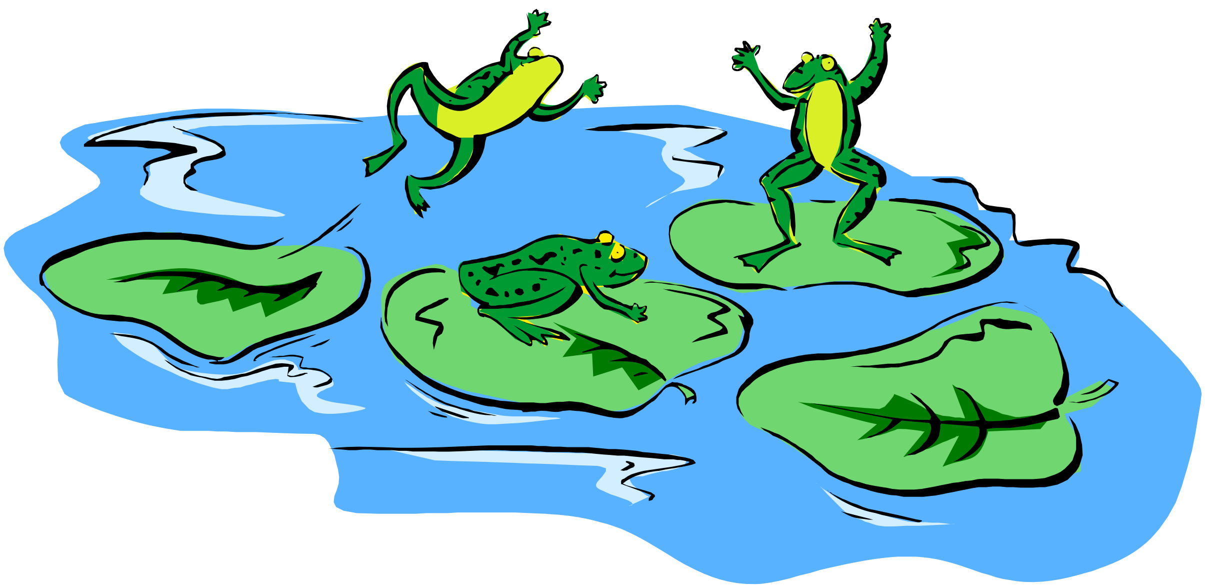
Biological/Natural System

5 Day Course #1204



March 18-22, 2013

Fleming Training Center

http://tn.gov/environment/fleming/

STATE OF TENNESSEE
Fleming Training Center

Biological/Natural Systems

Course # 1204
March 18-22, 2013

Monday March 18:

8:30	Overview of Wastewater Treatment	Dennis Conger
9:30	Wastewater Microbiology	Dennis
10:30	Cross Connection Control	Dennis
11:30	LUNCH	
12:30	Septic Tanks	Dennis
2:00	Constructed Wetlands; Aquatic Plants	Dennis

Tuesday, March 19:

8:30	Wastewater Lagoons	Dennis
10:15	Effluent Discharge (Surface Waters, Irrigation, Overland Flow)	Dennis
11:30	LUNCH	
12:30	Safety	Dennis
2:00	Pumps	Dennis

Wednesday, March 20

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

Thursday, March 21:

8:30	Sampling and Laboratory Analyses	Shannon Pratt
11:30	LUNCH	
12:30	Packed Bed Filters & Sand Filters	Dennis
2:00	Disinfection	Dennis

Friday, March 22:

8:30	Rules and Regulations Exam and Course Evaluation	Dennis

Fleming Training Center
Your Partner in Clean Water
http://tn.gov/environment/fleming

STATE OF TENNESSEE

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Biological/Natural System

Section 1

Introduction to Wastewater

Intro to Wastewater Treatment

Why do we treat waste?

Prevention of Pollution

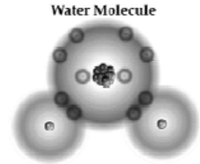
- Protection of receiving streams is main job
- Today's technology is capable of treating wastewater so that receiving streams are reasonably unaffected

Purpose of Wastewater Treatment

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

What is Pure Water?

Water Molecule



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

Organic waste discharged to receiving stream.
→ Aerobic microorganisms use up oxygen to metabolize organic waste.
→ Biological activity creates oxygen deficit in stream.
→ Aquatic organisms requiring oxygen to survive die off or migrate.
→ In the absence of oxygen, anaerobic microorganisms dominate.
→ Anaerobic activity causes putrification and odors

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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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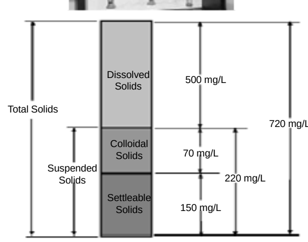
Solids

- 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.

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.

Reference Material

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

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

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.

Dissolved Oxygen

- Dissolved oxygen is oxygen that has been incorporated into water.
- Many aquatic animals require it for their survival.

Dissolved Oxygen

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

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Dissolved Oxygen

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

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Dissolved Oxygen

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

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Oxygen Demand

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

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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.

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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

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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.

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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

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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

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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.

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Chemical Oxygen Demand

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

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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.

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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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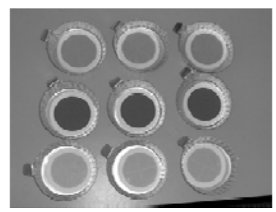
Solids

- 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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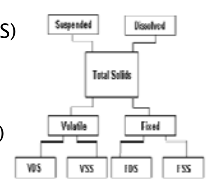
Solids

- 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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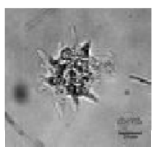
Microbial Organisms

- 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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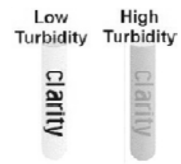
Turbidity

- 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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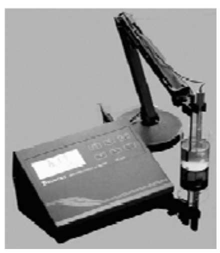
pH

- 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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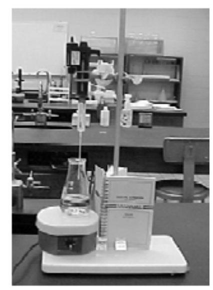
Alkalinity

- 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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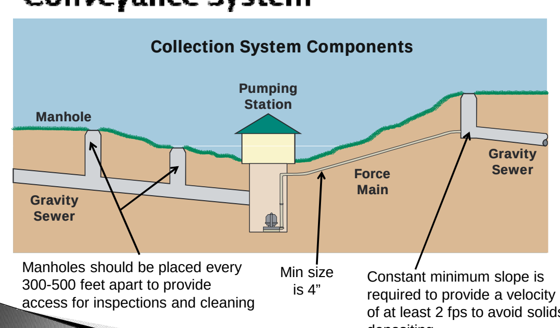
Wastewater Collection and Conveyance System



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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

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

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

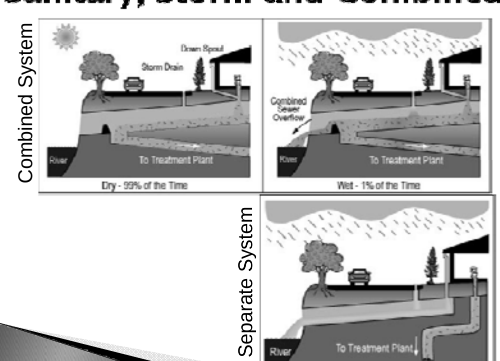
Wastewater Collection Safety

- 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

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

Sanitary, Storm and Combined



Wastewater Treatment Processes

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

Preliminary 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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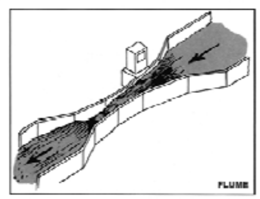
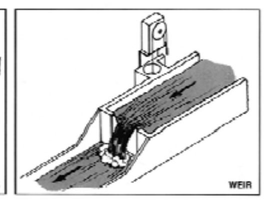
Flow Metering





- 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

Primary Treatment
- Sedimentation and Flotation

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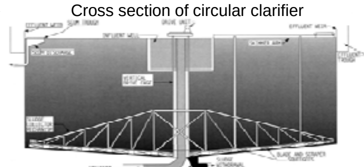
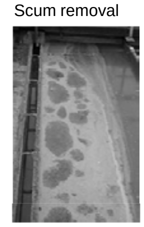
Primary Clarifier

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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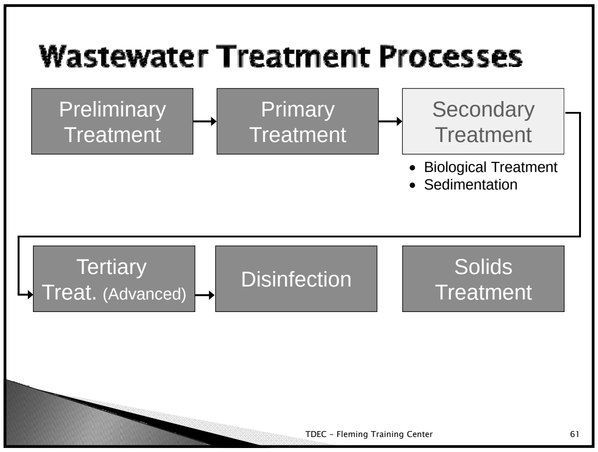
Wastewater Treatment Processes
Preliminary Treatment
Primary Treatment
Secondary Treatment
• Biological Treatment
• Sedimentation
Tertiary Treat. (Advanced)
Disinfection
Solids Treatment
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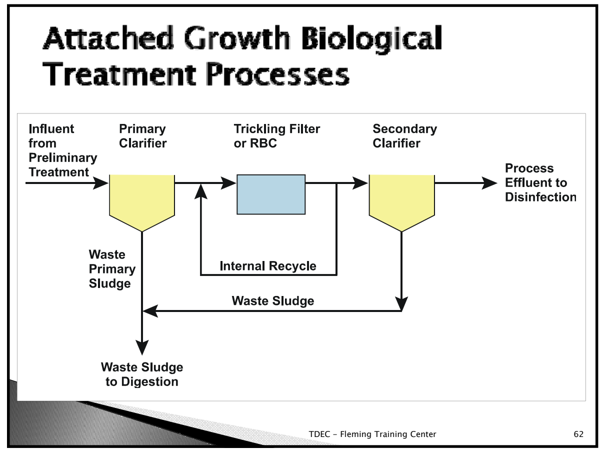
61


Attached Growth Biological Treatment Processes
Influent from Preliminary Treatment
Primary Clarifier
Trickling Filter or RBC
Secondary Clarifier
Process Effluent to Disinfection
Waste Primary Sludge
Internal Recycle
Waste Sludge
Waste Sludge to Digestion
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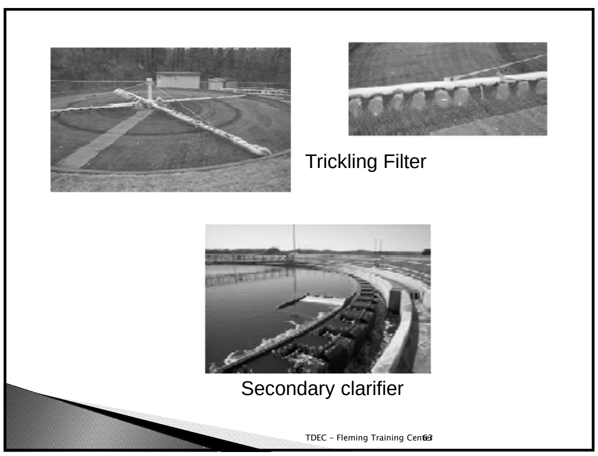
Trickling Filter
Secondary clarifier
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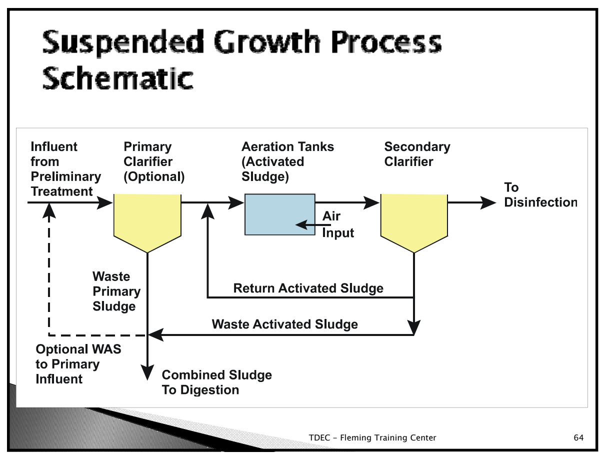
Suspended Growth Process Schematic
Influent from Preliminary Treatment
Primary Clarifier (Optional)
Aeration Tanks (Activated Sludge)
Secondary Clarifier
To Disinfection
Air Input
Waste Primary Sludge
Return Activated Sludge
Waste Activated Sludge
Optional WAS to Primary Influent
Combined Sludge To Digestion
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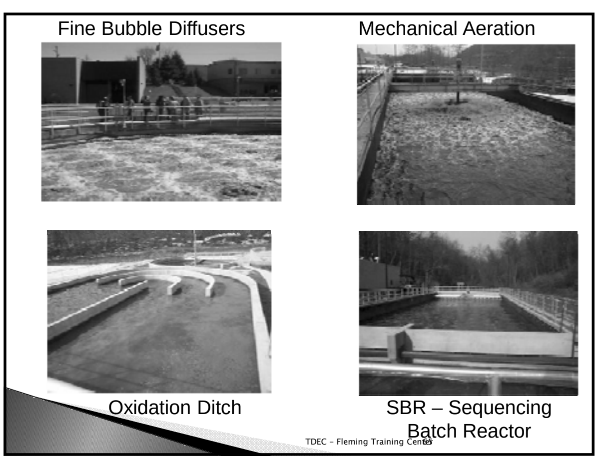
Fine Bubble Diffusers
Mechanical Aeration
Oxidation Ditch
SBR – Sequencing Batch Reactor
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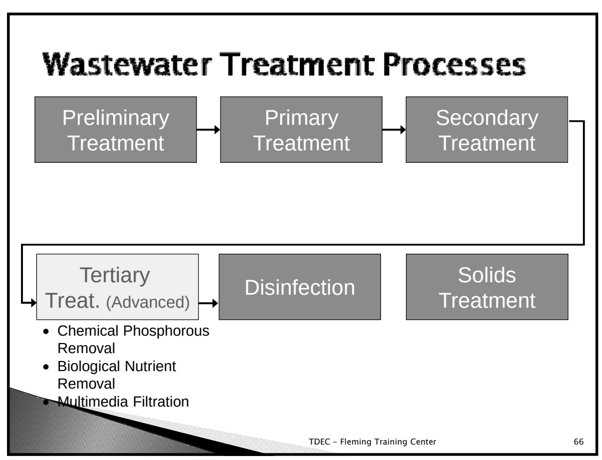
Wastewater Treatment Processes
Preliminary Treatment
Primary Treatment
Secondary Treatment
Tertiary Treat. (Advanced)
• Chemical Phosphorous Removal
• Biological Nutrient Removal
• Multimedia Filtration
Disinfection
Solids Treatment
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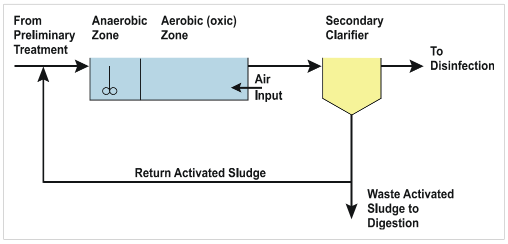
Biological Phosphorus Removal Process Schematic



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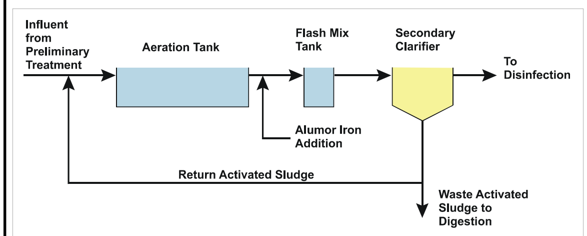
Chemical Precipitation Process Schematic



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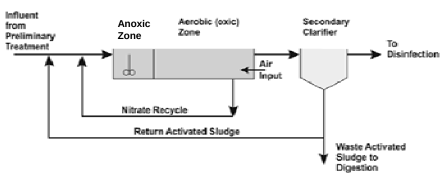
Denitrification Process Schematic



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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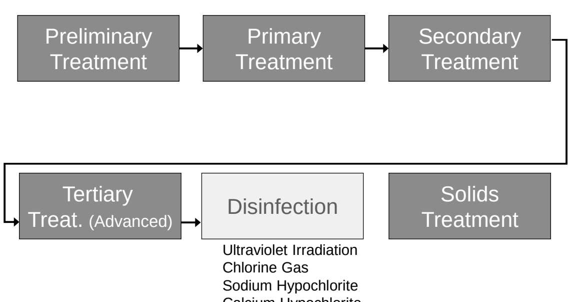
Wastewater Treatment Processes



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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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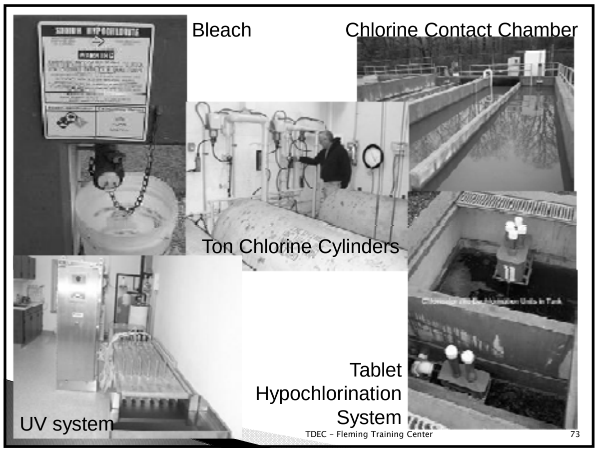
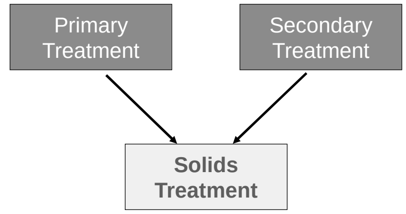


Solids Treatment



- Digestion
- Dewatering
- Disposal

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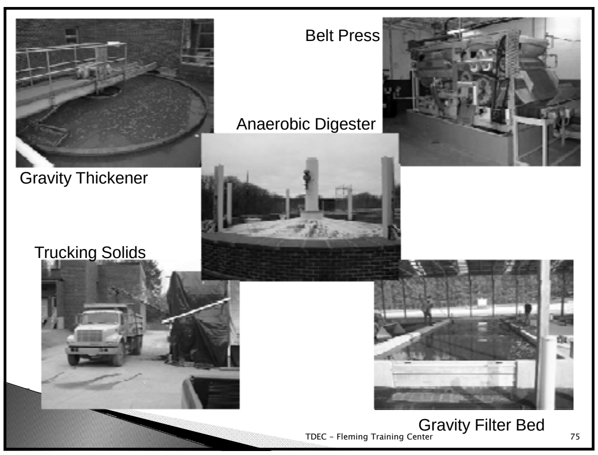
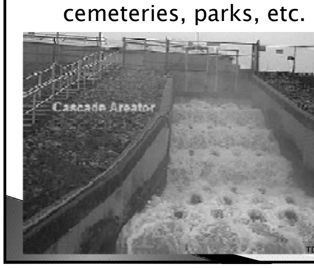


Effluent Discharge

- 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

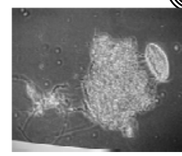
Section 2
Microbiology

Introduction to Microbiology

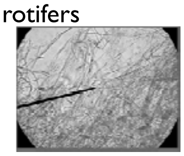
Biological Natural Systems

What are Microbes?

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



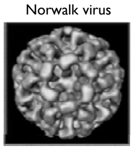
Crawling ciliate on activated sludge floc



Cyanobacteria

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

Why are they important?

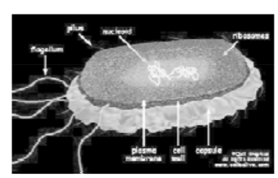
- Role in treatment systems
  - Removed in water treatment
  - Key role in wastewater treatment
  - Major role in problems & solutions to solid waste

What key role do they play?

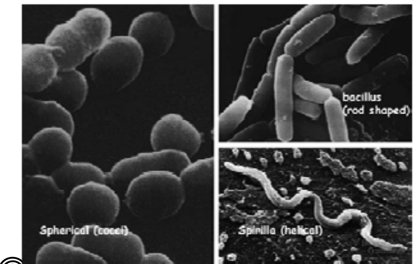
- In lagoons:
  - Bacteria
    - Tiny one-celled organisms
    - Work horse for treatment
  - Algae
    - Use the carbon dioxide the bacteria produce to make oxygen with the help of sunlight
  - Vascular Plants
    - Duckweed

Viruses and Bacteria

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



Bacteria Found in Wastewater



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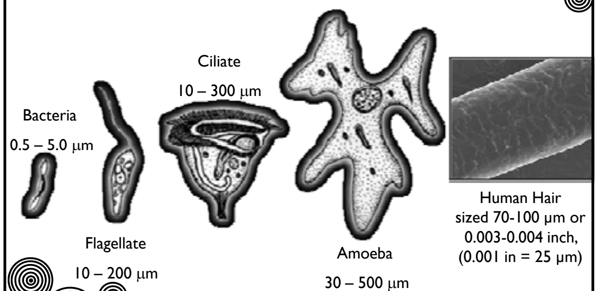
Size Range of Microorganisms



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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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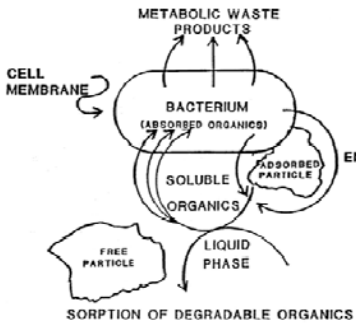
Bacteria "Eating"



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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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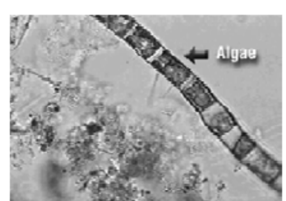
Green Algae

- 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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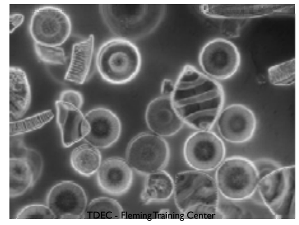
Diatoms

- 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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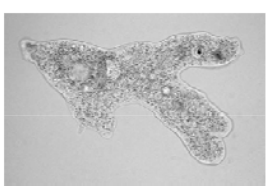
Amoeba

- 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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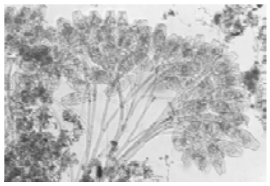
Ciliate

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



Stalked Ciliates

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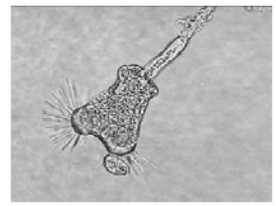
Ciliate

- 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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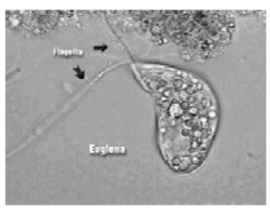
Flagellate

- 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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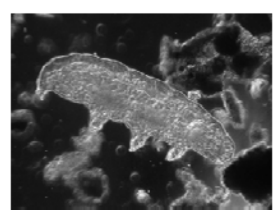
Water Bear

- 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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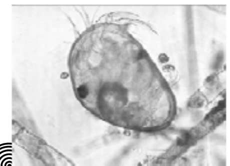
Other Metazoas

Ostracod

- Seedshrimp
  - Common in lagoons



Copepod

- Crustacean

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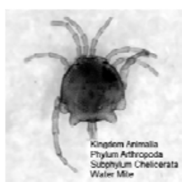
Other Metazoas

Cadoceran

- Water flea

Hydracarina

- Water mite



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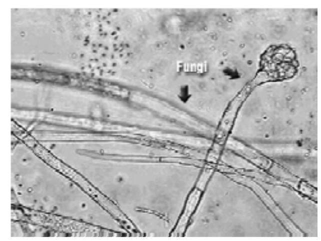
Fungi

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



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Section 3

Cross Connection Control

Cross-Connection Control

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Outline

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

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Basics of Cross-Connection Control

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/fleming/docs/crossconnection.pdf

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Authority

- 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?

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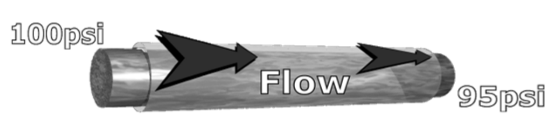
Hydraulics

- Water pressure naturally tends to equalize



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

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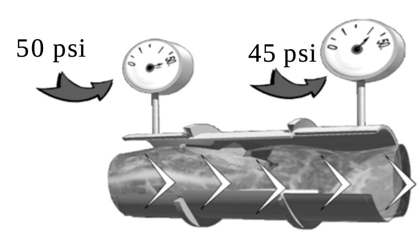
Normal Flow



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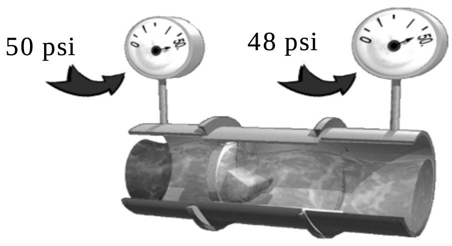
No Flow



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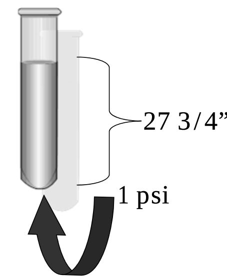
27 ¾ ” = 2.31 Feet of Head



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

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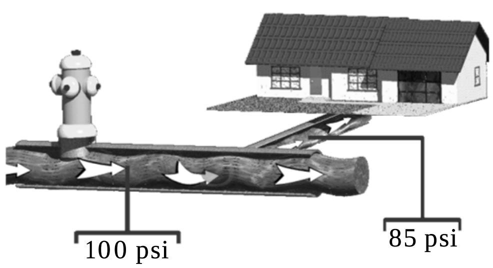
Normal Flow



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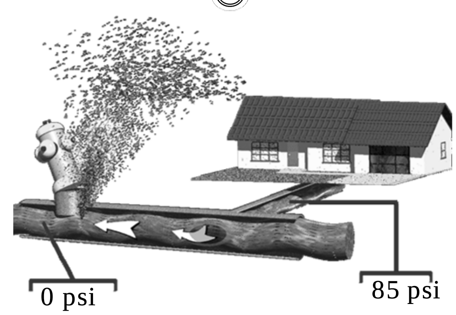
Reverse Flow



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Backflow

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

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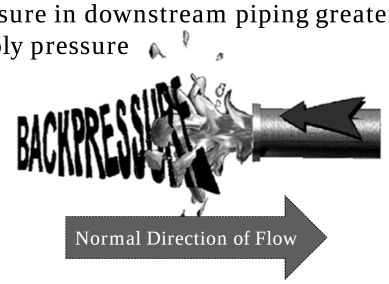
Backpressure

- Pressure in downstream piping greater than supply pressure



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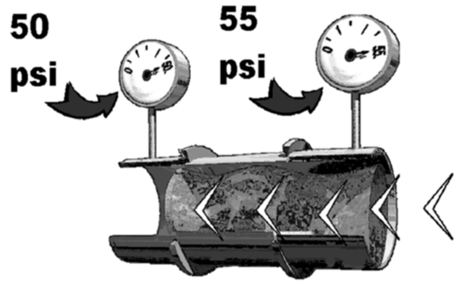
Backpressure



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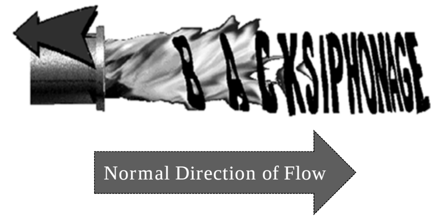
Backsiphonage

- Sub-atmospheric pressure in the water system



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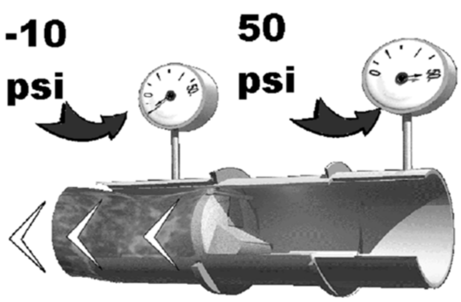
Backsiphonage



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Cross-Connection

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

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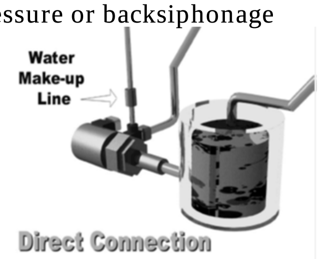
Direct Cross-Connection

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



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Indirect Cross-Connection

- An indirect cross-connection is subject to backsiphonage only

Submerged Inlet

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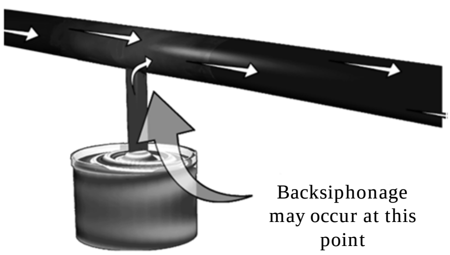
Aspirator Effect



Backsiphonage may occur at this point

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Degree of Hazard

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

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The Backflow Incident

For backflow to occur three conditions must be met:

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

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Five Means of Preventing Backflow

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

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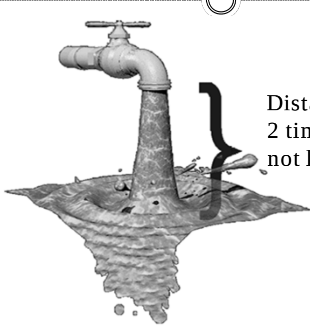
Air Gap



Distance:
2 times the diameter,
not less than 1 inch

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Approved Air Gap Separation

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

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	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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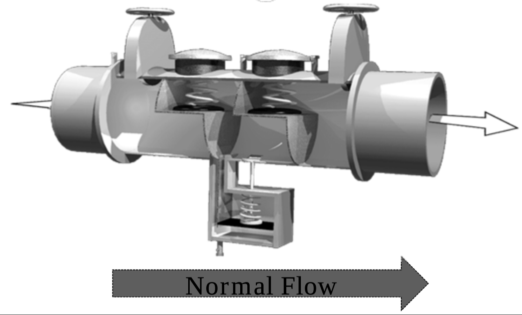
Reduced Pressure Principle Assembly



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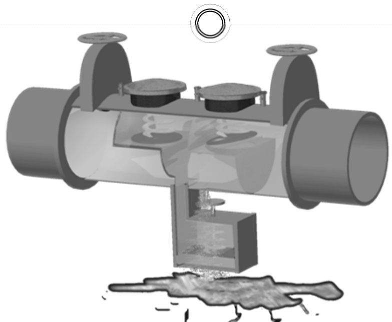
RP



Fouled Second Check with Backpressure

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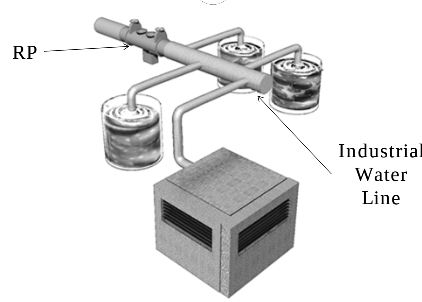
Where To Put an RP



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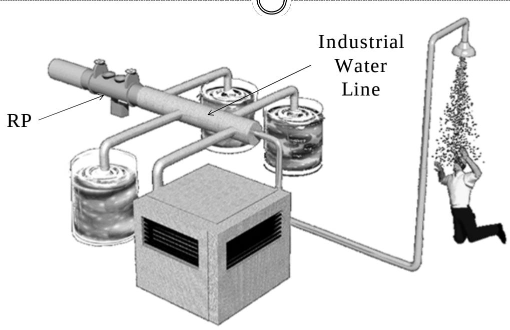
Where To Put an RP – Don't



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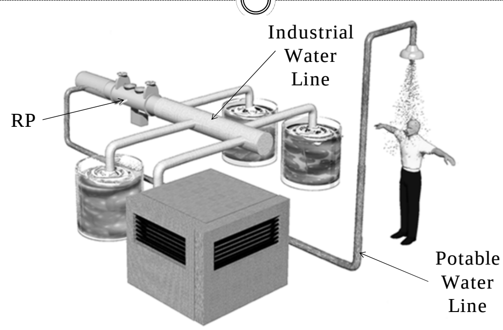
Where To Put an RP – Do



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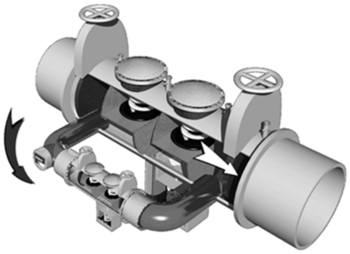
RP Detector Assembly

At least 3 GPM through bypass only

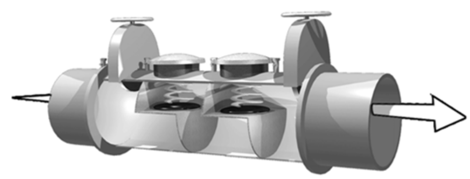


RP

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

	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**

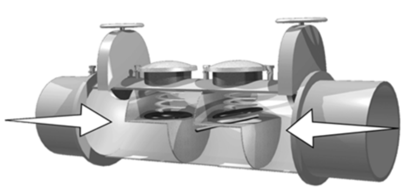
Double Check Valve Assembly (DC)



Normal Flow

Double Check Valve Assembly (DC)

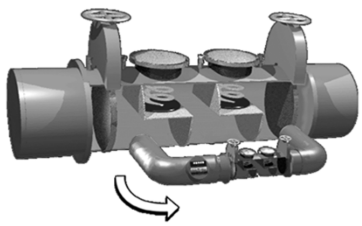
- Second check fouled during backpressure



Double Check Valve Assembly (DC)

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

DC Detector Assembly



At least 3 GPM through bypass only

	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**

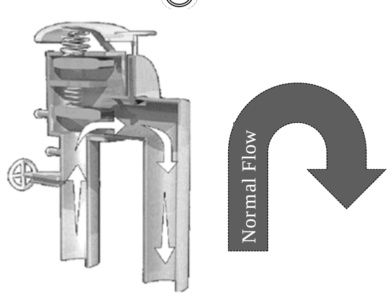
Proper Installation for DC and RP

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

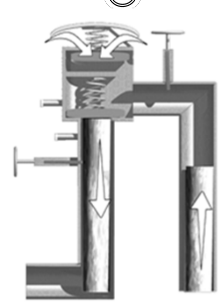
Proper Installation for DC and RP

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

Pressure Vacuum Breaker (PVB)

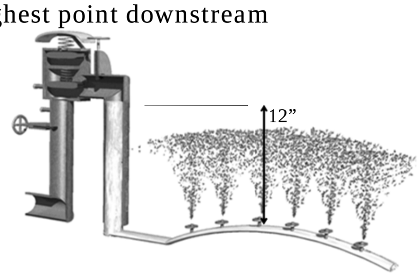


PVB Backsiphonage Condition



Installation of PVB

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



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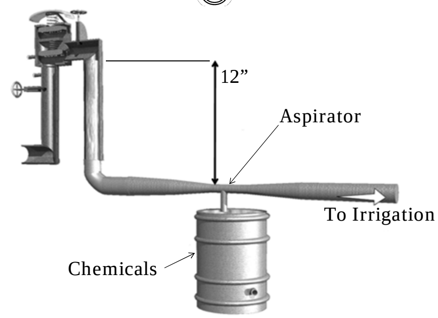
Pressure Vacuum Breaker



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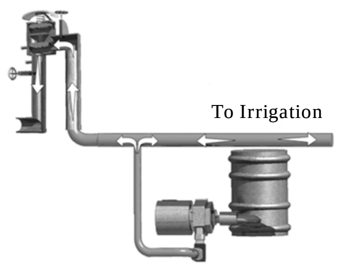
Pressure Vacuum Breaker

- Improper installation subject to backpressure



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Pressure Vacuum Breaker

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

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

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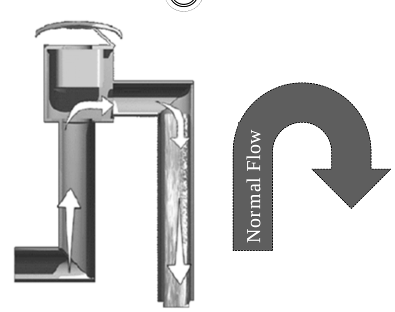
Atmospheric Vacuum Breaker (AVB)



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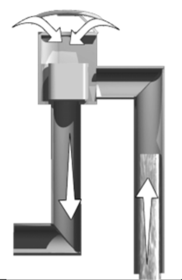
Atmospheric Vacuum Breaker (AVB)

- Backsiphonage condition



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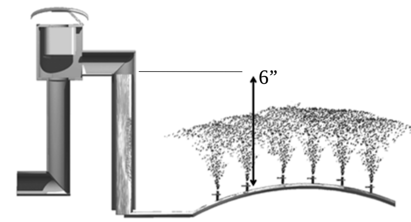
Installation of AVB

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



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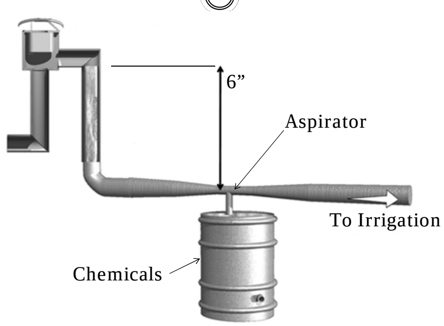
Atmospheric Vacuum Breaker



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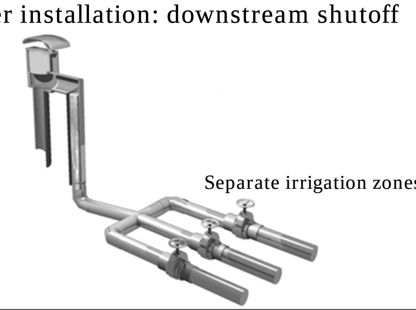
Atmospheric Vacuum Breaker

- Improper installation: downstream shutoff valves



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Atmospheric Vacuum Breaker

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

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

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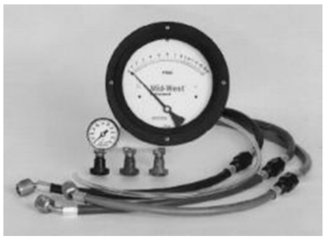
Testing of Assemblies

- Annual testing required
- Must be conducted by certified personnel



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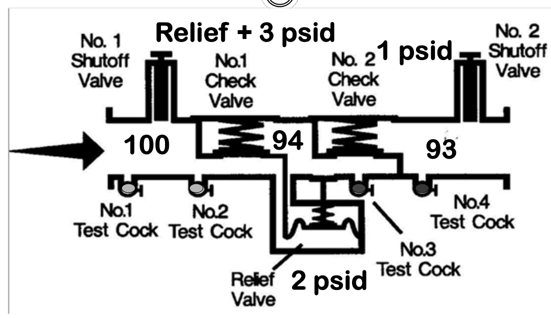
RP



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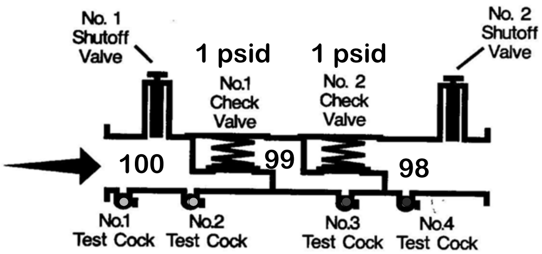
DC



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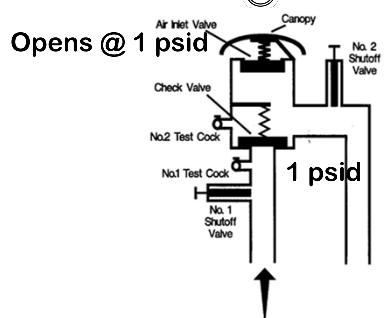
PVB



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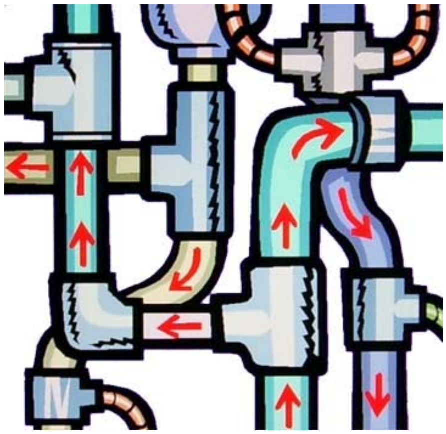


Vocabulary

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.

Chemical – A substance obtained by a chemical process or used for producing a chemical reaction.

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

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

Continuous Pressure – 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.

Cross Connection – (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.

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

Degree of Hazard – The danger posed by a particular substance or set of circumstances. Generally, a low degree of hazard 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.

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

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

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

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

Indirect Connection – 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

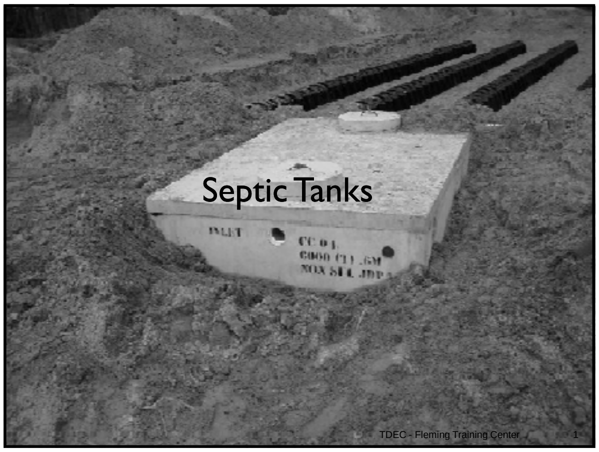
Review Question Answers:

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



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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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

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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

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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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Materials Of Construction

- Reinforced concrete
  - Most common
- Fiber glass
- Polyethylene
- Steel
  - 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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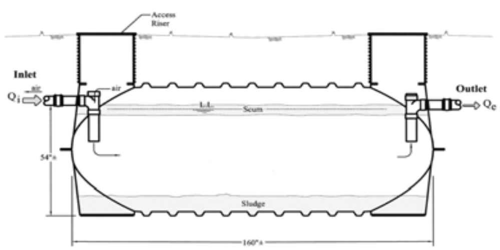
Sizing

- 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.
- Commercial size tanks
  - Based upon expected daily flow from commercial, institutional, and recreational facilities.

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

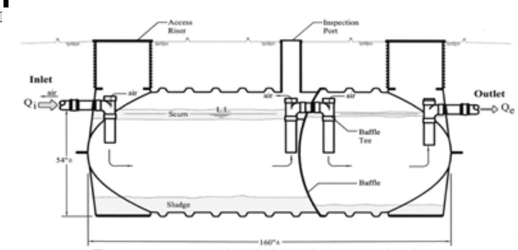
Typical Ribbed Fiberglass Septic Tanks



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.

Typical Ribbed Fiberglass Septic Tanks (continued)

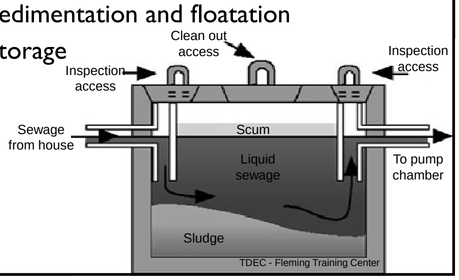


Two compartment tank with distinctly separate chambers.

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

Processes Within Septic Tank

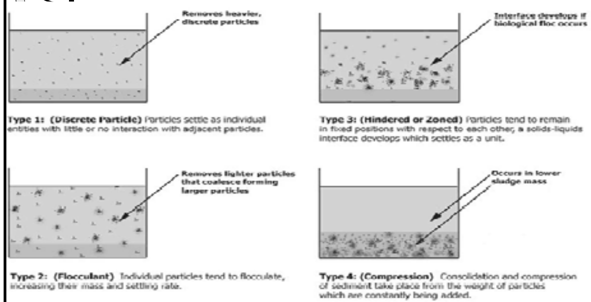
- Very complex physical, chemical and biological system
- Sedimentation and floatation
- Storage



Sedimentation Theory

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

Types Of Settling Phenomena



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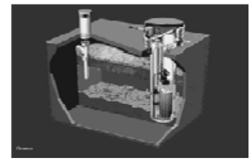
Compartmentation

- 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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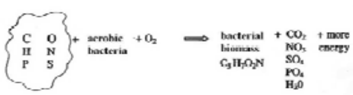
Biological Decomposition

- 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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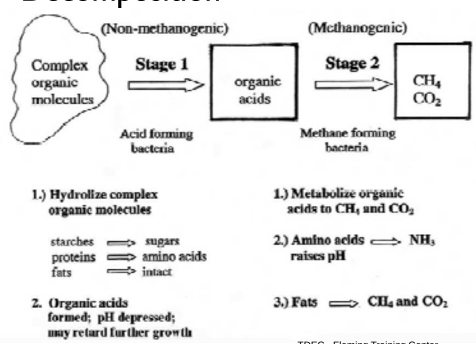
Two Stages In Anaerobic Decomposition



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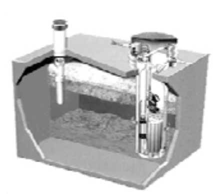
Single Compartments

- Typical Gravity Septic Tank



- Typical Dosing Septic Tank

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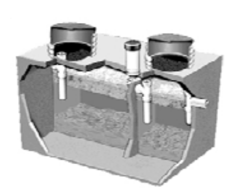
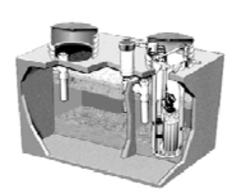
Two Compartments



- Typical Gravity Septic Tank



- Typical Dosing Septic Tank

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Reduction Of Organic Matter

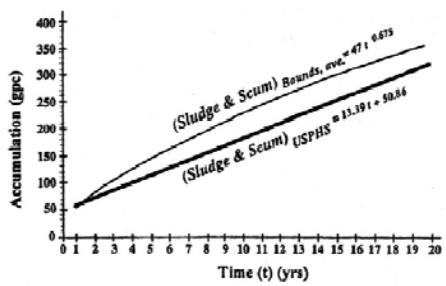
- Generates H_2S gas, which is odorous
  - Gases vented through house vent, risers or soil absorption system
- Performance

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

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

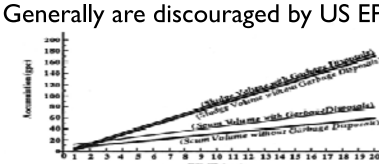
Rate of Septage Accumulation



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

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

Circular Tanks

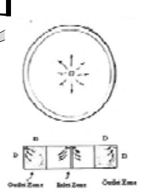


Figure a. Circular Tank Center Feed Elevation View

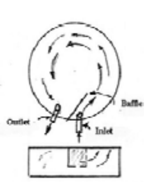
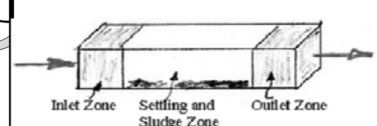
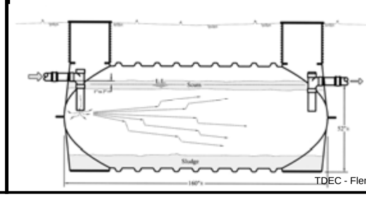


Figure b. Circular Tank Peripheral Feed Elevation view

Four Zones Of Settling



Four zones of settling in large tanks



Zones of settling in a septic tank

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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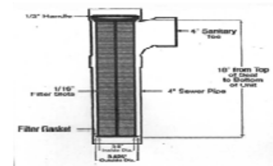
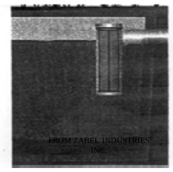
Outlet Filter Devices

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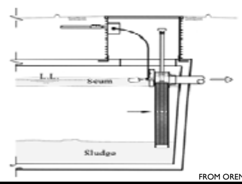

FROM ORENCO

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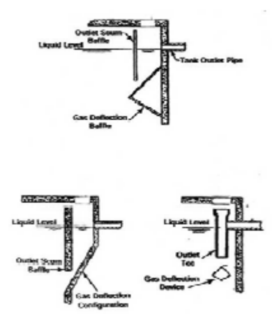
Outlet Filter Devices (Continued)



Gas deflection baffles

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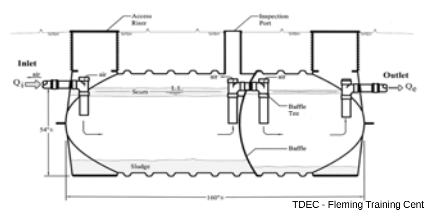
Access

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



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Floatation Collars

- Prevents tank from floating in high groundwater

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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

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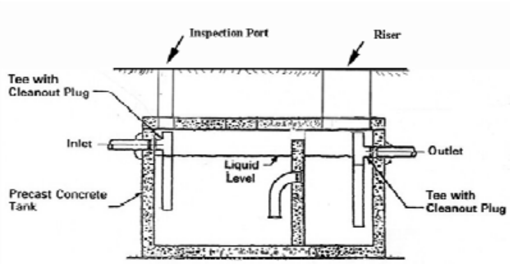
Double-Compartment Grease Trap



From US EPA Design Manual 1980

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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

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Septage

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

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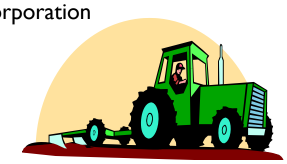
Septage Management

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



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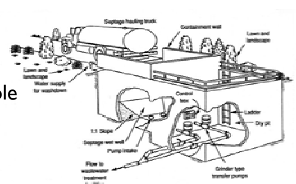
Septage Management

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



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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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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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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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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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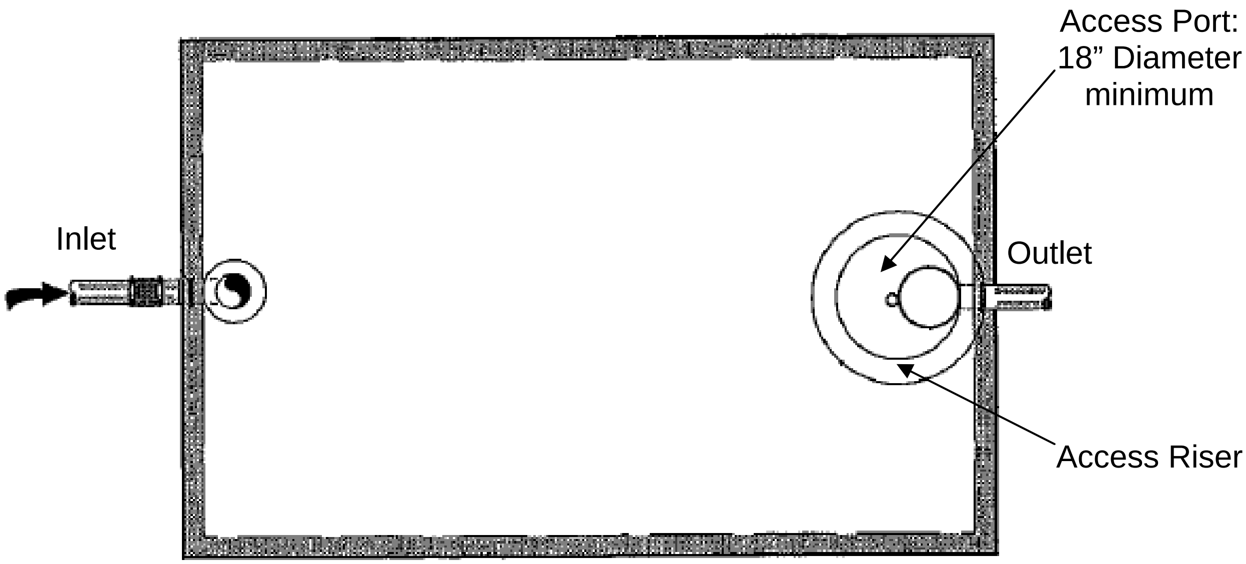
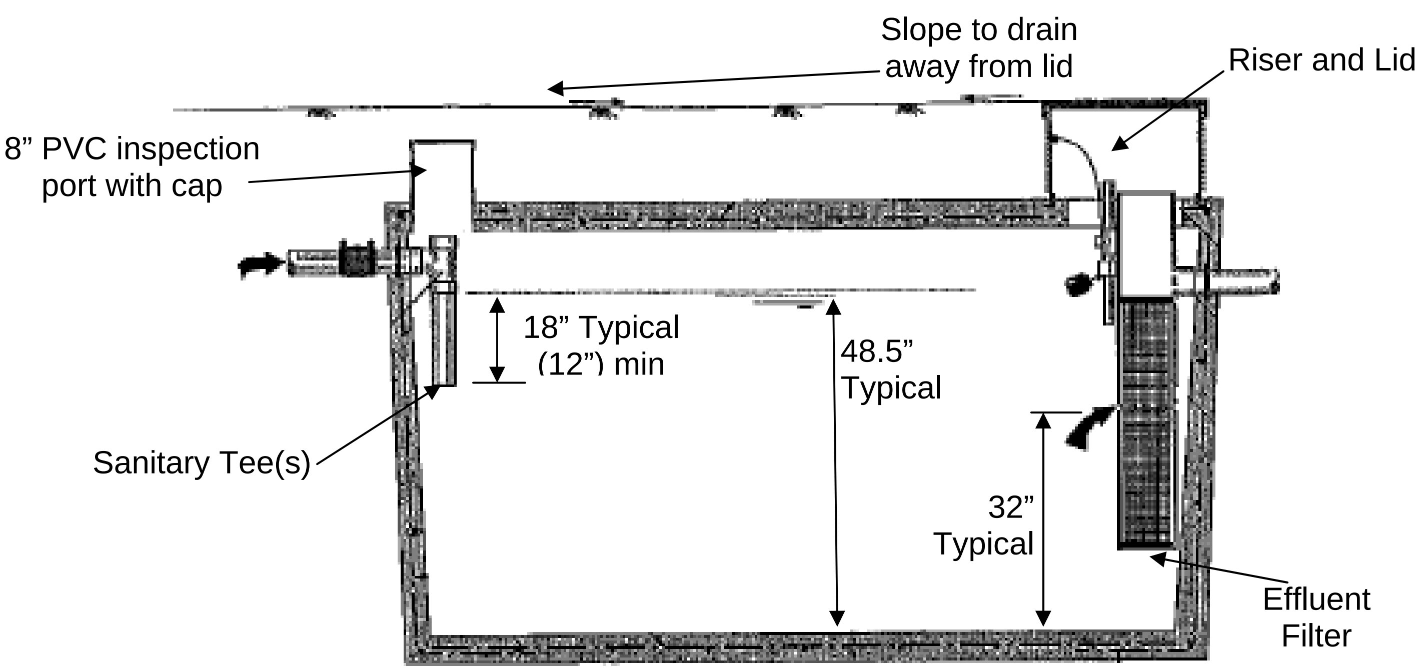
Single Compartment Septic Tank

Top View

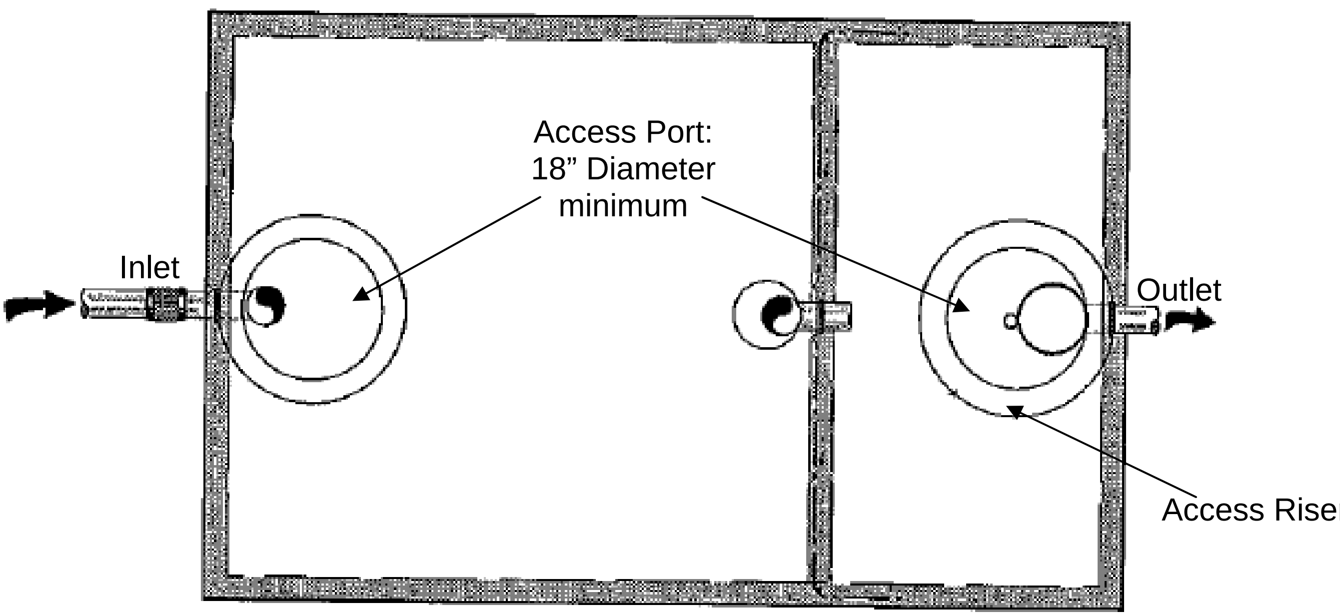


Side View

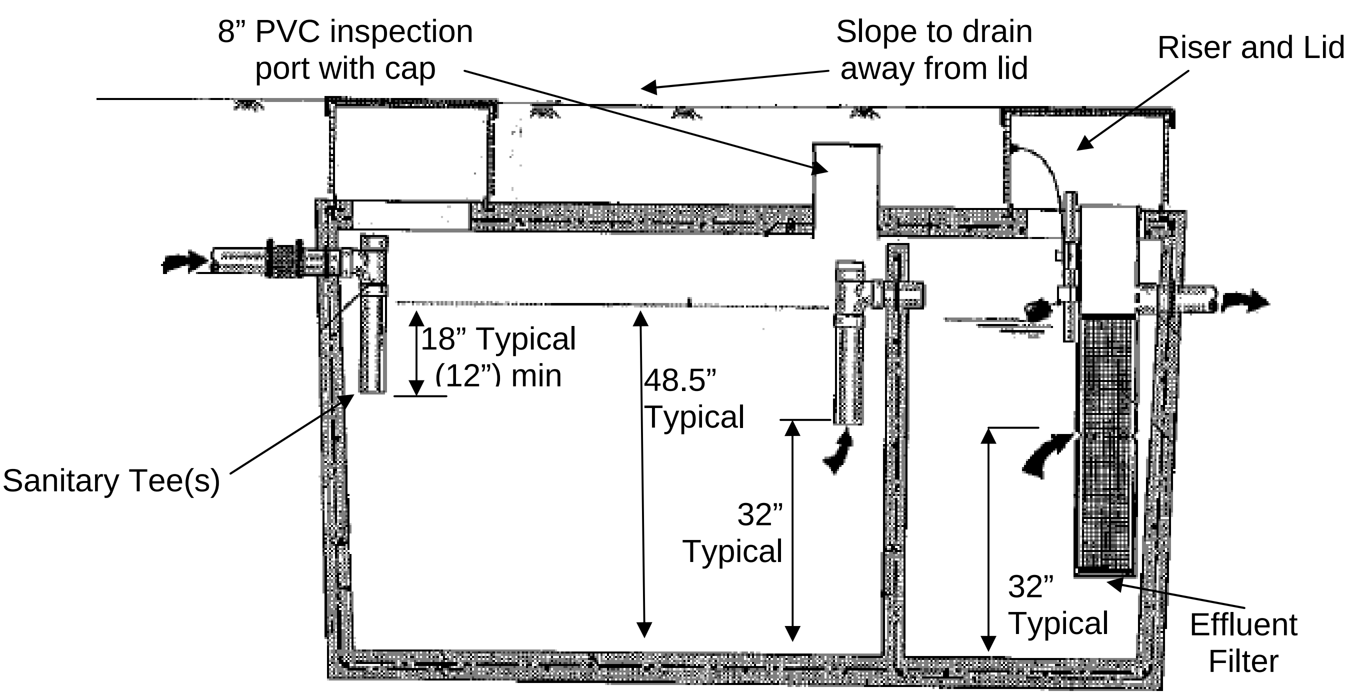


Two Compartment Septic Tank

Top View



Side View



Section 5

Wetlands

Wetlands

Treatment & Aquatic Plant Systems

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?

Constructed Treatment Wetlands & Aquatic Plant Systems

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

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"

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

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

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

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?

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

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

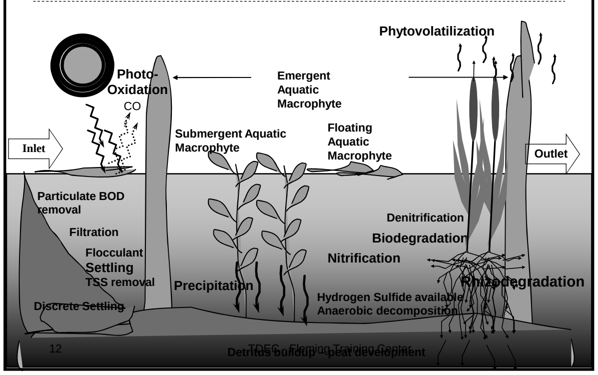
- Constructed Treatment Wetlands are specifically engineered with water quality improvement as the primary goal.
- Wetland design hence necessitates an understanding of the fundamental mechanisms of pollutant removal.

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

Discussed in the next 4 slides

Mechanisms



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.

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.

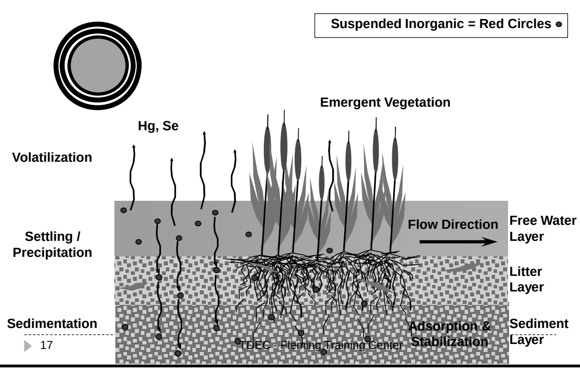
Mechanisms

- 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.

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.

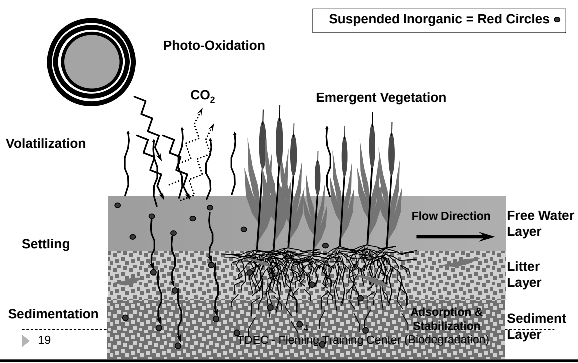
Chemical/Physical Mechanisms Treating Inorganic Compounds



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.

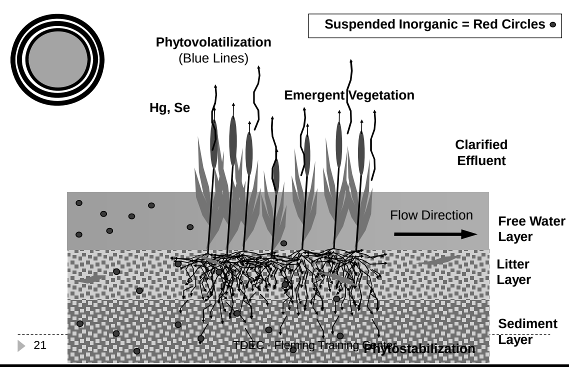
Chemical/Physical Mechanisms Treating Organic Compounds



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.

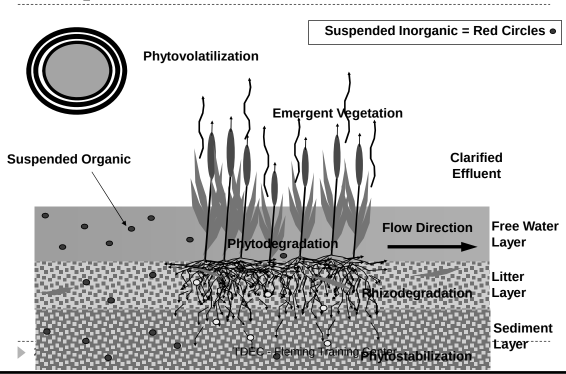
Biological Mechanisms Treating Inorganic Compounds



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.

Biological Mechanisms Treating Organic Compounds



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.

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

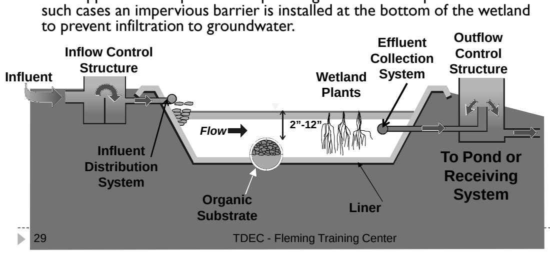
- Wetland systems are classified into SF, SSF, RB based on the flow pattern, matrix used as substrate.
  - Surface Flow (SF)
  - Subsurface Flow (SSF)

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.

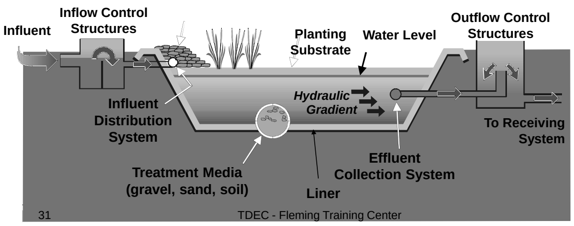


Subsurface Flow Wetland

- 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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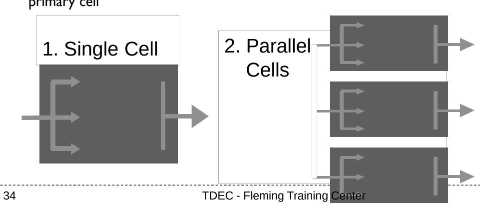
Typical Configurations of Constructed Wetlands

- 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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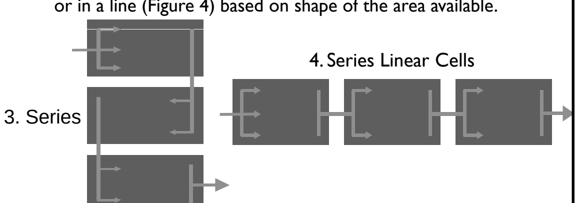
Typical Configurations of Constructed Wetlands

- 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.

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

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)

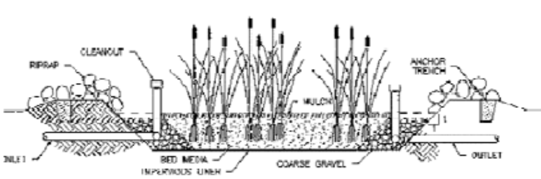
On-Site Waste Water

- 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

Liners & Berms

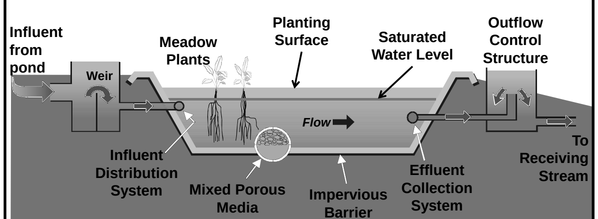
- Liners (synthetic or clay)
- Berms provide the basic containment structure for the constructed wetlands, and ensure that the basic hydrologic foundation of the wetlands is met.



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.

Wetland Inlet/Outlet Structures



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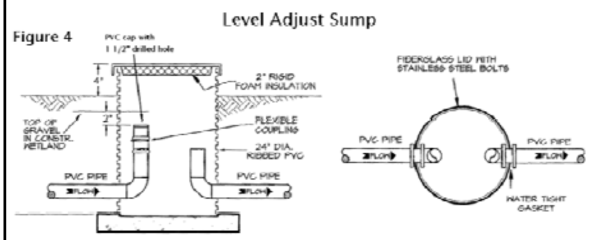
Level Adjust Sump



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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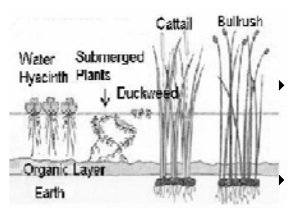
Plant Selection



- 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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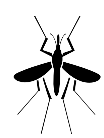
Operation & Maintenance

- 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

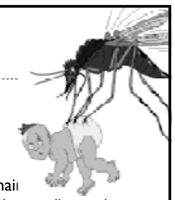
Federal Regulations

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

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

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

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.

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

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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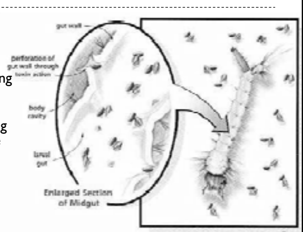
Mosquito Control with BTI

- 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

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.)

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

Disadvantages of Ponds

- May produce odors
- Require large land areas
- Are effected by climactic conditions
- May have high suspended solids levels in effluent
- Might contaminate groundwater

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.

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

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

$$CO_2 + H_2o \xleftrightarrow[\text{Respiration}]{\text{Photosynthesis}} O_2 + CH_2O$$

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

$$NH_4 + O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^- + H^+ + H_2O + \text{New Bugs}$$

Ammonia, Oxygen → Nitrite, Acid, Water

$$NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} NO_3^- + \text{New Bugs}$$

Nitrite, Oxygen → Nitrate

16

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Denitrification Reaction

$$NO_3 + \text{Food} \rightarrow CO_2^- + H_2O + N_2 + OH^- + \text{New Bugs}$$

Nitrate → Carbon Dioxide, Water, Nitrogen Gas, Alkalinity

17

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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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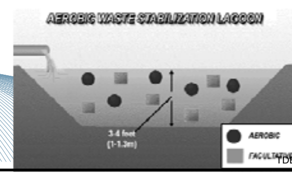
Aerobic Pond

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



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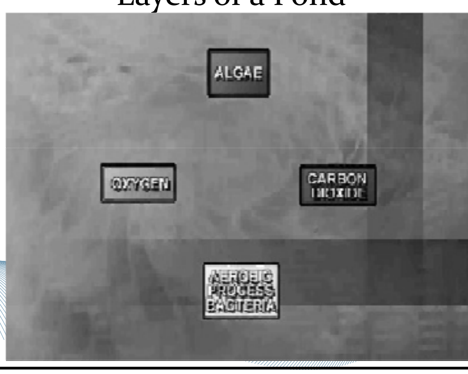
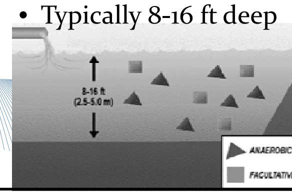
Decomposition in Aerobic Layers of a Pond



21

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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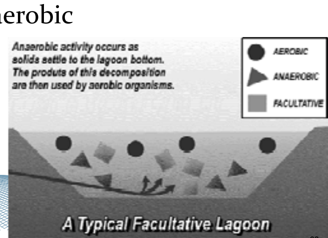
Facultative Lagoon

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



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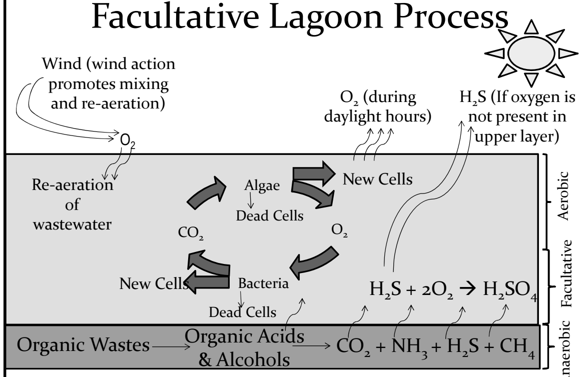
Facultative Lagoon Process



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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)

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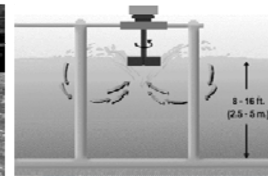
Mechanically Aerated Ponds

Stationary or floating aerators

Allows for higher organic loading or shorter detention time in lagoon



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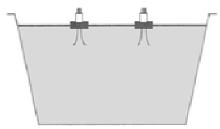
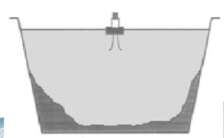
Aerated Lagoons: Partial vs. Complete Mix

- 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)





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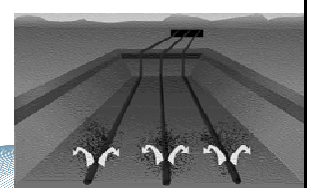
Diffused Aeration Lagoons

Less mixing; more efficient oxygen transfer



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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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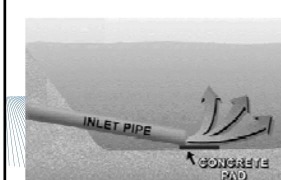
Pond Structures: Inlet

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



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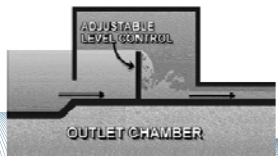
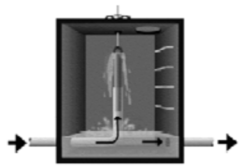
Pond Structures: Outlet

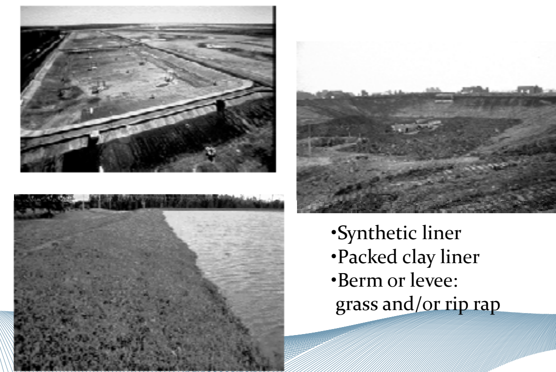
- Just below surface with scum baffle to minimize transfer of algae





Above: telescoping tube.

Left: flash boards



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

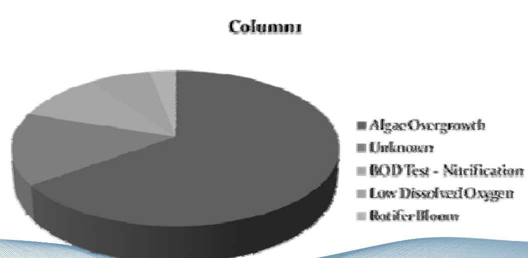
Factors Effecting Pond Operation

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

Factors Effecting Pond Operation

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

Causes of High Effluent BOD and TSS

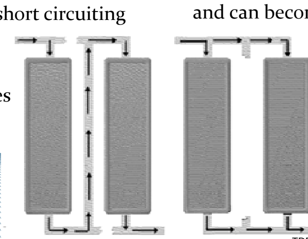


Lagoons in Series

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

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

Series

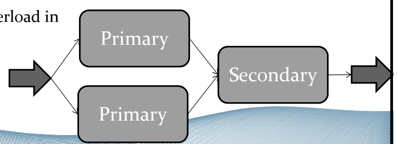


Parallel

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



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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

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Microorganisms in Wastewater Treatment Lagoons

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

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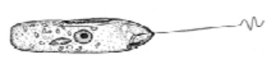
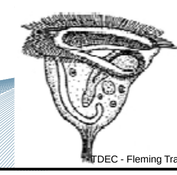
Protozoa

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





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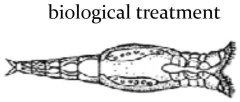
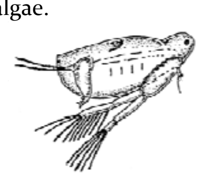
Metazoa

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





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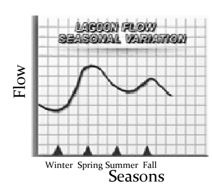
Monitoring Performance

- 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

43
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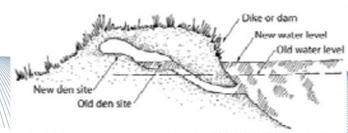
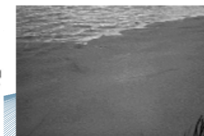
Daily O & M







44
TDEC - Fleming Training Center

Causes of Poor Quality Effluent

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

45
TDEC - Fleming Training Center

Low D.O. in Lagoon

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


46
TDEC - Fleming Training Center

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

47
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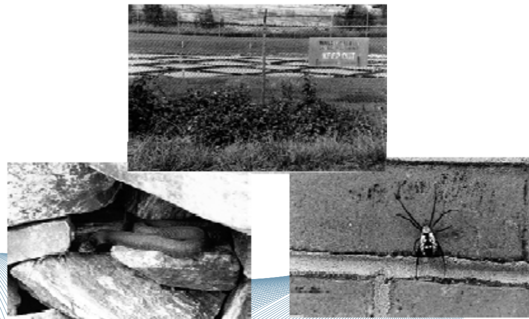
Lagoon Safety

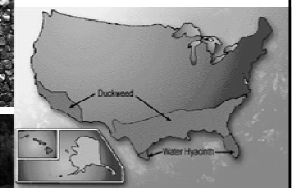
- Never work around a lagoon alone
- Never perform maintenance from a boat
- Never take a boat onto the lagoon alone

48
TDEC - Fleming Training Center

Lagoon Safety



Lagoon Effluent Polishing with Duckweed



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

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

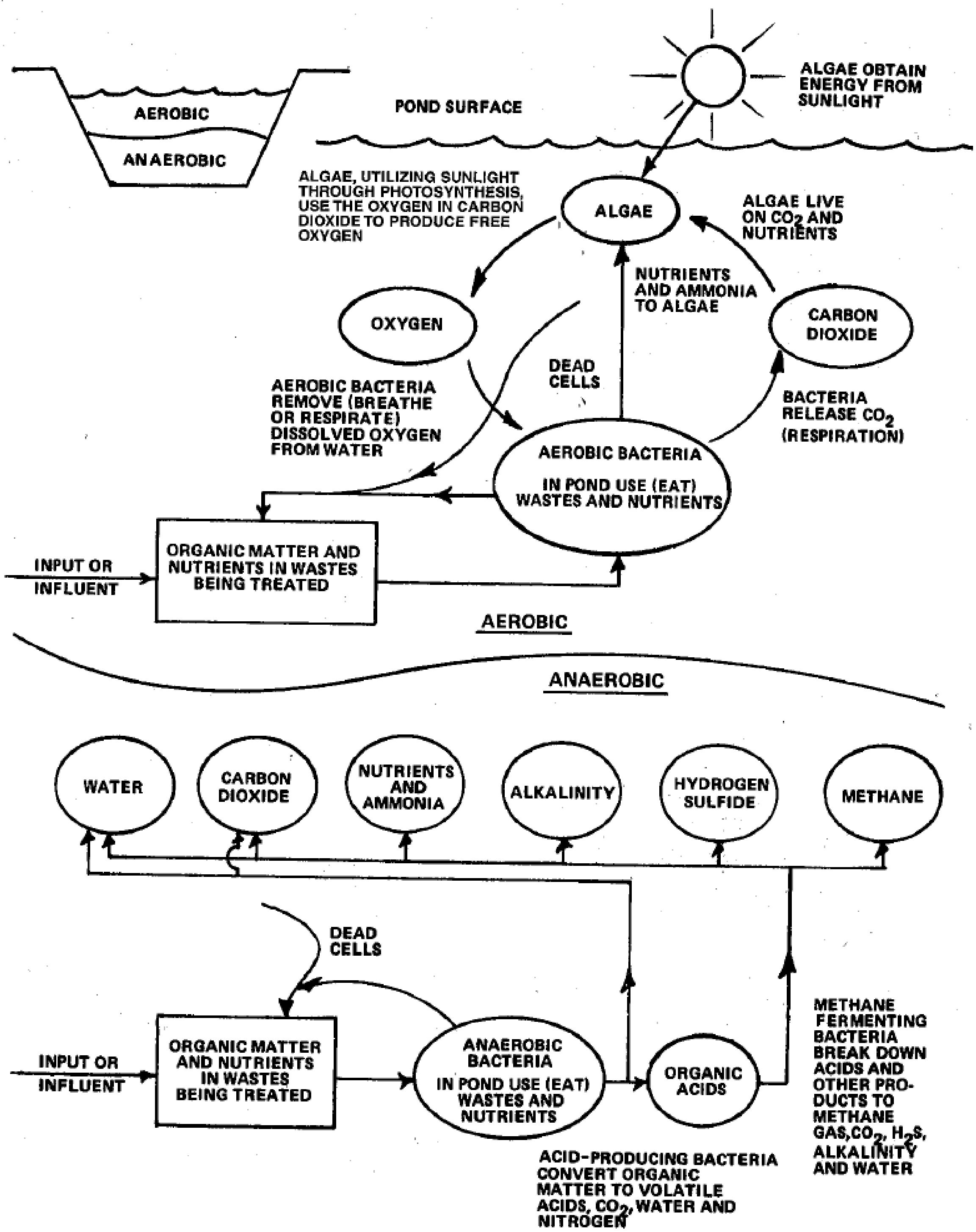


Fig. 9.3 Process of decomposition in aerobic and anaerobic layers of a pond

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.

$$\frac{Se}{So} = \frac{1}{1 + 2.3K_1 t}$$

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°C for complete mix
$K_1 = 0.12$ @20°C 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 <u>Pond Construction Details</u>

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

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1

EFFLUENT DISPOSAL

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

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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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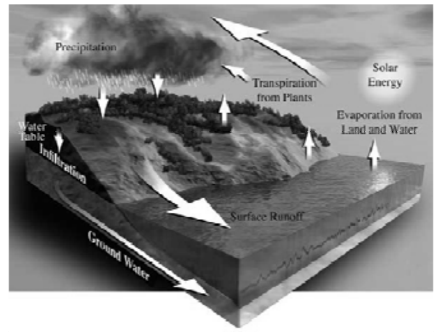
Land Treatment Systems

- 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

7

Hydrologic Cycle



8

Land Application System

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

9

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

10

Wastewater Reclamation: Land Application

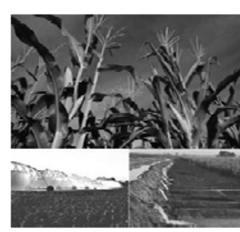
- Irrigation most common:
  - Ridge and furrow
  - Sprinklers
  - Surface/drip systems
- Overland flow

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

11

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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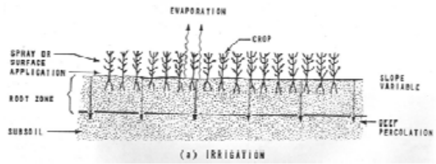
Irrigation



- 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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16

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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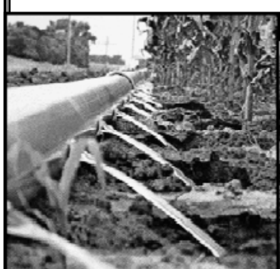
Irrigation – Ridge & Furrow



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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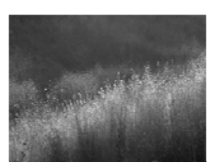
Overland Flow



- 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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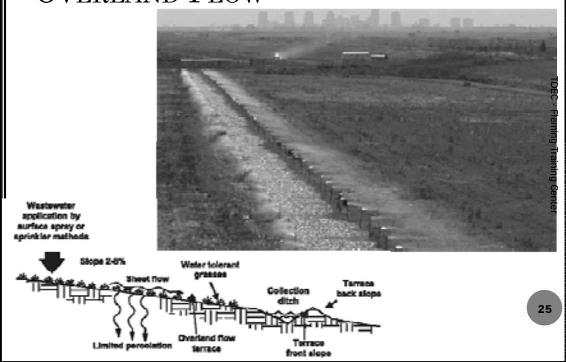
Overland Flow



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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
Surface Methods	Gated Pipe	Same as General, plus: Easy to clean Easiest to balance hydraulically	Same as General, plus: Potential for freezing and settling
Surface Methods	Slotted or Perforated Pipe	Same as General	Same as Gated Pipe, plus: Small openings clog Most difficult to balance hydraulically
Surface Methods	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
Cool Season Grass	Tall fescue	Perennial	bunch	seed	90-120
Cool Season Grass	Rye grass	Annual	sod	seed	60-90
Cool Season Grass	Redtop	Perennial	sod	seed	60-90
Cool Season Grass	KY bluegrass	Perennial	sod	seed	30-75
Cool Season Grass	Orchard grass	Perennial	bunch	seed	15-60
Warm Season	Common Bermuda	Perennial	sod	seed	30-45
Warm Season	Coastal Bermuda	Perennial	sod	sprig	30-60
Warm Season	Dallis grass	Perennial	bunch	seed	60-120
Warm Season	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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30

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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31

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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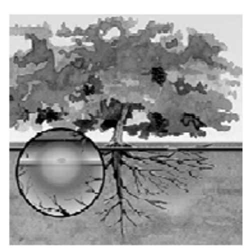
35

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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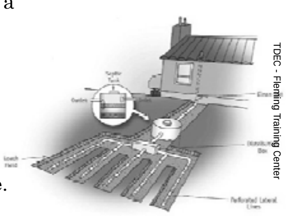
Leach Field Design

- 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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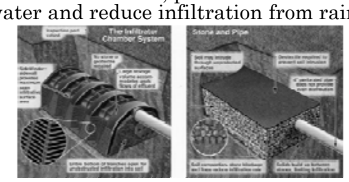
Leach Field Design

- 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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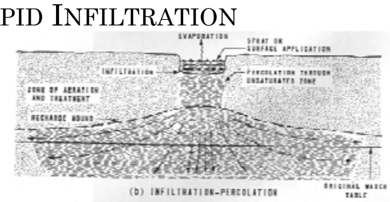
Rapid Infiltration



- 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

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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

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44

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

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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

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46

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

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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

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48

Section 8

Safety

Safety

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Safety

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

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General Duty Clause

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

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Before Leaving the Yard

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

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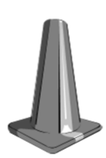
Traffic Safety



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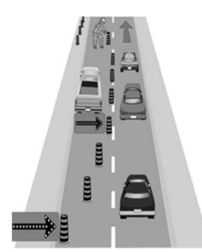
Traffic Control Zones

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



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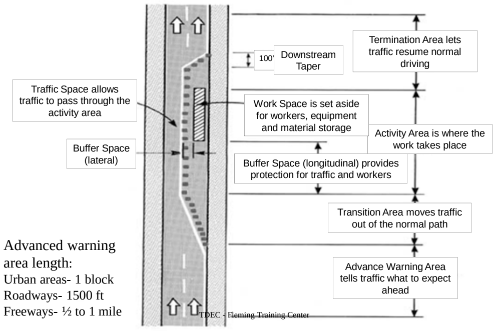
Traffic Control Zones



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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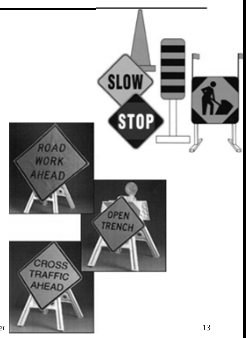
Traffic Signs

- 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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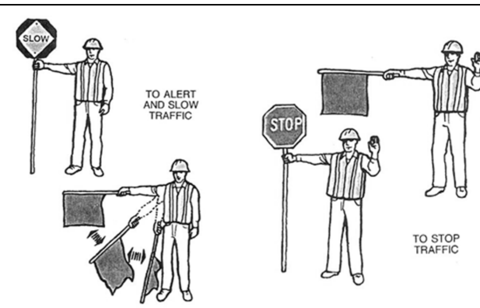
Flaggers



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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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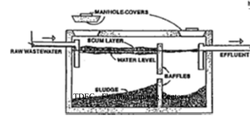
Confined Space Examples

- 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) $\rightarrow$ 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)**

Atmospheric Alarm Units

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

Atmospheric Alarm Units

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

Safety Procedures if Explosive Atmosphere Discovered

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

Ventilation

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

Infectious Disease Hazards

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

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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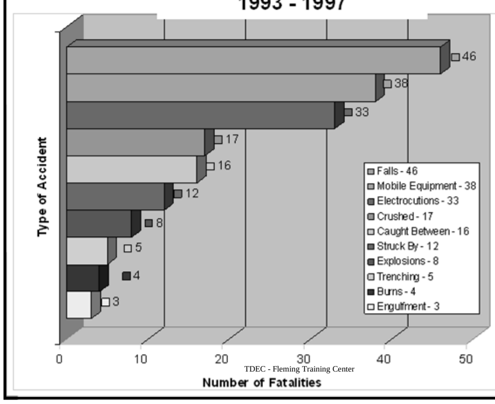
Top 10 Causes of Fatalities 1993 - 1997



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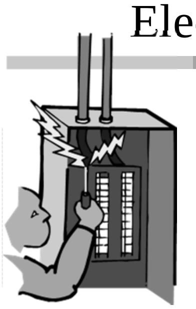
Electrical Safety



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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

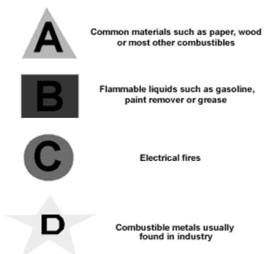
- Class C 
  - Use for areas electrical
  - Best is carbon dioxide extinguisher.
  - Using water to extinguish a class C fire risks electrical shock
- Class D
  - Used in areas with combustible metal hazards
  - Dry powder type
  - Use no other type for this fire.

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

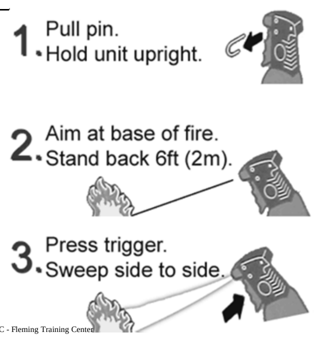


Fire Extinguishers

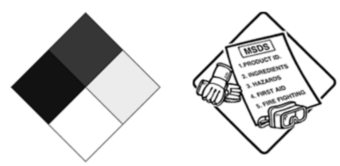
- To operate a fire extinguisher, remember the word PASS
  - **P**ull the pin. Hold the extinguisher with the nozzle pointing away from you
  - **A**im low. Point the extinguisher at the base of the fire.
  - **S**queeze the lever slowly and evenly.
  - **S**weep the nozzle from side-to-side.

Fire Extinguishers

Combo Extinguisher



Chemical Safety

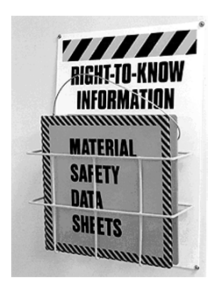


Personal Protective Equipment

- 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

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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.

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Degrees of Hazard

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

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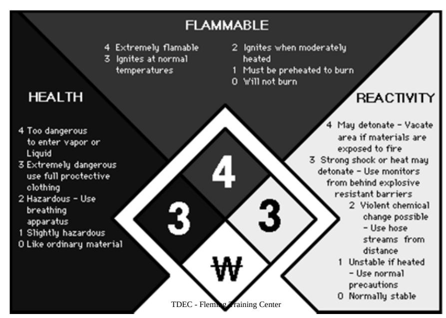
Chemical Label



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Special

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Terms

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

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Name of Gas and Chemical Formula	Spec. Gravity	Explosive Range		Common Properties	Physiological Effects	Most Common Source in Sewers	Method of Testing
		Lower Limit	Upper Limit				
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 purpose of the advance warning area?

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

Wastewater Pumps and Equipment Maintenance

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Wastewater Pumps

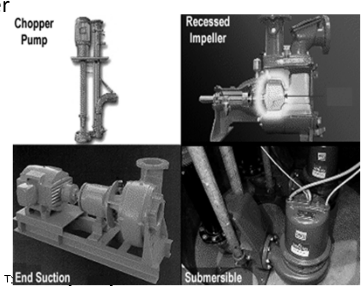
Raw wastewater pumps, Ames, IA

South Truckee Meadows, Reno, NV

TDEC - Fleming Training Center 2

Types of Pumps

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



Types of Pumps

- Velocity Pumps
- Positive-Displacement Pumps

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Velocity Pumps

- Spinning impeller or propeller accelerates water to high velocity in pump casing (or volute)

Volute

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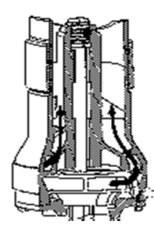
Velocity Pumps

- High velocity, low pressure water is converted to low velocity, high pressure water



Diffuser

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Velocity Pump Design Characteristics

- Axial - flow designs
  - Propeller shaped impeller adds head by lifting action on vanes
  - Water moves parallel to pump instead of being thrown outward
  - High volume, but limited head
  - Not self-priming

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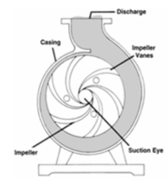
Velocity Pump Design Characteristics

- Radial flow designs
  - Water comes in through center (eye) of impeller
  - Water thrown outward from impeller to diffusers that convert velocity to pressure
  - The discharge is perpendicular to the pump shaft



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Velocity Pump Design Characteristics

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

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Types of Velocity Pumps

- Centrifugal pumps- most common type in wastewater lift stations
- Turbine pumps

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

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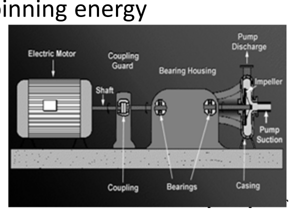
- Impeller rotates in sealed casing
- Impeller connected to motor which provides spinning energy



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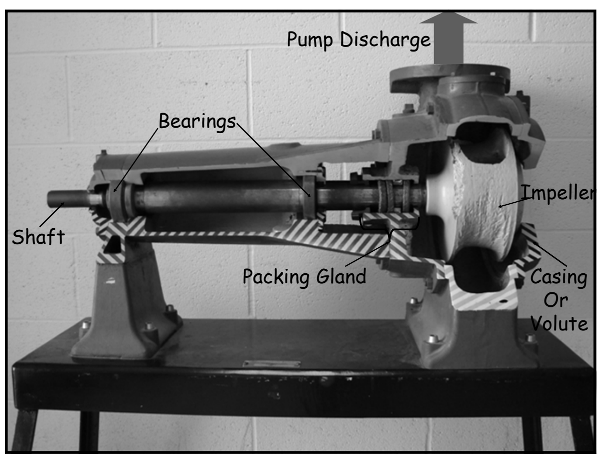
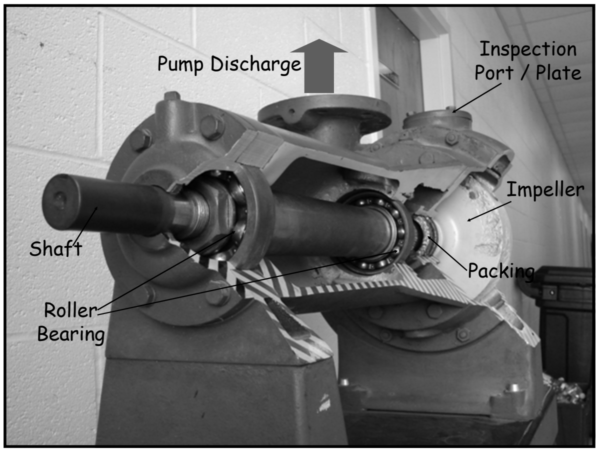
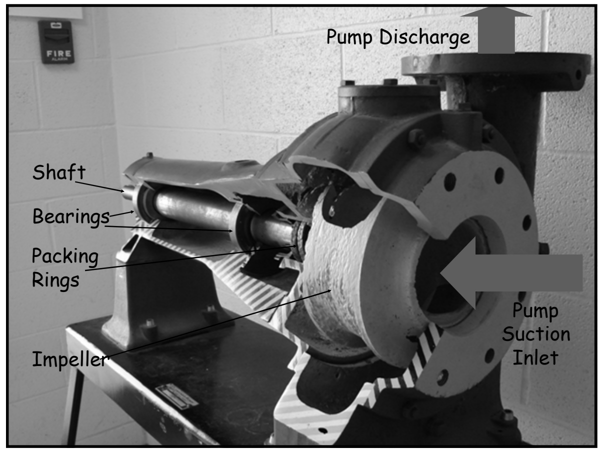
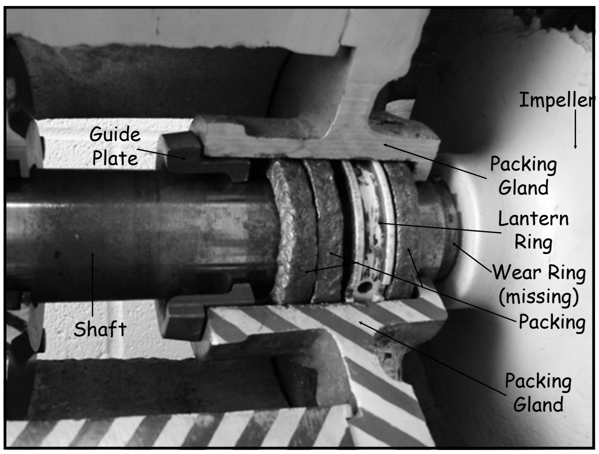


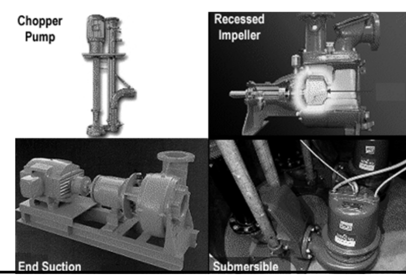






Centrifugal Pumps

- By varying size, shape, and width of impeller
- Wide range of flows and pressures can be achieved



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Self-Priming Pump Basics – Part 1

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Self-Priming Pump Basics – Part 2

GORMAN-RUPP PUMPS

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Vertical Turbine Pumps

- Impeller rotates in a channel of constant cross-sectional area
- Mixed or radial flow
- Create highest head available from velocity pumps

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Vertical Turbine Pumps

- Backflow limited
- Efficiencies up to 95% possible
- Water must be very clean

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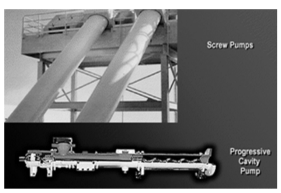
Positive-Displacement Pumps

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



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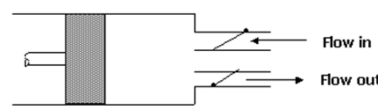
Positive-Displacement Pumps

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



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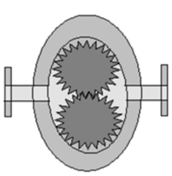
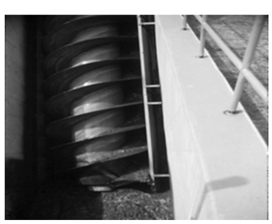
Positive-Displacement Pumps

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





Incline screw pumps handle large solids without plugging

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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

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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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Centrifugal Pump Operation

- Pump Starting and Stopping -
  - Impeller must be submerged for a pump to start
  - 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

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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

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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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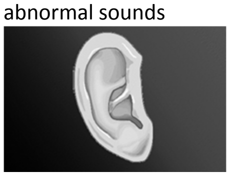
Monitoring Operational Variables

- 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

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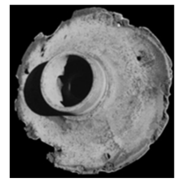
Monitoring Operational Variables



- 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

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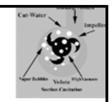
Suction Cavitation



- 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
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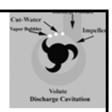
Discharge Cavitation



- 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
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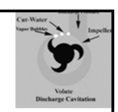
Discharge Cavitation



- 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
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Monitoring Operational Variables

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

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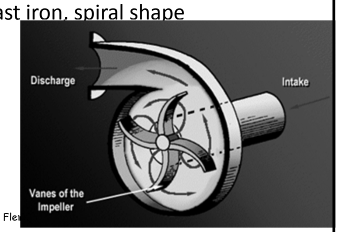
Mechanical Details of Centrifugal Pumps

- Casing
  - Designed to minimize friction loss as water is thrown outward from impeller
  - Usually made of cast iron, spiral shape



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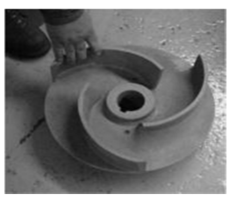
Mechanical Details of Centrifugal Pumps

- Impeller
  - Bronze or stainless steel
  - Closed; some single-suction have semi-open; open designs
  - Inspect regularly



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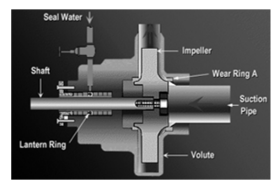
Mechanical Details of Centrifugal Pumps

- Wear rings
  - Restrict flow between impeller discharge and suction
  - Internal leakage is prevented by wear rings
    - Leakage reduces pump efficiency
  - Inspect regularly



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Mechanical Details of Centrifugal Pumps

- Shaft
  - Connects impeller to pump; steel or stainless steel
  - Should be repaired/replaced if grooves or scores appear on the shaft
- Shaft Sleeves
  - Protect sha ing rings

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Mechanical Details of Centrifugal Pumps

- 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

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Mechanical Details of Centrifugal Pumps

- 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
  - Joints of packing should be staggered at least 90°

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Mechanical Details of Centrifugal Pumps

- 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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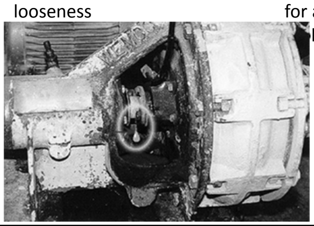
Packing Rings

- Advantages
  - Less expensive, short term
  - Can accommodate some looseness
- Disadvantages
  - Increased wear on shaft or shaft sleeve
  - Increased labor required for adjustment and [re]placement



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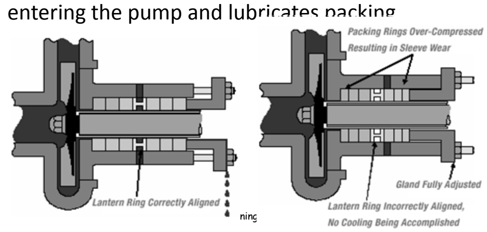
Mechanical Details of Centrifugal Pumps

- Lantern Rings
  - Perforated ring placed in stuffing box
  - Forms seal around shaft, helps keep air from entering the pump and lubricates packing



Mechanical Details of Centrifugal Pumps

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

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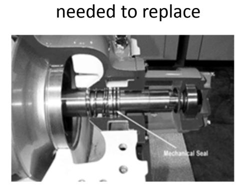
Mechanical Seal

- Advantages
  - Maintenance free
  - No wastewater leakage
  - Less wear on shaft and shaft sleeve
  - Should last for years
- Disadvantages
  - High initial cost
  - Great skill and care needed to replace



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Mechanical Details of Centrifugal Pumps

- 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
  - Types: ball, roller, sleeve

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Mechanical Details of Centrifugal Pumps

- 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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Inspection and Maintenance

- Inspection and maintenance prolongs life of pumps
- Necessary for warranty
- Keep records of all maintenance on each pump
- Keep log of operating hours

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Inspection: Impellers

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


This impeller was damaged by cavitation

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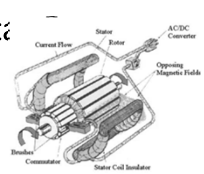
Pump Won't Sta



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

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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

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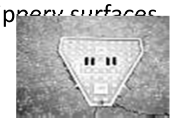
Pump Safety: Wet Wells

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


Manhole Cover, London

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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

- Megger: checks insulation resistance on motors, feeders, grounds, and branch circuit wiring

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Tools, Meters & Testers

- **Ohmmeter**: measures resistance in a circuit. Tests fuses, relays, resistors and switches.

- **Voltage tester**: determines if circuit is energized, measures voltage, tests for blown fuses, single phasing of motors, and grounds

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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

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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

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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

- Transformers are 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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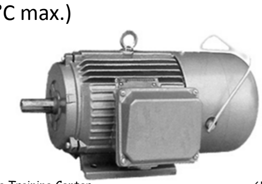
A.C. Induction Motor

- 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



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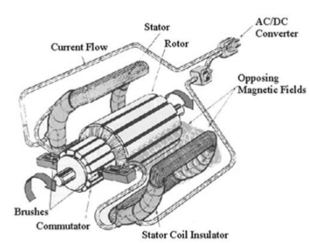
Motor Components



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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

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Motors

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

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Motors

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

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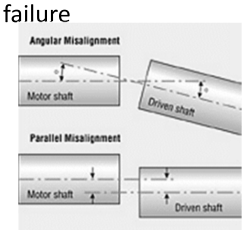
Misalignment of Pump & Motor

- Excessive bearing loading
- Shaft bending
- Premature bearing failure
- Shaft damage



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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
- 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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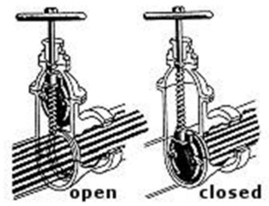
Valves

- Controlling device in piping systems to stop, regulate, check, or divert flow of liquids or gases
- 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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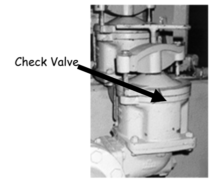
Valves

- 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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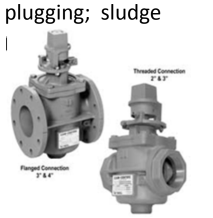
Valves

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



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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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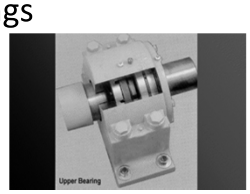
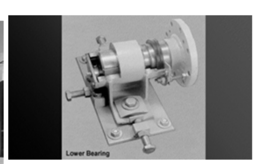
Bearings

- 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

- Keep facility clean, store tools in proper place
- Type of maintenance needed influenced by age, type & use of building
- Maintenance program includes:
  - Floors & roofs
  - Heating, cooling & ventilation
  - Lighting
  - Plumbing
  - Windows

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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 purpose 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 greatest cause 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

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    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