)(D²)(3.6)
0.7 = (2.826)(D²)
0.7 / 2.826 = D²
√0.25 = D²

0.50 = D
ft not inches
6 in = 0.5 ft

Diameter, ft



$$\underset{ft^3/time}{Q} = \underset{ft^2}{(A)} \quad \underset{(ft/time)}{(V)}$$

$$\underset{ft^3/time}{Q} = \text{(Factor from d/D Table)} \underset{(ft)(ft)}{(D)^2} \quad \underset{(ft/time)}{(vel)}$$

Flow through pipe flowing less than full

11. A 12-inch diameter pipeline has water flowing at a depth of 6 inches. What is the gpm flow if the velocity of the wastewater is 300 fpm?

D = 12 in = 1 ft
d = 6 in
vel = 300 ft/min

Q = (0.3927)(1 ft)(1 ft)(300 ft/min)
= (117.81 ft³/min)(7.48) = **881 gpm**

d/D = 6/12 = 0.5
→ 0.3927 on chart

12. A 10-inch diameter pipeline has water flowing at a velocity of 3.2 fps. What is the gpd flow rate if the water is at a depth of 5 inches?

D = 10 in = 0.8333 ft
d = 5 in
vel = 3.2 ft/sec

Q = (0.3927)(0.8333 ft)(0.8333 ft)(3.2 ft/sec)
= (0.8727 ft³/sec)(60)(1440)(7.48)
= **563,980 gpd**

d/D = 5/10 = 0.5
→ 0.3927 on chart

13. An 8-inch pipeline has water flowing to a depth of 5 inches. If the flow rate is 415.85 gpm, what is the velocity of the wastewater in fpm? → min – means flow needs to be in ft³/min

D = 8 in = 0.6667 ft
d = 5 in
Q = 415.85 gpm / 7.48 = 55.5949 ft³/min

d/D = 5/8 = 0.625 ≈ 0.63
→ 0.5212 on chart

Q = (d/D number)(D, ft)(D, ft)(vel)
55.5949 ft³/min = (0.5212)(0.6667 ft)(0.6667 ft)(vel)
55.5949 = (0.2316)(vel)
55.5949 / 0.2316 = vel
240 ft/min = vel

Lagoon Math

BOD Loading pg. 14-15

1. Calculate the BOD loading (lbs/day) on a pond if the influent flow is 390,000 gal/day with a BOD of 245 mg/L.

$$\text{BOD, lbs/d} = (\text{BOD, mg/L})(\text{Flow, MGD})(8.34)$$
$$= (245\text{ mg/L})(0.39\text{ MGD})(8.34)$$
$$= \boxed{796.9\text{ lbs/d}}$$

2. The BOD concentration of the wastewater entering a pond is 158 mg/L. If the flow to the pond is 220,000 gal/day, how many lbs/day BOD enter the pond?

$$\text{BOD, lbs/d} = (158\text{ mg/L})(0.22\text{ MGD})(8.34)$$
$$= \boxed{289.9\text{ lbs/d}}$$

3. The flow to a waste treatment pond is 175 gal/min. If the BOD concentration of the water is 221 mg/L, how many pounds of BOD are applied to the pond daily?

$$\frac{(175\text{ gpm})(1440)}{1{,}000{,}000} = 0.252\text{ MGD}$$

$$\text{BOD, lbs/d} = (221\text{ mg/L})(0.252\text{ MGD})(8.34)$$
$$= \boxed{464.5\text{ lbs/d}}$$

4. The BOD concentration of the influent wastewater to a waste treatment pond is 190 mg/L. If the flow to the pond is 125 gpm, how many pounds of BOD are applied to the pond daily?

$$\frac{(125\text{ gpm})(1440)}{1{,}000{,}000} = 0.18\text{ MGD}$$

$$\text{BOD, lbs/d} = (190\text{ mg/L})(0.18)(8.34)$$
$$= \boxed{285.2\text{ lbs/d}}$$

Organic Loading Rate

5. A 7.5-acre pond receives a flow of 200,000 gal/day. If the influent flow has a BOD content of 190 mg/L, what is the organic loading rate in lbs/day/ac on the pond?

$$OLR = \frac{(\text{BOD, mg/L})(\text{Flow, MGD})(8.34)}{\text{Pond Area, Acres}}$$

$$= \frac{(190\text{ mg/L})(0.2\text{ MGD})(8.34)}{7.5\text{ acres}}$$

$$= \boxed{42.3\text{ lbs/d/acre}}$$

6. A pond has an average width of 400 feet and an average length of 710 feet. The flow to the pond is 157,000 gal/day with a BOD content of 147 mg/L. What is the organic loading rate in lbs/day/ac on the pond?

$$\text{Pond Area, acres} = \frac{(710\text{ ft})(400\text{ ft})}{43{,}560\text{ ft}^2/\text{ac}} = 6.5197\text{ ac.}$$

$$OLR = \frac{(147\text{ mg/L})(0.157\text{ MGD})(8.34)}{6.5197\text{ ac}} = \boxed{29.5\text{ lbs/d/acre}}$$

7. The flow to a pond is 70,000 gpd with a BOD content of 124 mg/L. The pond has an average width of 220 feet and an average length of 382 feet. What is the organic loading rate in lbs/day/ac on the pond?

$$\text{Pond Area, acres} = \frac{(220\text{ ft})(382\text{ ft})}{43{,}560\text{ ft}^2/\text{ac}} = 1.92929\text{ ac}$$

$$OLR = \frac{(124\text{ mg/L})(0.07\text{ MGD})(8.34)}{1.92929\text{ ac}} = \boxed{37.5\text{ lbs/d/acre}}$$

BOD Removal Efficiency

8. The BOD entering a waste treatment pond is 207 mg/L. If the BOD in the pond effluent is 39 mg/L, what is the BOD removal efficiency of the pond?

$$\text{BOD Removal\%} = \frac{207\text{ mg/L} - 39\text{ mg/L}}{207\text{ mg/L}} \times 100\% = \boxed{81\%}$$

9. The influent of a waste treatment pond has a BOD content of 262 mg/L. If the BOD content of the pond effluent is 130 mg/L, what is the BOD removal efficiency of the pond?

$$\text{BOD Removal \%} = \frac{262 - 130}{262} \times 100 = \boxed{50\%}$$

10. The BOD entering a waste treatment pond is 280 mg/L. If the BOD in the pond effluent is 45 mg/L, what is the BOD removal efficiency of the pond?

$$\text{BOD Removal \%} = \frac{280 - 45}{280} \times 100 = \boxed{84\%}$$

11. The BOD entering a waste treatment pond is 140 mg/L. If the BOD in the pond effluent is 56 mg/L, what is the BOD removal efficiency of the pond?

$$\text{BOD Removal \%} = \frac{140 - 56}{140} \times 100 = \boxed{60\%}$$

Hydraulic Loading Rate

12. A 20-acre pond receives a flow of 3.3 acre-feet/day. What is the hydraulic loading rate on the pond in in./day?

$$\text{HLR} = \frac{\text{Flow, acre-feet/day}}{\text{Pond, acre}} \times 12\text{ in/ft} = \frac{3.3}{20} \times 12 = \boxed{2\text{ in/d}}$$

13. A 15-acre pond receives a flow of 5 acre-feet/day. What is the hydraulic loading rate on the pond in in./day?

$$\text{HLR} = \frac{5\text{ acre-feet/day}}{15\text{ acre}} \times 12\text{ in/ft} = \boxed{4\text{ in/d}}$$

Population Loading

14. A 4-acre wastewater pond serves a population of 1320 people. What is the population loading on the pond?

$$\text{Pop. Loading} = \frac{\text{persons}}{\text{acre}} = \frac{1320}{4} = \boxed{330}$$

15. A wastewater pond serves a population of 5460 people. If the pond covers 18.5 acres, what is the population loading on the pond?

$$\text{Pop. Loading} = \frac{5460 \text{ people}}{18.5 \text{ acres}} = \boxed{295}$$

Detention Time

16. A waste treatment pond has a total volume of 17 ac-ft. If the flow to the pond is 0.42 ac-ft/day, what is the detention time of the pond (days)?

$$DT = \frac{\text{vol, ac-ft}}{\text{flow, ac-ft/day}} = \frac{17 \text{ ac-ft}}{0.42 \text{ ac-ft/d}} = \boxed{40 \text{ days}}$$

17. A waste treatment pond is operated at a depth of 6 feet. The average width of the pond is 440 feet and the average length is 680 feet. If the flow to the pond is 0.3 MGD, what is the detention time in days?

$$DT = \frac{\text{Vol, gal}}{\text{Flow, gpd}} = \frac{(440 \text{ ft})(680 \text{ ft})(6 \text{ ft})(7.48)}{300{,}000 \text{ gpd}} = \boxed{45 \text{ days}}$$

18. The average width of the pond is 240 feet and the average length is 390 feet. A waste treatment pond is operated at a depth of 5 feet. If the flow to the pond is 70,000 gal/day, what is the detention time, in days?

$$DT = \frac{(240 \text{ ft})(390 \text{ ft})(5 \text{ ft})(7.48)}{70{,}000 \text{ gpd}} = \boxed{50 \text{ days}}$$

19. A waste treatment pond has an average length of 680 ft., an average width of 420 ft., and a water depth of 4 ft. If the flow to the pond is 0.47 ac-ft/day, what is the detention time for the pond in days?

$$\text{Vol, ac-ft} = \frac{(420\text{ ft})(4\text{ ft})(680\text{ ft})}{43{,}560\text{ ft}^2/\text{ac}} = 26.2259\text{ ac-ft}$$

$$DT = \frac{26.2259\text{ ac-ft}}{0.47\text{ ac-ft/d}} = \boxed{56\text{ days}}$$

ANSWERS:

1. 796.9 lbs/day
2. 289.9 lbs/day
3. 464.5 lbs/day
4. 285.2 lbs/day
5. 42.3 lbs/day/acre
6. 29.5 lbs/day/acre
7. 37.5 lbs/day/acre
8. 81%
9. 50%
10. 84%
11. 60%
12. 2 in/day
13. 4 in/day
14. 330
15. 295
16. 40 days
17. 45 days
18. 50 days
19. 56 days

Section 10

Applied Math for BNS
Chemical Dosage

- To convert between mg/L concentrations and % concentrations, use the conversion of 1% = 10,000 mg/L
- mg/L is "parts per million" concentration or ppm

Chemical Feed Rate (Full Strength), lbs/day

1. Determine the chlorinator setting (lbs/day) needed to treat a flow of 4.4 MGD with a chlorine dose of 3.2 mg/L.

   lbs/d = (dose, mg/L)(flow, MGD)(8.34 lbs/gal)
   = (3.2 mg/L)(4.4 MGD)(8.34)
   = **117.4 lbs/d**

2. The desired dosage for chlorine is 1.1 mg/L. If the flow to be treated is 1,660,000 gpd, how many lbs/day of chlorine is required?

   lbs/d = (1.1 mg/L)(1.66 MGD)(8.34)
   = **15.2 lbs/d**

3. Determine the chlorinator setting (lbs/day) needed to treat a flow of 1.2 MGD with a chlorine dose of 1.7 mg/L.

   lbs/d = (1.7 mg/L)(1.2 MGD)(8.34)
   = **17.0 lbs/d**

Math

4. To control hydrogen sulfide (H_2S) and odors in an 8-inch sewer, the chlorine dose must be 10 mg/L when the flow is 0.37 MGD. Determine the chlorine feed rate in lbs/day.

$$\text{lbs/d} = (10\text{ mg/L})(0.37\text{ MGD})(8.34)$$
$$= \boxed{30.9\text{ lbs/d}}$$

5. A wastewater flow of 3.8 cfs requires a chlorine dose of 15 mg/L. What is the desired chlorine feed rate in lbs/day?

$$\frac{(3.8\text{ cfs})(7.48)(60)(1440)}{1{,}000{,}000} = 2.4558\text{ MGD}$$
$$\text{lbs/d} = (15\text{ mg/L})(2.4558\text{ MGD})(8.34)$$
$$= \boxed{307\text{ lbs/d}}$$

6. A company contends a new product effectively controls roots in sewer pipes at a concentration of 150 mg/L if the contact time is 60 minutes. How many pounds of chemical are required, assuming perfect mixing, if 450 feet of 6-inch sewer were to be treated?

$$\text{vol.} = (0.785)(0.5\text{ ft})^2(450\text{ ft})(7.48) = 660.5775\text{ gal}$$
$$= 0.000660578\text{ MG}$$
$$\text{lbs} = (150\text{ mg/L})(0.000660578\text{ MG})(8.34)$$
$$= \boxed{0.83\text{ lbs}}$$

Chemical Feed Rate (Less than Full Strength), lbs/day

7. A total chlorine dose of 10.8 mg/L is required to treat a particular wastewater. If the flow is 2.77 MGD and the calcium hypochlorite has 65% available chlorine, calculate the lbs/day of hypochlorite required.

$$\text{lbs/d} = \frac{(\text{dose, mg/L})(\text{flow, MGD})(8.34)}{\%\text{chem. purity}}$$
$$= \frac{(10.8\text{ mg/L})(2.77\text{ MGD})(8.34)}{0.65}$$
$$= \boxed{384\text{ lbs/d}}$$

8. The desired dose of a polymer is 4 mg/L. The polymer literature provided indicates the compound is 60% active polymer. If a flow of 4.2 MGD is to be treated, how many lbs/day of polymer compound must be fed?

$$lbs/d = \frac{(4\ mg/L)(4.2\ MGD)(8.34)}{0.60}$$

$$= \boxed{234\ lbs/d}$$

9. The effluent from a wastewater lagoon requires a chlorine dose of 18 mg/L. If the average daily flow is 1,095,000 gpd and sodium hypochlorite (15% available chlorine) is to be used to disinfect the wastewater, how many lbs/day of hypochlorite are required?

$$lbs/d = \frac{(18\ mg/L)(1.095\ MGD)(8.34)}{0.15}$$

$$= \boxed{1096\ lbs/d}$$

10. Your town has been receiving complaints about odors in your sewer system. To correct the problem, you have decided to feed calcium hypochlorite (65% available chlorine). The recommended dose is 15 mg/L chlorine. If your flow is 75 gpm, how much calcium hypochlorite is required, lbs/day?

$$\frac{(75\ gpm)(1440)}{1,000,000} = 0.108\ MGD$$

$$lbs/d = \frac{(15\ mg/L)(0.108\ MGD)(8.34)}{0.65}$$

$$= \boxed{20.8\ lbs/d}$$

11. If sodium hypochlorite (15% available chlorine) is used instead in #10, how many gallons must be fed daily? (Assume 1 gallon of solution weighs 8.34 lbs.)

pg. 9 formula book

$$bleach, gpd = \frac{(dose, mg/L)(flow, MGD)}{\%\ available}$$

$$= \frac{(15\ mg/L)(0.108\ MGD)}{0.15} = \boxed{10.8\ gpd}$$

12. To inactivate and control slime in the collection system, sodium hydroxide (NaOH) can be fed at about 8,000 mg/L over one hour. If the NaOH solution is used to treat a section of 12-inch sewer 800 ft long, calculate the volume in gallons of NaOH solution required. (Assume 1 gallon solution weighs 8.34 lbs)

vol. = (0.785)(1 ft)²(800 ft)(7.48) = 4697.44 gal = 0.00469744 MG

gpd = (8,000 mg/L)(0.00469744) / 0.40

= 93.9 gpd

Chlorine Dose, Demand and Residual, mg/L pg. 9 formula book

13. A secondary wastewater effluent is tested and found to have a chlorine demand of 4.8 mg/L. If the desired chlorine residual is 0.9 mg/L, what is the desired chlorine dose, mg/L?

Dose = Demand + Residual
= 4.8 + 0.9
= 5.7 mg/L

14. The chlorine dose for a secondary effluent is 8.4 mg/L. If the chlorine residual after a 30 minute contact time is found to be 0.8 mg/L, what is the chlorine demand, mg/L?

8.4 = demand + 0.8
8.4 - 0.8 = demand
7.6 mg/L

15. What should the chlorinator setting be (lbs/day) to treat a flow of 3.9 MGD if the chlorine demand is 8 mg/L and a chlorine residual of 1.5 mg/L is desired?

Dose = 8 + 1.5 = 9.5
lbs/d = (9.5 mg/L)(3.9 MGD)(8.34)
= 309 lbs/d

16. A secondary effluent is tested and found to have a chlorine demand of 4.9 mg/L. If the desired residual is 0.8 mg/L, what is the desired chlorine dose (mg/L)?

Dose = 4.9 + 0.8
= 5.7 mg/L

17. The chlorine dosage for a secondary effluent is 8.8 mg/L. If the chlorine residual after 30 minutes of contact time is found to be 0.9 mg/L, what is the chlorine demand in mg/L?

8.8 = demand +
8.8 - 0.9 = demand
7.9 mg/L

18. The chlorine demand of a secondary effluent is 7.9 mg/L. If the chlorine residual of 0.6 mg/L is desired, what is the desired chlorine dosage in mg/L?

Dose = 7.9 + 0.6
= 8.5 mg/L

Chemical Dosage, mg/L pg. 5 formula book

19. The chlorinator is set to feed 31.5 lbs of chlorine per 24 hours for a plant flow of 1.6 MGD. Calculate the chlorine residual for a chlorine demand of 1.85 mg/L.

$$\text{Dose, mg/L} = \frac{\text{chemical feed, lbs/d}}{(\text{Flow, MGD})(8.34\ \text{lbs/gal})}$$

$$= \frac{31.5\ \text{lbs/d}}{(1.6\ \text{MGD})(8.34)} = 2.36\ \text{mg/L}$$

2.36 mg/L = 1.85 + Residual
2.36 - 1.85 = 0.51 mg/L

20. A wastewater plant has a flow of 2,570 gpm. If the chlorinator is feeding 93 pounds per day, what is the dose in mg/L?

$$\frac{(2570 \text{ gpm})(1440)}{1{,}000{,}000} = 3.7008 \text{ MGD}$$

$$\text{dose, mg/L} = \frac{93 \text{ lbs/d}}{(3.7008)(8.34)} = \boxed{3.0 \text{ mg/L}}$$

21. What should the chlorinator setting be in lbs/day to treat a flow of 4.0 MGD if the chlorinator demand is 9 mg/L and a chlorine residual of 1.7 mg/L is desired?

$$\text{dose, mg/L} = 9 \text{ mg/L} + 1.7 \text{ mg/L} = 10.7 \text{ mg/L}$$

$$\text{lbs/d} = (10.7 \text{ mg/L})(4.0 \text{ MGD})(8.34)$$

$$= \boxed{357 \text{ lbs/d}}$$

Hypochlorination pg. 9 formula book

22. How many pounds of HTH (65% available chlorine) will it take to make a 2% solution when dissolved in enough water to make 15 gallons of hypochlorite?

$$\text{lbs, HTH} = \frac{(\text{\% conc. hypo})(\text{hypo, gal})(8.34)}{\text{\% available}}$$

$$= \frac{(0.02)(15 \text{ gal})(8.34)}{0.65} = \boxed{3.8 \text{ lbs}}$$

23. How many pounds of 65% HTH are used to make 1 gallon of 3% solution?

$$\text{lbs, HTH} = \frac{(0.03)(1 \text{ gal})(8.34)}{0.65}$$

$$= \boxed{0.4 \text{ lbs}}$$

24. How many pounds of 65% available HTH is needed to make 5 gallons of 18% solution?

$$\text{lbs, HTH} = \frac{(0.18)(5 \text{ gal})(8.34)}{0.65}$$

$$= \boxed{11.5 \text{ lbs}}$$

Use the following information for problems 25 – 28:
At 8:00 a.m. on Monday morning a chlorine cylinder weighs 83 pounds. At 8:00 a.m. on Tuesday morning the same cylinder weighs 69 pounds.

25. What is the chlorinator feed rate in pounds per day?

83 lbs − 69 lbs = **14 lbs/d**

26. Estimate the chlorine dose in mg/L for the chlorinator. The flow totalizer reads 12,982,083 gallons at 8:00AM on Monday morning and 13,528,924 at 8:00AM on Tuesday morning. (Note: This totalizer does not zero out each morning.)

13,528,924 − 12,982,083 = 546,841 gal

$$\text{dose} = \frac{14 \text{ lbs/d}}{(0.546841 \text{ MG})(8.34)}$$

$$= \boxed{3.1 \text{ mg/L}}$$

27. If the setting on the chlorinator does not change, how many pounds of chlorine will be left in the cylinder on Friday morning at 8:00 a.m.?

(14 lbs/d)(3 d) = 42 lbs

69 − 42 = **27 lbs**

28. How many 150-lb chlorine cylinders will this water plant need in a month (with 30 days) if the chlorinator setting remains the same?

(14 lbs/d)(30d) = 420 lbs

$$\frac{420}{150} = 2.8 \approx \boxed{3 \text{ cylinders}}$$

Use the following information for problems 29 – 31:
At 8:00 a.m. on Friday morning a chlorine cylinder weighs 298 pounds. That afternoon at 4:00 p.m. the same cylinder weighs 216 pounds.

29. What is the chlorinator feed rate in pounds per day?

$298 - 216 = 82\text{ lbs}$

$\frac{82\text{ lbs}}{8\text{ hrs}} = (10.25\text{ lbs/hr})(24\text{ hrs/d}) = \boxed{246\text{ lbs/d}}$

30. How many pounds of chlorine will be in the cylinder at 8:00 a.m. on Saturday morning if the feed rate does not change?

$298 - 246 = \boxed{52\text{ lbs}}$

31. What is the minimum number of ton (~2000 lbs) cylinders the operator will need in a month with 31 days (at this feed rate)?

$(246\text{ lbs/d})(31\text{ d}) = \frac{7626\text{ lbs}}{2000\text{ lbs}} = 3.8 \approx \boxed{4\text{ cylinders}}$

Answers:

1. 117 lbs/day
2. 15.2 lbs/day
3. 3415 lbs
4. 30.9 lbs/day
5. 307 lbs/day
6. 0.83 lbs
7. 384 lbs/day
8. 234 lbs/day
9. 1096 lbs/day
10. 20.8 lbs/day
11. 10.8 gpd
12. 93.9 gpd
13. 5.7 mg/L
14. 7.6 mg/L
15. 309 lbs/day
16. 5.7 mg/L
17. 7.9 mg/L
18. 8.5 mg/L
19. 0.51 mg/L
20. 3.0 mg/L
21. 357 lbs/day
22. 3.8 lbs
23. 0.4 lbs
24. 11.5 lbs
25. 14 lbs/day
26. 3.1 mg/L
27. 27 lbs
28. 3 cylinders
29. 246 lbs/day
30. 52 lbs
31. 4 cylinders

Section 10

Applied Math for Wastewater Treatment Laboratory

Bacteriological, fecal coliform and *E. coli*

1. Calculate the geometric mean for the following fecal coliform test results: 60, 100, 0, 0, 40, 20, 20, 45, 55, 60, 20, 20

$$\sqrt[12]{(60)(100)(1)(1)(40)(20)(20)(45)(55)(60)(20)(20)}$$
$$= \sqrt[12]{5.7024 \times 10^{15}} = \boxed{21}$$

2. Calculate the geometric mean for the following fecal coliform test results: 0, 0, 50, 50, 25, 100, 100, 50, 75, 50

$$\sqrt[10]{(1)(1)(50)(50)(25)(100)(100)(50)(75)(50)}$$
$$= \sqrt[10]{1.171875 \times 10^{14}} = \boxed{26}$$

Solutions

3. How many mL of 0.7 N NaOH (V_1, N_1) is needed to get 750 mL of 0.05 N NaOH (V_2, N_2)?

$$(V_1)(N_1) = (V_2)(N_2)$$
$$(V_1)(0.7) = (750)(0.05)$$
$$V_1 = \frac{(750)(0.05)}{0.7} = \boxed{53.6 \text{ mL}}$$

4. How many mL of 0.5 N NaOH (V_1, N_1) react with 800 mL of 0.1 N HCl (V_2, N_2)?

$$(V_1)(0.5) = (800)(0.1)$$
$$V_1 = \frac{(800)(0.1)}{0.5} = \boxed{160 \text{ mL}}$$

Biochemical Oxygen Demand, BOD

- Blanks must not deplete more than 0.2 mg/L DO
- The sample must deplete at least 2.0 mg/L DO, if it does not, the dilution is too weak and report as inadequate depletion
- After 5 days of incubation at 20°C ± 1.0°C, the sample must have at least 1.0 mg/L DO, if less than, the sample was too strong

Section 10

5. Given the following information, determine the BOD of the wastewater:

Sample Volume = 5 mL   5/300 = 0.01667 = P
BOD Bottle Volume = 300 mL
Initial DO of Diluted Sample = 6 mg/L D_1
Final DO of Diluted Sample = 3.5 mg/L D_2

$$BOD = \frac{D_1 - D_2}{P} = \frac{6 - 3.5}{0.01667} = 150 \text{ mg/L}$$

6. Given the following information, determine the BOD of the wastewater:

Sample Volume = 10 mL   10/300 = 0.0333 = P
BOD Bottle Volume = 300 mL
Initial DO of Diluted Sample = 8.3mg/L D_1
Final DO of Diluted Sample = 4.2 mg/L D_2

$$BOD = \frac{8.3 - 4.2}{0.0333} = 123 \text{ mg/L}$$

7. Given the following primary effluent BOD test results, calculate the 7-day average:

April 10 – 190 mg/L
April 11 – 198 mg/L
April 12 – 205 mg/L
April 13 – 202 mg/L
April 14 – 210 mg/L
April 15 – 201 mg/L
April 16 – 197 mg/L

$$\frac{190 + 198 + 205 + 202 + 210 + 201 + 197}{7} = \frac{1403}{7} = 200 \text{ mg/L}$$

Alkalinity

8. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 24 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.2 to 4.5.

$$\text{Total Alk} = \frac{(\text{mL of titrant})(\text{N of sulfuric acid})(50{,}000)}{\text{sample vol, mL}}$$

$$= \frac{(24 \text{ mL})(0.02 \text{ N})(50{,}000)}{100 \text{ mL}}$$

$$= 240 \text{ mg/L}$$

Section 10

9. Calculate the total alkalinity in mg/L as $CaCO_3$ for a sample of raw wastewater that required 10.1 mL of 0.02N H_2SO_4 to titrate 100 mL sample from pH 7.5 to 4.5.

$$Alk = \frac{(10.1\,mL)(0.02\,mL)(50{,}000)}{100\,mL}$$

$$= \boxed{101\,mg/L}$$

Temperature

10. The influent to a treatment plant has a temperature of 72°F. What is the temperature expressed in degrees Celsius?

$$°C = (0.556)(°F - 32)$$

$$= (0.556)(72-32) = (0.556)(40) = \boxed{22.2°C}$$

11. Convert 56° F to degrees Celsius.

$$°C = (0.556)(56-32)$$

$$= (0.556)(24) = \boxed{13.3°C}$$

12. The effluent of a treatment plant is 22°C. What is this temperature expressed in degrees F?

$$°F = (1.8)(°C) + 32$$

$$= (1.8)(22) + 32$$

$$= 39.6 + 32$$

$$= \boxed{71.6°F}$$

Answers:

1. 21
2. 26
3. 53.6 mL
4. 160 mL
5. 150 mg/L
6. 123 mg/L
7. 200 mg/L
8. 240 mg/L
9. 101 mg/L
10. 22.2°C
11. 13.3°C
12. 71.6°F

Section 10

Applied Math for Wastewater
Pump Horsepower & Efficiency

1. A pump must pump 2,500 gpm against a total head of 73 feet. What horsepower (water horsepower) will be required to do the work?

$$Whp = \frac{(\text{flow, gpm})(\text{head, ft})}{3960}$$

$$= \frac{(2{,}500\text{ gpm})(73\text{ ft})}{3960} = 46\text{ hp}$$

2. A pump is delivering a flow of 1,035 gpm against 46.7 feet of head. What horsepower will be required?

$$Whp = \frac{(1035\text{ gpm})(46.7\text{ ft})}{3960}$$

$$= 12.2\text{ hp}$$

3. If a pump is to deliver 630 gpm of water against a total head of 102 feet, and the pump has an efficiency of 78%, what power must be supplied to the pump?

$$Bhp = \frac{(\text{flow, gpm})(\text{head, ft})}{(3960)(\text{pump eff., \%})}$$

$$= \frac{(630\text{ gpm})(102\text{ ft})}{(3960)(0.78)} = 20.8\text{ hp}$$

4. You have calculated that a certain pumping job will require 10.1 whp. If the pump is 84% efficient and the motor is 73% efficient, what motor horsepower will be required?

$$Mhp = \frac{Bhp}{\%\text{ motor eff.}} \qquad Bhp = \frac{Whp}{\%\text{ pump eff.}}$$

OR

$$Mhp = \frac{Whp}{(\%\text{ motor eff.})(\%\text{ pump eff.})} = \frac{10.1}{(0.84)(0.73)} = 16.5\text{ hp}$$

Math

5. What is the overall efficiency if an electric power equivalent to 36 hp is supplied to the motor and 16.3 hp of work is accomplished?

$$\%\text{Eff, overall} = \frac{\text{Whp}}{\text{Mhp}} \times 100$$

$$= \frac{16.3}{36} \times 100 = 45\%$$

6. A pump is discharging 1,250 gpm against a head of 71 feet. The wire-to-water efficiency is 82%. If the cost of power is \$0.028/kW hr, what is the cost of the power consumed during a week in which the pump runs 126 hours?

$$\text{Mhp} = \frac{(1250)(71)}{(3960)(.82)} = 27.33\text{hp}$$

$$\text{Cost, \$/hr} = (\text{Mhp})(0.746\ \text{kW/hp})(\text{cost, \$/kW-hr})$$

$$= (27.33)(0.746)(0.028)$$

$$= (\$0.57/\text{hr})(126\ \text{hrs}) = \$71.93$$

7. A wet well is 12 feet long and 10 feet wide. The influent valve to the wet well is closed. If a pump lowers the water level 2.6 feet during a 5-minute pumping test, what is the gpm pumping rate?

$$\text{Pump Rate, gpm} = \frac{(l,\text{ft})(w,\text{ft})(d,\text{ft})(7.48)}{\text{time, min}}$$

$$= \frac{(12\text{ft})(10\text{ft})(2.6\text{ft})(7.48)}{5\text{ min}}$$

$$= 467\ \text{gpm}$$

ANSWERS

1. 46 hp
2. 12.2 hp
3. 20.8 hp
4. 16.5 hp
5. 45.3%
6. \$71.93
7. 467 gpm

Section 11

Lab

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BNS - WASTEWATER LABORATORY

TDEC - Fleming Training Center 2

NPDES Permit

Effluent Characteristics	Effluent Limitations						Monitoring Requirements		
	Monthly Average Conc. (mg/l)	Monthly Average Amount (lb/day)	Weekly Average Conc. (mg/l)	Weekly Average Amount (lb/day)	Daily Maximum Conc. (mg/l)	Daily Minimum Percent Removal	Measurement Frequency	Sample Type	Sampling Point
$CBOD_5$	5	83	7.5	125	10	40	3/week	composite	effluent
(May 1 - Oct. 31)	Report	—	—	—	Report	—	3/week	composite	influent
$CBOD_5$	15	250	20	333	25	40	3/week	composite	effluent
(Nov. 1 - April 30)	Report	—	—	—	Report	—	3/week	composite	influent
Ammonia as N	1.2	20	1.8	30	2.4	—	3/week	composite	effluent
(May 1 - Oct. 31)									
Ammonia as N	2.8	47	4.2	70	5.6	—	3/week	composite	effluent
(Nov. 1 - April 30)									
Total Nitrogen* (May 1 - Oct. 31)	Report	—	—	—	Report	—	2/month	composite	effluent
Total Phosphorous* (May 1 - Oct. 31)	Report	—	—	—	Report	—	2/month	composite	effluent
Suspended Solids	30	500	40	667	45	40	3/week	composite	effluent
(May 1 - Oct. 31)	Report	—	—	—	Report	—	3/week	composite	influent
Suspended Solids							3/week	composite	effluent
(Nov. 1 - April 30)	Report	—	—	—	Report	—	3/week	composite	influent
Sanitary Sewer Overflows, Total Occurrences	Report						continuous	visual	NA
Dry Weather Overflows, Total Occurrences	Report						continuous	visual	NA
Bypass of Treatment, Total Occurrences	Report						continuous	visual	NA

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Reliable sampling data are obtained by collecting samples:

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

Operator with Improvised Sampling Device

Automated Samplers

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Samplers

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

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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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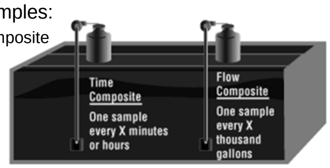
Composite Sample

- 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:
  - Fixed volume or time composite
  - Flow proportioned.



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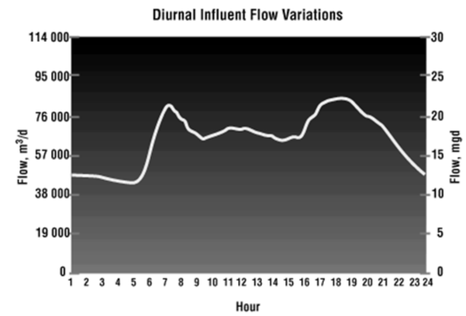
Flow Variations



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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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Sample Volume and Storage

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

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

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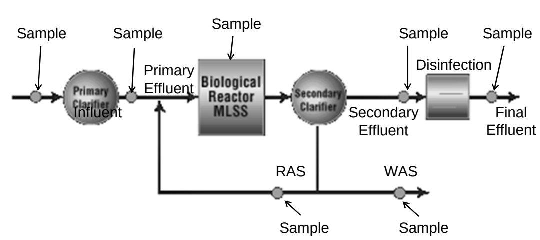
Sample Points



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Process Monitoring and Control Tests

- $cBOD_5$
- Microscopic Examination
- Temp
- Depth of sludge
- pH
- DO
- Nitrogen
  - Ammonia
  - Nitrate
  - Nitrite
  - Total Kjeldalh (TKN)

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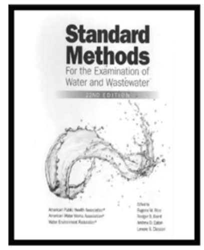
Analysis



- When you are ready to perform tests, refer to specific methods in *Standard Methods for the Examination of Water and Wastewater*

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This is a summary of the containers, sample volume, preservation and max holding time out of 40 CFR Part 136 Table II.

Parameter Number/Name	Container [1]	Preservation [2,3]	Maximum Holding Time [4]
Table IA - Bacterial Tests:			
1-5. Coliform, total, fecal, and E. coli	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	8 hours [22,23]
6. Fecal streptococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	8 hours [22]
7. Enterococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	8 hours [22]
8. Salmonella	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$ [5]	8 hours [22]
Table IA - Aquatic Toxicity Tests:			
9-12. Toxicity, acute and chronic	P, FP, G	Cool, ≤6 °C [16]	36 hours
Table IB - Inorganic Tests:			
1. Acidity	P, FP, G	Cool, ≤6 °C [18]	14 days
2. Alkalinity	P, FP, G	Cool, ≤6 °C [18]	14 days
4. Ammonia	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH<2	28 days
9. Biochemical oxygen demand	P, FP, G	Cool, ≤6 °C [18]	48 hours
10. Boron	P, FP, or Quartz	HNO_3 to pH<2	6 months
11. Bromide	P, FP, G	None required	28 days
14. Biochemical oxygen demand, carbonaceous	P, FP G	Cool, ≤6 °C [18]	48 hours
15. Chemical oxygen demand	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH<2	28 days
16. Chloride	P, FP, G	None required	28 days
17. Chlorine, total residual	P, G	None required	Analyze within 15 minutes
21. Color	P, FP, G	Cool, ≤6 °C [18]	48 hours
23-24. Cyanide, total or available (or CATC) and free	P, FP, G	Cool, ≤6 °C [18], NaOH to pH>10 [5,6], reducing agent if oxidizer present	14 days
25. Fluoride	P	None required	28 days
27. Hardness	P, FP, G	HNO_3 or H_2SO_4 to pH<2	6 months
28. Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes
31, 43. Kjeldahl and organic N	P, FP, G	Cool, ≤6 °C [18], H_2SO_4 to pH<2	28 days

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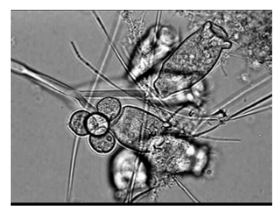
Microscopic Examination

- Microscopic examinations should be performed immediately after sample collection.



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Biochemical Oxygen Demand

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

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

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Biochemical Oxygen Demand

- 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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History of BOD

- A standard temperature at which BOD testing should be carried out was first proposed by the Royal Commission on Sewage Disposal in its eighth report in 1912:
  - “(c) An effluent in order to comply with the general standard must not contain as discharged more than 3 parts per 100,000 of suspended matter, and with its suspended matters included must not take up at 65° F (18-3° C.) more than 2.0 parts per 100,000 of dissolved oxygen in 5 days. This general standard should be prescribed either by Statute or by order of the Central Authority, and should be subject to modifications by that Authority after an interval of not less than ten years.”

Information from http://en.wikipedia.org/wiki/Biochemical_oxygen_demand

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History of BOD

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History of BOD

- This was later standardized at 68° F and then 20° C.
- Although the Royal Commission on Sewage Disposal proposed 5 days as an adequate test period for rivers of the United Kingdom of Great Britain and Ireland, longer periods were investigated for North American rivers.
- Incubation periods of 1, 2, 5, 10 and 20 days were being used into the mid-20th century.
- Keeping dissolved oxygen available at their chosen temperature, investigators found up to 99 percent of total BOD was exerted within 20 days, 90 percent within 10 days, and approximately 68 percent within 5 days.

Information from http://en.wikipedia.org/wiki/Biochemical_oxygen_demand

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History of BOD

- Variable microbial population shifts to nitrifying bacteria limit test reproducibility for periods greater than 5 days.
- The 5-day test protocol with acceptably reproducible results emphasizing carbonaceous BOD has been endorsed by the US EPA.
- 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.
- Stabilization, in this context, may be perceived in general terms as the conversion of food to living aquatic fauna.
- Although these fauna will continue to exert biochemical oxygen demand as they die, that tends to occur within a more stable evolved ecosystem.

Information from http://en.wikipedia.org/wiki/Biochemical_oxygen_demand

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History of BOD

- A 5-day duration for BOD determination has no theoretical grounding but is based on historical convention.
- Tchobanoglous and Schroeder (1985) provide the following background:
  - "In a report prepared by the Royal Commission on Sewage Disposal in the United Kingdom at the beginning of the century, it was recommended that a 5-day, 18.3°C, BOD value be used as a reference in Great Britain.
  - These values were selected because British rivers do not have a flow time to the open sea greater than 5 days and average long-term summer temperatures do not exceed 18.3°C.

Info from: http://water.usgs.gov/owq/FieldManual/Chapter7/NFMChap7_2_BOD.pdf

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Biochemical Oxygen Demand

- Requirements for valid BOD results:
  - Blank depletion must be ≤ 0.2 mg/L DO
    - Preferably <0.1 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

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Biochemical Oxygen Demand

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

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BOD Calculation

- Initial DO = 8.2 mg/L
- Final DO = 4.5 mg/L
- Sample Volume = 6 mL
- BOD_5, mg/L = $\frac{D_1 - D_2}{P}$
- Where P = % sample
  - 6/300 = 0.02
- BOD_5, mg/L = $\frac{8.2 - 4.5}{0.02}$

  = 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

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BOD Calculation

- P = 12/300 = 0.04
- BOD_5, mg/L = $\frac{8.1 - 4.0}{0.04}$

  = 102.5 mg/L

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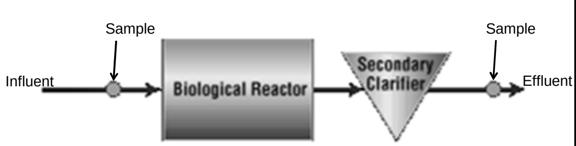
BOD Sampling Locations



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Chemical Oxygen Demand

- The COD test is used for more rapid assessment of organic strength.


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Chemical Oxygen Demand

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

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Suspended Solids

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

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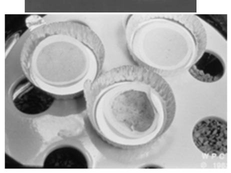
Suspended Solids

Technician Performing SS Test



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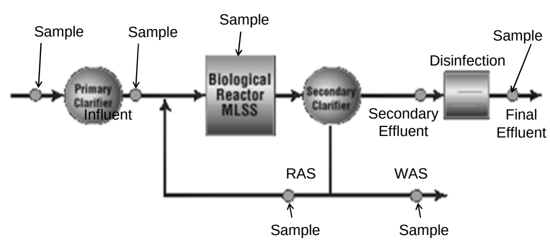
Suspended Solids Sample Points



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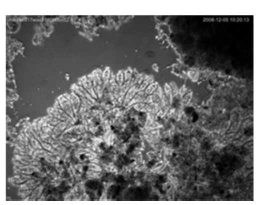
Microscopic Examination

- Microscopic examination of the water can provide valuable information.



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Microscopic Examination

- Provides information on the biological characteristics and health system and gives warning of process problems, such as poor settling or the presence of a toxic or inhibitory material
  - To do the test, first place a drop of well-mixed water on a slide
  - Place a cover slide on top

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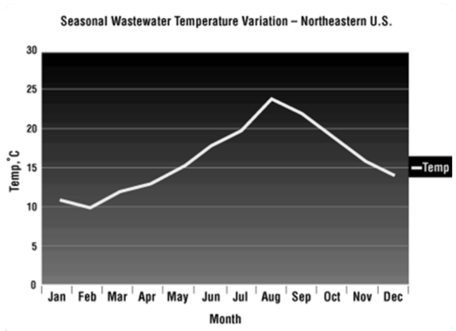
Temperature



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pH

- Power of hydrogen
  - Measurement of the hydrogen ion concentration
  - Each decrease in pH unit equals a 10x increase in acid
- Indicates the intensity of its acidity or basicity
- Scale runs from 0 to 14, with 7 being neutral
- Probe measures millivolts, then converts into pH units
  - Temperature affects millivolts generated, therefore you need a temperature probe as well for corrections
- 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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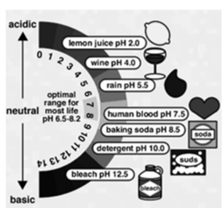
pH

- Calibrate daily with fresh buffers
  - Use at least two buffers
- 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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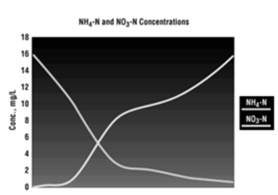
Nitrogen

- 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:
  - Amperometric titration
    - Less interferences such as color and/or turbidity
  - 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
  - Ioodmetric 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 most commonly used
  - Match color of sample to a standard
  - ***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) alters 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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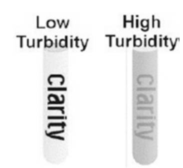
Turbidity

- 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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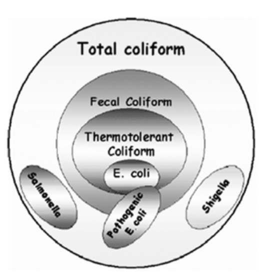
Coliform Bacteria

- 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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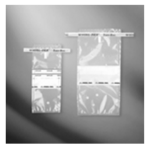
Coliform Bacteria

- Comprises all the aerobic and facultative anaerobic gram negative, nonspore-forming, rod-shaped bacteria that ferment lactose within 48 hours ~ 35ºC
- Coliform bacteria can be split into fecal and non-fecal groups
- The fecal group can grow at higher temperatures (45 ºC) than the non-fecal coliforms

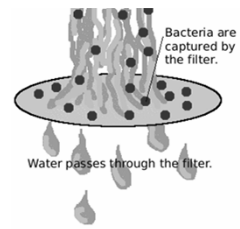
Sampling

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

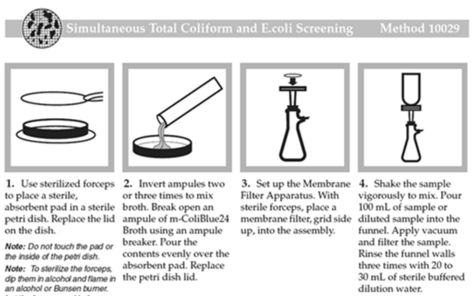


Approved Methods

- Coliform (fecal)
  - Number per 100 mL
    - Membrane filtration (SM9222 D-1997)
- E. coli
  - Number per 100 mL
    - Membrane filtration
      - m-ColiBlue24®
      - Modified mTEC agar (EPA Method 1603)
    - Multiple tub/multiple well (Colilert®) (SM9223 B-2004)



Membrane Filtration


Simultaneous Total Coliform and E.coli Screening Method 10029

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

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

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

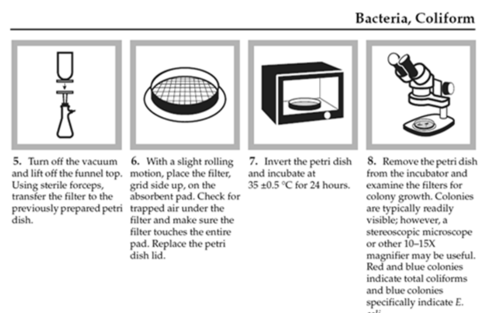
2. Invert ampules two or three times to mix broth. Break open an ampule of m-ColiBlue24 Broth using an ampule breaker. Pour the contents evenly over the absorbent pad. Replace the petri dish lid.

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

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

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

Membrane Filtration


Bacteria, Coliform

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

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

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

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

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

Membrane Filtration Equipment

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

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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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.
- Interferences
  - None, but excess particulates may cause colonies to grow together on a crowded filter or slow the sample filtration process.

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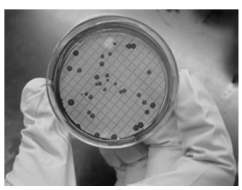
Fecal Coliform

- 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.
- Visually determine colony counts on membrane filters.
- Verify using 10-15 X binocular wide-field microscope.



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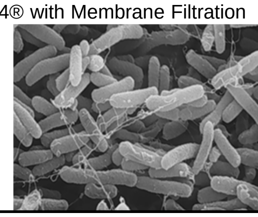
ESCHERICHIA COLI (E.COLI)

m-ColiBlue24® with Membrane Filtration



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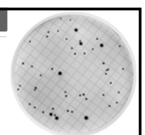
E. coli m-ColiBlue24®



- Incubation 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: 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.
- Visually determine colony counts 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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Expected Reactions of Various Microorganisms

- Known negative reaction (no growth) after 24-25 hours
  - *Pseudomonas aeruginosa*
    - *Variable reaction may be positive for total coliform when incubated longer than 25 hours*
  - *Proteus vulgaris*
  - *Aeromonas hydrophila*
- Some strains of the following microorganisms are known to produce a false-positive total coliform reaction (a red colony, but not a true total coliform)
  - *Serratia species*
  - *Hafnia alvei*
  - *Vibrio fluvialis*
  - *Aeromonas species*
  - *Proteus vulgaris*
  - *Providencia stuartii*
  - *Yersinia enterocolitica*
  - *Leclercia adecarboxylata*
  - *Ewingella americana*
  - *Staphylococcus species*
  - *Proteus mirabilis*

M-ColiBlue24® Trouble-Shooting Guide, Hach Company, www.Hach.com

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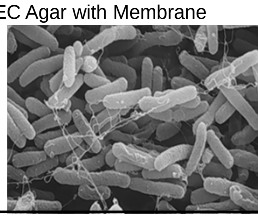
ESCHERICHIA COLI (E.COLI)

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 ± 0.5°C for 2 hours
  - Resuscitates injured or stressed bacteria
- Then incubate at 44.5 ± 0.2°C for 22 hours
- After incubation, remove the plate from the water bath or dry air incubator

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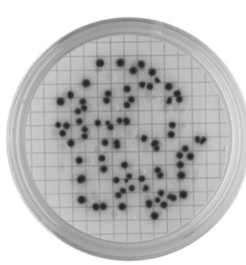
Method 1603

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

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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
  - Should be analyzed whenever a new batch of media or reagents is used
- Positive control
  - Should be analyzed 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 35ºC ± 0.5ºC.
  - Absence of growth indicates sterility of the filter
  - Run daily
- Method Blank
  - Filter a 50-mL volume of sterile buffered dilution water and place on a modified mTEC agar plate and incubate
  - Absence of growth indicates freedom of contamination from the target organism
  - Run daily
- Filtration Blank
  - Filter a 50-mL volume of sterile buffered dilution water and place on a TSA plate and incubate for 24 ± 2 hours at 35ºC ± 0.5ºC
  - Absence of growth indicates sterility of the buffer and filtration assembly
  - Run daily

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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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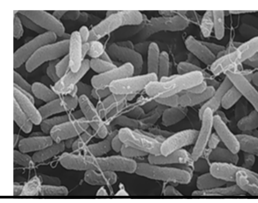
ESCHERICHIA COLI (E.COLI)

Colilert



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Colilert® & Colilert-18®

MPN Method

- 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±0.5°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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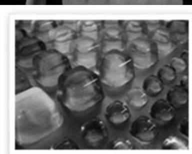
Colilert® & Colilert-18®

- 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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E. coli 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-Thermotolerant Escherichia coli Agar (Modified mTEC), September 2002, EPA-821-R-02-023

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All Bacteriological Checks

- Temperatures are documented twice daily at least 4 hours apart, when 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

- 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

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

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

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Geometric Mean

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

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Geometric Mean

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

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Geometric Mean

- Now, try one on your own:
- 20, 20, 210, 350
- Geometric Mean = 73.6

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Geometric Mean

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

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Sampling and Analysis Plan

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

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40 CFR 136 Method Update Rule

- You Have Heard it All Before
  - More Rules
  - More Testing
  - More Paperwork
  - More Cost
- But everything we do is regulated.

2012 Update of 136

Federal Register May 18, 2012

- Standard Methods approved by date not Edition
- Section 136.7 Quality Assurance and Quality Control.

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.**

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

Demonstration of Capability

- DOC once for each analyst
- Standard Methods 1020.B.1
  - As a minimum, include a reagent blank and at least 4 LFBs at a concentration between 10 times the MDL and the midpoint of a calibration curve.
  - Something to keep along with these records is a signed form (documentation) that analyst has read and understands all appropriate SOPs and Methods.
- What tests does this apply to?
  - Ammonia, BOD/cBOD, Chlorine, pH, DO, Total Phosphorus, TSS
- How often?
  - Once for each analyst.
    - Recommended yearly for backup analyst who does not perform tests frequently
    - EPA highly recommends running every 2-3 years for every analyst
  - Each analyst should have a file kept on their training within and for the lab.
- **2014 Update**
  - **DMRQA's were removed as acceptable DOC**
    - **Analyst have had a year, there should be at least 4 standards that have been analyzed and within limits to demonstrate capability.**

Method Detection Level

- MDL
- Standard Methods 1020.B.4
  - As a starting point for selecting the concentration to use when determining the MDL, us an estimate of five times the estimated true detection level
  - Ideally, prepare and analyze at least seven portions of this solution over a 3-day period to ensure the MDL determination is more representative of routine measurements as performed in the laboratory
- What tests does this apply to?
  - Ammonia, Chlorine and Total Phosphorus
- How often?
  - Annually
- 2014 Update – this is your reporting limit

What the heck IS an MDL study?

- It is a calculation that statistically gives the lowest concentration that a lab/facility can "see", that is detect an analyte
- Not practical for many analyses
- It is a bit tricky the first time, but KEEP RECORDS so next year it will be a breeze.
- Fresh samples prepared daily are preferred and it is recommended that samples are run over 3 days to give a more accurate account of how samples are run.

How MDL Studies are Performed

- Make seven very low level blank spikes (can be lower than the lowest point on your curve)
- Analyze all seven over several days and calculate the standard deviation
- Multiply the standard deviation by the "student t" for 7 values (3.14)
- You cannot "cherry pick" your results, they must be 7 samples in a row

MDL Calculations

- The result is the MDL (method detection level)
- The MDL must be greater than 1/10 the concentration of each spike
  - Example: if the spike was 3, the MDL cannot be lower than 0.3 (3 divided by 10)
- Keep up with the best spike value used for your MDL study so you don't have to go through several attempts each year

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, Total Phosphorus and TSS
- How often?
  - Depends on method QA/QC

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Laboratory Fortified Blank

- LFB
- Standard Methods 1020.B.6
  - A laboratory-fortified blank is a reagent water sample to which a known concentration of the analyte of interest has been added
  - Sample batch = 5% basis = 1 every 20 samples
    - At least once a month
  - Use an added concentration of at least 10 times the MDL, or less than or equal to the midpoint of the calibration curve
- What tests does this apply to?
  - Ammonia, BOD/cBOD, Chlorine, Total Phosphorus, TSS
- How often?
- For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria:
  - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
  - If a permit stated 5 analyses per week, we would suggest twice a month.
  - Once per month would be the minimum requirement.

TDEC - Fleming Training Center 98

Laboratory Fortified Matrix and Duplicate

- LFM/LFMD
- Also known as a spike and spike dup
- Standard Methods 1020.B.7
  - A laboratory matrix (LFM) is 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
  - Sample batch = 5% basis = 1 every 20 samples
    - At least once a month
  - Add a concentration less than or equal to the midpoint of the calibration curve
  - Preferably the same concentration as the LFB (laboratory fortified blank)
- Shows if there are interferences in the effluent matrix
- What tests does this apply to?
  - Ammonia and Total Phosphorus
- How often?
- For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria:
  - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
  - If a permit stated 5 analyses per week, we would suggest twice a month.
  - Once per month would be the minimum requirement.
- **2014 Update – Spike volume should be less than 1% of the volume.**
  - **Example: spike with 1 mL of 1000 mg/L into 100 mL sample will equal a 10 mg/L increase in ammonia concentration.**

TDEC - Fleming Training Center 99

Duplicate

- Dup
- Not a part of the 12 Steps of QA, an addition from the State of TN
- Standard Methods 1020.B.8
  - As a minimum, include one duplicate sample with each sample set or on a 5% basis
- Standard Methods 1020.B.12
  - Calculate the RPD (relative percent difference)
  - Equal to or less than 20% RPD
- What tests does this apply to?
  - BOD/CBOD, chlorine, pH, DO, TSS and Settleable Solids
- How often?
- For samples that need to be analyzed on a 5% basis or once for every 20 samples follow these criteria: (10% would be once every 10 samples for TSS)
  - If a permit stated that 3 analyses per week, we would allow for a LFB to be analyzed at least once per month.
  - If a permit stated 5 analyses per week, we would suggest twice a month.
  - Once per month would be the minimum requirement.

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Initial Calibration Verification & Continuing Calibration Verification

- ICV
  - 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
- CCV
  - 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**

TDEC - Fleming Training Center 101

Control Charts

- Accuracy Control Charts
- Standard Methods 1020 B.13.a
  - The accuracy chart for QC samples (e.g., reagent blanks, LFBs, calibration check standards and LFMs) is constructed from the average and standard deviation of measurements.
  - The accuracy chart includes upper and lower warning levels (WL) and upper and lower control levels (CL).
  - Common practice is to use ±2*s* and ±3*s* limits for the WL and CL, respectively, where *s* represents standard deviation.
- 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.

TDEC - Fleming Training Center 102

Control Charts

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

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:II)
- 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 you have a "boo boo", 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

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 ± 15%
  - MS/MSD ± 20%
  - ICV/CCV ± 10%
  - RPD ± 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.
- ***Influent and Effluent are 2 different samples***
- QC Frequency is usually lumped in with the definition of a "batch" and should be in the SOP of some kind

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

Ammonia SM4500-NH_3 D -1997

- 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-NH_3 D -1997

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

TDEC - Fleming Training Center 109

Total Residual Chlorine SM4500-Cl G - 2000, DPD

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

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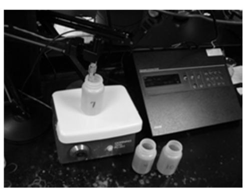
BOD_5/$cBOD_5$ SM5210 B – 2001 & Hach Method 10360

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

TDEC - Fleming Training Center 111

pH SM4500-H^+ B – 2000 Electrometric Method



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

TDEC - Fleming Training Center 112

TSS SM2540 D – 1997 Dried at 103-105^oC

- DOC
- LRB
- LFB
- Dup
- ICAL
- Corrective Action
- QC Acceptance
- Batch Size
- QC Frequency

TDEC - Fleming Training Center 113

Temperature SM2550 B – 2000 Thermometric Measurement

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

STATE OF TENNESSEE

NPDES PERMIT

No. TN00-----

Authorization to discharge under the
National Pollutant Discharge Elimination System (NPDES)

Issued By

Tennessee Department of Environment and Conservation
Division of Water Resources
401 Church Street
6th Floor, L & C Annex
Nashville, Tennessee 37243

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: **-------- STP**

is authorized to discharge: **treated municipal wastewater from Outfall 001**

from a facility located: **in -------, ------- County, Tennessee**

to receiving waters named: **--------- Creek at mile ---**

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 Sandra K. Dudley, Ph.D., P.E.
Director

CN-0759 RDAs 2352 and 2366

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MTS
TN0063771PMT.DOC

1.0. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1.1. NUMERIC AND NARRATIVE EFFLUENT LIMITATIONS

The City of -------- is authorized to discharge treated municipal wastewater from Outfall 001 to the ---------- Creek at mile 8.0. Discharge 001 consists of municipal wastewater from a treatment facility with a design capacity of 1.2 MGD. Discharge 001 shall be limited and monitored by the permittee as specified below:

Effluent Characteristics	**Effluent Limitations**						**Monitoring Requirements**		
	Monthly Average Conc. (mg/l)	Monthly Average Amount (lb/day)	Weekly Average Conc. (mg/l)	Weekly Average Amount (lb/day)	Daily Maximum Conc. (mg/l)	Daily Minimum Percent Removal	Measurement Frequency	Sample Type	Sampling Point
$CBOD_5$							3/week	composite	effluent
(May 1 - Oct. 31)	Report	—	—	—	Report	—	3/week	composite	influent
$CBOD_5$							3/week	composite	effluent
(Nov. 1 - April 30)	Report	—	—	—	Report	—	3/week	composite	influent
Ammonia as N						—	3/week	composite	effluent
(May 1 - Oct. 31)									
Ammonia as N						—	3/week	composite	effluent
(Nov. 1 - April 30)									
Total Nitrogen	—	—	—	—	Rpt (qtr avg)	Rpt (qtr load)	1/ quarter	composite	effluent
	—	—	—	—	Rpt (qtr avg)	Rpt (qtr load)	1/ quarter	composite	influent
Total Phosphorous	—	—	—	—	Rpt (qtr avg)	Rpt (qtr load)	1/ quarter	composite	effluent
	—	—	—	—	Rpt (qtr avg)	Rpt (qtr load)	1/ quarter	composite	influent
Suspended Solids							3/week	composite	effluent
	Report	—	—	—	Report	—	3/week	composite	influent
Sanitary Sewer Overflows, Total Occurrences	Report						continuous	visual	NA
Dry Weather Overflows, Total Occurrences	Report						continuous	visual	NA
Bypass of Treatment, Total Occurrences	Report						continuous	visual	NA

Note: The permittee shall achieve % removal of $CBOD_5$ and TSS on a monthly average basis. The permittee shall report all instances of overflow and/or bypasses. See Part 2.3.3.a for the definition of overflow and Part 1.3.5.1 for reporting requirements.

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

Note: See Part 1.2.3 for test procedures.

-------- STP
NPDES Permit TN00-----
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Effluent Characteristics	Effluent Limitations			Monitoring Requirements		
	Monthly Average	Daily Minimum	Daily Maximum	Measurement Frequency	Sample Type	Sampling Point
E. coli	126/100 ml (see the following paragraphs)	—	487 or 941/100 ml	3/week	grab	effluent
Chlorine residual (Total)	—	—	mg/l instantaneous	5/week	grab	effluent
Settleable solids	—	—	.0 ml/l	5/week	grab	effluent
Dissolved oxygen	—	.0 mg/l instantaneous	—	5/week	grab	effluent
pH (Standard Units)	—	.0	.0	5/week	grab	effluent
Flow (MGD)	Report	—	Report	7/week	continuous	influent
	Report	—	Report	7/week	continuous	effluent
Mercury, Total	mg/l	— —	— —	1/month	grab	effluent
Cyanide, Total	mg/l	— —	— —	1/month	grab	effluent
48 hr LC_{50}	Survival in % effluent			1/quarter	grab	effluent
IC_{25}	Survival, reproduction and growth in % effluent			1/quarter	composite	effluent

Note: See Part 3.4 for biomonitoring test and reporting requirements. See next page for percent removal calculations.

Note: See Part 1.2.3 for test procedures.

Total residual chlorine (TRC) monitoring shall be applicable when chlorine, bromine, or any other oxidants are added. The acceptable methods for analysis of TRC are any methods specified in Title 40 CFR, Part 136 as amended. The method detection level (MDL) for TRC shall not exceed 0.05 mg/l unless the permittee demonstrates that its MDL is higher. The permittee shall retain the documentation that justifies the higher MDL and have it available for review upon request. In cases where the permit limit is less that the MDL, the reporting of TRC at less than the MDL shall be interpreted to constitute compliance with the permit.

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.

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 85% 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:

$$\left[1 - \frac{\text{average of daily effluent concentration}}{\text{average of daily influent concentration}} \right] \times 100\% \quad = \% \text{ removal}$$

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:

$$\left[1 - \frac{\text{daily effluent concentration}}{\text{daily influent concentration}}\right] \times 100\% = \%\ \text{removal}$$

1.1. MONITORING PROCEDURES

1.1.1. Representative Sampling

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.

1.1.2. 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.

1.1.3. 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 1200-4-3-.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.

1.1.4. 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.

1.1.5. 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.

1.2. REPORTING

1.2.1. Monitoring Results

Monitoring results shall be recorded monthly and submitted monthly using Discharge Monitoring Report (DMR) forms supplied by the Division of Water Resources. Submittals shall be postmarked no later than 15 days after the completion of the reporting period. A completed DMR with an original signature shall be submitted to the following address:

TENNESSEE DEPT. OF ENVIRONMENT & CONSERVATION
DIVISION OF WATER RESOURCES
ENFORCEMENT & COMPLIANCE SECTION
L & C ANNEX 6TH FLOOR
401 CHURCH STREET
NASHVILLE TN 37243

A copy of the completed and signed DMR shall be mailed to the <EFO City> Environmental Field Office (EFO) at the following address:

TENNESSEE DEPT. OF ENVIRONMENT & CONSERVATION
DIVISION OF WATER RESOURCES
<EFO CITY> ENVIRONMENTAL FIELD OFFICE
<EFO ADDRESS>
<EFO CITY>, TN <ZIP>

A copy should be retained for the permittee's files. 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.

The electronic submission of DMR data will be accepted only if formally approved beforehand by the division. For purposes of determining compliance with this permit, data approved by the division to be submitted electronically is legally equivalent to data submitted on signed and certified DMR forms.

1.2.2. 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.

1.2.3. 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.

1.2.4. 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, Chattanooga, Columbia, Cookeville, Memphis, Johnson City, or Knoxville. Reports shall be submitted by the 15th day of the month following data collection.

1.2.5. Bypass and Overflow Reporting

1.3.5.1. Report Requirements

A summary report of known or suspected instances of overflows in the collection system or bypass of wastewater treatment facilities shall accompany the Discharge Monitoring Report. The report must contain the date and duration of the instances of overflow and/or bypassing and the estimated quantity of wastewater released and/or bypassed.

The report must also detail activities undertaken during the reporting period to (1) determine if overflow is occurring in the collection system, (2) correct those known or suspected overflow points and (3) prevent future or possible overflows and any resulting bypassing at the treatment facility.

On the DMR, the permittee must report the number of sanitary sewer overflows, dry-weather overflows and in-plant bypasses separately. Three lines must be used on the DMR form, one for sanitary sewer overflows, one for dry-weather overflows and one for in-plant bypasses.

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.

1.2.6. Reporting Less Than Detection

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 1200-4-3-.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.

1.3. 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.

1.4. 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.

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 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 1200-4-5-.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. "**Overflow**" means any release of sewage from any portion of the collection, transmission, or treatment system other than through permitted outfalls.

b. Overflows are prohibited.

c. The permittee shall operate the collection system so as to avoid overflows. No new or additional flows shall be added upstream of any point in the collection system, which experiences chronic overflows (greater than 5 events per year) or would otherwise overload any portion of the system.

d. Unless there is specific enforcement action to the contrary, the permittee is relieved of this requirement after: 1) an authorized representative of the Commissioner of the Department of Environment and Conservation has approved an engineering report 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 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 more than 5 overflows have occurred from a single point in the collection system for reasons that may not warrant the self-imposed moratorium or completion 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 ------- system, then the City must request that the division reactivate the pretreatment program. This must be done prior to the industrial discharge taking place.

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.

3a. The permittee has been delegated the primary responsibility and therefore becomes the "control authority" for enforcing the 40 CFR 403 General Pretreatment Regulations. Where multiple plants are concerned the permittee is responsible for the Pretreatment Program for all plants within its jurisdiction. The permittee shall implement and enforce the Industrial Pretreatment Program in accordance with Section 403(b)(8) of the Clean Water Act, the Federal Pretreatment Regulations 40 CFR 403, Tennessee Water Quality Control Act Part 63-3-123 through 63-3-128, and the legal authorities, policies, procedures, and financial provisions contained in its approved Pretreatment Program, except to the extent this permit imposed stricter requirements. Such implementation shall require but not limit the permittee to do the following:

i. Carry out inspection, surveillance, and monitoring procedures which will determine, independent of information supplied by the industrial user (IU), whether the IU is in compliance with the pretreatment standards;

ii. Require development, as necessary, of compliance schedules for each IU for the installation of control technologies to meet applicable pretreatment standards;

iii. Require all industrial users to comply with all applicable monitoring and reporting requirements outlined in the approved pretreatment program and IU permit;

iv. Maintain and update, as necessary, records identifying the nature and character of industrial user discharges, and retain such records for a minimum of three (3) years;

v. Obtain appropriate remedies for noncompliance by an IU with any pretreatment standard and/or requirement;

vi. Publish annually, pursuant to 40 CFR 403.8 (f)(2)(viii), a list of industrial users that have significantly violated pretreatment requirements and standards during the previous twelve-month period.

vii. Maintain an adequate revenue structure for continued operation of the pretreatment program.

viii. Update its Industrial Waste Survey at least once every five years. Results of this update shall be submitted to the Division of Water Resources, Pretreatment Section within 120 days of the effective date of this permit, unless such a survey has been submitted within 3 years of the effective date.

ix. Submit a written technical evaluation of the need to revise local limits within 120 days of the effective date of this permit to the state pretreatment program coordinator. The evaluation shall include the most recent pass-through limits proposed by the division. The technical evaluation shall be based on practical and specialized knowledge of the local program and not be limited by a specified written format.

4a. The division is not requiring implementation of a pretreatment program, but the permittee is voluntarily maintaining its program in a dormant stage. The program will remain dormant as long as no significant industries discharge process wastewater into the collection system and the city completes the activities listed below to the satisfaction of the division. Should a significant industrial user request permission to discharge process wastewater into the ------- STP system, then the city must request that the division reactivate the pretreatment program. This must be done prior to the industrial discharge taking place. A dormant program may be inactivated by the division should the city not implement the following activities:

i. 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;

ii. Maintain and update, as necessary, pretreatment language in --------- STP's Legal Authority and Enforcement Response Plan in order to keep them current with state and federal regulations;

iii. Provide an annual report briefly describing the permittee's pretreatment program activities over the previous twelve-month period. Reporting periods shall cover January 1 through December 31. The report shall be submitted to the Division of Water Resources, Central Office and a copy to the appropriate Environmental Field Office no later than the January 28th immediately following each reporting period. Each report shall conform to the format set forth in the State POTW Dormant Program Annual Report Package.

iv. Submit results of sampling of the influent and effluent of the wastewater treatment plant. At least once each annual reporting period, the permittee shall analyze the wastewater treatment plant influent and effluent for the following pollutants, using the prescribed sampling procedures:

Pollutant	**Sample Type**
chromium (III)	24-hour composite
chromium (VI)	24-hour composite
copper	24-hour composite
lead	24-hour composite
nickel	24-hour composite
zinc	24-hour composite
cadmium	24-hour composite
mercury	grab
silver	24-hour composite
total phenols	grab
cyanide	grab

If any particular pollutant is analyzed more frequently than is required, the permittee shall report the maximum and average values on the annual report. All upsets, interferences, and pass-through violations must also be reported on the annual report, the actions that were taken to determine the causes of the incidents and the steps that have been taken to prevent the incidents from recurring.

b. The permittee shall enforce 40 CFR 403.5, "prohibited discharges". Pollutants introduced into the POTW by a non-domestic source shall not cause pass through or interference as defined in 40 CFR Part 403.3. These general prohibitions and the specific prohibitions in this section apply to all non-domestic sources introducing pollutants into the POTW whether the source is subject to other National Pretreatment Standards or any state or local pretreatment requirements.

Specific prohibitions. Under no circumstances shall the permittee allow introduction of the following wastes in the waste treatment system:

i. Pollutants which create a fire or explosion hazard in the POTW;

ii. Pollutants which will cause corrosive structural damage to the treatment works, but in no case discharges with pH less than 5.0 unless the system is specifically designed to accept such discharges.

iii. Solid or viscous pollutants in amounts which will cause obstruction to the flow in the treatment system resulting in interference.

iv. Any pollutant, including oxygen-demanding pollutants (BOD, etc.) released in a discharge at a flow rate and/or pollutant concentration which will cause interference with the treatment works.

v. Heat in amounts which will inhibit biological activity in the treatment works resulting in interference, but in no case heat in such quantities that the temperature at the treatment works exceeds 40°C (104°F) unless the works are designed to accommodate such heat.

vi. Any priority pollutant in amounts that will contaminate the treatment works sludge.

vii. Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;

viii. Pollutants which result in the presence of toxic gases, vapors or fumes within the POTW in a quantity that may cause acute worker health and safety problems;

ix. Any trucked or hauled pollutants except at discharge points designated by the POTW.

c. The permittee shall notify the Tennessee Division of Water Resources of any of the following changes in user discharge to the system no later than 30 days prior to change of discharge:

i. New introductions into such works of pollutants from any source which would be a new source as defined in Section 306 of the Act if such source were discharging pollutants.

ii. New introductions of pollutants into such works from a source which would be subject to Section 301 of the "Federal Water Quality Act as Amended" if it were discharging such pollutants.

iii. A substantial change in volume or character of pollutants being introduced into such works by a source already discharging pollutants into such works at the time the permit is issued.

This notice will include information on the quantity and quality of the wastewater introduced by the new source into the publicly owned treatment works, and on any anticipated impact on the effluent discharged from such works. If this discharge necessitates a revision of the current NPDES permit or pass-through guidelines, discharge by this source is prohibited until the Tennessee Division of Water Resources gives final authorization.

d. Reporting Requirements

The permittee shall provide a semiannual report briefly describing the permittee's pretreatment program activities over the previous six-month period. Reporting periods shall end on the last day of the months of March and September. The report shall be submitted to the Division of Water Resources, Central Office and a copy to the appropriate Environmental Field Office no later than the 28th day of the month following each reporting period. For control authorities with multiple STPs, one report should be submitted with a separate Form 1 for each STP. Each report shall conform to the format set forth in the State POTW Pretreatment Semiannual Report Package which contains information regarding:

i. An updated listing of the permittee's industrial users.

ii. Results of sampling of the influent and effluent of the wastewater treatment plant. At least once each reporting period, the permittee shall analyze the wastewater treatment plant influent and effluent for the following pollutants, using the prescribed sampling procedures:

(approved and developing programs)

Pollutant	**Sample Type**
chromium, trivalent	24-hour composite
chromium, hexavalent	24-hour composite
total chromium	24-hour composite
copper	24-hour composite
lead	24-hour composite
nickel	24-hour composite
zinc	24-hour composite
cadmium	24-hour composite
mercury	24-hour composite
silver	24-hour composite
total phenols	grab
cyanide	grab

If any particular pollutant is analyzed more frequently than is required, the permittee shall report the maximum and average values on the semiannual report. All upsets, interferences, and pass-through violations must also be reported on the semiannual report, the actions that were taken to determine the causes of the incidents and the steps that have been taken to prevent the incidents from recurring.

At least once during the term of this permit, the permittee shall analyze the effluent from the STP (and report the results in the next regularly scheduled report) for the following pollutants:

chromium III	cyanide	phthalates, sum of the following: bis (2-ethylhexyl) phthalate butyl benzylphthalate di-n-butylphthalate diethyl phthalate
chromium VI	silver	
copper	benzene	
lead	carbon tetrachloride	
nickel	chloroform	
zinc	ethylbenzene	1,2 trans-dichloroethylene
cadmium	methylene chloride	tetrachloroethylene
mercury	naphthalene	Toluene
phenols, total	1,1,1 trichloroethane	trichloroethylene
chromium, total		

iii. Compliance with categorical and local standards, and review of industrial compliance, which includes a summary of the compliance status for all permitted industries. Also included is information on the number and type of major violations of pretreatment regulations, and the actions taken by the POTW to obtain compliance. The effluent from all significant industrial users must be analyzed for the appropriate pollutants at least once per reporting period.

iv. A list of industries in significant non-compliance as published in local newspapers in accordance with the requirements set forth in 40 CFR 403.8(f)(2)(viii).

v. A description of all substantive changes made to the permittee's pretreatment program. Any such changes shall receive prior approval. Substantive changes include, but are not limited to, any change in any ordinance, major modification in the program's administrative structure, local limits, or a change in the method of funding the program.

vi. Summary of permittee's industrial user inspections, which includes information on the number and type of industry inspected. All significant industrial users must be inspected at least once per year.

3.3. SLUDGE MANAGEMENT PRACTICES

a. The permittee must comply with 40 CFR 503 et seq. Sludge shall be sampled and analyzed at a frequency dependant both on the amount of sludge generated annually and on the disposal practice utilized. Whenever sampling and analysis are required by 40 CFR 503, the permittee shall report to the division the quantitative data for the following parameters:

1)	Arsenic	7)	Nickel
2)	Cadmium	8)	Selenium
3)	Copper	9)	Zinc
4)	Lead	10)	Nitrite plus Nitrate, NO_2, + NO_3 as N
5)	Mercury	11)	Total Kjeldahl Nitrogen, as N
6)	Molybdenum	12)	Ammonia, NH_3, as N

This sludge analysis must be submitted by February 19th of each calendar year. This information shall be submitted to the Division of Water Resources, Central Office, 401 Church Street, 6th Floor Annex, Nashville TN 37243-1534, Attention: Sludge Coordinator, Municipal Facilities Section.

b. Land application of sludge shall halt immediately if any of the following concentrations are exceeded:

POLLUTANT	CONCENTRATION (mg/kg[1])
Arsenic	75
Cadmium	85
Zinc	7500
Copper	4300
Lead	840

POLLUTANT	CONCENTRATION (mg/kg[1])
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100

1 Dry Weight Basis

Monthly average pollutant concentrations shall not exceed Table 3 of 40 CFR §503.13. If they are exceeded cumulative pollutant loading rates are to be calculated and recorded and shall not exceed Table 2 of 40 CFR §503.13 for the life of the land application site.

c. If land application is the final disposition of the wasted sludge, the permittee shall provide pathogen reduction, sludge stabilization and comply with land and crop usage controls as listed in 40 CFR Part 503, as authorized by the Clean Water Act. Records must be maintained by the permittee that indicate compliance or non-compliance with this rule. If the permittee is required to report to EPA, copies of all reports should be sent to the division, at the address listed in paragraph 1 of this section.

d. Before land applying municipal sludge the permittee must obtain approvals for each site(s) in writing from the division using the latest revision of Guidelines for

Land Application or Surface Disposal of Biosolids, unless the sludge being land applied meets the pollutant concentrations of 40 CFR 503.13(b)(3), the Class A pathogen requirements in 40 CFR 503.32(a), and one of the vector attraction reduction requirements in 40 CFR 503.33 (b)(1) through (b)(8).

e. Reopener: If an applicable "acceptable management practice" or numerical limitation for pollutants in sewage sludge promulgated under Section 405(d)(2) of the Clean Water Act, as amended by the Water Quality Act of 1987, is more stringent than the sludge pollutant limit or acceptable management practice in this permit, or controls a pollutant not limited in this permit, this permit shall be promptly modified or revoked and reissued to conform to the requirements promulgated under Section 405(d)(2). The permittee shall comply with the limitations by no later than the compliance deadline specified in the applicable regulations as required by Section 405(d)(2) of the Clean Water Act.

f. Notice of change in sludge disposal practice: The permittee shall give prior notice to the director of any change planned in the permittee's sludge disposal practice. If land application activities are suspended permanently and sludge disposal moves to a municipal solid waste landfill, the permittee shall contact the local Division of Solid Waste Management office address for other permitting and approvals (see table below):

Division of Solid Waste Management			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	540 McCallie Avenue, Suite 550	37402-2013	(423) 634-5745
Jackson	1625 Hollywood Drive	38305	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 432-4015
Columbia	2484 Park Plus Drive	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	3711 Middlebrook Pike	37921	(865) 594-6035
Memphis	8383 Wolf Lake Drive, Bartlett	38133-4119	(901) 371-3000
Nashville	711 R.S. Gass Boulevard	37243-1550	(615) 687-7000

This one paragraph applies only if sludge disposal is to a municipal solid waste landfill: (delete above)

The current method of sludge disposal is to a municipal solid waste landfill (or co - composting facility). This method of disposal is controlled by the rules of the Tennessee Division of Solid Waste Management (DSWM) and Federal Regulations at 40 CFR 258. If the permittee anticipates changing its disposal practices to either land application or surface disposal, the Division of Water Resources shall be notified prior to the change. A copy of the results of pollutant analyses required by the Tennessee Division of Solid Waste Management (DSWM) and / or 40 CFR 258 shall be submitted to the Division of Water Resources.

The following sludge language applies for lagoon systems: (delete above)

a. The permittee shall give prior notice to the director of any change planned in the permittee's sludge disposal practice. In the event the ------- STP removes any sludge from any lagoon the permittee must comply with 40 CFR 503 et seq.

b. Before land applying municipal sludge the permittee must obtain approvals for each site(s) in writing from the division using the latest revision of Guidelines for Land Application or Surface Disposal of Biosolids, unless the sludge being land applied meets the pollutant concentrations of 40 CFR 503.13(b)(3), the Class A pathogen requirements in 40 CFR 503.32(a), and one of the vector attraction reduction requirements in 40 CFR 503.33 (b)(1) through (b)(8).

c. If sludge disposal moves to a municipal solid waste landfill, the permittee shall contact the local Division of Solid Waste Management office address for other permitting and approvals (see table below):

Division of Solid Waste Management			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	540 McCallie Avenue, Suite 550	37402-2013	(423) 634-5745
Jackson	1625 Hollywood Drive	38305	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 432-4015
Columbia	2484 Park Plus Drive	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	3711 Middlebrook Pike	37921	(865) 594-6035
Memphis	8383 Wolf Lake Drive, Bartlett	38133-4119	(901) 371-3000
Nashville	711 R.S. Gass Boulevard	37243-1550	(615) 687-7000

3.4. BIOMONITORING REQUIREMENTS, CHRONIC

The permittee shall conduct a 3-Brood *Ceriodaphnia dubia* Survival and Reproduction Test and a 7-Day Fathead Minnow *(Pimephales promelas)* Larval Survival and Growth Test on samples of final effluent from Outfall 001.

The measured endpoint for toxicity will be the inhibition concentration causing 25% reduction in survival, reproduction and growth (IC_{25}) of the test organisms. The IC_{25} shall be determined based on a 25% reduction as compared to the controls, and as derived from linear interpolation. The average reproduction and growth responses will be determined based on the number of *Ceriodaphnia dubia* or *Pimephales promelas* larvae used to initiate the test.

If the permit limit is 100%, use this table:

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
Permit Limit (PL)	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**0.0625 X PL**	**Control**
% effluent					
100	**50**	**25**	**12.5**	**6.25**	**0**

If the permit limit is at or above 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**Control**
% effluent					
100	**xx**	**0.0**	**0.0**	**0.0**	**0**

If the permit limit is above 25%, but below 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**(100+PL)/2**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
100	**50**	**xx**	**0.0**	**0.0**	**0**

If the permit limit is at or below 25%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
4 X PL	**2 X PL**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
0	**0**	**xx**	**0.0**	**0.0**	**0**

The dilution/control water used will be moderately hard water as described in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013 (or the most current edition). A chronic standard reference toxicant quality assurance test shall be conducted with each species used in the toxicity tests and the results submitted with the discharge monitoring report. Additionally, the analysis of this multi-concentration test shall include review of the concentration-response relationship to ensure that calculated test results are interpreted appropriately.

Toxicity will be demonstrated if the IC_{25} is less than or equal to the permit limit indicated for each outfall in the above table(s). Toxicity demonstrated by the tests specified herein constitutes a violation of this permit.

All tests will be conducted using a minimum of three 24-hour flow-proportionate composite samples of final effluent collected on days 1, 3 and 5. If, in any control more than 20% of the test organisms die in 7 days, the test (control and effluent) is considered invalid and the test shall be repeated within two (2) weeks. Furthermore, if the results do not meet the acceptability criteria in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013 (or the most current edition), or if the required concentration-response review fails to yield a valid relationship per guidance contained in Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing, EPA-821-B-00-004 (or the most current edition), that test shall be repeated. Any test initiated but terminated before completion must also be reported along with a complete explanation for the termination.

CHOOSE 1 OF THE 2 PARAGRAPHS BELOW. USE PARAGRAPH (1) WHEN DILUTION RATIO IS GREATER THAN 500 TO 1:

(1)

The toxicity tests specified herein shall be conducted yearly (1/yr) for Outfall 001 and begin no later than 90 days from the effective date of this permit. Monitoring frequency will be 1/quarter when a non-categorical Significant Industrial User (SIU) or a Categorical Industrial User (CIU) discharges to the treatment works.

(2)

The toxicity tests specified herein shall be conducted quarterly (1/Quarter) for Outfall 001 and begin no later than 90 days from the effective date of this permit.

In the event of a test failure, the permittee must start a follow-up test within 2 weeks and submit results from a follow-up test within 30 days from obtaining initial WET testing results. The follow-up test must be conducted using the same serial dilutions as presented in the corresponding table(s) above. **The follow-up test will**

not negate an initial failed test. In addition, the failure of a follow-up test will constitute a separate permit violation.

In the event of 2 consecutive test failures or 3 test failures within a 12-month period for the same outfall, the permittee must initiate a Toxicity Identification Evaluation/Toxicity Reduction Evaluation (TIE/TRE) study within 30 days and so notify the division by letter. This notification shall include a schedule of activities for the initial investigation of that outfall. **During the term of the TIE/TRE study, the frequency of biomonitoring shall be once every three months.** Additionally, the permittee shall submit progress reports once every three months throughout the term of the TIE/TRE study. The toxicity must be reduced to allowable limits for that outfall within 2 years of initiation of the TIE/TRE study. Subsequent to the results obtained from the TIE/TRE studies, the permittee may request an extension of the TIE/TRE study period if necessary to conduct further analyses. The final determination of any extension period will be made at the discretion of the division.

The TIE/TRE study may be terminated at any time upon the completion and submission of 2 consecutive tests (for the same outfall) demonstrating compliance. Following the completion of TIE/TRE study, the frequency of monitoring will return to a regular schedule, as defined previously in this section as well in Part I of the permit. **During the course of the TIE/TRE study, the permittee will continue to conduct toxicity testing of the outfall being investigated at the frequency of once every three months but will not be required to perform follow-up tests for that outfall during the period of TIE/TRE study.**

Test procedures, quality assurance practices, determinations of effluent survival/reproduction and survival/growth values, and report formats will be made in accordance with Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013, or the most current edition.

Results of all tests, reference toxicant information, copies of raw data sheets, statistical analysis and chemical analyses shall be compiled in a report. The report will be written in accordance with Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Water to Freshwater Organisms, EPA-821-R-02-013, or the most current edition.

Two copies of biomonitoring reports (including follow-up reports) shall be submitted to the division. One copy of the report shall be submitted along with the discharge monitoring report (DMR). The second copy shall be submitted to the local Division of Water Resources office address (see table below):

Division of Water Resources			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	540 McCallie Avenue, Suite 550	37402-2013	(423) 634-5745
Jackson	1625 Hollywood Drive	38305	(731) 512-1300
Cookeville	1221 South Willow Avenue	38506	(931) 432-4015
Columbia	2484 Park Plus Drive	38401	(931) 380-3371
Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	3711 Middlebrook Pike	37921	(865) 594-6035
Memphis	8383 Wolf Lake Drive, Bartlett	38133-4119	(901) 371-3000
Nashville	711 R.S. Gass Boulevard	37243-1550	(615) 687-7000

3.5. BIOMONITORING REQUIREMENTS, ACUTE

The permittee shall conduct a 48-hour static acute toxicity test on two test species on samples of final effluent from Outfall 001. The test species to be used are Water Fleas (Ceriodaphnia dubia) and Fathead Minnows (Pimephales promelas).

The measured endpoint for toxicity will be the concentration causing 50% lethality (LC_{50}) of the test organisms. The LC_{50} shall be determined based on a 50% lethality as compared to the controls, and as derived from linear interpolation.

If the permit limit is 100%, use this table:

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
Permit Limit (PL)	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**0.0625 X PL**	**Control**
% effluent					
100	**50**	**25**	**12.5**	**6.25**	**0**

If the permit limit is at or above 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**0.125 X PL**	**Control**
% effluent					
100	**xx**	**0.0**	**0.0**	**0.0**	**0**

If the permit limit is above 25%, but below 90%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
100% Effluent	**(100+PL)/2**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
100	**50**	**xx**	**0.0**	**0.0**	**0**

If the permit limit is at or below 25%, use this table:
(enter the permit limit in the appropriate field, highlight the entire row, press F9)

Test shall be conducted and its results reported based on appropriate replicates of a total of five serial dilutions and a control, using the percent effluent dilutions as presented in the following table:

Serial Dilutions for Whole Effluent Toxicity (WET) Testing					
4 X PL	**2 X PL**	**Permit Limit (PL)**	**0.50 X PL**	**0.25 X PL**	**Control**
% effluent					
0	**0**	**xx**	**0.0**	**0.0**	**0**

The dilution/control water used will be moderately hard water as described in Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012 (or the most current edition). An acute standard reference toxicant quality assurance test shall be conducted with each species used in the toxicity tests and the results submitted with the discharge monitoring report. Additionally, the analysis of this multi-concentration test shall include review of the concentration-response relationship to ensure that calculated test results are interpreted appropriately.

Toxicity will be demonstrated if the LC_{50} is less than or equal to the permit limit indicated for each outfall in the above table(s). Toxicity demonstrated by the tests specified herein constitutes a violation of this permit.

All tests will be conducted using four separate grab samples of final effluent, to be used in four separate tests, and shall be collected at evenly spaced (6-hour) intervals over a 24-hour period. If in any control, more than 10% of the test organisms die in 48 hours, the test (control and effluent) is considered invalid and the test shall be repeated within two (2) weeks. Furthermore, if the results do not meet the acceptability criteria in Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012 (or the most current edition), if the required concentration-response review fails to yield a valid relationship per guidance contained in Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing, EPA-821-B-00-004 (or the most current edition), that test shall be repeated. Any test initiated but terminated before completion must also be reported along with a complete explanation for the termination.

The toxicity tests specified herein shall be conducted quarterly (1/Quarter) for Outfall 001 and begin no later than 90 days from the effective date of this permit.

In the event of a test failure, the permittee must start a follow-up test within 2 weeks and submit results from a follow-up test within 30 days from obtaining initial WET testing results. The follow-up test must be conducted using the same serial dilutions as presented in the corresponding table(s) above. The follow-up test will not negate an initial failed test. In addition, the failure of a follow-up test will constitute a separate permit violation.

In the event of 2 consecutive test failures or 3 test failures within a 12-month period for the same outfall, the permittee must initiate a Toxicity Identification Evaluation/Toxicity Reduction Evaluation (TIE/TRE) study within 30 days and so notify the division by letter. This notification shall include a schedule of activities for the initial investigation of that outfall. During the term of the TIE/TRE study, the frequency of biomonitoring shall be once every three months. Additionally, the permittee shall submit progress reports once every three months throughout the term of the TIE/TRE study. The toxicity must be reduced to allowable limits for that outfall within 2 years of initiation of the TIE/TRE study. Subsequent to the results obtained from the TIE/TRE studies, the permittee may request an extension of the TIE/TRE study period if necessary to conduct further analyses. The final determination of any extension period will be made at the discretion of the division.

The TIE/TRE study may be terminated at any time upon the completion and submission of 2 consecutive tests (for the same outfall) demonstrating compliance. Following the completion of TIE/TRE study, the frequency of monitoring will return to a regular schedule, as defined previously in this section as well in Part I of the permit. During the course of the TIE/TRE study, the permittee will continue to conduct toxicity testing of the outfall being investigated at the frequency of once every three months but will not be required to perform follow-up tests for that outfall during the period of TIE/TRE study.

Test procedures, quality assurance practices and determination of effluent lethality values will be made in accordance with Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012, or the most current edition.

Results of all tests, reference toxicant information, copies of raw data sheets, statistical analysis and chemical analysis shall be compiled in a report. The report shall be written in accordance with Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms, EPA-821-R-02-012, or the most current edition.

Two copies of biomonitoring reports (including follow-up reports) shall be submitted to the division. One copy of the report shall be submitted along with the discharge monitoring report (DMR). The second copy shall be submitted to the local Division of Water Resources office address (see table below):

Division of Water Resources			
Office	**Location**	**Zip Code**	**Phone No.**
Chattanooga	540 McCallie Avenue, Suite 550	37402-2013	(423) 634-5745
Jackson	1625 Hollywood Drive	38305	(731) 512-1300
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Johnson City	2305 Silverdale Road	37601	(423) 854-5400
Knoxville	3711 Middlebrook Pike	37921	(865) 594-6035
Memphis	8383 Wolf Lake Drive, Bartlett	38133-4119	(901) 371-3000
Nashville	711 R.S. Gass Boulevard	37243-1550	(615) 687-7000

3.6. PLACEMENT OF SIGNS

Within sixty (60) days of the effective date of this permit, the permittee shall place and maintain a sign(s) at each outfall and any bypass/overflow point in the collection system. For the purposes of this requirement, any bypass/overflow point that has discharged five (5) or more times in the last year must be so posted. The sign(s) should be clearly visible to the public from the bank and the receiving stream. The minimum sign size should be two feet by two feet (2' x 2') with one-inch (1") letters. The sign should be made of durable material and have a white background with black letters.

The sign(s) are to provide notice to the public as to the nature of the discharge and, in the case of the permitted outfalls, that the discharge is regulated by the Tennessee Department of Environment and Conservation, Division of Water Resources. The following is given as an example of the minimal amount of information that must be included on the sign:

Permitted CSO or unpermitted bypass/overflow point:

UNTREATED WASTEWATER DISCHARGE POINT
------- STP
(423) 263-9441
NPDES Permit NO. TN00-----
TENNESSEE DIVISION OF WATER RESOURCES
1-888-891-8332 ENVIRONMENTAL FIELD OFFICE - Chattanooga

NPDES Permitted Municipal/Sanitary Outfall:

TREATED MUNICIPAL/SANITARY WASTEWATER
------- STP
(423) 263-9441
NPDES Permit NO. TN00-----
TENNESSEE DIVISION OF WATER RESOURCES
1-888-891-8332 ENVIRONMENTAL FIELD OFFICE - Chattanooga

No later than sixty (60) days from the effective date of this permit, the permittee shall have the above sign(s) on display in the location specified.

3.7. ANTIDEGRADATION

Pursuant to the Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-3-.06, titled “Tennessee Antidegradation Statement,” which prohibits the degradation of high quality surface waters and the increased discharges of substances that cause or contribute to impairment, the permittee shall further be required, pursuant to the terms and conditions of this permit, to comply with the effluent limitations and schedules of compliance required to implement applicable water quality standards, to comply with a State Water Quality Plan or other state or federal laws or regulations, or where practicable, to comply with a standard permitting no discharge of pollutants.

The pump/lift station inspection language is for permittees in Johnson City:

3.8. PUMP/LIFT STATION INSPECTION

All pump/lift stations > or = 100 gpm must be inspected five (5) days a week. In populated areas, all stations < 300 gpm may alternately be equipped with alarms, lights and or horns. In populated areas, all stations > or = 300 gpm may alternately be equipped with true remote sensing telemetry systems. All stations < 100 gpm must be inspected as necessary to ensure proper operation. The inspector shall note the date, time and inspector initials in a bound log notebook.

4.0. DEFINITIONS AND ACRONYMS

4.1. DEFINITIONS

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 or removal of habitat.

"***De Minimis***" - Alterations, other than those resulting in the condition of pollution or new domestic wastewater discharges, that represent either a small magnitude or a short duration shall be considered a de minimis impact and will not be considered degradation for purposes of implementing the antidegradation policy. Discharges other than domestic wastewater will be considered de minimis if they are temporary or use less than five percent of the available assimilative capacity for the substance being discharged. Water withdrawals will be considered de minimis if less than five percent of the 7Q10 flow of the stream is removed (the calculations of the low flow shall take into account existing withdrawals). Habitat alterations authorized by an Aquatic Resource Alteration Permit (ARAP) are de minimis if the division finds that the impacts are offset by a combination of impact minimization and/or insystem mitigation.

If more than one activity has been authorized in a segment and the total of the impacts uses no more than ten percent of the assimilative capacity, available habitat, or 7Q10 low flow, they are presumed to be de minimis. Where total impacts use more than ten percent of the assimilative capacity, available habitat, or 7Q10 low flow they may be treated as de minimis provided that the division finds on a scientific basis that the additional degradation has an insignificant effect on the resource and that no single activity is allowed to consume more than five percent of the assimilative capacity, available habitat or 7Q10 low flow.

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 **"*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.

A "***subecoregion***" 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. ACRONYMNS 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

BOD_5 – five day biochemical oxygen demand

BPT – best practicable control technology currently available

$CBOD_5$ – five day carbonaceous biochemical oxygen demand

CEI – compliance evaluation inspection

CFR – code of federal regulations

CFS – cubic feet per second

CFU – colony forming units

CIU – categorical industrial user

CSO – combined sewer overflow

DMR – discharge monitoring report

D.O. – dissolved oxygen

E. coli – Escherichia coli

EFO – environmental field office

LB(lb) - pound

IC_{25} – inhibition concentration causing 25% reduction in survival, reproduction and growth of the test organisms

IU – industrial user

IWS – industrial waste survey

LC_{50} – 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

NOEC – no observed effect concentration

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

RATIONALE

------- STP
NPDES PERMIT No. TN00-----
DATE: 4/24/2013
Permit Writer: -----------

1. FACILITY INFORMATION

------- STP
------- General Manager
-------, ------ County, Tennessee
(---) --------
Treatment Plant Average Design Flow: -- MGD
Percentage Industrial Flow: %
Treatment Description: Activated sludge plant with chlorination and dechlorination

2. RECEIVING STREAM INFORMATION

----- Creek at mile --
Watershed Group: -----
Hydrocode: -------
Low Flow: 7Q10 = MGD (CFS)
Low Flow Reference:
USGS Water-Resource Investigation Report -------
Station #--------
Tier Designation: Not evaluated at this time.
Stream Classification Categories:

Domestic Wtr Supply	Industrial	Fish & Aquatic	Recreation
		X	X
Livestock Wtr & Wlife	Irrigation	Navigation	
X	X		

Water Quality Assessment: Fully/Partially/Not supporting

3. CURRENT PERMIT STATUS

Permit Type:	Municipal
Classification:	Major/Minor
Issuance Date:	31-MAR-09
Expiration Date:	31-MAR-13
Effective Date:	01-MAY-09

FEDERAL REGISTER

Vol. 77 Friday,
No. 97 May 18, 2012

Part II

Environmental Protection Agency

40 CFR Parts 136, 260, et al.
Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; Analysis and Sampling Procedures; Final Rule

Table II - Required Containers, Preservation Techniques, and Holding Times

Parameter Number/Name	Container[1]	Preservation[2, 3]	Maximum Holding Time[4]
Table IA - Bacterial Tests:			
1-5. Coliform, total, fecal, and E. coli	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5]	8 hours[22,23]
6. Fecal streptococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5]	8 hours[22]
7. Enterococci	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5]	8 hours[22]
8. Salmonella	PA, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5]	8 hours[22]
Table IA - Aquatic Toxicity Tests:			
9-12. Toxicity, acute and chronic	P, FP, G	Cool, ≤6 °C[16]	36 hours
Table IB - Inorganic Tests:			
1. Acidity	P, FP, G	Cool, ≤6 °C[18]	14 days
2. Alkalinity	P, FP, G	Cool, ≤6 °C[18]	14 days
4. Ammonia	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
9. Biochemical oxygen demand	P, FP, G	Cool, ≤6 °C[18]	48 hours
10. Boron	P, FP, or Quartz	HNO_3 to pH<2	6 months
11. Bromide	P, FP, G	None required	28 days
14. Biochemical oxygen demand, carbonaceous	P, FP G	Cool, ≤6 °C[18]	48 hours
15. Chemical oxygen demand	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
16. Chloride	P, FP, G	None required	28 days
17. Chlorine, total residual	P, G	None required	Analyze within 15 minutes
21. Color	P, FP, G	Cool, ≤6 °C[18]	48 hours
23-24. Cyanide, total or available (or CATC) and free	P, FP, G	Cool, ≤6 °C[18], NaOH to pH>10[5, 6], reducing agent if oxidizer present	14 days
25. Fluoride	P	None required	28 days
27. Hardness	P, FP, G	HNO_3 or H_2SO_4 to pH<2	6 months
28. Hydrogen ion (pH)	P, FP, G	None required	Analyze within 15 minutes
31, 43. Kjeldahl and organic N	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
Table IB - Metals:[7]			
18. Chromium VI	P, FP, G	Cool, ≤6 °C[18], pH = 9.3 - 9.7[20]	28 days
35. Mercury (CVAA)	P, FP, G	HNO_3 to pH<2	28 days
35. Mercury (CVAFS)	FP, G; and FP-lined cap[17]	5 mL/L 12N HCl or 5 mL/L BrCl[17]	90 days[17]
3, 5-8, 12, 13, 19, 20, 22, 26, 29, 30, 32-34, 36, 37, 45, 47, 51, 52, 58-60, 62, 63, 70-72, 74, 75. Metals, except boron, chromium VI, and mercury	P, FP, G	HNO_3 to pH<2, or at least 24 hours prior to analysis[19]	6 months
38. Nitrate	P, FP, G	Cool, ≤6 °C[18]	48 hours

Parameter Number/Name	Container [1]	Preservation [2, 3]	Maximum Holding Time [4]
39. Nitrate-nitrite	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
40. Nitrite	P, FP, G	Cool, ≤6 C[18]	48 hours
41. Oil and grease	G	Cool to ≤6 °C[18], HCl or H_2SO_4 to pH<2	28 days
42. Organic Carbon	P, FP, G	Cool to ≤6 °C[18], HCl, H_2SO_4, or H_3PO_4 to pH<2	28 days
44. Orthophosphate	P, FP, G	Cool, to ≤6 °C[18,24]	Filter within 15 minutes; Analyze within 48 hours
46. Oxygen, Dissolved Probe	G, Bottle and top	None required	Analyze within 15 minutes
47. Winkler	G, Bottle and top	Fix on site and store in dark	8 hours
48. Phenols	G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
49. Phosphorous (elemental)	G	Cool, ≤6 °C[18]	48 hours
50. Phosphorous, total	P, FP, G	Cool, ≤6 °C[18], H_2SO_4 to pH<2	28 days
53. Residue, total	P, FP, G	Cool, ≤6 °C [18]	7 days
54. Residue, Filterable	P, FP, G	Cool, ≤6 °C [18]	7 days
55. Residue, Nonfilterable (TSS)	P, FP, G	Cool, ≤6 °C [18]	7 days
56. Residue, Settleable	P, FP, G	Cool, ≤6 °C [18]	48 hours
57. Residue, Volatile	P, FP, G	Cool, ≤6 °C [18]	7 days
61. Silica	P or Quartz	Cool, ≤6 °C [18]	28 days
64. Specific conductance	P, FP, G	Cool, ≤6 °C [18]	28 days
65. Sulfate	P, FP, G	Cool, ≤6 °C [18]	28 days
66. Sulfide	P, FP, G	Cool, ≤6 °C [18], add zinc acetate plus sodium hydroxide to pH>9	7 days
67. Sulfite	P, FP, G	None required	Analyze within 15 minutes
68. Surfactants	P, FP, G	Cool, ≤6 °C [18]	48 hours
69. Temperature	P, FP, G	None required	Analyze
73. Turbidity	P, FP, G	Cool, ≤6 °C [18]	48 hours
Table IC - Organic Tests [8]			
13, 18-20, 22, 24-28, 34-37, 39-43, 45-47, 56, 76, 104, 105, 108-111, 113. Purgeable Halocarbons	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5]	14 days
6, 57, 106. Purgeable aromatic hydrocarbons	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5], HCl to pH 2 [9]	14 days [9]
3, 4. Acrolein and acrylonitrile	G, FP-lined septum	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$, pH to 4-5[10]	14 days [10]
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols [11]	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$	7 days until extraction,40 days after extraction
7, 38. Benzidines [11, 12]	G, FP-lined cap	Cool, ≤6 °C [18], 0.008% $Na_2S_2O_3$ [5]	7 days until extraction [13]

CHAPTER 13

Plant Flow Measurement and Sampling

13.1 Purpose

13.2 Flow Measurement

- 13.2.1 General Considerations
- 13.2.2 Parshall Flumes
- 13.2.3 Sharp Crested Weirs
- 13.2.4 Venturi and Modified Flow Tube Meters
- 13.2.5 Other Flow Metering Devices
- 13.2.6 Hydrograph Controlled Release (HCR) Systems

13.3 Sampling

- 13.3.1 Automatic Sampling Equipment
- 13.3.2 Manual Sampling
- 13.3.3 Long Outfall Lines
- 13.3.4 Sampling Schedules

PLANT FLOW MEASUREMENT AND SAMPLING

13.1 Purpose

Complete and accurate flow measuring and sampling are essential in the proper treatment of wastewater. Compliance with discharge limits requires proper flow measurement and sampling. They provide the operator with the information to optimize process control and operational costs, as well as providing an accurate data base of flows and process performance which can be used to analyze changes in operational strategy or assist future plant design.

13.2 Flow Measurement

13.2.1 General Considerations

13.2.1.1 Facilities for measuring the volume of sewage flows should be provided at all treatment works.

13.2.1.2 Plants with a capacity equal to or less than 100,000 gallons per day (gpd) shall be equipped, as a minimum, with a primary metering device such as: a Parshall flume having a separate float well and staff gauge, a weir box having plate and staff gauge, or other approved devices. Continuous recording devices may be required where circumstances warrant.

13.2.1.3 Plants having a capacity of greater than 100,000 gpd shall be provided with indicating, recording, and totalizing equipment using strip or circular charts and with flow charts for periods of 1 or 7 days. The chart size shall be sufficient to accurately record and depict the flow measured.

13.2.1.4 Flows passed through the plant and flows bypassed shall be measured in a manner which will allow them to be distinguished and separately reported.

13.2.1.5 Measuring equipment shall be provided which is accurate under all expected flow conditions (minimum initial flow and maximum design peak flow). The accuracy of the total flow monitoring system (primary device, transmitter, and indicator) must be acceptable. The effect of such factors as ambient temperature, power source voltage, electronic interference, and humidity should be considered. Surges must be eliminated to provide accurate measurement. Two primary devices and flow charts may be required in some cases.

13.2.1.6 Metering devices within a sewage works shall be located so that recycle flow streams do not inadvertently affect the flow measurement. In some cases,
measurement of the total flow (influent plus recycle) may be desirable.

13.2.1.7 All clarifiers must be provided with a means for accurate flow measurement of sludge wasting and sludge return lines so that solids handling can be controlled. Sludge digesters, thickeners, and holding tanks should be provided with some way to determine the volume of sludge added or removed. This can be accomplished by a sidewall depth scale or graduation in batch operations.

13.2.1.8 Flow meter and indicator selection should be justified considering factors such as probable flow range, acceptable headloss, required accuracy, and fouling ability of the water to be measured. For more detailed information the consultant is encouraged to read the EPA Design Information Report "Flow Measurement Instrumentation"; Journal WPCF, Volume 58, Number 10, pp. 1005-1009. This report offers many installation details and considerations for different types of flow monitoring equipment.

13.2.1.9 Flow splitter boxes shall be constructed so that they are reliable, easily controllable, and accessible for maintenance purposes.

13.2.1.10 Where influent and effluent flow-proportional composite sampling is required, separate influent and effluent flow measuring equipment is required.

13.2.1.11 Consideration should be given to providing some types of flow meters with bypass piping and valving for cleaning and maintenance purposes.

13.2.2 Parshall Flumes

Parshall Flumes are ideal for measuring flows of raw sewage and primary effluents because clogging problems are usually minimal.

The properly sized flume should be selected for the flow range to be encountered. All Parshall Flumes must be designed to the specified dimensions of an acceptable reference.

The following requirements must be met when designing a Parshall Flume.

13.2.2.1 Flow should be evenly distributed across the width of the channel.

13.2.2.2 The crest must have a smooth, definite edge. If a liner is used, all screws and bolts should be countersunk.

13.2.2.3 Longitudinal and lateral axes of the crest floor must be level.

13.2.2.4 The location of the head measuring points (stilling well) must be two-thirds the length of the converging sidewall upstream from the crest. Sonar-type devices are only acceptable when foaming or turbulance is not a problem.

13.2.2.5 The pressure tap to the stilling well must be at right angles to the wall of the converging section.

13.2.2.6 The invert (i.e., inside bottom) of the pressure tap must be at the same elevation as the crest.

13.2.2.7 The tap should be flush with the flume side wall and have square, sharp corners free from burrs or other projections.

13.2.2.8 The tap pipe should be 2 inches in size and be horizontal or slope downward to the stilling well.

13.2.2.9 Free-flow conditions shall be maintained under all flow rates to be encountered by providing low enough elevations downstream of the flume. No constrictions (i.e., sharp bends or decrease in pipe size) should be placed after the flume as this might cause submergence under high flow conditions.

13.2.2.10 The volume of the stilling well should be determined by the conditions of flow. For flows that vary rapidly, the volume should be small so that the instrument float can respond quickly to the changes in rate. For relatively steady flows, a large-volume stilling well is acceptable. Consideration should be given to protecting the stilling well from freezing.

13.2.2.11 Drain and shut-off valves shall be provided to empty and clean the stilling well.

13.2.2.12 Means shall be provided for accurately maintaining a level in the stilling well at the same elevation as the crest in the flume, to permit adjusting the instrument to zero flow conditions.

13.2.2.13 The flume must be located where a uniform channel width is maintained ahead of the flume for a distance equal to or greater than fifteen (15) channel widths. The approach channel must be straight and the approaching flow must not be turbulent, surging, or unbalanced. Flow -lines should be essentially parallel to the centerline of the flume.

13.2.3 Sharp Crested Weirs

The following criteria are for V-notch weirs, rectangular weirs with and without end contractions, and Cipolletti weirs. The following details must be met when designing a sharp crested weir:

13.2.3.1 The weir must be installed so that it is perpendicular to the axis of flow. The upstream face of the bulkhead must be smooth.

13.2.3.2 The thickness of the weir crest should be less than 0.1 inch or the downstream edge of the crest must be relieved by chamfering at a 45° angle so that the horizontal (unchamfered) thickness of the weir is less than 0.1 inch.

13.2.3.3 The sides of rectangular contracted weirs must be truly vertical. Angles of V-notch weirs must be cut precisely. All corners must be machined or filed perpendicular to the upstream face so that the weir will be free of burrs or scratches.

13.2.3.4 The distance from the weir crest to the bottom of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot.

13.2.3.5 The distance from the sides of the weir to the side of the approach channel must be greater than twice the maximum weir head and is never to be less than one foot (except for rectangular weirs without end contractions.)

13.2.3.6 The nappe (overflow sheet) must touch only the upstream edges of the weir crest or notch. If properly designed, air should circulate freely under and on both sides of the nappe. For suppressed rectangular weirs (i.e., no contractions), the enclosed space under the nappe must be adequately ventilated to maintain accurate head and discharge relationships.

13.2.3.7 The measurement of head on the weir must be taken at a point at least four (4) times the maximum head on the crest upstream from the weir.

13.2.3.8 The cross - sectional area of the approach channel must be at least eight (8) times that of the nappe at the crest for a distance upstream of

15-20 times the maximum head on the crest in order to minimize the approach velocity. The approach channel must be straight and uniform upstream of the weir for the same distance, with the exception of weirs with end contractions where a uniform cross section is not needed.

13.2.3.9 The head on the weir must have at least three (3) inches of free fall at the maximum downstream water surface to ensure free fall and aeration of the nappe.

13.2.3.10 All of the flow must pass over the weir and no leakage at the weir plate edges or bottom is permissable.

13.2.3.11 The weir plate is to be constructed of a material equal to or more resistant than 304 Stainless Steel.

13.2.4 Venturi and Modified Flow Tube Meters

The following requirements should be observed for application of venturi meters:

13.2.4.1 The range of flows, hydraulic gradient, and space available for installation must be suitable for a venturi meter and are very important in selecting the mode of transmission to the indicator, recorder, or totalizer.

13.2.4.2 Venturi meters shall not be used where the range of flows is too great or where the liquid may not be under a positive head at all times.

13.2.4.3 Cleanouts or handholes are desirable, particularly on units handling raw sewage or sludge.

13.2.4.4 Units used to measure air delivered by positive - displacement blowers should be located as far as possible from the blowers, or means should be provided to dampen blower pulsations.

13.2.4.5 The velocity and direction of the flow in the pipe ahead of the meter can have a detrimental effect on accuracy. There should be no bends or other fittings for 6 pipe diameters upstream of the venturi meter, unless treated effluent is being measured when straightening vanes are provided.

13.2.4.6 Other design guidelines as provided by manufacturers of venturi meters should also be considered.

13.2.5 Other Flow Metering Devices

Flow meters, such as propeller meters, magnetic flow meters, orifice meters, pitot tubes, and other devices, should only be used in applications in accordance with the manufacturer's recommendations and design guidelines.

13.2.6 Hydrograph Controlled Release (HCR) Systems

For plants utilizing HCR systems, accurate stream flow measurements are required. Detailed plans must be submitted outlining the construction of the primary stream flow measuring device and the associated instrumentation. The following factors should be emphasized in the design.

13.2.6.1 Accuracy over the flow range required for effluent discharge limiting purposes.

13.2.6.2 Operational factors such as cleaning and maintenance requirements.

13.2.6.3 Cost

The use of sharp crested weirs as described in Section 13.2.3 will not be allowed due to the installation requirements such as approach channel details and upstream pool depth and since entrapment and accumulation of silt and debris may cause the device to measure inaccurately. Parshall Flumes may be used due to their self-cleaning ability but field calibration will be required. Self-cleaning V-notch weirs are recommended due to their accuracy in low flow ranges. The weir can be made self-cleaning by sloping both sides of the weir away from the crest. The top portion of the crest shall be covered with angle-iron to prevent its breakdown. The angle of the V-notch should be determined by the stream characteristics; however, a smaller angle will increase accuracy in the low flow range. The primary device shall be built with sufficient depth into the stream bed to prevent undercutting and sufficient height to cover the required flow range.

It is recommended that the wastewater system director, engineer, or other city official contact the U.S. Geological Survey (USGS), Water Resources Division, in Nashville, Tennessee, for assistance with the design and installation of the flow measuring device. They offer a program which shares much of the costs for designing and maintaining the device. After visiting the site, they can assist with the design of a self-cleaning weir for the stream. They provide the consultant with a field design that shows the proper location and installation of the weir. From this field design, the consultant must provide detailed plans to the State. The wastewater system is responsible for constructing the weir at their own cost. The flow measuring station is installed, maintained, and calibrated by USGS personnel so that accurate results are insured. The primary device will record continuous flow of the stream and can be designed to send a feedback signal to the WWTP for other purposes such as controlling plant discharge rates. This program benefits both the local wastewater system, the State of Tennessee, and the USGS, as it adds to stream flow data bases archived for public use. Cost sharing allows the flow measuring station to be built and operated at a lower cost for all parties concerned.

13.3 Sampling

13.3.1 Automatic Sampling Equipment

The following general guidelines should be adhered to in the use of automatic samplers:

13.3.1.1 Automatic samplers shall be used where composite sampling is necessary.

13.3.1.2 The sampling device shall be located near the source being sampled, to prevent sample degradation in the line.

13.3.1.3 Long sampling transmission lines should be avoided.

13.3.1.4 If sampling transmission lines are used, they shall be large enough to prevent plugging, yet have velocities sufficient to prevent sedimentation. Provisions shall be included to make sample lines cleanable. Minimum velocities in sample lines shall be 3 feet per second under all operating conditions.

13.3.1.5 Samples shall be refrigerated unless the samples will not be effected by biological degradation.

13.3.1.6 Sampler inlet lines shall be located where the flow stream is well mixed and representative of the total flow.

13.3.1.7 Influent automatic samplers should draw a sample downstream of bar screens or comminutors. They should be located before any return sludge lines or scum lines.

13.3.1.8 Effluent sampling should draw a sample immediately upstream of the chlorination point. This will eliminate the need to dechlorinate and then re-seed the sample.

13.3.2 Manual Sampling

Because grab samples are manually obtained, safe access to sampling sites should be considered in the design of treatment facilities.

13.3.3 Long Outfall Lines

Many wastewater systems are constructing long outfall lines to take advantage of secondary or equivalent permit limits. Due to possible changes in effluent quality between the treatment facility and the outfall, a remote sampling station will be required at or near the confluence of the outfall line and the receiving stream on all outfall lines greater than one mile in length. Dissolved oxygen, fecal coliform, and chlorine residual may have to be measured at the remote sampling station for permit compliance purposes.

13.3.4 Sampling Schedules

Samples must be taken and analyzed for two purposes: permit compliance and process control. Any time a new permit is issued, a sampling schedule for permit compliance will be determined by the Division of Water Pollution Control. An additional sampling program needs to be set up for process control purposes. This would include all testing required for completing the monthly operational report, as well as any other tests that might aid the operation of the plant. This schedule can be determined by the Division of Water Pollution Control, Wastewater Treatment Section or the appropriate field office once final plans are approved. The designer shall provide safe access points to collect representative influent and effluent samples of all treatment units and to collect samples of all sludge transmission lines. This makes it possible to determine the efficiency of each treatment process. Additional information about methods of analyses can be obtained from the Federal Register 40 CFR Part 136. Information about sampling locations and techniques can be obtained from the EPA Aerobic Biological Wastewater Treatment Facilities Process Control Manual and EPA's NPDES Compliance Inspection Manual.

Section 12

Packed Bed Filters

Packed Bed Filters

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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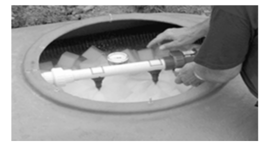
Packed Bed Filters Introduction

- Secondary treatment units
- Follow primary treatment in a septic tank
- Fixed film treatment systems
  - Biomass grows on media
- A passive aerobic system
- Examples: open sand filter, RSF, open cell foam, textile, peat moss.



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PBF Treatment Process

- Wastewater applied in small doses
- Percolates over media in thin film
- Organisms on media contact wastewater
  - Can't let them dry out
- ***Air maintained in media pores***
- Oxygen transferred into the thin film and to organisms
- Aeration may be active or passive

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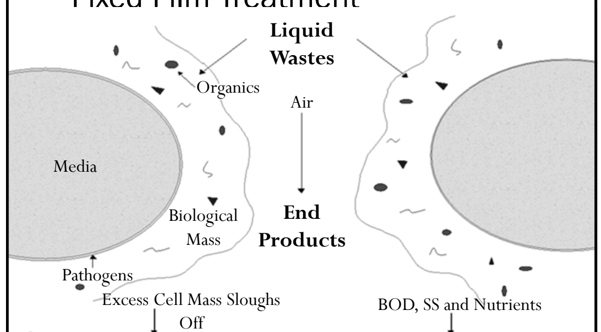
Fixed Film Treatment



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Theory of Operation

- Organisms are "fixed" on media surface
- WW is "micro-dosed" to the filter
- WW is treated as it moves over media surfaces in contact with organisms

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Modes of Treatment

- Filtration and trapping of organic matter and pathogens
- Adsorption of pathogens, ammonium and some phosphorus
- Biological decomposition of organic matter
- Biochemical transformations

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Typical Concentrations of Effluent from Septic Tanks and PBFs

	BOD, mg/L	TSS, mg/L	Nitrate – N, mg/L	Ammonia – N, mg/L	DO, mg/L	Fecal Coliform, cfu/100 mL
Septic Tank	130 – 250	30 – 130	0 – 2	25 – 60	Less than 2	$10^5 – 10^7$
PBF	5 – 25	5 – 30	15 – 30	0 – 4	3 – 5	$10^2 – 10^4$

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Packed Bed Filter Effluent vs. Septic Tank Effluent

- Low oxygen demand (BOD) → 90% removed
- Low in total and volatile solids → 90% removed
- Will not form a significant biomat in soils
- Low in pathogens → 99% removed
- Significant reduction total nitrogen – 40-80% removed

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Two Major Categories of PBF

- Single Pass: through once
- Recirculating: part passes through more than once

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Media Types

- Natural and mineral media
  - Sand and gravel
  - Expanded shale
  - Cinders
  - Limestone
  - Activated carbon
  - Peat or peat fiber

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Manufactured Media Types

- Textile fabric
- Open cell foam cubes
- Hard plastic
- Crushed recycled glass
- Chipped recycled tires
- Processed slag

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Sand and Gravel Filters

- Designed and constructed to operate in either single pass or recirculating mode
- Media must meet specific specifications
- Must (generally) be processed to provide the right gradation
  - Sometimes crushed
  - Screened for proper gradation
  - Washed
- Must be handled carefully after processing to maintain the specification and remain free of fines

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Biological Processes

- Biofilm forms on sand grains
- Oxygen around the film promotes aerobic activity
- Many microorganism species present at all times
- Most in the upper 12 inches
- Insufficient food limits organisms in lower layers
- Most BOD removal occurs in the top few inches
- Organic matter consumed by microbes in the biofilm

Important Biological Design Parameters

- Choice of media
  - Surface area
  - Void space
- Provision for aeration
  - Active
  - Passive
- Small doses of wastewater applied uniformly
  - Keeps flow in the biofilm – i.e. unsaturated flow
  - Provides residence time in thin films on surfaces
  - Prevents displacing air from voids

More on Biological Processes

- Nitrogen removal is a biological process
- Nitrifying bacteria convert ammonium-N (NH_4)and organic-N to nitrate-N (NO_3)
- Most conversion to NO_3 occurs in the top 12 inches
- In small pores and lower in the filter, oxygen concentrations are reduced and biological Denitrification is thought to occur in smaller saturated pores
- Nitrogen gas (N_2) is released to the air

Oxygen Requirements of a PBF

- Based on the BOD_5 and Nitrogen load applied
- BOD_5 load applied is determined by flow and concentration of applied effluent
  - lbs BOD_5/day = (BOD_5, mg/L)(Q, MGD)(8.34)
  - lbs TKN/day = (TKN, mg/L)(Q, MGD)(8.34)
  - lbs O_2/day = (1.2)(BOD_5, lbs/day) + (4.6)(TKN, lbs/day)

Single Pass Systems

- Any of the media options may be used in either single pass or recirculating mode
- Natural/Mineral media are more likely to be used in single pass mode
- Manufactured media are usually used in recirculating mode

Single Pass Sand Filters

- Several designs are in use
  - Free access (open)
  - Buried single pass
  - Pressure dosed single pass

Free Access Sand Filters

- Oldest form for individual sites
- Used for community wastewater treatment since late 1800's in Massachusetts
- May be large – several acres in size
- Depth ranged from 3 to 8 feet

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Free Access Sand Filters

- Wastewater is pump or siphon dosed to the filter, discharged at a single point
- Gravity flow over the surface of the filter
- Require frequent maintenance of the surface to break up or remove accumulated solids

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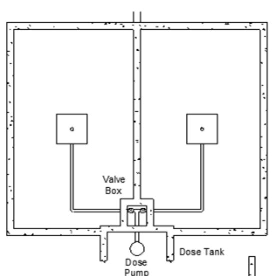
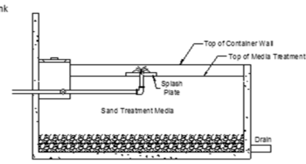


Two Cell Open or Free Access Sand Filter

← Plan View

Cross Section →



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Buried, Gravity Fed Single Pass Sand Filters

- Distribution is through 4-inch diameter pipe with large (1/2" +) perforations
- Septic tank effluent flows by gravity to the filter at whatever rate it flows from the tank
- Poor distribution limits the life
- Effluent quality is better than might be expected, similar to pressure dosed single pass systems

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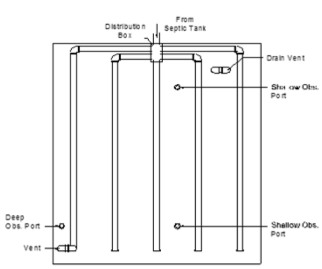
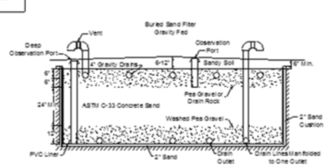


Buried Gravity Flow Single Pass Sand Filter

← Plan View

Cross Section →



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Pressure Dosed Single Pass Sand Filters (SPSF)

- The preferred system – uniform application
- Pump control can include a timer so that effluent can be "micro-dosed" to the sand filter uniformly over time as well as space
- Provides the ultimate in slow, unsaturated flow
  - Assures film flow
  - Long residence time for biological reactions
  - Air remains in pores for oxygen diffusion into the moisture films on surfaces – to microbes

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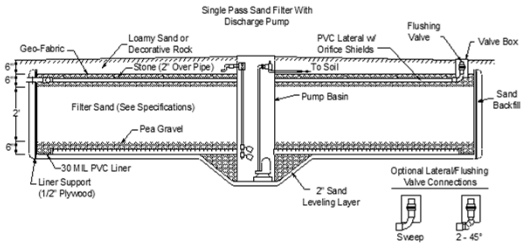
Single Pass Pressure Dosed Sand Filter With Pump Basin – Cross Section



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SPSF Sand System Design

- **Surface area loading = 1–1.25 gpd/ft^2 (design Q)**
- **Media depth 24 inches**
- Maximum soil cover 8–12 inches
- Texture of soil cover: sand or loamy sand
- Bottom layer: 6–8 inches of pea gravel around drain
- Maximum flow distance to 4" slotted drain: 15 ft

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SPSF Cut-Away Illustration

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SPSF Showing Valve Boxes Over Cleanouts

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Hydraulic and Organic Loading -- SPSF

- Typical design hydraulic loading is 1–1.2 gpd/ft^2
- For cold climates, keep hydraulic load < 1.0 gpd
- Dose volume < 0.5 gal/orifice/dose
- Typical doses per day: 18–24

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Maintenance For SPSF

- Good maintenance is key
- Maintenance minimum annually
- First visit MUST be within the first few weeks of use
  - To catch construction damage or errors
  - To be sure controls are set correctly for the use pattern
  - To check for leaks, including leaky tanks
  - To advise owner/resident on SPSF use
  - To be sure landscaping does not add depth, compact or cause other damage

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Maintenance Routine for the SPSF

- The septic tank(s) should be inspected periodically (not every visit) and pumped as needed
- Flush pressure pipe network
- Check pressure at end of laterals: compare with previous
- Check sand filter for ponding (in monitoring tubes)
- Check pump controls for proper operation
- Read pump run-time meter and event counter
- Check pump voltage (off and while pumping) and amp draw while pumping
- Pull and observe the final effluent in a clear sample bottle checking for clarity and odor.

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Drainfield Check as Part of Maintenance Visit

- Check for wetness around the drainfield
- Note vegetation patterns
- Note ponding level in observation tubes
- Observe surface flow patterns
  - Be sure surface runoff is directed away from drainfield and SPSF
  - Roof water/downspout drainage away from system

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Recirculating Systems

- Recirculation is used in many wastewater treatment processes, usually to retain organism populations
- Recirculating sand filter concept was introduced by Hines and Favreau in the 1970's.
- Involve mixing a portion of the filtered effluent with incoming septic tank effluent
- This blended effluent can be applied to filter media at higher loading rates

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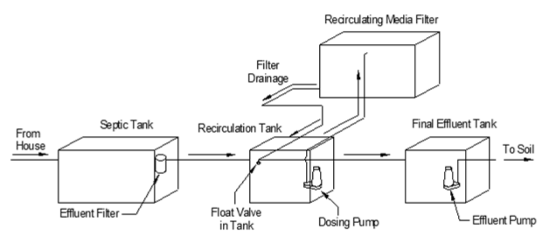
Recirculating Packed Bed Filter Schematic



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Achieving Recirculation

- Drainage from the filter is directed through a flow divider
  - One part is sent to final dispersal
  - 3 – 5 parts, more or less, are returned to the recirc. tank for another pass through the filter
- The pump control timer is set to deliver the desired total quantity of flow to the filter daily
  - Qf = Qi (Rr +1)

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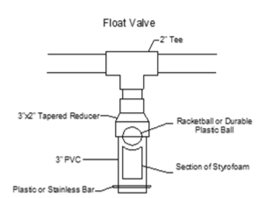
Simple Float Valve Illustration



- Valve is mounted in the recirc. tank on the filter drain return line
- When the valve is closed, all the flow is sent to final dispersal
- When the valve is open, all the flow drops into the tank
- By setting the timer for the correct total daily flow to the filter, the system provides the proper recirculation ratio.

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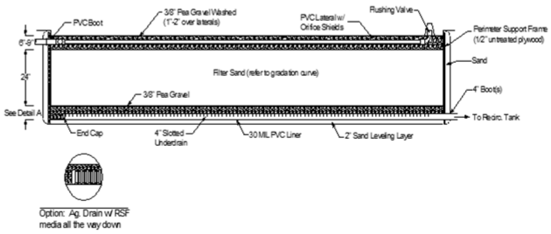
Typical RSF Cross Section



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Adapted from Orenco Systems, Inc.
Note, this may not be the best drawing

Benefits of Recirculation

- Diluted effluent is applied to the filter
  - Can apply effluent a greater forward flow loading rate
  - Less odor
- Smaller filter for a given flow
- Can withstand somewhat higher strength incoming wastewater
- Can cope with flow variations, including peak flows
- Provides a means for making adjustments for variations in flow and strength through varying recirculation ratios

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Typical RSF Media

- Fine gravel media with effective size of 2.5 – 3 mm
- Note lack of fines on the media
- This is a good material for an RSF for domestic effluent

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Recirculation Tank Design

- Size: volume equal to daily design flow
- Configuration:
  - Septic tank effluent and return flow from filter enter at same end of the tank to mix
  - Pump(s) to filter are at opposite end of tank
  - Provide long flow path to pump end
  - Pumps mounted up off tank floor
    - Preferably in a vault with effluent screen ahead of pump intake
    - Intake to pump system at mid-depth of tank

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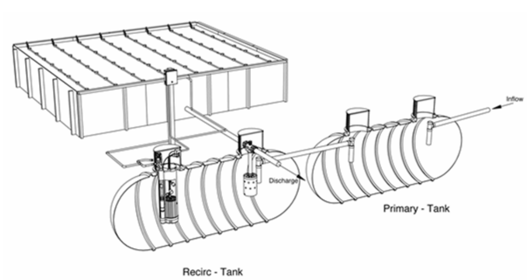
RSF -- Recirculation Tank Illustration



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Multiple Cell Community RSF Makes Maintenance Easier

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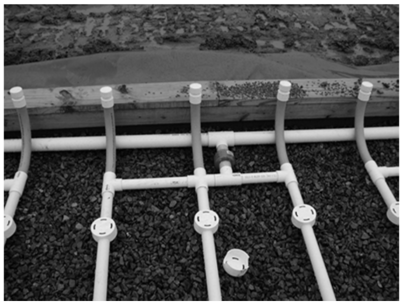
Laterals End with Constant Flow Out



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Sand Filter Frame Ready for Media

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Sand Filter Drain Network

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RSF Effluent Quality

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RSF Maintenance Tasks

- Check observation sumps in S.F. for ponding
- Flush distribution system lines
- Check pressure to determine orifice clogging
- Clean orifices as needed
- Make sure drain(s) are not submerged and can "breath" air into filter

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RSF Maintenance Tasks

- Check pump controls for proper operation and adjustment
- Check pump voltage – off and while pumping
- Check pump amp draw while pumping
- Check Soil Absorption System observations sumps
- Check sludge and scum in septic tank(s) & pump tank

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PBF Controls

- Control systems for pumps and dosing are critical to proper operation
- Uniform distribution and small, frequent doses are required for best treatment
- Timer control for pumps is preferred
- For single pass systems, timers can be turned on and off by floats

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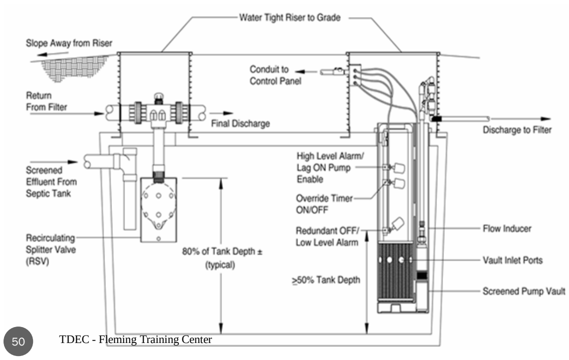
Pump in a recirc. tank with floats to control the timer, alarms, and a second pump



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Float Type Controls

- Floats may contain mechanical or mercury switches
- Should be mounted on a separate bracket or float "tree"
  - Separate from pump discharge pipe
  - Removable as a unit for float position adjustment
  - Allow pump removal without disturbing floats
- Floats must be positioned so as not to become inhibited by chords, other floats, or piping

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Pump Selection

- Pumps used are usually submersible
  - High head turbine pumps – a converted well pump
  - Effluent pumps – higher flow, low head
- Turbine pumps are desirable for feeding distribution systems with small holes (typical 1/8")
  - Steep curve assists in providing self cleaning
  - Head increases rapidly as flow is reduced
- If effluent pumps are used, in-line screens can be added to help protect against orifice clogging
- Both types of pumps, if selected for effluent applications, will provide long service life
- Liquid levels should be designed to keep pumps submerged.

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Peat Filters

- Peat is excellent media for PBFs
- Forms: fiber, moss, pellets or prefabricated peat bales
- Modular, ready to set in place and connect up
- Peat is carefully chosen and often processed

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Peat Filters (cont.)

- Typically used in single pass mode
- Peat houses a wide variety of microflora from bacteria to nematodes
- Peat deteriorates over time and must be replaced
- Good, long term performance
- Effluent quality similar to sand filters, but much less space required: about 1/6 as much

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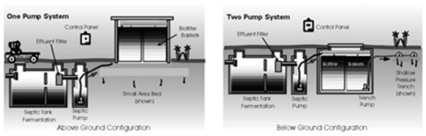
Open Cell Foam Filters

- Developed for use in Ontario as the “Waterloo Biofilter”
- Polyurethane foam (2” cubes)
- Wastewater sprayed over the top of media
- Long retention time in the filter provides good treatment
- Sometimes requires forced air



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Waterloo® Open Cell Foam Filters

- Foam cubes have large surface area and large void volume percentage.
- Foam is not decomposed by organisms in wastewater.
- Media 36 to 102” deep.
- Doses/day: 80 to 140.

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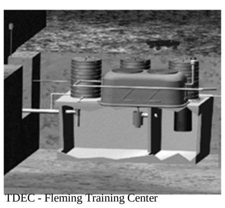
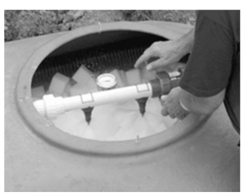
SCAT® Open Cell Foam Filter

- Hydraulic load: 11 to 16 gpd/ft^2
- Helical spray nozzle @ 5 to 8 psi
- Void space: 30%
- Dose Volume: 1.2 to 1.5 gal/ft^2





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AdvanTex® Textile Filter

- Most has geosynthetic or geotextile fabric
- Vertical sections of fabric are 2 ft long hung side by side
- Wastewater applied in small, uniform doses several times per hour
- Hydraulic load:
  - 25 to 35 gpd/ft^2 (very high due to increased surface area)

South Blount Utility has these and the effluent then goes to a drip field

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AdvanTex® Textile Filter

- Operated in recirculating mode
- Aerobic conditions maintained due to large volume of pore space (90%)
- BOD and TSS removed efficiently
- Ammonia is nitrified
- Denitrification for nitrogen removal possible

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Conclusion

- Media Filters are capable of providing reliable, long term service and excellent effluent quality if they are:
  - Properly sited
  - Properly designed
  - Properly used by the owner/occupant
  - Properly maintained on a regular basis
- The greatest challenge to be addressed before widespread adoption of technologies like PBF’s can be commonplace is the development and public acceptance of management organizations and fee structures to assure that the systems are properly maintained on a regular basis.

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Section 13

Disinfection

Wastewater Disinfection and Chlorination

TENNESSEE DEPARTMENT OF ENVIRONMENT AND CONSERVATION

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Removal of Pathogenic Microorganisms

- Wastewater treatment removes some of the pathogenic microorganisms through these processes:
  - Physical removal through sedimentation and filtration
  - Natural die-off in an unfavorable environment
  - Destruction by chemicals introduced for treatment purposes

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Disinfection vs. Sterilization

- Disinfection is the destruction of all pathogenic microorganisms
  - Chlorination of wastewater is considered adequate when the
    - fecal coliform count has been reduced to 200 cfu/100 mL or less
    - E. coli count has been reduced to 126 cfu/100 mL or less
- Sterilization is the destruction of ALL microorganisms

**cfu = colony forming unit

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Pathogenic Organisms

- Diseases that are spread through water are:
  - Viral
    - Polio
    - Hepatitis A
  - Protozoa
    - Amebic Dysentary
    - Giardiasis
    - Cryptosporidiosis
  - Bacterial
    - Cholera
    - Typhoid
    - Salmonellosis
    - Shigellosis, a bacillary dysentery
    - Gastroenteritis from enteropathogenic Escherichia coli

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Disinfection

- The main objective of disinfection is to prevent the spread of disease by protecting:
  - Public water supplies
  - Receiving waters used for recreational purposes
    - Protect water where human contact is likely
  - Fisheries and shellfish growing areas
  - Irrigation and agricultural waters

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Chlorine Chemicals

- Elemental chlorine
  - Yellow-green gas or amber liquid
  - 100% chlorine
- Sodium hypochlorite - bleach
  - Clear, pale yellow liquid
  - 5-15% chlorine
- Calcium hypochlorite - HTH
  - White, pale yellow granules or tablets
  - 65% chlorine
- Chlorine dioxide
  - Green-yellow gas generated on-site

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Chlorine

- Reacts with:
  - Organic matter
  - Hydrogen sulfide (H_2S)
  - Iron
  - Phenols
  - Manganese
  - Nitrite
  - Ammonia
  - And lastly used for disinfection

(Organic matter through Ammonia: Chlorine Demand)

Chemistry of Chlorination

$Cl_2 + H_2O \rightarrow HOCl + HCl$
hypochlorous acid, hydrochloric acid

- Hypochlorous acid
  - Most effective disinfectant
  - Prevalent at pH less than 7
    Dissociates at higher pH:

    $HOCl \rightarrow H^+ + OCl^-$
    hypochlorite ion
  - Hypochlorite ion is only 1% as effective as hypochlorous acid.

Chemistry of Hypochlorination

$NaOCl + H_2O \rightarrow HOCl + NaOH$
hypochlorous acid

- Sodium hypochlorite will slightly raise the pH because of the sodium hydroxide (NaOH)

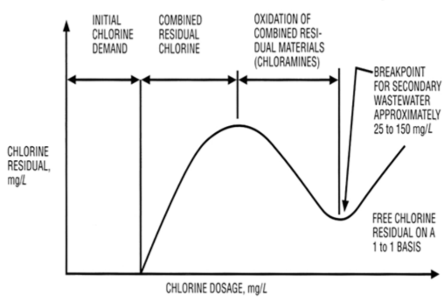
$Ca(OCl)_2 + 2H_2O \rightarrow Ca(OH)_2 + 2HOCl$

- Calcium hypochlorite does the same

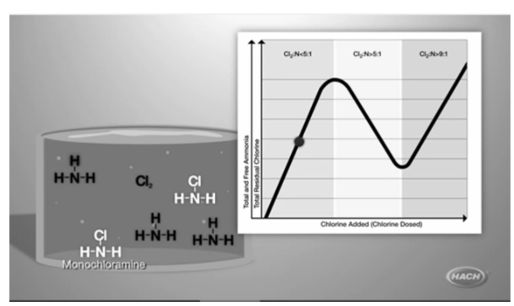
Chlorine Dioxide (ClO_2): Chemistry

- Made onsite and very unstable
- $2NaClO_2 + Cl_2 \rightarrow 2NaCl + 2ClO_2$
  Sodium Chlorite, Chlorine, Sodium Chloride, Chlorine Dioxide
- $2ClO_2 + H2O \rightarrow ClO_3^- + ClO_2^- + 2H^+$
  Chlorine dioxide, Water, Chlorate Ion, Chlorite Ion, Hydrogen Ion

Breakpoint Chlorination Curve



Chlorine & Chloramination Curves



Factors Influencing Disinfection

- Injection point and method of mixing
- Design or shape of contact chamber
- Contact time
  - Most contact chambers are designed to give 30 min contact time
- Effectiveness of upstream processes
  - The lower the SS, the better the disinfection
- Temperature
- Dose and type of chemical
- pH
- Numbers and types of microorganisms

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Chlorine Demand

- Chlorine demand can be caused by environmental factors such as:
  - Temperature
  - pH
  - Alkalinity
  - Suspended solids
  - Biochemical and chemical oxygen demand
  - Ammonia nitrogen compounds

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Application Points for Chlorination

- Collection system
- Prechlorination
- Plant chlorination
- Chlorination before filtration
- Post-chlorination

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Collection System

- Odor control
  - Aeration may be most cost efficient
- Corrosion control
- BOD control
  - Decrease the load imposed on the STP

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Prechlorination

- The addition of chlorine to wastewater at the entrance to the treatment plant, ahead of settling units and prior to the addition of other chemicals
  - Aids in:
    - Odor control
    - Decrease BOD load
    - Settling
    - Oil removal

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Plant Chlorination

- Chlorine can be added to wastewater during treatment
  - The point of application depends on the desired results
- Emergency measure only, use extreme care when chlorinating in the treatment process because you may interfere or inhibit biological treatment processes
- Aids in:
  - Control of odors
  - Corrosion
  - Sludge bulking
  - Digester foam
  - Filter flies
  - Trickling Filter Ponding

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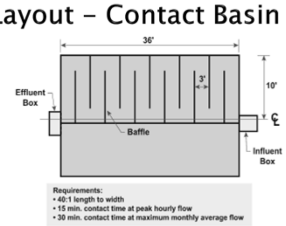
Chlorination Before Filtration

- Kills algae and other large biological organisms in water or in filters
  - Biological growth may cause filters to clog which would cause the need to backwash more frequently

Post-chlorination

- Post-chlorination is defined as the addition of chlorine to municipal or industrial wastewater following other treatment processes
  - Point of application should be called a Chlorine Contact Chamber or Basin
  - Sole purpose is disinfection
  - A highly nitrified effluent can be difficult to disinfect, adding 1.5 mg/L of ammonia to the effluent of the nitrification process can correct the problem

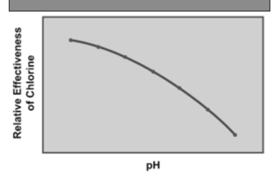
Typical Layout - Contact Basin



- Requirements:
  - 30:1 length to width
    - The total length of the channel created by the baffles should be 30 times the distance between the baffles
  - 15 min. contact time at peak hourly flow
  - 30 min. contact time at max monthly avg. flow

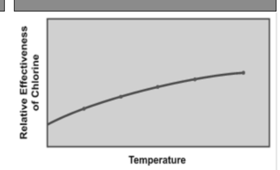
Relative Effectiveness

vs. pH



The lower the ph (<6), the disinfection action increases because hypochlorous acid is formed from chlorine and has 40 to 80 times greater disinfection potential.

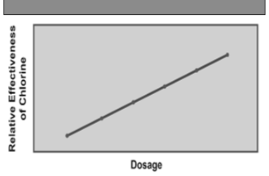
vs. Temperature



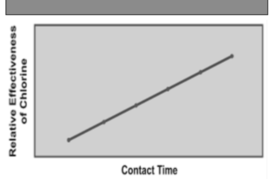
When the temperature increases the disinfection action of chlorine increases.

Relative Effectiveness

vs. Dosage

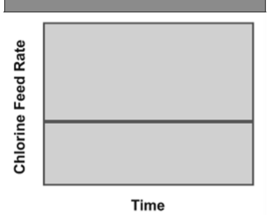


vs. Contact Time

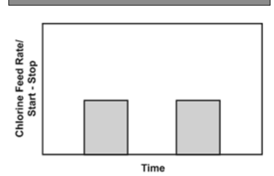


Types of Feed Control

Manual Control

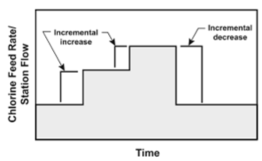


Start Stop Control

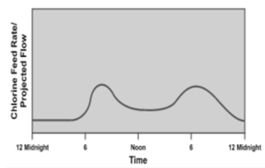


Types of Feed Control

Step Rate Control



Timed Program Control



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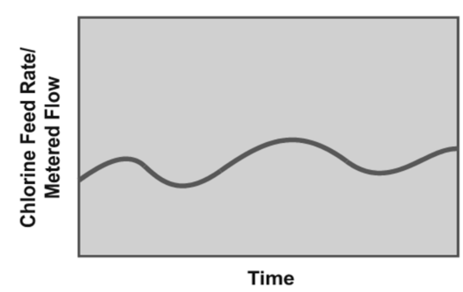
Flow Proportional Control



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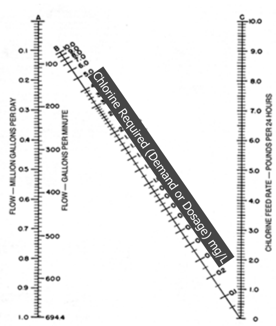
Chlorination Control Nomograph

- Nomogram is a chart or diagram containing three or more scales used to solve problems with three or more variables



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Chlorine Hazards

- Chlorine gas is:
  - 2.5 times heavier than air
  - Extremely toxic
  - Corrosive in moist atmospheres
- Exhaust fans should be located at floor level in the chlorine room.

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Chlorine Leaks

- To locate chlorine leaks you should use a commercial ammonia water (containing 28-30% ammonia as NH_3 which is the same as 58% ammonium hydroxide, NH_4OH, or commercial 26° Baumé)
  - The ammonia water can be put in a polyethylene squeeze bottle about half full and squeeze the ammonia vapors around potential Cl_2 leak.
  - When ammonia vapor comes in contact with chlorine, a white cloud of ammonia chloride is formed.
  - A ammonia soaked rag wrapped around a stick will also do.
  - Household ammonia is not strong enough.
- Never put water on a chlorine leak because the mixture of water and chlorine will increase the rate of corrosion at the leak.

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Chlorine Leaks

- To shut down a gas chlorination system for maintenance:
  - Turn off the chlorine gas supply
  - Wait for the rotameter ball to drop to 0 lbs
  - Turn off the injector water supply to insure that all gas has been expelled

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Physiological Response to Chlorine Gas

Effect	Parts of Chlorine Gas per Million Parts of Air by Volume (ppm)
Slight symptoms after several hours' exposure	1*
Detectable odor	0.08 – 0.4
60-min inhalation without serious effects	4
Noxiousness	5
Throat irritation	15
Coughing	30
Dangerous from ½ - 1 hour	40
Death after a few deep breaths	1,000

*OSHA regs specify that exposure to chlorine shall at NO time exceed 1 ppm.

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Chlorine

- Chlorine is available in:
  - 150 lb cylinders
  - 1 ton containers
  - Up to 90 ton railroad cars
- These containers under normal conditions of temperature and pressure contain chlorine as a liquid and a gas form.
  - If you take chlorine from the bottom of the container, it will be liquid
  - If you take chlorine from the top of the container, it will be gas
  - Liquid chlorine expands in volume by 460 times as a gas at atmospheric pressure

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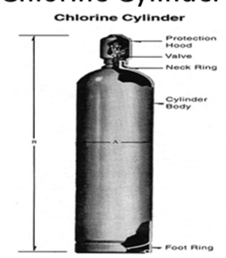
Chlorine Cylinder (100 or 150 lb.)



Net Cylinder Contents	Approx. Tare, Lbs.*	Dimensions, Inches	
		A	B
100 Lbs.	73	8¼	54½
150 Lbs.	92	10¼	54½

* Stamped tare weight on cylinder shoulder does not include valve protection hood.

- The fusible plug melts at 158-165°F to prevent build-up of excessive pressure and possible rupture
- Cylinders must be kept away from direct heat
- It is not advisable to draw more than 40 lbs of chlorine in a 24-hr period because of the danger of freezing and slowing down the chlorine flow

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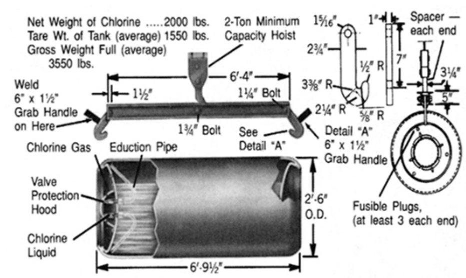
Ton Container



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Ton Container

- Ton tanks weigh ~ 3,700 pounds
- Most ton tanks have 6-8 fusible plugs that are designed to melt at the same temperature range as the safety plug in the cylinder valve
- Ton tanks should be stored and used on their sides, above the floor or ground on steel or concrete supports
- Ton tanks should be placed on trunnions
- The upper valve will discharge chlorine gas and he lower valve will discharge liquid chlorine
- The max withdrawal rate for a ton container is 400 lbs/day.

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Chlorine Repair Kits

Kit B

Kit A

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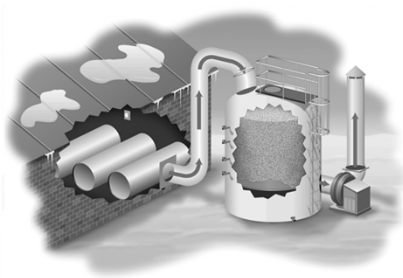
Chlorine Scrubber



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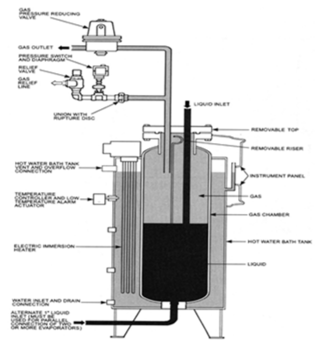
Evaporator

- Installed where large amounts of chlorine are fed
- An evaporator is a hot water heater surrounding a steel tank and the liquid chlorine is evaporated to gas at 110-120°F



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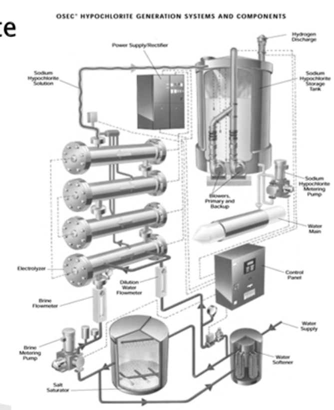
Hypochlorite Generator



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Dechlorination

- Dechlorination is the physical or chemical removal of all traces of residual chlorine remaining after the disinfection process and prior to the discharge of the effluent to the receiving waters
- Removal methods:
  - Aeration
  - Sunlight
  - Long detention time
  - Chemicals

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Chemicals Used for Dechlorination

- Sulfur dioxide
  - SO_2
  - One-to-one basis
  - Most popular
- Sodium sulfite
  - Na_2SO_3
- Sodium bisulfate
  - $NaHSO_3$
- Sodium metabisulfite
  - $Na_2S_2O_5$
- Sodium Thiosulfate
  - $Na_2S_2O_3$

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Sulfur Dioxide

- Colorless gas with a characteristic pungent odor
- Not flammable or explosive
- Not corrosive unless in a moist environment it can form sulfuric acid
- Detecting for sulfur dioxide leaks is done the same way for chlorine by using ammonia vapor dispenser or ammonia soaked rags.

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Application Point

- The typical application point is just before discharge into receiving stream
- This allows for maximum time for disinfection to take place

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Physiological Response to Sulfur Dioxide

Effect	Concentration
Lowest concentration detectable by odor	3-5 ppm
Lowest concentration immediately irritating to throat	8-12 ppm
Lowest concentration immediately irritating to eyes	20 ppm
Lowest concentration causing coughing	20 ppm
Maximum allowable concentration for 8-hr exposure	10 ppm
Maximum allowable concentration for 1-hr exposure	50-100 ppm
Tolerable (briefly)	150 ppm
Immediately dangerous concentration	400-500 ppm
OSHA 8-hour TWA (Time Weighted Average) is 2 ppm and the 15-minute STEL (Short Term Exposure Limit) is 5 ppm	

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Ultraviolet Radiation

- Ultraviolet radiation is commonly referred to as ultraviolet light or UV
- With growing concern with safety of chlorine handling and the possible health effects of chlorination by-products, UV is gaining popularity
- UV disinfection may become a practical alternative to chlorine disinfection at STP

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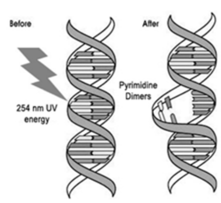
Ultraviolet Radiation

- A UV system transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material.
  - When UV radiation penetrates the cell wall of an organism, it destroys the cell's ability to reproduce
  - UV radiation, generated by an electrical discharge through mercury vapor, penetrates the genetic material of microorganisms and retards their ability to reproduce.



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Ultraviolet Radiation

- The effectiveness of a UV system depends on:
  - Characteristics of the WW
  - Intensity of the UV radiation
  - Amount of time the microorganisms are exposed to the radiation
  - Reactor configuration

  - For anyone treatment plant, the disinfection success is directly related to the concentration of colloidal and particulate constituents in the WW

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UV – System Components

- Mercury arc lamps
- Reactor
- Ballast

- Source of UV can either be low-pressure or medium pressure mercury arc lamp with low or high intensities.

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UV – System Components

- The optimum wavelength to effectively inactivate microorganisms is in the range of 250-270 nm.
- The intensity of the radiation emitted from the lamp dissipates as the distance from the lamp increases.
- Low-pressure lamps emit essentially monochromatic light at a wavelength of 253.7 nm.
- Standard lengths of the low-pressure lamps are 0.75 and 1.5 meters with diameters of 1.5-2.0 cm.
- The ideal lamp wall temperature is between 95-122°

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Low Pressure UV Lamps

- Lamp assemblies mounted in a rack(s) that are immersed in flowing water
- Can be enclosed in a vessel or in an open channel
  - Enclosed in vessels in pressure systems
- Placed either horizontal and parallel to flow or vertical and perpendicular to flow
- Number of lamps determines water depth in channel

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UV – System Components

- Medium-pressure lamps are generally used for large facilities
- They have approximately 15-20 times the germicidal UV intensity of low-pressure lamps
- The medium-pressure lamp disinfect faster and has greater penetration capability because of its higher intensity.
- However, these lamps operate at higher temperatures with higher energy consumption

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UV Operation

- Lamp output declines as they age
  - Operators must monitor output and replace bulbs that no longer meet design standards
- Turbidity and flow must be monitored
  - Suspended particles can shield microorganisms from the UV light
  - Flows should be somewhat turbulent to ensure complete exposure of all organisms to the bulbs
- UV light does NOT leave a residual like chlorine
  - Bacteriological tests must be run frequently to ensure adequate disinfection is taking place
  - Microorganisms that were not killed may be able to heal themselves

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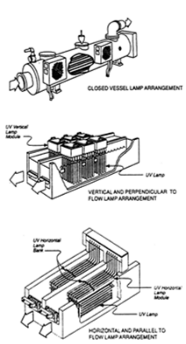
Typical UV Lamp Configurations

- Closed vessel lamp arrangements are more typically found in drinking water plants
- Wastewater plants normally have UV bulbs placed in an open channel either horizontal or perpendicular to flow



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Safety with UV Systems

- The light from a UV lamp can cause serious burns to your eyes and skin
- Always take precautions to protect your eyes and skin
- NEVER look into the uncovered sections of the UV chamber without protective glasses
- UV lamps contain mercury vapor, which is a hazardous substance that can be released if the lamp is broken

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Maintenance

- Quartz sleeves
  - Cleaning frequency depends on water quality and treatment chemicals
  - Dip modules in nitric acid or phosphoric acid for 5 minutes to remove scale
  - Cleaned by removing modules from channel or by in-channel cleaning
  - In-channel cleaning requires back-up channel and greater volume of cleaning solution
    - Precautions should be taken to protect concrete walls of channel from being damaged by acid

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Maintenance

- UV lamps
  - Service life ranges from 7,500 – 20,000 hours
  - Depends on
    - Level of suspended solids
    - Frequency of on/off cycles
    - Operating temperature of lamp electrodes
  - Lamp output drops 30-40% in first 7,500 hours
  - Lamp electrode failure is most common cause of lamp failure
  - Do not throw used lamps in garbage can
    - Must be disposed properly due to mercury content

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UV - Advantages

- Effective at inactivating most viruses, spores and cysts
- Physical process rather than a chemical disinfectant
  - Eliminates the need to generate, handle, transport or store toxic/hazardous or corrosive chemicals
- No residual effect that can be harmful to humans or aquatic life
- User-friendly for operators
- Shorter contact time when compared with other disinfectants
  - Approximately 20-30 seconds with low-pressure lamps
- Requires less space than other methods

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UV - Disadvantages

- Low dose may not effectively inactivate some viruses, spores or cysts
- Organisms can sometimes repair and reverse the destructive effects of UV through a “repair mechanism” known as photo reactivation, or in the absence of light known as “dark repair”
- Preventive maintenance program is necessary to control fouling of tubes
- Turbidity and TSS in the WW can render UV disinfection ineffective
  - UV disinfection with low-pressure lamps is not as effective for secondary effluent with TSS levels above 30 mg/L
- Not as cost-effective as chlorination, bust costs are competitive when chlorination and dechlorination is used and fire codes are met

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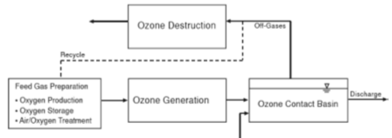
Process of Ozone Disinfection



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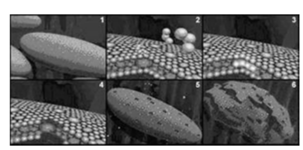
Effects of Ozone on Bacteria



Ozone disinfection steps:
1 – Computer animation of a bacterial cell
2 – Close-up of an ozone molecule on the bacterial cell wall
3 – Ozone penetrates the cell wall and causes corrosion
4 – Close-up of the effect of ozone on the cell wall
5 – Bacterial cell after it has come in contact with a number of ozone molecules
6 – Cell destruction (lysis)

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Ozone

O_2 + Energy → O + O
O + O_2 → O_3

- Produced when oxygen (O_2) molecules are dissociated by an energy source into oxygen atoms and subsequently collide with an oxygen molecule to form a stable gas, ozone (O_3)
- Most WW plants generate ozone by imposing a high voltage alternating current (6-20 kilovolts) across a dielectric discharge gap that contains an oxygen-bearing gas.
- Ozone is generated on-site because it is unstable and decomposes to elemental oxygen in a short amount of time after generation.

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Ozone

- Extremely dry air or pure oxygen is exposed to a controlled, uniform high-voltage discharge at a high or low frequency.
- The dew point of the feed gas must be -60°C (-76°F) or lower
- The gas stream generated from air will contain about 0.5-3.0% ozone by weight
  - Pure oxygen will form approximately 2-4 times that concentration
    - If pure oxygen is used, the off-gases from the contact chamber can be recycled to generate ozone or for reuse in the aeration tank

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Ozone

- After generation, ozone is fed into a down-flow contact chamber containing the wastewater
- The main purpose of the contactor is to transfer ozone from the gas bubble into the bulk liquid while providing sufficient contact time for disinfection
- The commonly used contactor types diffused bubble are
  - Positive pressure injection
  - Negative pressure (Venturi)
  - Mechanically agitated
  - Packed tower
- Because it is consumed quickly, it must be contacted uniformly in a near plug flow contactor
- Residual ozone measured by the iodometric method
- Dissolved ozone measured by Indigo test

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Equipment

- Ozone Generator
- Consists of a pair of electrodes separated by a gas space and a layer of glass insulation
- Air passes through the empty space
- Electrical discharge occurs across the gas space and ozone is formed

Oxygen from air + Electrical voltage → Ionized oxygen + Heat
O_2 + electricity → 2(O)

Ionized oxygen + Non-ionized oxygen → Ozone
2(O) + 2(O_2) → 2 (O_3)

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Maintenance

- Inspect electrical equipment and pressure vessels monthly
- Conduct a yearly preventive maintenance program
  - Should be done by a factory representative or an operator trained by the manufacturer
- Lubricate moving parts according to manufacturer's recommendations

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Safety

- Ozone is a toxic gas and is a hazard to plants and animals
- When ozone breaks down in the atmosphere, the resulting pollutants can be very harmful
- Ozone contactors must have a system to collect ozone off-gas.
  - Ozone generating installations must include a thermal or catalytic ozone destroyer

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Ozone – Advantages

- More effective than chlorine in destroying viruses and bacteria
- Short contact time (10-30 min)
- No harmful residues left in water
- No re-growth of microorganisms
  - Except for those protected by particulates in water
- Generated on-site
  - Fewer safety problems associated with shipping and handling
- Elevates DO levels in effluent
  - Can eliminate needs for post aeration
  - Can raise DO levels in receiving stream

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Ozone – Disadvantages

- Low dose may not effectively inactivate some viruses, spores and cysts
- More complex technology
  - Requiring more complex equipment and efficient contacting systems
- Very reactive and corrosive
  - Requiring corrosive-resistant materials such as stainless steel
- Not economical for WW with high levels of solids, BOD, COD or total organic carbon (TOC)
- Extremely irritating and possibly toxic to humans at concentrations of 1 ppm or greater in air
- Cost can be high in capital and power intensiveness

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Design Criteria

http://www.tn.gov/environment/water/water-quality_publications.shtml

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Chapter 10 – Disinfection

- 10.1.1 – Disinfection as a minimum shall
  - A. Protect public water supply
  - B. Protect fisheries and shellfish waters
  - C. Protect irrigation and agricultural waters
  - D. Protect water where human contact is likely

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Chapter 10 – Disinfection

- 10.1.2.1 – Chlorination
  - Chlorination using dry chlorine is the most commonly applied method of disinfection and should be used unless other factors, including chlorine availability, costs, or environmental concerns, justify an alternative method

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Chapter 10 – Disinfection

- 10.1.3 – Dechlorination
  - Capability to add dechlorination should be considered in all new treatment plants. Dechlorination of chlorinated effluents shall be provided when permit conditions dictate the need

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Chapter 10 – Disinfection

- 10.2.1.4 – Chlorine Gas Withdrawal Rates
  - The maximum withdrawal rate for 100- and 150-pound cylinders should be limited to 40 pounds per day per cylinder
  - When gas is withdrawn from 2,000-pound containers, the withdrawal rate should be limited to 400 pounds per day per container

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Chapter 10 – Disinfection

- 10.2.2.4 – Contact Period
  - Contact chambers shall be sized to provide a minimum of 30 minutes detention at average design flow and 15 minutes detention at daily peak design flow, whichever is greater. Contact chambers should be designed so detention times are less than 2 hours for initial flows.

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Chapter 10 – Disinfection

- 10.2.2.5 – Contact Chambers
  - The contact chambers should be baffled to minimize short-circuiting and backmixing of the chlorinated wastewater to such an extent that plug flow is approached.
  - Provision shall be made for removal of floating and settleable solids from chlorine contact tanks or basins without discharging inadequately disinfected effluent

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Chapter 10 – Disinfection

- 10.2.2.5 – Contact Chambers (continued)
  - A readily accessible sampling point shall be provided at the outlet end of the contact chamber

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Chapter 10 – Disinfection

- 10.2.2.6 (a) – Dechlorination with Sulfur Dioxide
  - Sulfur dioxide can be purchased, handled and applied to wastewater in the same way as chlorine
  - Sulfur dioxide dosage required for dechlorination is 1 mg/L of SO_2 for 1 mg/L of chlorine residual expressed as Cl_2

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Chapter 10 – Disinfection

- 10.2.2.8 – Residual Chlorine Testing
- Equipment should be provided for measuring chlorine residual.
- There are five EPA accepted methods for analysis of total residual chlorine and they are
  - 1) Ion Selective Electrode
  - 2) Amperometric End Point Titration Method
  - 3) Iodometric Titration Methods I & II
  - 4) DPD Colormetric Method
  - 5) DPD Ferrous Titrimetric Method

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Chapter 10 – Disinfection

- 10.2.2.8 – Residual Chlorine Testing (continued)
- Where the discharge occurs in critical areas, the installation of facilities for continuous automatic chlorine residual analysis and recording systems may be required.

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Chapter 10 – Disinfection

- 10.2.3.1(a) – Design Details (Housing – General)
  - An enclosed structure shall be provided for the chlorination equipment
  - Chlorine cylinder or container storage area shall be shaded from direct sunlight

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Chapter 10 – Disinfection

- 10.2.3.1(a) – Design Details (Housing – General) (continued)
  - Chlorination systems should be protected from fire hazards and water should be available for cooling cylinders or containers in case of fire
  - If gas chlorination equipment and chlorine cylinders or containers are to be in a building used for other purposes, a gastight partition shall separate this room from any other portion of the building

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Chapter 10 – Disinfection

- 10.2.3.1(b) – Design Details (Housing – Heat)
  - Chlorinator rooms should have a means of heating and controlling the room air temperature above a minimum of 55°F
  - A temperature of 65° F is recommended

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Chapter 10 – Disinfection

- 10.2.3.1(b) – Design Details (Housing – Heat) (continued)
  - The room housing chlorine cylinders or containers in use should be maintained at a temperature less than the chlorinator room, but in no case less than 55°F unless evaporators are used and liquid chlorine is withdrawn
  - All rooms containing chlorine should also be protected from excess heat

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Chapter 10 – Disinfection

- 10.2.3.1(c) – Design Details (Housing – Ventilation)
  - All chlorine feed rooms and rooms where chlorine is stored should be force-ventilated, providing one air change per minute except “package” buildings with less than 16 ft^2 of floor space
  - The entrance to the air exhaust duct from the room should be near the floor and the point of discharge should be so located as not to contaminate the air inlet to any building or inhabited areas

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Chapter 10 - Disinfection

- 10.2.3.1(e)
  - Dechlorination equipment (SO_2) shall not be placed in the same room as the Cl_2 equipment. SO_2 equipment is to be located such that the safety requirements of handling Cl_2 are not violated in any form or manner

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Chapter 10 - Disinfection

- 10.2.3.6 – Handling Equipment
  - Handling equipment should be provided as follows for 100- and 150-pound cylinders:
    - A hand truck specifically designed for cylinders
    - A method for securing cylinders to prevent them from falling over

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Chapter 10 - Disinfection

- 10.2.3.6 – Handling Equipment (continued)
  - Handling equipment should be provided as follows for 2,000-pound container:
    - Two-ton capacity hoist
    - Cylinder lifting bar
    - Monorail or hoist with sufficient lifting height to pass one cylinder over another
    - Cylinder trunnions to allow rotating the cylinders for proper connection

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Chapter 10 - Disinfection

- 10.2.4.1 – Leak Detection and Controls
  - A bottle of 56% ammonium hydroxide solution shall be available for detecting chlorine leaks
  - All installations utilizing 2,000-pound containers and having less than continuous operator attendance shall have suitable continuous chlorine leak detectors

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Chapter 10 - Disinfection

- 10.2.4.2 – Breathing Apparatus
  - At least <u>two</u> gas masks in good operating condition and of a type approved by the National Institute for Occupational Safety and Health (NIOSH) as suitable for high concentrations of chlorine gas shall be available at all installations where chlorine gas is handled and shall be stored outside of any room where chlorine is used or stored

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Chapter 10 - Disinfection

- 10.3.2 – Ultraviolet Disinfection – Application
  - UV disinfection may be substituted for chlorination, particularly whenever chlorine availability, cost or environmental benefits justify its application. For tertiary treatment plants where dechlorination is required for chlorine toxicity is suspected, UV disinfection is a viable alternative

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Disinfection Vocabulary

______1. Breakpoint
______2. Chlorination
______3. Combined Residual
______4. CxT Value
______5. Disinfection Residual
______6. Disinfection
______7. Disinfection By-Product
______8. Free Chlorine Residual
______9. Organic Substance
______10. Ozone Generator
______11. Sterilization
______12. Trihalomethane
______13. UV Disinfection
______14. Waterborne Disease

A. The process of destroying all organisms in water.
B. The product of the residual disinfectant concentration C and the corresponding disinfectant contact time T.
C. The water treatment process that kills disease-causing organisms in water.
D. A device that produces ozone by passing an electrical current through air or oxygen.
E. The point at which the chlorine dose has met the demand.
F. A chemical substance of animal or vegetable origin, having carbon in its molecular structure.
G. Disinfection using ultraviolet light.
H. The process of adding chlorine to water to kill disease-causing organisms.
I. The residual formed after the chlorine demand has been satisfied.
J. An excess of chlorine left in water after treatment. Indicates that an adequate amount of disinfectant has been added to ensure complete disinfection.
K. Compound formed when organic substances such as humic and fulvic acids react with chlorine.
L. Chemical compounds that are formed by the reaction of disinfectants with organic compounds in water.
M. The chlorine residual produced by the reaction of chlorine with substances in the water. It is not as effective as free residual.
N. A disease caused by waterborne organism.

Disinfection Review Questions

1. List four infectious diseases that can be transmitted by water:
   -
   -
   -
   -

2. What are limitations of UV disinfection?

3. Name the three types of chlorine commonly used in wastewater treatment and give a short description of each:
    -
    -
    -

4. Define breakpoint.

5. When chlorine is added to water, it breaks down into two products. Name them:
    -
    -

6. Which of the two products (in #5) is the most effective disinfectant?

7. Why is chlorination less effective at a higher pH?

Answers to Vocabulary and Questions

Vocabulary:

1. E
2. H
3. M
4. B
5. J
6. C
7. L
8. I
9. F
10. D
11. A
12. K
13. G
14. N

Questions:

1. Typhoid fever, infectious hepatitis, dysentery, cholera
2. Water must pass close to lamp; water must be of good quality; no residual
3.
   - gas – greenish-yellowish gas; pungent, noxious odor; toxic if inhaled; 2.5x heavier than air
   - NaOCl – Sodium hypochlorite, liquid, bleach; can cause burns on skin; 5-15% strength
   - $Ca(Ocl)_2$ – Calcium hypochlorite, solid; 65% strength, fire hazard, can cause burns
4. Addition of chlorine to water or wastewater until the chlorine demand has been satisfied. At this point, further additions of chlorine result in a residual that is directly proportional to the amount of chlorine added beyond the breakpoint.
5. HOCl (hypochlorous acid) and OCl^- (hypochlorite ion)
6. HOCl (hypochlorous acid)
7. Hypochlorous acid breaks down into hypochlorite ion, which is only 1% as effective

Section 14

Rules and Regs

DESIGN CRITERIA FOR SEWAGE WORKS

The entire Design Criteria for Sewage Works can be found at http://www.tn.gov/environment/water/water-quality_publications.shtml toward the bottom of the page.

CHAPTER 15

Managed Wastewater Dispersal Using Drip Irrigation

DECENTRALIZED DOMESTIC WASTEWATER TREATMENT SYSTEMS

15.1 Preface

This chapter presents the method to determine the proper design for decentralized wastewater treatment systems (DWWTS). DWWTS are systems that are not the traditional, centralized/regionalized wastewater treatment systems. DWWTS treat domestic, commercial and industrial wastewater using water tight collection, biological treatment, filtration and disinfection. These systems typically will utilize land application with either surface or subsurface effluent dispersal.

15.2 General Considerations

15.2.1 Ownership

Plans for sewer systems including domestic wastewater treatment systems will not be approved unless ownership and responsibility for operation are by a municipality, publicly owned utility, or a privately owned public utility regulated by the Tennessee Regulatory Authority (TRA). The owner is defined as the entity responsible for the operation of the system. The property being served is defined as the user.

Legal title to tanks, pumps, or other components should be vested with the owner. The objective of having title invested to the owner rather than the user is to avoid potential for cost disputes over equipment selection and repair methods. Regardless of where title is vested, the owner should completely control all tanks, pumps, service lines and other components of the system on private property. This requirement is essential to assure operable hydraulics and overall system reliability.

The owner shall possess a recorded general easement or deed restriction to enter the private property being served, and to access the system and its components. Access must be guaranteed to operate, maintain, repair, restore service and remove sludge.

Owners should operate and maintain facilities without interruption, sewage spills on the grounds, sewage backup into buildings, or other unhealthy conditions.

15.2.2 Planning

The applicant should contact the Division of Water Pollution Control as early as possible in the planning process. If a discharge to surface waters is proposed, the treatment works will be designated an appropriate Reliability Classification as detailed in Chapter 1 of this design criteria. Also for proposed surface water discharges, the designer should refer to the Wastewater Discharge Checklist, Appendix 15-A.

15.3 Design Basis

Small systems are more sensitive to influent problems due to a reduction in hydraulic or organic buffering capacity. Small systems are much more susceptible to flow variations due to daily, weekend or seasonal fluctuations. An accurate characterization of the waste and flow conditions should be projected for the site and should include flow, BOD_5, TSS, ammonia and, oil and grease.

15.3.1 Hydraulic Loading

For residential developments, the flows given below are generally considered appropriate for design purposes. For developments that include a preponderance of larger homes, higher flows should be considered. For non-residential flows, the engineer should use the tables given in Appendix 15-A. If the engineer determines that it is necessary to deviate from those values, then he/she must submit the basis for design flow, both average and peak. The type of collection system should be given serious consideration when determining total flow to the wastewater treatment plant.

For systems using water tight collection, the recommended design flow should be 300 gallons per day per unit. For projects dealing with commercial or very large residential developments, design flows should reflect expected variations from conventional systems and be evaluated and approved by the Division of Water Pollution Control based upon site-specific evaluation.

15.3.2 Engineering Report

An engineering report is required for all wastewater treatment projects. Small treatment plants require different design considerations than larger plants. During the design of a small treatment facility, the design engineer should evaluate the feasibility of various process alternatives. Except for systems proposed to serve single residential units, all other small flow systems or systems proposing to use land application for effluent dispersal should also submit an application for an NPDES permit or a State Operation Permit (SOP) to the Division of Water Pollution Control (Note: Exceptions may be contained in Memorandum of Agreement between the Divisions of Water Pollution Control and Ground Water Protection). The SOP application should include an engineering report, Water Pollution Control soils map, soil profile descriptions derived from soil borings and pit evaluations to determine soil type, texture and structure for all areas proposed for drip dispersal or spray irrigation as described in Chapters 17 and 16 of this criteria.

15.3.3 Pollutant Loading

While best engineering judgments for waste characterizations are sometimes necessary, an attempt should be made to project this character from similar facilities, instead of the absolute use of flow tables. For example, excess ammonia should be considered during design of a treatment system for a rest stop, truck stop or recreational vehicle park.

These types of facilities can have a significantly higher influent ammonia concentration than typical domestic systems

15.4 Preliminary Treatment

Preliminary treatment involves the removal of large solids that could damage pumps and equipment in the downstream treatment process. Such treatment may include properly designed and water tight septic tanks, or filters.

15.4.1 Septic Tank Effluent Pumping (**STEP**) and Septic Tank Effluent Gravity (**STEG**) Systems

An effluent sewer is a wastewater collection and treatment system shared by multiple users, consisting of multiple watertight septic tanks (to capture and remove gross solids, oil and grease), and small diameter watertight piping to convey wastewater from the tanks to a treatment facility and common dispersal area. Treated "clear" effluent from the mid-depth of the septic tank is filtered (through an effluent filter or screened pump vault) and transported under pressure via the pressurized collection system. An effluent sewer may include septic tank effluent pumping (STEP) systems, or septic tank effluent gravity (STEG) systems, or both. In a STEP system, the effluent is pumped from the septic tank under pressure while in a STEG system, pressurization is achieved using hydrostatic pressure (gravity).

Septic tanks should be sized to accommodate a minimum of two and one-half (2.5) times the design daily sewage flow anticipated to flow through the tank. Additionally, septic tanks may be either compartmentalized or not, since unbaffled tanks allow the tank to be pumped from either end. **All tanks regardless of size must be water-tight as evidenced by post installation testing and structurally sound by design as certified by a Licensed Professional Engineer stamp on tank plans and structural analysis**. Tanks may be made of concrete or other structurally sound materials such as fiberglass Water testing is preferred with the water level being a minimum of 3-inches above the top of the cover for the tank. If vacuum testing, it is preferred that the tank be capable of maintaining 4-inches of mercury (HG) without loss for five (5) minutes. However, at minimum the tank must meet the water pressure testing and vacuum testing in accordance with ASTM C1227. Structural soundness will usually require reinforcing bars incorporated into the tank walls, sides, top, and bottom. Acceptable burial depths and loading conditions should be explicitly noted on the drawings and made available to installers.

All tanks should be equipped with rubber inlet and outlet boots installed through the tank wall and sealed to the piping with stainless steel band clamps. All tanks should be equipped with water-tight risers over the inlet and outlet of the tank. The riser should have a water tight seal to the top of the tank. Access risers should extend to grade and be equipped with a water-tight lid bolted or locked to the riser.

15.4.1.1 - STEP Tanks

In a typical septic tank system, household sewage is pretreated in a watertight septic tank where gross solids and grease are held back. A "clear" effluent from the mid-depth of the tank is transported to a common or lateral sewer. In a septic tank effluent pump (STEP) system, the effluent is pumped from the septic tank under pressure to a small-diameter, pressurized collector sewer.

In most cases, a single phase, ½ HP effluent pump is adequate for septic tank effluent. However, if a working head over 150 feet is expected, a higher horsepower pump may be required.

The effluent pump should be located within a screened pump vault. The vault, at a minimum, should be fitted with 1/8-inch mesh polyethylene screen and a 4-inch diameter PVC (or equivalent) flow inducer for a high head pump.

The pump chamber should also include float switches that turn the pump on and off and activate high and low level alarms.

15.4.1.2 - STEG Tanks

Effluent may also flow by gravity, where available hydraulic gradient allows, to small-diameter gravity collector lines. Gravity system tanks should be equipped with an effluent filter that at a minimum consists of a 1/8-inch mesh polyethylene screen housed within a PVC (or equivalent) vault. The lateral from the tank to the collection line should be laid at a uniform grade with no high points.

15.4.2 Grinder Pumps

For systems served by grinder pumps, all raw wastewater should be collected from individual buildings/dwellings and transported to the pressure or gravity system by appropriately sized pumps. For restaurants or facilities with commercial-grade kitchen facilities, grease and oil interceptors (as described in 15.4.4) should be installed prior to the grinder pump.

All pumps must have adequate operating curves that allow for pumping into the pressurized common line under maximum head conditions. Additionally, each pump must be equipped with properly installed and approved backflow prevention assembly. Furthermore, tanks must be watertight and located above the seasonal groundwater table where possible. Where it is not possible to locate tanks above the seasonal groundwater table, the design engineer must provide antibuoyancy calculations and specify appropriate antiflotation devices. Installations should ensure that odors are minimized.

15.4.3 Grease and Oil

Facilities with commercial-grade kitchen facilities should be equipped with an effective grease and oil interceptor. Other potential sites of grease/oil production should be investigated by the design engineer.

One or more interceptors in series are required where grease or oil waste is produced that could hinder sewage disposal or treatment, and/or create line stoppages. Interceptors must be located so as to provide easy access for inspection, cleaning and maintenance. In commercial-grade kitchen facilities, the dishwasher(s) must not be connected to the primary grease trap and/or separator. A separate device may be required to allow for cooling of the dishwasher discharge prior to primary treatment.

As vegetable oil usage has become more common, it should be understood that oils will not solidify until approximately 70^{o} F. or less. Therefore, the minimum interceptor design should be a baffled, three-compartment, elongated chamber to allow for cooling with a capacity of at least 1,500 gallons. The design should be in accordance with accepted engineering practice. Tanks must also be sized in accordance with local requirements. The tank should be buried, with manhole accesses to all compartments. Tanks should be manufactured and furnished with access openings having a minimum diameter of twenty-one (21) inches. The tank top should be able to support a minimum of 2500 lb. wheel load. Inlet plumbing should be designed to penetrate 18 inches or more below the discharge invert elevation. In order to demonstrate water-tightness, tanks (including all risers and lids) must be tested prior to acceptance by filling with either air or water in accordance with ASTM standard C1227-05.

15.5 Secondary Treatment Design

The following secondary systems should be evaluated for small flow designs.

15.5.1 Fixed Media Biological Reactors

A fixed media biological reactor (FMBR) is an aerobic, fixed film process that uses sand, gravel or other media to provide secondary treatment of septic tank effluent. The FMBR typically consists of a septic tank and recirculating tank, media bed with a special distribution system installed within a structure or excavation lined with impervious synthetic liner and a flow splitter device.

Design considerations include the media size, type and surface area, the required bed area and depth, dose volumes and dosing frequency.

All sites for fixed media reactors should be properly prepared before installation. For reactors that are installed directly on soil with a synthetic liner (as opposed to package units with rigid bottoms), the liner may lie directly on the graded soil if it is free from material that might puncture the liner. Otherwise, a layer of sand or other suitable material should be placed below the liner to protect it from puncturing.

15.5.1.1 Granular Media Reactor

The media bed should be sized by comparing the organic and hydraulic loads and then using the more restrictive of the two. Table 15-1 gives suggested design parameters for the reactor, support bedding and underdrain media. All media should be washed and screened to limit fines to less than 1% by weight passing a 100 screen (0.15 mm).

Table 15-1. Suggested Design Parameters for Granular Media Reactors

Design Parameter	Effective Size (D_{10})	Depth	Design Value
Reactor Media:			
Sand or other, similar granular media	1.5-2.5 mm (Uniformity Coefficient = 1-3)	24 to 30 inches	3-5 gpd/ft^2 (hydraulic loading – forward flow) $\leq$ 6.2 lb BOD_5 /1000 ft^2/day (organic loading)
Gravel or other, similar granular media	0.6 - 1 cm diameter	24 – 30 inches	10 - 15 gpd/ft^2 (hydraulic loading – forward flow) $\leq$ 10 lb BOD_5 /1000 ft^2/day (organic loading)
Underdrain Media	#57 inch stone	12-18 inches	

A synthetic media may also be used as long as it meets the above criteria.

A minimum of 30 mil impermeable synthetic liner is required for the bottom and sides of the filter.

15.5.1.2 Other Fixed Media Reactors

These systems will be approved on a case-by-case basis. The design engineer must provide adequate rationale that such systems are preferable to more traditional granular media reactors.

15.5.1.3 Distribution and Underdrain System

15.5.1.3.1 – Spacing

Distribution mechanisms should ensure uniform application of the applied flow to the surface of the media. These mechanisms may involve spray nozzles in synthetic media reactors or drilled or perforated pipe in sand filter or other fixed media reactors. For sand filters, the distribution pipes should be spaced on 18-inch centers or less.

Underdrain lines, where used, should be spaced no farther than 8-feet on center.

15.5.1.3.2 – Sizing of Lines

Distribution pipes should be no smaller than 1-inch.

Clean-out caps should be provided on the ends of the distribution pipes.

In the underdrain system, pipes should have a minimum inside diameter of 4 inches. As an alternative, collection vaults may also be employed.

15.5.1.4 Recirculation Tank and Pump System

Where a separate recirculation tank is used, the tank may serve as a wetwell for the septic tank effluent and treated, recirculated effluent to be pumped to the media bed. The minimum tank volume should equal the design daily flow.

The tank should be equivalent in strength and materials to the septic tank as described in 15.4.1. No internal baffles are necessary. An access manhole is necessary for replacement of submersible dosing pumps if such are used.

A minimum of two alternating recirculation pumps are required for commercial multiuser FMBRs. Recirculating pump operation should be time-controlled. Float switches are required and should be wired in parallel with the timer to control the pumps during periods of either low or high wastewater flows, and as a back-up in case of timer malfunction.

A quick disconnect coupler and hanger pipe are recommended for pump removal and convenience. Additionally, panels for operation of FMBRs should also feature programmable digital timers and multiple settings for optimizing dosing during normal and peak flow conditions.

15.5.1.5 Flow Splitter

The system should be equipped with a device or computerized process control that allows for reactor effluent to be split between the recycle stream and discharge to either the disinfection system and/or drip disposal area. It is recommended that the designer choose a device that provides flexibility in setting the recycle ratio.

15.5.1.6 Dosing Chamber

Where the treated effluent is intended to be distributed through a drain field, drip dispersal system or other land application mechanisms, a dosing chamber should be employed, sized and equipped to provide timed-dosing of the daily wastewater flow with adequate reserve storage capacity for system malfunctions. The dosing chamber should be equipped with an audible visual or other approved high-water alarm set to provide notification to the owner/operator of a malfunction when the design high water level is exceeded and the emergency reserve capacity is being used. A low-water cutoff device must be provided to prevent damage to the pump during low-water conditions. A programmable timer and control panel should be employed to regulate the dosing frequency and volume, and to record wastewater flow, the number of doses and other pertinent dosing data.

Time dosing should be utilized to dose the absorption field or zones. The frequency of dosing must be based upon the soil's hydraulic loading rate and the design flow. Fields or zones should be time dosed to ensure the total twenty-four (24) hour wastewater effluent flow is applied in a 24-hour period.

15.6 Disinfection and Fencing

Disinfection of effluent is required prior to spray irrigation. Disinfection of effluent will be required for drip dispersal of unfenced drip irrigation if the drip field access is classified as either “Open Access” (where drip areas are used for ball fields, playgrounds, picnic areas, golf courses, etc.) or “Attractive Access” (where open spaces are maintained similar to residential lawns with easy access and with grass maintained at short heights, but with the area undeveloped for recreational purposes). In these cases, if the entire drip dispersal area is properly fenced, disinfection of the effluent is not required.

Disinfection of effluent may not be required for drip dispersal of unfenced drip irrigation if the drip field access is classified as either “Inhibited Access” (where drip areas are allowed to return to natural vegetation and are used for wildlife food plots or other similar uses and where routine access by humans is discouraged by growth of vegetation) or “Difficult Access” (where drip areas are located on generally steep, greater than 10% slopes, on heavily wooded slopes, and access by humans will be rare due to terrain, location, or vegetation).

In the design of UV disinfection units there are three basic areas that should be considered:

a. Reactor hydraulics – adequate residence time.

b. Factors affecting transmission of UV light to the microorganisms.

c. Properties of the wastewater being disinfected.

In addition, an automatic self-cleaning mechanism is recommended to ensure proper performance of the UV system.

As an alternative to disinfection, the drip field may be fenced with a 4-foot chain link, woven wire fence, wooden, four-strand barbed wire, or other as approved by the Department of Environment and Conservation.

15.7 Oxidation Ponds and Artificial Wetlands

15.7.1 Oxidation Ponds

1. The maximum design loading on the primary cell(s) should be 30 lbs BOD_5 per acre per day.
2. The design average flow rate should be used to determine the volume required to provide a minimum combined storage capacity of 90 days in the stabilization ponds. The minimum recommended operating depth is 3 feet for facultative ponds and 10 feet for aerated ponds.
3. The minimum number of cells should be three when the system is designed to discharge to surface waters.
4. The shape of the cells should be such that there are no narrow, L-shaped or elongated portions. Round or rectangular ponds are most desirable. Rectangular ponds should generally have a length not exceeding three times the width. Dikes should be rounded at the corners to minimize accumulation of floating material.

15.7.2 Basis of Wetland Design

The artificial wetland treatment system has been around since the 1980's. Like other land application systems, artificial wetlands are site specific. Consequently, all proposals will be reviewed on a site-by-site basis. This section is limited to subsurface flow wetlands utilizing gravel or other granular media. Free-water surface wetlands can also be used, but their design follows different parameters and approval will be on case-by-case basis.

1. Design
   a. Artificial wetlands designed to discharge to surface waters will have to meet NPDES permit limits at all times and must be designed accordingly.
   b. Artificial wetlands are designed on the basis of a BOD removal rate which is assumed to follow the classic first order removal equation corrected for temperature.
   c. The minimum recommended detention time for treatment of normal domestic waste in the artificial wetland system is 4 to 7 days.
   d. The recommended depth of flow in the wetland system should be between 18 and 24 inches, with twenty-four (24) inches as the recommended optimum depth.
   e. The aspect ratio of the wetland is determined by the design flow and substrate cross sectional area perpendicular to the flow. The aspect ratio should be such that one-third (⅓) of the available flow rate, as determined by Darcy' Law, is preserved and all flow remains subsurface. This will generally result in a rectangular configuration with a length to width ratio of between 1:1 and 1:3.

f. Seepage rates in the artificial wetland areas will be addressed on a site-by-site basis based upon in-situ material, groundwater depth and the groundwater use. Generally, no compaction will be required on wetland pond bottoms. The berms should be compacted to at least 90 percent of Standard Proctor Density.

g. The bottom of the artificial wetland treatment units should not have a slope greater than 0.2%.

h. Due consideration should be given to multiple wetland cells and to possible future expansion on suitable land when the original land acquisition is made for flexibility and for maximum operational capability.

2. Construction

a. The project site should be protected from surface inflow waters. The site should also be protected such that the top of the wetland surface is at least one foot above the 100 year flood elevation.

b. In order to prevent erosion and channelization at the inlet of the wetland, a discharge header should be utilized. The header should be equipped with removable end-plugs so the line may be drained to prevent freeze-up. Uniform distribution of wastewater to prevent short-circuiting through the wetland should be assured. It is recommended that the header outlet elevation be at or above the maximum design depth.

c. It is recommended that pipes and flumes located in or near inlet and discharge structures will not be in a completely submerged condition to maintain the integrity of the system and reduce freeze-up problems.

d. A suitable discharge structure from the wetland should be utilized. The structure should be adjustable so that the depth in the wetland may be modified as needed.

e. Care should be taken to establish the vegetation as soon as possible after construction. However, it is difficult to establish the vegetation in winter or mid to late summer. The emergent vegetation, once established, should prevent the erosion of the berms of the system. Riprap may be required around the inlet and outlet structures of the wetland. A cover crop may be planted on the interior slopes to prevent erosion prior to the establishment of the emergent vegetation. Consideration may be given to the use of excelsior blanket over seeding.

f. The exterior and interior slopes of the wetland berms surrounding the wetland basins should not be steeper than 3H:1V.

g. The top width of the berms should be a minimum of eight feet.

h. Following the final grade, the substrate should consist of a minimum of two feet of clean ¾-inch to 11/2-inch stone (#57).

i. The dike elevation should be a minimum of two feet above the high water level in the wetland.

j. If groundwater contamination is a potential problem, the bottom of the wetland may be sealed with a suitable material. However, generally no liner will be necessary in the artificial wetland.

k. Aluminum, concrete, or PVC pipe or other material generally accepted for sewers should be specified for the piping requirements in the wetland. Provisions may be required to prevent the settling of the piping structures under load. It is recommended where structures are partially or completely submerged in ice conditions that a flexible piece of pipe be installed to allow for some movement of structure.

l. The effluent discharge structure should be equipped with a suitable flow monitoring device, such as a flume or V-Notch weir, to monitor flows leaving the treatment site. Staff gages for measuring depths in structures should be provided where flow monitoring is required.

m. In order to accurately monitor influent flows to the artificial wetland system, an influent measurement structure should be included.

n. The entire wetland area must be enclosed with a suitable fence to provide public safety, exclude livestock and to discourage trespassing.

o. Warning signs must be provided along the fence around the treatment facility. There must be at least one sign on each side of the facility, with a minimum spacing of 500 feet.

p. Removable screens should be provided on pipe ends to prevent entrance of trash and wildlife.

3. Vegetation Establishment

   a. Specifications for the seeding of the artificial wetland should as a minimum include:

      1. Plant species
      2. Plant distribution (vegetative zone)
      3. Planting (including time restraints)
      4. Fertilization
      5. Water level control and site maintenance.

   b. Placing top soil in the graded wetland area is generally not required. Substrate properties generally do not limit the establishment of a wetland.

c. Only indigenous plant species should be used, preferably collected within a 100 mile radius. Preferred species include, but are not limited to:

1. Typha Latifolia - Common cattail,
2. Typha Angustifolia - Narrow leaf cattail,
3. Scirpus spp. - Bullrush, and/or
4. Phragmites communis - Reed.

d. Transplanting of live or dormant plant stock will achieve greater success than seed. However, the plants have to be set into the gravel with their roots near the water level in the wetland. Transplanting of reeds is by placing a section of rhizome containing the “eye” in the shallow surface of the gravel.

e. Seeding should generally be accomplished in the spring. Also, at least one fertilization should be required, preferably shortly after seed germination or at one month. The recommended fertilizer is the standard 10- 10-10 or 20-10-10 mixture at a rate of 600 lbs/ac or 300 lbs/ac, respectively. Where wastewater stabilization ponds exist, fertilization may not be necessary, as the nutrients in wastewater may suffice.

f. For seeding, the following is recommended:

The seed should be broadcast uniformly over the substrate at a rate of 10 viable seeds per square foot. The seeds should be cultivated to subsurface depths of 0 to 1 inch followed by lightly packing, rolling or dragging the tilled surface. Flood the site with 1-2 inches of water until the seeds germinate and become several inches tall. At this time, the area should be fertilized.

g. For transplanting (the recommended method of vegetation establishment) the propagule should be transplanted, as a minimum, on a two foot grid. The number of transplants required may be calculated from Equation 15-1:

$$N = (L/D + 1) \times (W/D + 1)$$ (**Equation 15-1**)

where:

N = Number of transplants

D= Distance between transplants

L = Length of site (ft.)

W = Width of site (ft.)

Transplanting on a two foot grid should provide a uniform vegetative cover in one growing season. Transplants should be kept moist, but not flooded to submerged conditions. The transplants should also be fertilized, preferably with controlled release fertilizer such as Osmocote 18-5-11 for fall and winter planting, Osmocote 18-6-12 for spring planting, and Osmocote 19-6-12 for summer planting. Refer to suppliers instructions when transplanting.

15.8 **Lagoons** (***Note: This chapter does not replace Chapter 9***)

- The maximum allowable seepage is 0.0625 inches per day.
- A lagoon must be artificially lined with clay, bentonite, plastic, rubber, concrete, or other materials to prevent groundwater pollution.
- Lagoons can be round, square, or rectangular with rounded corners. Their length should not exceed three times their width, and their banks should have outside slopes of about three units horizontal to one unit vertical.
- A lagoon must be surrounded by a 4-foot high fence with a locking gate and sign.
- There should be a 2 x 2 ft concrete pad in the center of the lagoon directly below the opening of the outlet pipe to protect the integrity of the liner.

There should be a minimum of 2 feet between the bottom of the lagoon and groundwater. The liquid depth of a lagoon should be maintained between 2 to 5 feet.

There should be a depth marker near the center of the lagoon.

A minimum of 1 foot of freeboard should be maintained.

15.9 **Package Activated Sludge Plants**

For any activated sludge or fixed film process, the criteria presented in Chapters 4, 5, 6, 7, 8, 10, 11, and 12 of these design criteria must be utilized for each unit process.

The design should include aerobic digestion or sludge holding for sludge wasting. A sludge wasting schedule should be included in the engineering report to better define operator time requirements. The disposal site or landfill should be given. Where tertiary filters are employed, the use of an equalization tank is mandatory. Also, based on the Reliability Classification as determined by the appropriate WPC field office, multiple units and standby power (or a generator) may be required. These costs should be included in the cost effective/reliability analysis.

APPENDIX 15-A

Table A-1. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Airport	Passenger	2 - 4	3
Apartment House	Person	40 - 80	50
Automobile Service Station	Vehicle served	8 - 15	12
	Employee	9 - 15	13
Bar	Customer	1 - 5	3
	Employee	10 - 16	13
Boarding House	Person	25 - 60	40
Department Store	Toilet Room	400 - 600	500
	Employee	8 - 15	10
Hotel	Guest	40 - 60	50
	Employee	8 - 13	10
Industrial Building (Sanitary waste only)	Employee	7 - 16	13
Laundry (self-service)	Machine	450 - 650	550
	Wash	45 - 55	50
Office	Employee	7 - 16	13
Public Lavatory	User	3 - 6	5
Restaurant (with toilet)	Meal	2 - 4	3
Conventional	Customer	8 - 10	9
Short order	Customer	3 - 8	6
Bar/cocktail lounge	Customer	2 - 4	3
Shopping Center	Employee	7 - 13	10
	Parking Space	1 - 3	2
Theater	Seat	2 - 4	3

Table A-2. Typical Wastewater Flow Rates from Institutional Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	**Typical**
Assembly Hall	Seat	2 - 4	3
Hospital, Medical	Bed	125 -240	165
	Employee	5 - 15	10
Hospital, Mental	Bed	75 - 140	100
	Employee	5 - 15	10
Prison	Inmate	80 - 150	120
	Employee	5 - 15	10
Rest Home	Resident	50 - 120	90
	Employee	5 - 15	10
School, day-only:			
With cafeteria, gym, showers	Student	15 - 30	25
With cafeteria only	Student	10 - 20	15
Without cafeteria, gym, or showers	Student	5 - 17	11
School, boarding	Student	50 - 100	75

Table A-3. Typical Wastewater Flow Rates from Commercial Sources
(Source: Crites and Tchobanoglous, 1998**)**

FACILITY	UNIT	Flow, gallons/unit/day	
		Range	Typical
Apartment, resort	Person	50 - 70	60
Bowling Alley	Alley	150 - 250	200
Cabin, resort	Person	8 - 50	40
Cafeteria	Customer	1 - 3	2
	Employee	8 - 12	10
Camps:			
Pioneer Type	Person	15 - 30	25
Children's, with central toilet/bath	Person	35 - 50	45
Day, with meals	Person	10 - 20	15
Day, without meals	Person	10 - 15	13
Luxury, private bath	Person	75 - 100	90
Trailer Camp	Person	75 - 125	125
Campground-developed	Person	20 - 40	30
Cocktail Lounge	Seat	12 - 25	20
Coffee Shop	Customer	4 - 8	6
	Employee	8 - 12	10
Country Club	Guests on-site	60 - 130	100
	Employee	10 -15	13
Dining Hall	Meal Served	4 - 10	7
Dormitory/bunkhouse	Person	20 - 50	40
Fairground	Visitor	1 - 2	2
Hotel, resort	Person	40 - 60	50
Picnic park, flush toilets	Visitor	5 - 10	8
Store, resort	Customer	1 - 4	3
	Employee	8 - 12	10
Swimming Pool	Customer	5 - 12	10
	Employee	8 - 12	10
Theater	Seat	2 - 4	3
Visitor Center	Visitor	4 - 8	5

APPENDIX 15-B

Recirculation Tank/Pump System Example Calculation

Given: 20,000 gpd (14 gpm) system a desired 4:1 recycle rate and numerous small doses.

1. Pumping volume = (1440 min/day / (On + Off time)) x On time x # of pumps x Pump Capacity
2. 80,000 gpd = (1440 min/day / (On Off Time) x On Time x 4 x 45 gpm
3. 80,000 gpd/(1440 min/day x 4 x 45 gpm) = On time/(On + Off time)
4. On time/(On + Off time) = 0.31
5. On time = 0.31 On + 0.31 Off
6. 0.69 On = 0.31 Off
7. Off = 2.22 On
8. Choose 2 minutes On: Off = 4.44 minutes
9. Total dosing cycle = 6.44 minutes.
10. Adjust dose cycle if calculated pumping volume is less than minimum recommended for selected recycle rate
11. Note: The above is an iterative process. The quickest solution is to pick a cycle time, divide it into 1440 min/day, multiply by the On time, multiply by the number of pumps, and multiply by the pump capacity. Compare this number to the desired total pumping volume including recycle. If too little increase On time. If too much decrease on time. .